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Cooking Energy Fuel Transition in Rural Bihar: A Comprehensive Review of Household Fuel Choices and the Dynamics of LPG Adoption

Amit Yadav[1],

[1]Research Scholar, Department of Economic Studies &Policy, Central University of South Bihar, Gaya Bihar

Abstract: This review paper explores the patterns and dynamics of cooking energy fuel transitions in rural Bihar, with a particular focus on household decision-making regarding fuel choice and the adoption of LPG. It aims to synthesize existing literature on socio-economic, cultural, environmental, and policy factors influencing energy transitions. By identifying barriers and enablers to LPG adoption, this study seeks to provide a holistic understanding of the challenges and opportunities for promoting cleaner cooking fuels in rural settings. The findings will inform strategies for enhancing energy access and supporting sustainable development goals in Bihar and similar contexts.

Keywords: Cooking Energy Transition, Household Fuel Choice, LPG Adoption, Rural Bihar, Energy Access,Biomass Fuels,Clean Cooking Fuels

Introduction

This chapter offers a thorough analysis of the research on households in urban as well as rural settings, ensuring the switch from traditional Solid Biomass Fuels (SBFs) to clean or modern cooking energy, such as Liquefied Petroleum Gas (LPG) while emphasizing the wide range of theories offered to comprehend the dynamics of this transition. It also offers a more profound knowledge of the transition to clean cooking fuel by summarizing previous studies' positive and negative effects, specifically for rural Indian households. This chapter offers insightful analyses of the complications involved in the switch to clean cooking energy, providing an extensive understanding of its consequences for rural households and the larger socio-economic environment.

1.1 Introduction to Household Fuel Usage in Rural India

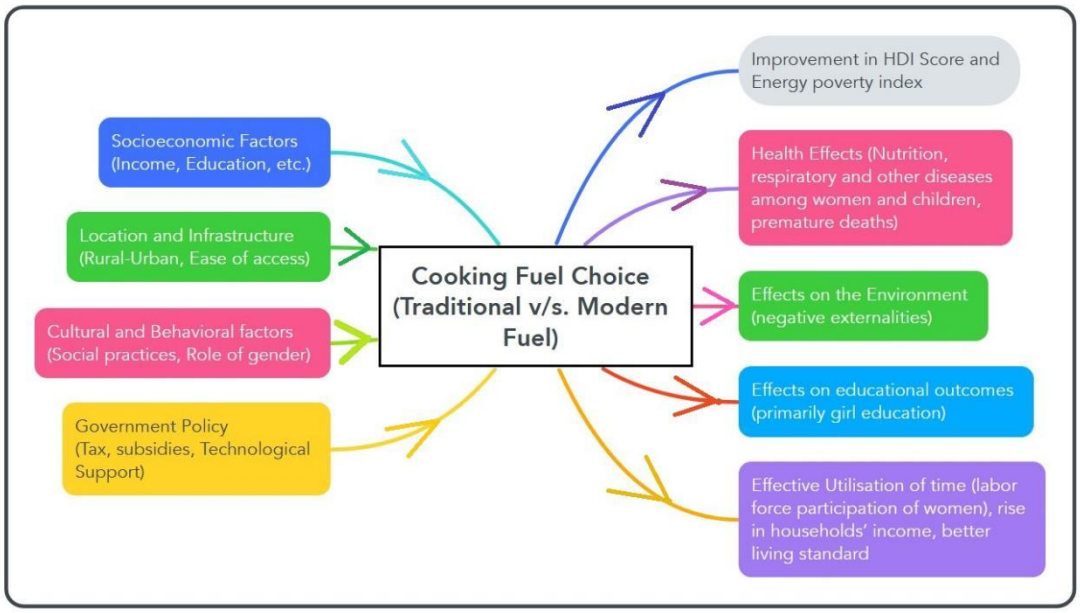
In rural India, household fuel use is rooted in environmental, cultural, and socioeconomic factors. Traditional biomass fuels, such as firewood, cow dung, and agricultural waste, have long been the primary energy sources for cooking in rural regions. Although these fuels are widely available and frequently accessible, using them has serious adverse effects on the environment and human health. Smoke and pollutants from burning biomass can cause respiratory issues, infections within the eyes, and other health problems, especially for women and children who spend more time around cooking stoves. Furthermore, gathering and processing these fuels can be extremely physically demanding and time-consuming.

