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# Differences in firewood users' and LPG users' perceived relationships between cooking fuels and women's multidimensional wellbeing in rural India.

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## Abstract

Clean cooking fuels are generally assumed to bring health and other benefits for women compared to solid fuels, suggesting they should be preferred. However, despite the availability of clean cooking fuels like liquefied petroleum gas (LPG), the scale of solid fuel use in rural India remains large. Here we examine women's position on fuel transition and multidimensional wellbeing through qualitative analysis of data from focus group discussions with comparable groups of women who have versus have not transitioned to LPG. We show that women who use firewood believe their cooking fuel supports their wellbeing in several ways, and see no enabling relationship between LPG use and wellbeing. In contrast, LPG users – who were previous firewood users - claim LPG has enabled wellbeing. These results suggest that perspectives on the relationship between fuel and wellbeing shift following transition, due to the realisation of new advantages. Understanding differences in perspectives of women using different fuels is vital in unpacking the dynamics of cooking fuel transition.

## Introduction

Universalising access to clean cooking fuels is one of the goals that India is increasingly grappling with<sup>1-3</sup>. At 780 million people (approx. 11% of the world's population), India has more people relying on solid fuels for cooking than any other country in the world, and estimates indicate that India will stay in this top position at least until the end of 2030<sup>4</sup>. Providing universal access to clean cooking fuels has been identified as one of the Sustainable Development Goals (SDGs), to which India is a signatory. Achieving SDG7 contributes to achieving several other SDGs and their targets<sup>5,6</sup>, in particular no poverty (Goal 1); good health and wellbeing (Goal 3); gender equality (Goal 5); and reduced inequality (Goal 10)<sup>7</sup>. However, the scale of solid fuel use in rural areas signals that the widespread uptake and sustained use of clean fuels is a distant reality<sup>8</sup>. It would seem that either efforts to introduce cleaner fuels have been insufficient, or we have not clearly understood the dynamics of cooking fuel transition.

There is no shortage of literature highlighting the relationship between gender and cooking fuel, unequivocally pointing to three conclusions. First, it is mostly women who are exposed to health problems due to the inefficient combustion of solid fuels<sup>9-11</sup>. Second, it is primarily women who collect solid fuels, limiting their time for other productive purposes<sup>12-15</sup> and exposing them to further physical risk<sup>16-18</sup>. Third, women as the primary cooks have a significant role to play in transforming their cooking practices to enable a transition to cleaner fuel<sup>19-21</sup>. These conclusions often lead policymakers and energy scholars to assume that given the benefits of improved health and reduced cooking time, women would unequivocally prefer clean cooking fuels; however, this assumption needs further examination.

Notably, there is a severe lack of research that examines experiences of using different cooking fuels from the perspectives of women themselves<sup>22</sup>. Given the social reality that in rural India women are considered the primary cooks, it is critical to unravel how they see the relationship between their wellbeing and the cooking fuel they use (without necessarily validating the view that cooking is a woman's job). Therefore, in this paper we aim to extend understanding of women's position on fuel transition through in-depth engagement with comparable groups of women who have versus have not transitioned from using firewood to cooking with liquid petroleum gas (LPG) in rural India. In so doing, we draw two sets of comparisons of the connections they make between the use of specific cooking fuels and their wellbeing: comparisons between the fuels, and comparisons between the views of firewood users and LPG users.

We frame wellbeing in the terms of the Capability Approach (CA)<sup>23,24</sup>, an influential but particular approach to assessing people's wellbeing and devising interventions for social justice<sup>25</sup>, which is also foundational to the United Nation's Human Development Index (HDI). Two important concepts underpin the CA, 'functioning' and 'capability'<sup>23,26</sup>. Functionings are the things/states that a person values doing or being, such as being nourished and healthy, or having meaningful relationships<sup>27</sup>. A capability refers to the substantive freedom or opportunity to realise a valued functioning<sup>28</sup>. Supplementary Note 1 provides more details on the CA. Wellbeing, from a CA lens, should be assessed in terms of the capabilities that a person has. It is important to note that not all possible capabilities are equally imperative to basic wellbeing, and so for policy purposes we are generally interested in a more specific set.

To assess how cooking fuel relates to wellbeing from a capabilities perspective, following Day, et al.<sup>29</sup>, we refer to Nussbaum's central capabilities. Nussbaum<sup>24</sup> outlines a set of central capabilities for universal application (Table 1), which she argues to be non-substitutable and non-reducible, and

essential for wellbeing. She emphasises that these capabilities play a central role in everything people do and plan in their life<sup>30</sup>.

Table 1. Nussbaum's list of central capabilities (abridged from Nussbaum<sup>30</sup>, pp. 33-34).

Capability	Definition
Life	Being able to live a human life of normal length.
Bodily health	Being able to have good health
Bodily integrity	Being able to move freely from place to place. Being able to feel secure against violent assault; to have adequate shelter.
Senses, imagination and thought	Being able to use the senses, to imagine, think, and reason; to use imagination and thought in connection with producing works and events of one's own choice.
Emotions	Being able to have attachments to things and people outside ourselves; to love who love and care for us, to grieve at their absence.
Practical reason	Being able to form a conception of the good and to engage in critical reflection about the planning of one's life.
Affiliation	Being able to live with and towards others, to recognise and show concern for other human beings, to engage in various forms of social interaction. Having the social bases of self-respect and non-humiliation; being able to be treated as a dignified being whose worth is equal to that of others.
Other species	Being able to live with concern for and in relation to animals, plants, and the world of nature.
Play	Being able to laugh, to play, to enjoy recreational activities.
Control over one's environment	(A. Political) Being able to participate effectively in political choices that govern one's life; having the right of political participation. (B. Material) Being able to hold property and having property rights on an equal basis with others. Being able to work as human being.

We conducted focus group discussions (FGDs) with women in Chittoor district in Andhra Pradesh, India. Supplementary Table 1 details the cooking fuels used in Chittoor in 2001 and 2011. To select study villages, we relied on local key informants. With their help, we chose four villages in the same district - two villages where all the households used firewood as their primary cooking fuel and two villages where the majority used LPG as their primary cooking fuel. No household in any village reported using intermediate cooking technologies, such as improved cookstoves, nor use of dung as cooking fuel. These villages, being in close proximity, were highly similar, except for their castes and cooking fuels. Residents of one of the villages with LPG users belonged to a higher caste than the other LPG-using and two firewood-using villages. However, all villages were similar in terms of occupations and income (all were below the poverty line), and cultural practices. Details on the sampling rationale and village profiles are provided in Supplementary Note 2.

We found that women who used firewood believed their cooking fuel supported their wellbeing in terms of several essential capabilities, despite believing that firewood was detrimental to their health. Firewood and LPG users had contrasting perspectives about wellbeing and cooking with LPG. Firewood users did not perceive there would be any enabling relationship between LPG and wellbeing, but expected that using LPG would have a negative impact on some capabilities. However, LPG users - who were previous firewood users - felt that LPG had enabled wellbeing in multiple dimensions, partly due to the quicker cooking time which allowed them to reallocate time for enabling other capabilities. LPG users also saw fewer connections between firewood and wellbeing, which implies that a once-valued outcome can become obsolete following transition to an improved fuel.

