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LPG as a clean cooking fuel: Adoption, use, and impact in rural India☆

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ABSTRACT

Liquefied petroleum gas (LPG) is by far the most popular clean cooking fuel in rural India, but how rural households use it remains poorly understood. Using the 2014–2015 ACCESS survey with over 8500 households from six energy-poor Indian states, our study reports on results from a comprehensive survey of LPG use in rural India using a holistic approach to understanding the integration of a clean cooking fuel into rural household's energy mixes. There are three principal findings: (i) fuel costs are a critical obstacle to widespread adoption, (ii) fuel stacking is the prevailing norm as few households stop using firewood when adopting LPG, and (iii) both users and non-users have highly positive views of LPG as a convenient and clean cooking fuel. These findings show that expanding LPG use offers great promise in rural India, but affordability prevents a complete transition from traditional biomass to clean cooking fuels.

1. Introduction

Liquefied petroleum gas (LPG) is, by a wide margin, the most popular clean cooking fuel in rural India. At the same time, results from the 2011 Indian Census show that only 11% of rural households use LPG as their primary cooking fuel; the rest rely on burning solid fuels—firewood, coal, and dung—to address their daily cooking and heating needs (Tripathi et al., 2015). Important policy efforts are being made to improve access and adoption of LPG in rural Indian households in hopes of addressing the massive health, economic, and social burdens of widespread solid fuel use. Cooking with solid fuels is recognized as a significant global health hazard, with women and children facing the greatest risks (Lim et al., 2013). There is now strong evidence from field studies and systematic analyses suggesting that clean fuels, as opposed to cleaner improved wood-burning stoves, are necessary to bring air pollution exposure below the World Health Organization standard over the long term (Simon et al., 2014; Pope et al., 2017; Sambandam et al., 2015). The adoption of clean fuels—like LPG, electricity, or ethanol—is a critical first step towards achieving the health benefits suggested by the burden of disease attributable to air pollution exposure resulting from solid fuel combustion for cooking. However, sustained clean fuel use that *displaces* the majority of traditional solid fuel use is paramount to realizing benefits, since even limited solid fuel combustion leads to substantial increased health risk (Johnson and Chiang, 2015).

The burdens of disease (Lim et al., 2013), socio-economic impacts (Kowsari and Zerriffi, 2011; Duflo et al., 2008), environment effects (e.g., accelerated degradation, depletion of local resources (Ghilardi et al., 2009; Masera et al., 2006)), and climate consequences (Bond et al., 2004; Jeuland and Pattanayak, 2012) from solid fuel use around the world are massive. As a result, national transitions to clean fuels can have large multi-sectoral impacts. Through numerous policy initiatives promoting LPG access (*Ujjwala*) and greater subsidies for the poor ("Give it Up"), the Indian government has sought to capitalize on the potential *golden thread* of cooking fuels, which can be linked to 10 Sustainable Development Goals.[1] A recent discussion has highlighted the relationship between clean cooking's multiple objectives (e.g., health, climate, environmental protection, local and women's empowerment), discussing in particular climate versus health benefits (Goldemberg et al., 2018), noting that achieving health goals is sometimes limited by sustainability-oriented objectives to mitigate greenhouse gas emissions. Given the limited net climate impacts from improved wood-burning, Goldemberg et al. (2018) ultimately argue that the health and social benefits of clean cooking fuels merit primary emphasis. At the same time, the ultimate goal may be electric stoves—especially high-efficiency induction stoves—powered by renewable energy, as in Ecuador (Goldemberg et al., 2018). In addition, clean fuels

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like LPG or electricity may offer greater potential climate benefits than improved cookstoves (Rosenthal et al., 2018). Given the pressing need to reduce the burden of disease from air pollution exposure, this study adopts a health-centered framework when considering decisions about household cooking transitions.

Although LPG promises tremendous benefits, researchers still have a limited understanding of its adoption and use in rural households. Prior studies have recognized the importance of factors such as affordability (Cheng and Urpelainen, 2014; Alkon et al., 2016), age of household head and primary cook (Lewis and Pattanayak, 2012), and social factors like religion, caste, and gender (Lewis and Pattanayak, 2012; Bhojvaid et al., 2014; Sehjpal et al., 2014) in determining household decision-making patterns. However, a shared limitation of all these studies is that they focus primarily on the adoption of clean cooking fuels. They do not offer a comprehensive overview of the multiple dimensions of clean cooking fuels: adoption, sustained use, and impact. While the decision to adopt a clean cooking fuel is an important first step, households must also decide how much and to what end they want to use the fuel considering its advantages, disadvantages, availability, and cost. The role that clean cooking fuels play after adoption, and after integration into daily routines, warrants more attention. This study combines detailed investigation into stable (that is, outside of an experimental context where patterns are evolving and subject to intervention removal) household fuel use patterns with a large sample size.