However, there has been a critical motivation in recent years to move rural people toward more sustainable and clean energy sources, primarily liquefied petroleum gas (LPG). The Pradhan Mantri Ujjwala Yojana (PMUY), which attempts to give women in low-income households free LPG connections, is the most prominent measure the Indian government has launched to promote LPG. In addition to improving health outcomes, this program aims to lessen the environmental effects of using biomass fuel and enhance the general quality of life by cutting down on time spent gathering firewood. Despite these initiatives, many families in rural India still use traditional fuels, making the adoption of LPG challenging. Economic constraints, irregular LPG supplies, and cultural preferences for conventional cooking techniques influence this. Several households utilize a combination of LPG and biomass daily because they view LPG as an additional fuel rather than a substitute. Income inequality makes switching to LPG even more difficult because lower-income households need help to afford the ongoing expenses of LPG refills. Since easy access alone does not ensure persistent adoption, this dichotomy between access and sustained usage constitutes a significant field of research. Census 2011 shows the abysmal condition of fuel choice in Indian households. Though LPG is the most preferred cooking fuel in rural India, only 11% of rural households use LPG as their primary cooking fuel.

1.2 Conceptual Framework of the Study

The conceptual framework for understanding the determinants and effects of using solid biomass cooking energy (such as wood, charcoal, and crop residues) versus LPG (Liquefied Petroleum Gas) can be illustrated (see Figure 1.1) around several key dimensions that are following.

Figure 1.1 The Conceptual Framework



Source: Drawn from the review of the studies

1.3 Economic and Income Factors Influencing Fuel Choice

Literature suggests that income and energy poverty share close ties in urban areas. In contrast, rural areas are still aspiring to abandon the usage of biomass and to make a shift towards LPG as their primary source of cooking energy. For example, Khandeker et al. (2012) found that the pattern applies to urban areas but not to rural India. Hanna and Olivia (2015) exploited an experiment by Banerjee et al. (2011) that aimed to improve the livelihoods of people with low incomes in Murshidabad, West Bengal. The experiment targeted about 800 households, randomly assigning around half to an asset transfer program administered by Bandhan, a local NGO. It appears contrary to the energy ladder hypothesis. However, several studies substantiate the energy ladder hypothesis but favor fuel stacking. These studies question the amount and habitual usage of LPG as many households are still stuck with traditional solid biomass fuel as their primary source of cooking energy because of easy access, lower price, difficulties in refilling cylinders, and lack of awareness (Kar et al., 2019; Swain & Mishra, 2020). Swarup and Rao (2015) used data from three rounds of NSSO's household consumer expenditure surveys- (July 1993-94), the 61st (July 2004- June 2005), and the 66th round (July 2009-June 2010) approving multiple fuels strategy or "fuel stacking" primarily by rural households of India. Daripa and Dinda (2022) studied the hurdles in Fuel Choice and Consumption in Rural India using NSSO data, and showed that income does not appear as an essential determinant of firewood choice decisions; instead, it significantly determines quantity consumption.