## Firewood users' perspectives

In our analysis of the FGDs with firewood users, only 6 central capabilities were found to be associated with either of the cooking fuels. Figure 1(A) shows the capabilities that, according to our interpretation, were connected to the use of firewood and LPG, with enabling and constraining relationships marked positive and negative respectively. Strikingly, firewood users made no positive links at all between LPG and any central capabilities. Conversely, they discussed firewood as enabling four central capabilities. Only bodily health was felt to be constrained by firewood use, being much more spoken of in terms of a constraining relationship (17 times) than an enabling relationship (twice).

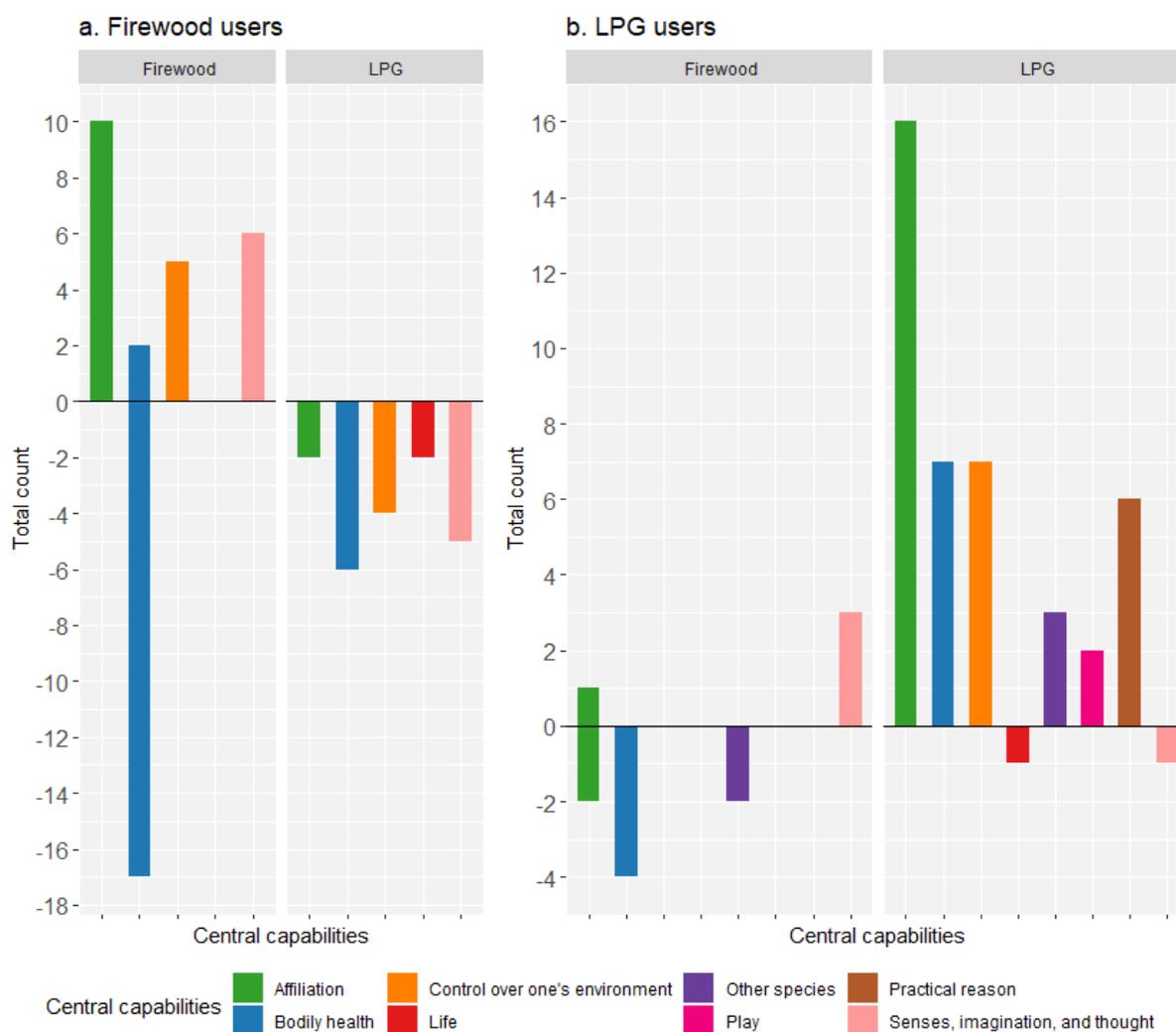


Figure 1. Relationships between capabilities and the cooking fuels. The number of times ('Total count') the association was made between each capability and firewood or LPG use in the discussions among (a) firewood users, and (b) LPG users); negative values denote constraining relationships and positive values represent enabling relationships.

Further analysis to detail how firewood users felt these capabilities were enabled or constrained by the cooking fuels (Figure 2) revealed 6 positive and 5 negative outcomes/possible outcomes that we assigned to relevant capabilities (see also Supplementary Table 2). Note that these outcomes are based on the participants' viewpoints; no objective assessments of the relationships were performed. Some indicative quotes against each capability and selective outcomes/possible

outcomes are presented in Table 2, although it should be noted that other parts of the surrounding discussion were also relevant to the interpretation and classification. A detailed analysis, including quotes from the FGDs against all identified capabilities and outcomes, is presented in Supplementary Note 3.