The purpose of this study is to offer a comprehensive assessment of LPG use in rural households of India. Findings from this study come from the 2014–2015 ACCESS survey with 8568 households from 714 villages in six north Indian states, offering a wealth of data on different dimensions of LPG adoption, use, and impact in rural India (Aklin et al., 2016). Importantly, the data presented in this study represent long-term cooking patterns and arrangements. Furthermore, a valuable contribution of this study is its holistic approach to characterizing household cooking fuel mixes. Past analyses—of ACCESS and other large-scale energy access surveys—have focused individually on stove or fuel adoption (Patnaik and Tripathi, 2017), use, or independently on cooking satisfaction (Baquié and Urpelainen, 2017). Furthering these efforts, this study triangulates findings using diverse results of household LPG adoption, fuel use patterns, and perceptions of cooking fuels. In doing so, results deeply describe the integration of LPG into household cooking mixes and move beyond the acknowledgement of fuel stacking realities to push the understanding of its motivations and the specific roles of LPG and secondary solid fuel use in household energy end uses. In doing so, this study offers guidance for clean cooking fuel policies and programs in India and also around the world.

Results can be summarized in three core messages. First, both the cost of LPG connections and the monthly cost of the fuel are crucial obstacles to widespread adoption and use. Second, fuel stacking continues to characterize cooking with LPG in rural India. Fewer than 60% of LPG users consider it their primary cooking arrangement, and even in this group households frequently use solid fuels to cook different dishes. The remaining 40%, in turn, mostly use LPG to prepare tea and snacks. In total, only 4% of LPG-owning households use the fuel exclusively. Finally, LPG is not only a very popular and much appreciated fuel among its users, but even households not using LPG consider it a superior alternative to traditional choices such as firewood and cow dung. Nonetheless, fuel stacking is the norm.

These three central patterns have two important implications for research and practice on clean cooking fuels. The first is that cost, instead of inferior performance, is the critical obstacle to widespread adoption. Access to LPG, through increased connections (where a household acquires a stove and is placed in administrative records), in rural India has been transformed in the last decade: between 2010 and 2013 alone, nearly 45 million new LPG connections were established in India—primarily to rural households—and the nation's official goal is 80% of households cooking with a clean fuel by 2019 (Jain et al., 2015). However, the cost of and access to cylinders (because of still-limited distribution routes) has until now not caught up to the LPG access promotions. As a result, actual LPG use is constrained, leading rural households to continue using potentially health-harming solid fuels.

The second implication is that even if Indian policymakers manage to solve the problems of cost and affordability, fuel stacking remains a fundamental obstacle to better social and health outcomes. India is not alone in this effort; for instance, in the past decade Indonesia transitioned 50 million households' primary cooking fuel from kerosene to LPG (Budya and Arofat, 2011) (see Quinn et al., 2018 for a discussion of 11 clean cooking fuel case studies, including Indonesia, Ghana, and Peru). There is clear demand around the world for continued and increased effort to provide access to clean cooking facilities (Daly and Walton, 2017) but this is just a first step. The long-term benefits from clean fuels, and all efforts to promote clean fuels, depend on *both* the continued use of clean fuels after adoption and the reduction of traditional cooking technologies. Improved understanding of households' established cooking patterns with clean fuels, and motivations for continued solid fuel use after clean fuel adoption, is needed to provide clean fuels that comprehensively address all household energy needs and may be used exclusively in the long term.

2. Literature review

Data analysis is motivated in three steps. First, a description of the need for cleaner cooking. Second, a discussion of the literature on the adoption and use of clean cooking fuels. Finally, a review of the Indian case.

2.1. Limitations of improved wood-burning stoves

Today, one-third of the world's population still relies on solid fuels for cooking and heating. Burning solid fuels in ineffciently in traditional stoves is the leading cause of death for children under the age of 5 and the greatest global environmental health risk. The term household air pollution serves to encompass a range of exposures to air pollution resulting from the combustion of solid fuels, including outdoor exposures near the home and the contribution of prevalent solid fuel combustion for cooking to ambient air pollution (Chafe et al., 2014; Conibear et al., 2018). Furthermore, the term incorporates other exposure sources like space heating, lighting, and non-solid fuels (e.g., kerosene). Implicit in the term household air pollution is that multiple clean energy options may be needed to lower exposure to air pollution. There has been much attention drawn towards interventions to lower air pollution exposure from cooking with solid fuels. Smith and Sagar (2014) term the two central choices *making the available clean* and *making the clean available*. Determining the best path has not been straightforward.

Until recently, most interventions have focused on the adoption and sustained use of improved wood-burning cookstoves—stoves that burn available, free-of-cost firewood efficiently. Hundreds of cookstove designs were engineered and made commercially available globally to promote improved energy efficiency or some form of smoke exhaust ventilation. The variability in cookstove designs responded to differences in cooking styles around the world and also to different approaches to improving combustion efficiency. Detailed discussion of improved cookstove design and performance is available elsewhere (Jetter et al., 2012; Kshirsagar and Vilas, 2014; Mehetre et al., 2017); briefly, there are three principal designs: (i) natural draft cookstoves, which are free-convection driven (the most popular and low-cost); (ii) forced-draft cookstoves, which rely on fans to mix fuel, air, and flame for more complete combustion (the most promising for reducing emissions and the most expensive); and (iii) chimney stoves that focus on venting emissions outside the home (popular in Central and South America). Although improved cookstoves often perform well under laboratory conditions (Jetter et al., 2012)—especially forced-draft