1.4 Policy Interventions and Their Impact on LPG Adoption

The study by Mani et al. (2020), using panel data from rural households in six central states of India from 2014–2015 and 2018, assessed the determinants of cooking energy transition from solid fuels to LPG. Ranjan and Singh (2020) argued that though PMUY has successfully made its reach to 80 million new connections to the BPL households since its launch in 2018, they brought out evidence that a considerable number of inactive LPG connections, which continue to increase— from 35.8 million inactive connections in the country in 2017 to 43.2 million in 2019. In another study, Gupta and Pelli (2021) examined the two

rounds (61st and 66th) of NSSO data and attempted to establish a causal link between electrification and adopting LPG as cooking fuel in rural India. They found that electrification decreased the probability of adopting LPG and increased the probability of adopting biomass as cooking fuel in rural India. They argued that electrification brings an additional financial burden to rural households' finances. Meanwhile, biomass is available for these households at almost no cost. It pushes them down the energy ladder.

Cheng and Urpelainen (2014) studied fuel stacking in India intertemporally, and in this endeavor, they analyzed India's National Sample Survey data between 1987 and 2010. They found a decline in fuel stacking in lighting, as people replaced electricity with kerosene, but increasing in cooking, as LPG does not substitute the traditional biomass. They applied a two-stage statistical model to analyze individual households' decisions regarding fuel stacking. They concluded that there was a negative relationship between high household income and fuel stacking for lighting. However, they found an increase in fuel stacking with the rise in income in the case of cooking energy. Such startling findings sought for major positive shock through policy intervention.

On the other hand, Akter et al. (2023) used the ACCESS data and found contradictory results. They found a positive effect of an improvement in the quality and reliability of electricity on LPG adoption and use, as well as non-adoption of traditional cooking fuel. They provide a rationale for improvement in economic well-being behind this switch. Such contradictions are not unusual when India's development process is in transition. Swarup and Rao (2015) found that usage of solid fuels declines with the rise in income in urban areas, whereas it shows income neutrality in rural households; that is, Households in the high-income strata show limited aversion to using solid fuels in rural areas.

Accessing and using modern energy sources is an important Sustainable Development Goal (SDG-7). The Movement towards a higher energy ladder or shifting towards clean energy sources in household kitchens is essential in discussing people's living standards in an economy. A high proportion of such households potentially raises productivity and strengthens the socio-economic development of the economy. Chindarkar et al. (2021) in their study found that the households' economic status positively determines the Willingness to pay for the exclusive use of LPG, i.e., households with irregular cash flows (captured by type of primary occupation) are less likely to pay for the exclusive use of LPG compared to households with regular cash flows. It also means that traditional solid cooking fuels are inferior goods whose consumption is likely to shrink with the rise in household income. Sharma and Dash (2022) used primary data collected by the Access to Clean Cooking Energy and Electricity- Survey of States (ACCESS) 2014-15. They applied the Multinomial logit model (MNL) to identify the determinants of household cooking energy preferences in India. They found that households with regular and fixed sources of income are less likely to use solid fuels. They also conducted locational analysis and indicated that people prefer traditional fuels in areas with high forest cover. Sadath and Acharya (2018) used IHDS data to use a multi-dimensional approach to measure energy poverty. Their research highlights a noteworthy trend: As economic development progresses, there is an evident decline in energy poverty, with this correlation strengthening over time.

1.5 Education as Catalysts for Clean Energy Transition

Interestingly, among the various factors contributing to economic development, education emerges as a particularly potent force in alleviating energy poverty, surpassing the impact of income. Furthermore, the study underscores the close association between energy poverty and socio-economic disadvantage in India. Specifically, it notes that marginalized communities such as Dalits and Adivasis experience disproportionately higher levels of energy poverty and struggle to catch up with the national average in reducing this disparity. Additionally, the research underscores a disparity between urban and rural areas, with urban regions exhibiting lower levels of energy poverty than their rural counterparts. Eradication of energy poverty shares a close relationship with the improved Human Development Indicator (HDI). According to the World Energy Outlook 2004, the increase in HDI scores at lower energy and electricity consumption levels is more rapid than at higher levels. It means that for poor countries, even modest energy and electricity consumption increases lead to more significant improvements in human development. Sankhyayan and Dasgupta (2019) used various rounds of NSSO data and estimated a positive correlation between usages of LPG and HDI in Indian states. Their finding suggests that states with a higher share of households using LPG also score high on HDI. They also found that the transition from the traditional source of cooking energy to LPG is costly, which makes the movement difficult. A higher HDI score implies a better education, health, and income.