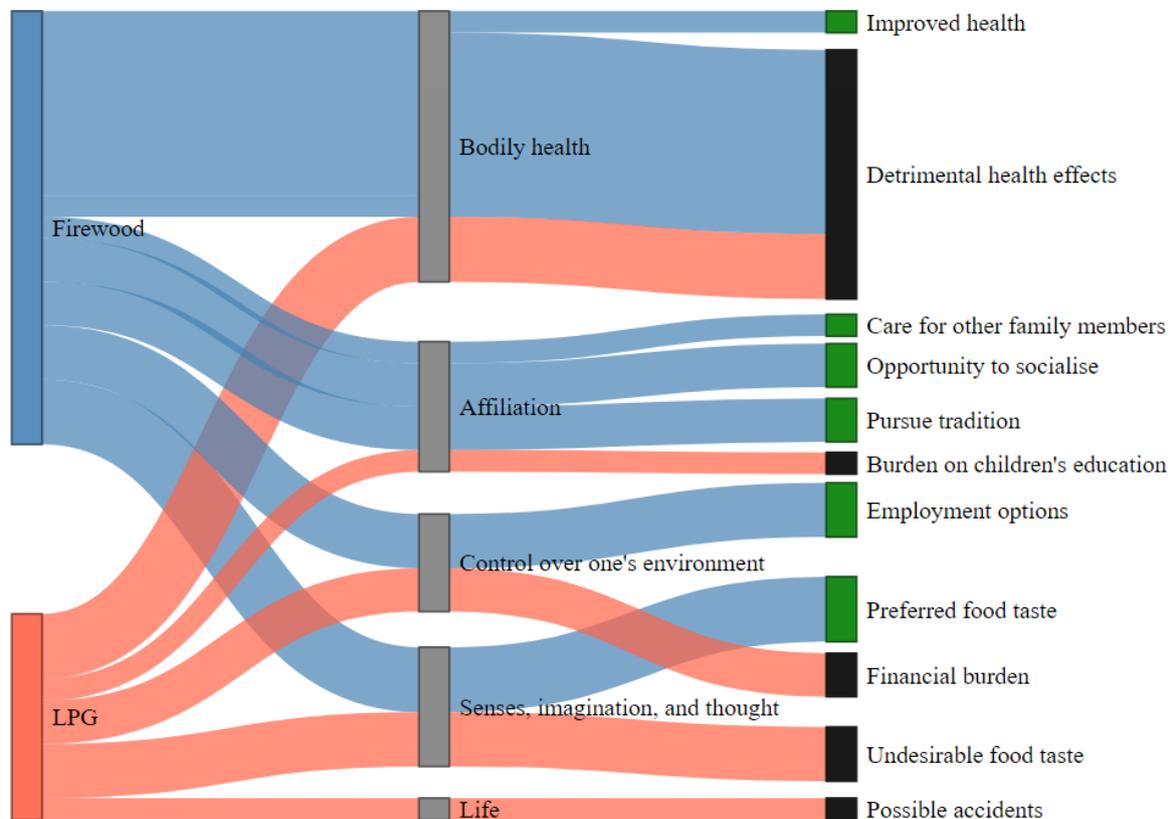


Figure 2. Outcomes of the relationships between the cooking fuels and capabilities among firewood users. The blue strands show the connections between firewood (left), capabilities (middle) and outcomes/potential outcomes (right), while the red strands indicate connections made between LPG (left), capabilities (middle) and outcomes/potential outcome (right) that emerged from the discussions with firewood users. The black and green outcomes denote constraining and enabling relationships respectively. The widths of the strands indicate the frequency of connections made between the fuel, capability and outcome or potential outcome.

According to our interpretation, firewood users saw both firewood and LPG as having relationships with bodily health, control over one's environment, affiliation, and senses, imagination and thought capabilities. The bodily health capability was most often connected with firewood. Firewood users mentioned that firewood not only causes detrimental health effects, but also contributes positively to health, whereas they mentioned LPG only in a negative connection with health. For firewood users, cooking with firewood improved their financial wellbeing and therefore control over their material environment because selling firewood generated income; LPG, on the other hand, was perceived to cause financial burden because of the associated expenditure. Affiliation-related outcomes were mentioned by firewood users mostly in connection with firewood, and they were all positive. For them, firewood enables care for family members, opportunity to socialise, and pursue ancestral traditions. LPG was identified as a constraint to affiliation, in that it was perceived to undermine women's ability to enable their children's education because of the expenditure burden. In relation to the senses, imagination and thought capability, firewood was mentioned as having only an enabling relationship, creating opportunity to enjoy their preferred food taste, and LPG only

a limiting relationship, causing undesirable food taste. With the life capability, participants reported negative connections with LPG only, discussing their fear of a fatal LPG canister explosion.

Table 2. Indicative quotes against capabilities and selected outcomes / possible outcomes among firewood users.

Capabilities	Outcomes/possible outcomes	Indicative quotes
Cooking fuel- Firewood		
Bodily health	Detrimental health effects	<i>It [Firewood] causes burning sensation in eyes.</i>
Control over one's environment	Employment options	<i>Mostly women sell firewood. Money from selling firewood is spent on the weekly markets.</i>
Affiliation	Opportunity to socialise	<i>We go to the forest with our relatives and friends. We discuss our problems with each other while collecting firewood.</i>
Senses, imagination, and thought	Preferred food taste	<i>Food cooked with firewood tastes good.</i>
Cooking fuel- LPG		
Bodily health	Detrimental health effects	<i>It [LPG] causes health problems [e.g. hair loss and abdomen pain].</i>
Control over one's environment	Financial burden	<i>We cannot buy LPG...It is because we have some other problems at home, so that money is spent on that.</i>
Affiliation	Burden on children's education	<i>Having LPG might affect our ability to meet children's school expenses.</i>
Senses, imagination and thought	Undesirable food taste	<i>Food does not taste good with LPG.</i>
Life	Possible (fatal) accidents	<i>We are afraid of LPG. If we keep it idle, it will explode and ruin our life.</i>

## LPG users' perspectives

In our analysis of the discussions with LPG users, we made links between 8 of Nussbaum's 10 central capabilities and cooking fuels (either firewood or LPG; Figure 1(B)). Notably, LPG users did not report many enabling relationships between firewood and capabilities. They mentioned relationships between firewood and capabilities 12 times, 8 of which related to a constraining relationship. Bodily health was the most discussed capability reported to be negatively affected by the use of firewood as a cooking fuel, with negative effects on affiliation and on other species also discussed. Enabling relationships were mentioned a few times in relation to affiliation and to senses, imagination and thought. In contrast, enabling relationships between LPG and central capabilities were reported 43 times out of a total 45 connections made. According to LPG users, LPG enabled 6 central capabilities, with affiliation the most discussed, followed by bodily health, control over one's environment, and practical reason. Life and senses, imagination and thought were the only capabilities discussed as being constrained by LPG.

Further analysis of the more specific outcomes that participants associated with each fuel (see Figure 3) revealed 11 positive and five negative outcomes/possible outcomes associated with capabilities (see also Supplementary Table 3). Some indicative quotes against each capability and selective outcomes/possible outcomes are presented in in Table 3. A detailed analysis, including

quotes from the FGDs against all identified capabilities and outcomes, is presented in Supplementary Note 3.

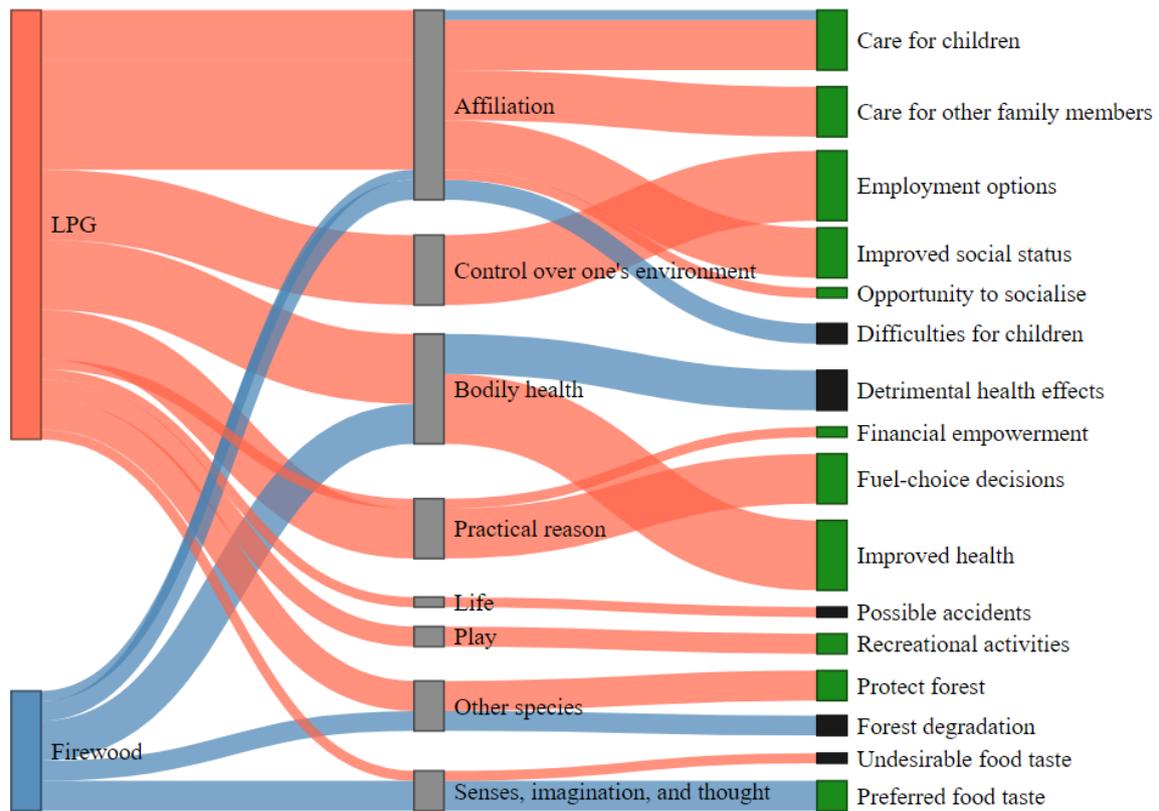


Figure 3. Outcomes and possible outcomes of the relationships between the cooking fuels and capabilities among LPG users. Blue strands indicate the connections between firewood (left), capabilities (middle) and outcomes (right), whilst red strands indicate the connections made between LPG (left), capabilities (middle) and outcomes (right). The black and green outcomes denote constraining and enabling relationships respectively. The widths of the connections indicate the frequency of the connection made, i.e. the more mentions of a relationship between the cooking fuel and the outcome, the wider the strand.