Pandey and Chaubal (2011) in rural India and Yonas Alem et al. (2016), in their empirical study in urban Ethiopia, found education a vital determinant of households' cooking fuel choice. Gould and Urpelainen (2020) surveyed 10000 households from Kerala and Rajasthan and examined the role of education and attitudinal changes of people towards adoption of LPG. They found that education leads to LPG adoption but not through attitudinal changes. Adoption of LPG in households' kitchens potentially disengages children from the collection of firewood and may substitute their time with attending schools, which subsequently adds human capital (Nankhuni & Findeis, 2004; Ndiritu & Nyangena, 2011; Levison et al., 2018; Frempong et al. 2021). O'Brien et al. (2021) found that if a household relies on fuelwood as the primary source of cooking, the probability of a child attending school in that household decreases by 84 percent in Vietnam. Moreover, Biswas and Das (2022), in their study in rural India, found detrimental effects of time spent on solid fuel collection and educational outcomes, including learning outcomes.

1.6 Environmental and Health Impacts of Biomass Use

Smoke from solid fuel used for cooking and other household activities is the largest source of ambient air pollution. Solid Biomass for cooking is the main contributor to air pollution and disease in developing countries. For example, in their scientific study, Salvi and Barnes (2009) found that exposure to biomass smoke is the most significant risk factor for Chronic obstructive pulmonary disease (COPD) globally. Gupta (2019) analyzed data from "WHO Survey of Global Ageing and Adult Health (WHO-SAGE 2007-2008)" in his study and established a relationship between solid fuel use and lung obstruction primarily among women members of households in India. He further argued that the negative externality the neighboring households created also affects the health of people who use clean cooking fuels. Continuous exposure to solid biomass

fuel smoke is associated with disease burden and mortality of household members, especially of women and children. Rao et al. (2021) have found that 20–50% of the pollutants in ambient air originate from indoor solid fuel combustion. smoke from burning Biomass within and around their houses and by affluent urban households with higher consumption emissions per capita. Sen et al. (2023) utilized data from the nationally representative Multiple Indicator Cluster Surveys conducted between 2017 and 2019 in 15 developing countries, encompassing three countries from South Asia and twelve from Sub-Saharan Africa, and evaluated the relationship between energy poverty and child disability.

Chafe et al. (2021) estimated the proportion and concentrations of particulate matter in household cooking with solid fuels for the years 1990, 2005, and 2010 in 170 countries and argued that lower-income rural households are more vulnerable to face mortality risks mainly from household air pollution caused by their use of biomass-burning cookstoves. In India, Ames et al. (2020) collected primary data from 587 families, including 632 women, and studied the effects of biomass used as cooking fuel on rural women's health in southern India. These women reported the harmful effects of fuel use on their health. Chandyo (2023) measured the association between exposure to household biomass fuel in infancy and leukocyte telomere length (LTL)[1] at 18–23 months of age among 497 children from Bhaktapur, Nepal. Chronic exposure to HAP is associated with shorter telomere length in adults. Naturally, telomeres get shortened with age. Shorter telomeres refer to an increase in the likelihood of incidence of diseases and reduced survival.

Moreover, Owili et al. (2017) investigated the association between cooking fuel and the risk of under-five mortality in Sub-Saharan Africa (SSA) using the Demographic Health Survey data of 23 SSA countries (n = 783,691) and found that the use of charcoal and biomass was associated with the risk of under-five mortality in SSA. Naz et al. (2016) studied the National Family and Health Survey (NFHS) over the period 1992–2006 (a total of 166,382 children). They found that using cooking fuel in the household is associated with an increased risk of mortality in children under five years.

1.7 Gender Dimensions in Fuel Choice and Usage

Nazif-Muñoz et al. (2020) used the 2011–2012 Ghana's Multiple Indicator Cluster Surveys–UNICEF (N = 3326 children; 3–4 years) and established that Solid Fuel Use was associated with developmental delays in Ghanaian girls. The finding indicates gender disparities in susceptibility to indoor pollution. The above points invite the attention of policymakers and society to intervene and spread awareness to obliterate households' indoor air pollution.

In recent decades, many researchers across the globe have conducted substantial research on the gender dimension of using solid biomass as the primary energy source. These studies seek the attention of policymakers to encourage women's role in household decision-making and promote their engagement in outdoor economic activities. The gender viewpoint probes how individuals' economic opportunities, social positioning, roles, and social relationships are shaped and influenced by their gender. According to the Time Use Survey 2019, married women in India spend 222.5 minutes cooking daily, while men spend only 4.8

[1] Chandyo, R. K., Schwinger, C., Kvestad, I., Ulak, M., Ranjitkar, S., Shrestha, M., ... & Strand, T. A. (2023). The association between household biomass fuel use and leukocyte telomere length among toddlers in Bhaktapur, Nepal. *Journal of Exposure Science & Environmental Epidemiology*, *33*(3), 448-454.

minutes daily. It shows that women in India spend 46.2 times more time cooking than married men. Comparing the Time Use Survey 1998 (Comprises six states of India) and 2019 (All-India), the allocation of time in cooking has increased from 192.9 minutes per day (in 1998) to 222.5 minutes per day, whereas it has come down from 5.1 minutes per day (in 1998) for men to 4.8 minutes per day. The figures do not indicate only the social positioning of women but also the rigidity of socio-cultural norms in Indian society.

Moreover, children in a household spend more time with their mothers, thus also exposed to indoor air pollution. Gould and Urpelainen (2019) found that the likelihood of adoption of LPG is associated with women's participation in household decision-making. Taking a deviation, Afridi et al. (2022) conducted a randomized control trial experiment in a district in India to evaluate the impact of information on LPG adoption by rural households. To achieve their objective, they divided randomly selected villages of the chosen district into three groups. They intervened in the first group by providing information about the health benefits of LPG, health benefits, and subsidies for procurement of LPG to the second group, and they controlled the third group. They found that the second group succeeded in saving only five minutes in cooking, while they observed no significant change in the first group. Though the information campaign seemed ineffective, Williams et al. (2020) and Fandiño-Del-Rio et al. (2022) found that providing LPG stoves and cylinders for free was effective in Peru. Williams et al. (2020) examined data collected from Peru through a randomized control trial applied to 180 women aged 25-64. In the trial, the treatment group of 90 women was provided with LPG stoves, unrestrained LPG cylinders for a year, and training for LPG use. They found that, on average, the treatment group saved 5.8 hours per week on cooking and collection of biomass. Fandiño-Del-Rio et al. (2022) parallel collected data on household air pollution levels from the households of the same treatment group and found a sharp reduction in the pollution level even below the 24-hour World Health Organization air quality guidelines. Though the intervention is costly, i.e., free provisioning of LPG to the households, it provides essential insights to the policymakers. Further, Choudhury and Desai (2020) used the Indian Human Development Survey (IHDS), a panel survey of over 41,000 households conducted in two waves in 2004-05 and 2011–12, respectively, show that among the wealthiest quintile, only about 40 percent of the households rely solely on clean fuel. They also explored the gender dimension of using cooking fuel. For example, Vyas et al. (2021) used the Survey of Rural Sanitation and Solid Fuel Use (RSFU), 2018, and primary quantitative and qualitative data collected from the rural parts of four north Indian states: Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh and blames the patriarchal gender norms and attitudes are responsible factors behind the pervasive use of solid fuels in this region. They further argued that the low status of women in society restricts their participation in economic activities beyond the boundaries of their homes. Su and Azam (2023) analyzed the Indian Time Survey, 2019, and found that LPG reduces cooking time and increases employment among married women. Daripa and Dinda (2022) also found that the decline in biomass consumption is significantly affected by education and in women-headed households. In one of the remarkable findings, Kishore and Spears (2014) considered the sex of the first child as a proxy measure for women's status and argued that son preference conveys higher status to women whose first child is male.