We found both LPG and firewood to be related to affiliation, bodily health, other species, and senses, imagination and thought capabilities. According to LPG users, using LPG enabled them to maintain or improve social status, care for children, care for other family members, and provided opportunity to socialise, thereby improving the affiliation capability. Firewood, in contrast, caused difficulties for children because of the slower cooking time with the fuel although, at the same time, it helped them to take care of children because they used firewood as a (low cost) option to boil water for their children to bathe. In relation to the bodily health capability, participants explained that firewood use impedes the capability to be healthy, resulting in detrimental health effects, whereas LPG use had enabled an improvement in their health. LPG users explained that using firewood damages the forest, while LPG use helps to save the forest, hence inferring negative and positive associations between the other species capability and firewood and LPG respectively. With the senses, imagination and thought capability, LPG was identified as a barrier to, and firewood as an enabler of, pleasurable experiences, relating to being able to enjoy food with preferred taste.

Further, LPG users mentioned elements of control over one's environment, life, play, and practical reason capabilities in connection with LPG only. The perceived relationship with control over one's (material) environment mainly related to LPG enabling women to have paid employment options.

With the life capability, LPG was mentioned in a negative association, due to the potential explosion of LPG canisters and the potential injury or deaths of family members. Cooking with LPG, according to the users, enables the play capability, by generating opportunity to enjoy time with friends for recreational activities. The relationship between LPG and the practical reason capability was expressed mainly in relation to being able to make decisions due to the expansion of cooking fuel choices and employment options.

Several of the relationships between the central capabilities and the cooking fuels identified by LPG users were connected with the time required to cook using the particular fuel. For example, the negative connection with affiliation due to difficulties meeting children's needs was because they felt that slow cooking with firewood could result in children being late for school. Similarly, the positive relationship between LPG and the control over one's environment capability was due to the reduced cooking time, providing opportunity for women to use the saved time to generate income through productive activities (see Supplementary Note 3).

Table 3. Indicative quotes against capabilities and selected outcomes / possible outcomes among LPG users.

Capabilities	Outcomes/possible outcomes	Indicative quotes
Cooking fuel- LPG		
Affiliation	Improved social status	<i>If we cook with LPG, people think that we have a high social status</i>
Control over one's environment	Employment options	<i>We save time cooking with LPG, then we go to our agriculture work; if we want to go for work then we can cook fast, eat and go.</i>
Practical reason	Fuel choice decisions	<i>Having LPG is good because we can decide which fuel to use based on the given circumstances, for example, if we are tired, we use LPG, and if we are sick, we use LPG.</i>
Bodily health	Improved health	<i>Eyes are not affected [because of no smoke]</i>
Life	Possible accidents	<i>People are afraid of LPG. We should be careful if we have children at home.</i>
Play	Recreational activities	<i>We save time by cooking with LPG... We start watching TV shows by 7 pm and finish by 9 pm. We watch TV together, which helps us forget our difficulties.</i>
Other species	Protect forest	<i>We cut trees for firewood, and forest get diminished. We bought LPG to stop cutting trees.</i>
Senses, imagination and thought	Undesirable food taste	<i>I cannot eat food cooked with LPG [because of its taste].</i>
Cooking fuel- Firewood		
Affiliation	Difficulties for children	<i>If we cook with firewood, children may be late [for school] because cooking with firewood takes time.</i>
Bodily health	Detrimental health effects	<i>Some health problems with smoke, like eyes burning and breathing difficulties.</i>
Other species	Forest degradation	<i>We cut trees for firewood, and forest gets diminished.</i>
Senses, imagination and thought	Preferred food taste	<i>Food cooked on traditional stoves with firewood tastes good.</i>

## Summary of Differences Between LPG and Firewood Users

In Figure 4, we compare firewood and LPG in terms of links made between the fuel, central capabilities and specific outcomes / possible outcomes, between comparable groups of women who have versus have not transitioned to clean cooking fuel. It is clear that LPG users and firewood users largely did not make the same links. Nevertheless, there are some areas of agreement. Both firewood users and LPG users identified that firewood constrains the central capability of bodily health, with firewood users discussing this more overall than LPG users. Both firewood users and LPG users mentioned that LPG may be a threat to life, due to potential for explosions, although this was not a frequently raised concern in either set of users. Both groups mentioned that food cooked on firewood tastes better, relating to the capability of senses, imagination and thought, and conversely that food cooked on LPG does not taste good, though the latter was more commonly expressed by firewood users.

Firewood users identified some positive links between firewood use and capabilities that LPG users did not. Notably, they identified that firewood enables affiliation, through allowing them to carry on tradition, and because gathering firewood allowed them to spend time with other community members and strengthen those social bonds. Using firewood also meant they relieved their husbands of potential financial stress. They also identified that gathering and selling firewood could help them with their control over their material environment, because it allowed them to generate an income of their own. Firewood users also identified some negative links between LPG use and central capabilities that LPG users did not, most clearly a perceived constraining relationship with health, because of a belief that food cooked on LPG was less healthy. LPG users did not mention this belief, although some did believe the food was less tasty. Firewood users also identified that LPG might be a financial burden, limiting control over one's material environment, and also potentially constraining children's educational opportunities (affiliation).

What is very noticeable is that LPG users identified several ways in which LPG enables central capabilities that were not identified by firewood users reflecting on LPG. LPG users identified that LPG enables affiliation because it improves or maintains social status, and that the faster cooking time enables better care for others. They discussed the health benefits at some length, enabling the capability of bodily health, and also an enabling relationship with control over their material environment, as the faster cooking time allowed them to do other, paid work instead. They identified that LPG helped relations with other species, in that it helped to protect forests. They also identified LPG enabling play, and also practical reason by giving them a degree of choice over fuel, employment and finances. Capability constraints that LPG users identified for firewood that firewood users did not related to the damage to forests (other species capability), and the potential interference in children's education because the time taken to cook with firewood could make them late for school (affiliation).

Although these capability-outcomes relationships are the subjective assessment of women themselves, from an outside perspective with an interest in women's empowerment, some of the relationships might be problematic - for example, the identification of pursuing ancestral traditions and relieving their husbands of potential financial stress as enabling outcomes of the affiliation capability. As external observers we might observe that the continuation of firmly-established traditions can be related to the continuation of male-privileges in society<sup>31</sup>. Similarly, the depiction of 'husbands' as the sole bearers of financial stress in the households demonstrated the gender-unequal social structure of the study villages. On a positive note, however, our findings suggest that

making a transition to LPG has helped empower women to take control of some of the household expenditures.

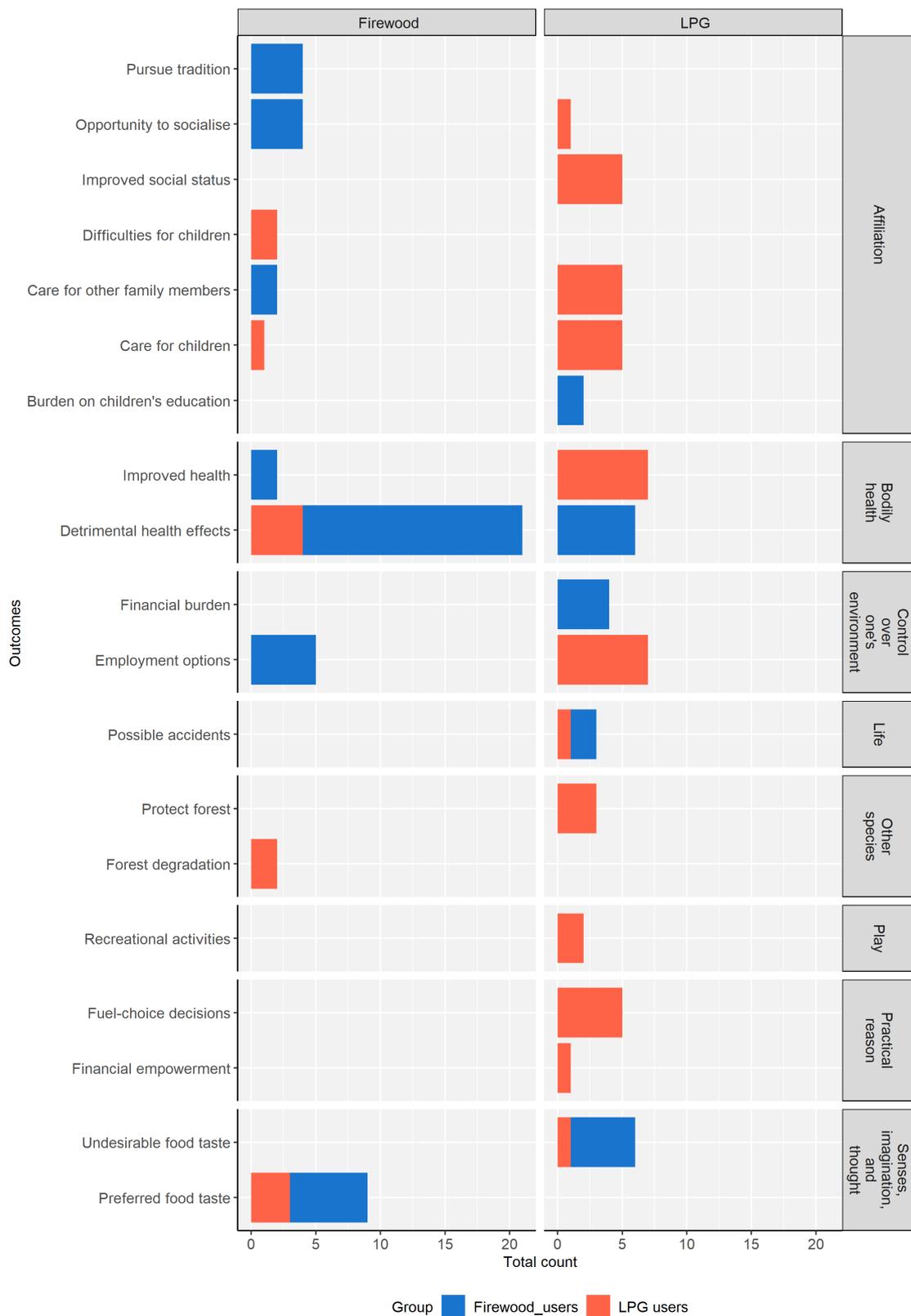


Figure 4. Comparison of capabilities between the cooking fuels. Links between capabilities (right) and outcomes (left) made by firewood users (blue) and LPG users (red). 'Total count' refers to the number of times the capability-outcome associations were made in the discussions.

## Discussion

The lack of access to clean energy is a gender issue<sup>6,13,14</sup>. The repercussions of cooking with solid fuels fall predominantly on women<sup>32</sup> because they generally do most of the cooking in India and South Asia<sup>12</sup>. When women, as primary cooks, were not consulted in improved cooking practice interventions, such programs did not succeed as expected<sup>13</sup>. Increasingly, policies promoting improved fuels, such as LPG, are targeting women as primary beneficiaries, rather than their male counterparts, the Pradhan Mantri Ujjwala Yojana (PMUY) being an example<sup>33,34</sup>. In this study, we engaged with women to explore their perspectives regarding the cooking fuels they use, which we analysed using a CA lens. To be clear, there was no objective assessment of the capabilities and outcomes; the findings presented in this paper relating to capabilities and cooking fuels are based on the worldview of the participants themselves.

This research identifies three key lessons that have important implications for how the relationships between cooking fuels and women's wellbeing appear to women themselves. First, both fuels were felt by users to support at least some key dimensions of wellbeing. Despite a widespread consensus that using firewood has several negative impacts on the wellbeing of women e.g.<sup>12,35</sup>, we found that women using firewood felt that it contributed to their wellbeing in other ways that correspond to important capabilities. Understanding this helps to explain why people may not be persuaded to switch to cleaner fuels based only on seemingly obvious health benefits. Further, the two fuels were felt to support some of the same capabilities, but in different ways. This is clearest with respect to affiliation, where firewood users felt that firewood collection and usage provided them with opportunities to socialise and also to carry on tradition, whilst LPG users felt that LPG helped them to gain or maintain social status and to provide better hospitality. With regards to managing fuel transitions, this points to the necessity of understanding the multi-dimensional ways in which established fuels are felt to support wellbeing, which will help to unpack users' needs in specific contexts<sup>36</sup>, looking for ways in which the same capabilities might be supported by cleaner fuels, and reassuring people of this. It is, however, noteworthy that, in practical terms, some outcomes/potential outcomes that fall under the same capability may have different relative weights or meanings from the perspectives of users, so that one outcome may not entirely be substituted for another. Nevertheless, outcomes that link to the same capability are likely to be more potentially tradeable than those that link to different capabilities.

Second, considering that LPG users had been firewood users in the past, our interpretation is that perspectives on the relations between cooking fuels and capabilities change following transition. No longitudinal data was available to compare the views of LPG users before and after the transition to substantiate this, but the proximity and strong similarity of the villages in other respects (see Supplementary Note 2) lends weight to the conclusion that the fuel transition was the reason for the different perspectives. It is also noticeable that LPG users, who stacked wood to some extent, and firewood users shared some views on firewood, such as that food tastes better cooked on firewood, which further indicates some overlapping perspectives at a transitional stage. A possible alternative explanation is that households with different preferences gravitate to different fuels<sup>37</sup>, but if fuel usage was an outcome of individual choice in this way we would expect to see a broadly similar mix of firewood and LPG users in all 4 villages, which was not the case; rather, villages had collectively made a transition or not.

Importantly, it seems that LPG users see more advantages in LPG than non-users. Based on our groups, they also don't see some of the anticipated disadvantages. Whilst firewood users spoke several times of LPG being bad for health, mainly linked to the perceived taste and integrity of food

cooked over LPG, LPG users mentioned only health benefits, and although some preferred the taste of food cooked over firewood, they did not make any association between this and health. Also important is that while firewood users mentioned that LPG would be a financial burden (affecting control over one's material environment) which is highly cited as a barrier to transition to clean fuels in existing literature e.g. <sup>35,38,39</sup>, and thought it might compromise their ability to pay for their children's education, LPG users felt that LPG use expanded their capability of control over their material environment by giving them more choices and freeing up time for paid work, and also that the time saved helped them to get their children to school. Note that the villages did not have different income levels.

There were positive outcomes mentioned by firewood users that appeared to be lost when women transitioned to LPG, specifically, pursuing traditions. The question therefore arises of what happens to those positive outcomes after switching to a new fuel. Although we did not pursue this question with our participants, the fact that LPG users did not mention this supports our argument that perspectives change following cooking fuel transition. That is, it appears that a once-valued outcome can become obsolete because of the change in circumstances, and the realisation of new advantages.

Third, several of the wellbeing benefits of LPG use in terms of capabilities enabled were predicated on the time saved by using LPG rather than firewood. With this saved time, women were able to do a number of other things such as enjoy recreation with friends and neighbours and support their children's education. Thus, LPG use contributed to the central capabilities of play, and control over their material environment, but not directly; rather, by freeing up the resource of time which could then be converted to other capabilities (see Supplementary Figure 1) and to the resource of money. An important consideration here is that these outcomes that are a result of the time saved are likely to be much more context-specific (a critical consideration in energy planning <sup>36</sup>) than some other more direct relationships between fuels and capabilities such as the impact on bodily health. In a different community, prioritisation of how to use women's saved time might be different, and the choice might be less under the women's control. In the communities we researched, women were able to reallocate this saved time to doing paid work, and were able to choose how to spend the extra income resource themselves, but as Listo <sup>22</sup> cautions, we should not assume that women's empowerment and control is an inevitable outcome of fuel transitions.

These lessons point to the possible value in intervention-related work of enabling peer learning. Wolske, et al. <sup>40</sup> describe two types of communication channels relating to 'peer effects': active, which trigger deliberative processing, and passive, which enable intuitive processing. Peer learning between users and non-users of new fuels could open both: active channels, through discussion with fellow women, and passive channels, by observing their cooking practices. Herington, et al. <sup>41</sup> argue that change in cooking practices can be motivated by the relative rewards and incentives, which can be extrinsic, e.g. praise from others, and intrinsic by nature, e.g. a sense of belonging. In light of this, a beneficial approach could be to organise interaction programs between firewood users and LPG users to inform firewood users about the positive wellbeing outcomes of LPG, help address concerns, and promote learning from each other.

The study has some limitations that point to important avenues for future research. First, the study villages were similar in most respects, for example, socioeconomics, electricity access, education, major occupations, and cultural practices. However, one of the two LPG-adopted villages belonged to a higher class. Given the potency of the caste system in India, the possibility of caste being an explanatory factor in the LPG uptake, or more pertinently here, how the benefits of transition are perceived or play out, cannot entirely be ignored. Although a few previous studies did not find a

significant influence of caste in cooking fuel transition, particularly in rural India <sup>19,41,42</sup>, the role of caste privileges in energy transition needs to be examined in more depth. Therefore, we recommend a careful consideration of the caste system in similar future research.

Second, although the CA is an established framework in assessing wellbeing, it comes with some challenges (discussed in Supplementary Note 1). Using a CA lens, our study points to change in women's perspectives in relation to wellbeing in multiple dimensions, once they switch from firewood to LPG. Future research should consider studying the relationship between cooking fuel transition and change in perspectives, ideally using longitudinal data.

Third, although LPG users may have achieved the same capability as firewood users, e.g. affiliation, specific outcomes under the capability may have different meanings or values to the users. As a starting point, assuming outcomes within a capability to be potentially tradeable is helpful. However, it would be useful for future research to examine this assumption in more detail.

Finally, our discussions framed the cooking fuel choice as a binary one, between firewood and LPG. This reflects the reality in the villages, where no household reported using intermediate options such as improved cookstoves; for them the choice was indeed between firewood and LPG. A possible reason for this could be the rollout of national and state schemes, such as the PMUY <sup>3,33,34,43</sup>, to universalise access to clean fuel, LPG in particular. Nevertheless, further research could usefully explore the relationship between improved cookstoves and capabilities in order to understand their potential to ease the transition from firewood to cleaner fuels <sup>44</sup>.

## Methods

### Data collection

A central aim of the study was to chart the perceived relationship between women's wellbeing and their cooking fuels. We used a CA framing to define wellbeing, which also informed our research design. Alkire <sup>45</sup> argues that to evaluate wellbeing, researchers must deeply engage with their participants because wellbeing, in most cases, is hard to quantify. This position is a principal reason behind using a predominantly qualitative approach of inquiry.

For data collection, we used the focus group discussion (FGD) methodology. Marshall and Rossman <sup>46</sup> write, "an individual's attitude and beliefs are socially constructed; they do not form in vacuum" (p. 128), and FGDs are an important tool to explore collective beliefs, perceptions and attitudes <sup>47</sup>. The focus group model is beneficial if the participants share common contextual characteristics <sup>48</sup>. Additionally, since the villages were predominantly either LPG users or firewood users, it appeared that the decisions to switch fuels had a strong social dimension, rather than individual. Thus, we found it appropriate to use FGDs to discuss their fuel use. We purposefully involved only women in these FGDs because cooking was assigned as a responsibility of women in the study villages, and it was important to create a space outside the direct influence of men to allow women to openly express their views regarding the cooking fuels they use.

Prior to data collection for this study, a scoping visit to rural villages in Andhra Pradesh, India was conducted in November 2016. This visit was important to understand the Indian rural context and design the data collection strategy. Different interviewing and FGD methods and questions for data collection were tested, based on which a FGD guide with semi-structured questions was developed for final data collection. All the FGDs were framed in terms of cooking fuel and wellbeing, but the

central capabilities were used as an analytical framework; capabilities were not discussed directly. A copy of the FGD guide used in the study is provided in Supplementary Note 4.

Data was collected from four villages in Chittoor district, Andhra Pradesh from November 2017 to February 2018. The study villages were selected with the help of a local non-governmental organisation, Foundation for Ecological Security, working in the rural energy and environmental management sector. To enable comparison, we needed at least one village with a significant number of households relying on firewood for cooking, and at least one village with a significant number of households who had already transitioned to use predominantly LPG. Two villages (villages 3 and 4) had already made the transition and two villages (villages 1 and 2) used firewood primarily during the time of data collection.

The NGO had prior engagement with the selected villages. Key informants were identified with the help of the NGO. In village 1 and 4, the key informants were the chairpersons of women's groups, established to run environmental awareness programs. In village 2 and 4, the key informants were local community leaders, who have been instrumental in forest conservation in the communities. The selection of the participants was done collectively with local key informants and the NGO, based on the convenience and availability of the participants to participate. The final selection of the participants was done in three stages:

1. A mass meeting with community members (both men and women) in each village was organised, at which, the objective of the project was discussed with the members. As guided by the ethics committee of the lead author's institution, project information sheets, translated into the local language, were distributed to the meeting attendees. Social mapping exercises identified households based on their primary cooking fuels. We thus arrived at a set of firewood users from the firewood using villages, and a set of LPG users from the LPG using villages. It should be noted that those who had transitioned to LPG might also sometimes use firewood; the firewood users on the other hand were unlikely to use LPG, but they had seen others using LPG.
2. We collected the names of the participants who showed interest in participating in the study. Written consent from participants was sought, using consent forms translated into the local language. Then, FGDs were scheduled on the basis of the participants' preferred date and time. This resulted in all FGDs taking place in the evening after 7 pm, when women had finished their cooking and household chores.
3. Although we had achieved a required number of participants after the end of the mass meetings, not everyone turned up on the day. To recruit additional participants for further groups, we employed a snowball sampling technique<sup>46</sup>, in which existing participants were requested to suggest potential participants among their circle of friends and relatives.

We engaged with a total of 70 women, in 10 focus group discussion (FGDs). Six out of 10 FGDs were with firewood users and 4 with LPG users. All the FGDs were moderated by the lead author, which was crucial to ensure consistency and increase coherence across all the FGDs. An interpreter was recruited for translating the discussions from the local language to English and vice versa during the FGDs. To minimise interpreter biases, the interpreter was acquainted with basic research skills and research ethics, which proved to be a critical step for data collection.

During the FGDs, participants were further divided into sub-groups, enabling them to discuss the given topic and respond. One member from each sub-group responded to the FGD questions after discussion in their respective teams. This approach was helpful to address the potential dominance

of some individuals and encourage others to open up. On average, it took around 1.5 hours to complete a FGD. All FGDs were audio-recorded and transcribed for data analysis. The number of groups was determined based on the 'saturation' principle<sup>49</sup>, meaning no significant information would emerge from further data collection. Saturation was reached after six FGDs with firewood users and 4 FGDs with LPG users.

## Data analysis

The firewood and LPG FGDs were analysed separately, using R software<sup>50</sup>. The RQDA package<sup>51</sup> was used to extract references made by participants in relation to the central capabilities. To do so, the cleaned transcripts were loaded into the RQDA package. Then, the transcripts were read and re-read multiple times to identify passages that we interpreted as associated with any of the ten central capabilities, as described in Table 1; these passages were then manually coded as outcomes. Both positive and negative references to capabilities were recorded as outcomes and scored +1 and -1 respectively. The cumulative scores received by each capability were used to plot Figure 1.

The number of outcomes or possible outcomes identified within each capability ranges from one to six. Some passages were coded against more than one capability. For reliability, the authors reviewed and compared the outcomes and the associated capabilities separately. Since the data set is small, no statistical measures were needed to test the inter-rater reliability. After the independent coding, a manual calculation was performed, which showed 84% of the codes were matched. Cases where there was not full initial agreement were dealt with by discussing the discrepancy and arriving at agreement on how to proceed, e.g. by recoding or excluding, which we were able to do in all cases.

At the end of this exercise, two data frames, one each for LPG and firewood users, were created, which contained the cooking fuel type (LPG and firewood), the associated capabilities and the outcomes. The relationships between cooking fuels, capabilities and outcomes are schematically presented for firewood and LPG users respectively in Figure 2 and Figure 3.

Once the data frames were created, we used the tidyverse package<sup>52</sup> for tidying the data and plot the bar charts (Figure 1 and Figure 4). The networkD3 package<sup>53</sup> was used to produce Sankey diagrams (Figure 2 and Figure 3). The ggpubr<sup>54</sup>, htmlwidgets<sup>55</sup> and gridExtra<sup>56</sup> packages were also used to tidy visualisations.

## Data availability

For confidentiality reasons, the raw FGD transcripts are restricted. All the data behind figures are publicly available as source data at <https://doi.org/10.25919/5f6d34f11fa7a>

## Code availability

All the codes used for data analysis and visualisations in this study are publicly available at <https://doi.org/10.25919/5f6d35259e92c>.

## References

- 1 IEA. India Energy Outlook. (International Energy Agency, 2015).
- 2 Kar, A., Pachauri, S., Bailis, R. & Zerriffi, H. Capital cost subsidies through India's Ujjwala cooking gas programme promote rapid adoption of liquefied petroleum gas but not regular use. *Nature Energy* 5, 125-126, doi:10.1038/s41560-019-0536-6 (2020).

- 3 Dabadge, A. Subsidizing connections to the poor. *Nature Energy* **4**, 724-725,  
doi:10.1038/s41560-019-0433-z (2019).
- 4 IEA. Energy Access Outlook 2017: From Poverty to Prosperity. (International Energy Agency,  
Paris, France, 2017).
- 5 Fuso Nerini, F. *et al.* Mapping synergies and trade-offs between energy and the Sustainable  
Development Goals. *Nature Energy* **3**, 10-15, doi:10.1038/s41560-017-0036-5 (2017).
- 6 Rosenberg, M., Armanios, D. E., Aklin, M. & Jaramillo, P. Evidence of gender inequality in  
energy use from a mixed-methods study in India. *Nature Sustainability* **3**, 110-118,  
doi:10.1038/s41893-019-0447-3 (2019).
- 7 Bhallamudi, I. & Lingam, L. Swaying between saving the environment and mitigating  
women's domestic drudgery: India's efforts at addressing clean cooking fuels. *Gender,  
Technology and Development* **23**, 36-54, doi:10.1080/09718524.2019.1587888 (2019).
- 8 Laursen, L. India's energy subsidy slowdown. *Nature Energy* **1**, 1-4,  
doi:10.1038/nenergy.2016.56 (2016).
- 9 Dutta, S. & Banerjee, S. Exposure to Indoor Air Pollution & Women Health: The Situation in  
Urban India. *Environment and Urbanization Asia* **5**, 131-145,  
doi:10.1177/0975425314521545 (2014).
- 10 Alim, M. A. *et al.* Respiratory involvements among women exposed to the smoke of  
traditional biomass fuel and gas fuel in a district of Bangladesh. *Environmental Health and  
Preventive Medicine* **19**, 126-134, doi:10.1007/s12199-013-0364-4 (2014).
- 11 Smith, K. R. *et al.* Millions dead: how do we know and what does it mean? Methods used in  
the comparative risk assessment of household air pollution. *Annu Rev Public Health* **35**, 185-  
206, doi:10.1146/annurev-publhealth-032013-182356 (2014).
- 12 Practical Action. Gender and Livelihoods Impacts of Clean Cookstoves in South Asia.  
*Washington (DC): Global Alliance for Clean Cookstoves (<http://cleancookstoves.org/binarydata/RESOURCE/file/000/000/363-1.pdf>, accessed 17 February 2016)* (2014).
- 13 Pachauri, S. & Rao, N. D. Gender impacts and determinants of energy poverty: are we asking  
the right questions? *Current Opinion in Environmental Sustainability* **5**, 205-215,  
doi:<http://dx.doi.org/10.1016/j.cosust.2013.04.006> (2013).
- 14 Parikh, J. Hardships and health impacts on women due to traditional cooking fuels: A case  
study of Himachal Pradesh, India. *Energy Policy* **39**, 7587-7594,  
doi:10.1016/j.enpol.2011.05.055 (2011).
- 15 Sagar, A. D. Alleviating energy poverty for the world's poor. *Energy Policy* **33**, 1367-1372,  
doi:10.1016/j.enpol.2004.01.001 (2005).
- 16 Sovacool, B. K. The political economy of energy poverty: A review of key challenges. *Energy  
for Sustainable Development* **16**, 272-282, doi:10.1016/j.esd.2012.05.006 (2012).
- 17 Gaye, A. Access to Energy and Human Development. 1-21 (UNDP, 2007).
- 18 Borah, S. Fire Wood Collection: A Back Breaking Work for Tribal Farm Women. *Developments  
in Agricultural and Industrial Ergonomics: Women at Work (Vol. 2)* **1**, 132 (2009).
- 19 Malakar, Y., Greig, C. & van de Fliert, E. Resistance in rejecting solid fuels: Beyond availability  
and adoption in the structural dominations of cooking practices in rural India. *Energy  
Research & Social Science* **46**, 225-235, doi:10.1016/j.erss.2018.07.025 (2018).
- 20 Smith, K. R. & Sagar, A. Making the clean available: Escaping India's Chulha Trap. *Energy  
Policy* **75**, 410-414, doi:10.1016/j.enpol.2014.09.024 (2014).
- 21 Sehgal, R., Ramji, A., Soni, A. & Kumar, A. Going beyond incomes: Dimensions of cooking  
energy transitions in rural India. *Energy* **68**, 470-477,  
doi:<http://dx.doi.org/10.1016/j.energy.2014.01.071> (2014).
- 22 Listo, R. Gender myths in energy poverty literature: A Critical Discourse Analysis. *Energy  
Research & Social Science* **38**, 9-18, doi:10.1016/j.erss.2018.01.010 (2018).
- 23 Sen, A. *Inequality reexamined*. (Russell Sage Foundation ; Oxford [England], 1992).

- 24 Nussbaum, M. C. *Women and human development : the capabilities approach*. (Cambridge, Eng. : New York : Cambridge University Press, 2000).
- 25 Robeyns, I. The Capability Approach: a theoretical survey. *Journal of Human Development* **6**, 93-117, doi:10.1080/146498805200034266 (2005).
- 26 Robeyns, I. The capability approach in practice\*. *Journal of Political Philosophy* **14**, 351-376 (2006).
- 27 Alkire, S. Why the Capability Approach? *Journal of Human Development* **6**, 115-135, doi:10.1080/146498805200034275 (2005).
- 28 Alkire, S. *Valuing freedoms : Sen's capability approach and poverty reduction*. (Oxford ; New York : Oxford University Press, 2002).
- 29 Day, R., Walker, G. & Simcock, N. Conceptualising energy use and energy poverty using a capabilities framework. *Energy Policy* **93**, 255-264, doi:<http://dx.doi.org/10.1016/j.enpol.2016.03.019> (2016).
- 30 Nussbaum, M. C. *Creating Capabilities*. (Harvard University Press, 2011).
- 31 Mehta, S. R. in *Women in the Indian Diaspora: Historical Narratives and Contemporary Challenges* (ed Amba Pande) 15-26 (Springer Singapore, 2018).
- 32 IEA. Energy Poverty: How to make modern energy access universal? , 1-40 (Paris, France, 2010).
- 33 Mani, S., Jain, A., Tripathi, S. & Gould, C. F. The drivers of sustained use of liquified petroleum gas in India. *Nature Energy*, doi:10.1038/s41560-020-0596-7 (2020).
- 34 Gol. *Pradhan Mantri Ujjwala Yojana*, <<http://www.pmujjwalayojana.com/>> (2017).
- 35 Pachauri, S. et al. in *Global Energy Assessment: Toward a Sustainable Future*. (ed Global Energy Assessment Writing Team) Ch. 19, 1401-1458 (2012).
- 36 Broto, V. C. et al. A research agenda for a people-centred approach to energy access in the urbanizing global south. *Nature Energy* **2**, 776-779, doi:10.1038/s41560-017-0007-x (2017).
- 37 Malakar, Y. Studying household decision-making context and cooking fuel transition in rural India. *Energy for Sustainable Development* **43**, 68-74, doi:10.1016/j.esd.2017.12.006 (2018).
- 38 Wickramasinghe, A. Energy access and transition to cleaner cooking fuels and technologies in Sri Lanka: Issues and policy limitations. *Energy Policy* **39**, 7567-7574, doi:<http://dx.doi.org/10.1016/j.enpol.2011.07.032> (2011).
- 39 Viswanathan, B. & Kavi Kumar, K. S. Cooking fuel use patterns in India: 1983–2000. *Energy Policy* **33**, 1021-1036, doi:<http://dx.doi.org/10.1016/j.enpol.2003.11.002> (2005).
- 40 Wolske, K. S., Gillingham, K. T. & Schultz, P. W. Peer influence on household energy behaviours. *Nature Energy* **5**, 202-212, doi:10.1038/s41560-019-0541-9 (2020).
- 41 Herington, M. J., Lant, P. A., Smart, S., Greig, C. & van de Fliert, E. Defection, recruitment and social change in cooking practices: Energy poverty through a social practice lens. *Energy Research & Social Science* **34**, 272-280, doi:10.1016/j.erss.2017.09.001 (2017).
- 42 Jagadish, A. & Dwivedi, P. In the hearth, on the mind: Cultural consensus on fuelwood and cookstoves in the middle Himalayas of India. *Energy Research & Social Science* **37**, 44-51, doi:<https://doi.org/10.1016/j.erss.2017.09.017> (2018).
- 43 Kar, A., Pachauri, S., Bailis, R. & Zerriffi, H. Using sales data to assess cooking gas adoption and the impact of India's Ujjwala programme in rural Karnataka. *Nature Energy* **4**, 806-814, doi:10.1038/s41560-019-0429-8 (2019).
- 44 GACC. *Global Alliance For Clean Cookstoves*, (2015).
- 45 Alkire, S. Choosing Dimensions: The Capability Approach and Multidimensional Poverty. *IDEAS Working Paper Series from RePEc* (2008).
- 46 Marshall, C. & Rossman, G. B. *Designing qualitative research*. Vol. 5th (SAGE, 2011).
- 47 Bryman, A. *Social research methods*. Vol. 3rd (Oxford University Press, 2008).
- 48 Litosseliti, L. *Using focus groups in research*. (London : Continuum, 2003).

- 49 Miles, M. B. & Huberman, A. M. *Qualitative data analysis : an expanded sourcebook / Matthew B. Miles, A. Michael Huberman*. 2nd ed.. edn, (Thousand Oaks, Calif. : Sage Publications, 1994).
- 50 R Core Team. R: A language and environment for statistical computing. (R Foundation for Statistical Computing, Vienna, Austria, 2018).
- 51 Huang, R. RQDA: R-based Qualitative Data Analysis. R package version 0.3.1. (2018).
- 52 Wickham, H. tidyverse: Easily Install and Load the 'Tidyverse'. R package version 1.2.1. (2017).
- 53 Allaire, J. J., Gandrud, C., Russel, K. & Yetman, C. networkD3: D3 JavaScript Network Graphs from R. R package version 0.4. (2017).
- 54 Kassambara, A. ggpubr: 'ggplot2' based pulication ready plots. R package version 0.2.5. (2020).
- 55 Vaidyanathan, R., Xie, Y., Allaire, J. J., Cheng, J. & Russel, K. htmlwidgets: HTML widgets for R. R package version 1.5.1. (2019).
- 56 Auguie, B. gridExtra: Miscellaneous functions for "Gird" graphics. R package version 2.3. (2017).

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## Author contributions

YM designed the overall study, collected the data, performed the data cleaning, wrote the codes for data analysis and produced the figures. YM and RD conceptualised the manuscript, performed manual data analysis, developed the interpretation and wrote, edited and revised the paper.