Srinivasan and Carattini (2020) used various rounds of NSSO's Consumer Expenditure surveys (from 1983 up till 2011-12), Access to Clean Cooking Energy and Electricity Survey of States (ACCESS), and IHDS (2005-06 and 20111-12) examined the role of social spillovers on cooking fuel choice and usage among Indian households. They found an intimate linkage between people's association with certain groups or organizations and LPG adoption. They argued that people in a social network share information about the usage of LPG and its associated benefits. Chindarkar et al. (2021) used 'Access to Clean Cooking Energy and Electricity: Survey of States (2018)' (ACCESS, 2018)[2] data in their study and argued the dominance of the economic status of the households over various socio-demographic factors in determining the Willingness to Pay (WTP) for adoption of LPG.

Though they found a positive and statistically significant association between households' size and willingness to Pay for LPG, they did not find any significant impact of participation of women in household decision-making, the household head's education, and the respondent's caste and religion on their WTP. Kuo and Azam (2018) examined the cooking fuel choice behavior of the households in rural and urban India individually, using the IHDS data (2004-05 and 2011-12) and found that in rural areas, households from marginalized communities, including SCs, STs, and OBCs, are more inclined to exclusively rely on unclean fuel, in contrast to households from the non-Muslim others group. Furthermore, these disadvantaged households in rural areas are less prone to using solely clean fuel or proper cooking stacks compared to their non-Muslim counterparts. Conversely, in urban settings, SC/ST households are more likely to resort to improper cooking stacks than non-Muslim households. It is crucial to note that, akin to rural areas, households from marginalized backgrounds, such as SC/STs and OBCs, are more predisposed to using only unclean fuel and less likely to adopt clean fuel alternatives when compared to households from the non-Muslim other group.

Soni and Chatterjee (2023) analyzed IHDS, a household-level panel data, to uncover the factors influencing the adoption of clean cooking technologies and the sustained use of clean fuels in India. By investigating the interplay between household energy choices, institutional dynamics, and social capital, they adopted a dual approach: they utilized logistic regression analysis to investigate the adoption of stove technologies. Their findings reveal that active participation in local community organizations and trust in local governance positively correlate with adopting stove technologies and expenditure on Liquefied Petroleum Gas (LPG). They also found that female education and their involvement in women-led networks emerge as significant catalysts in driving fuel adoption among households.

Khanwilkar et al. (2021) examined the usage of LPG among tribal and socially backward communities living in the Central Indian Highlands Landscape (CIHL). They collected data from 4994 tribal households from 500 villages and found a marginal switch towards LPG. These households are beneficiaries of PMUY. Because these households are located within the forest, the abundance of Biomass prevents them from adopting LPG as their cooking fuel. Additionally, Patil et al. (2021), in their qualitative study conducted on

[2] The data is a survey of 9072 rural households from six states, 54 districts, and 756 villages. The six states covered are – Bihar, Jharkhand, Madhya Pradesh, Odisha, Uttar Pradesh, and West Bengal.

tribal communities in the Pune district, argue against increasing LPG subsidy, which might lead to replacing Biomass with LPG.

Conclusion

The review paper highlights the harmful consequences of using Biomass as primary cooking fuel, primarily for women and children. Such consequences manifest in low human capital generation, poor health outcomes, a rise in mortality risk, and a reduction in women's labor force participation. The literature suggests that the PMUY is a successful scheme to the extent that it has reached out to the dwellings of the forest. Literature suggests that the major challenge with the scheme is that access to LPG is not translated into sustained usage. It is also evident that poor adoption of LPG is a distinct feature of rural India due to income neutrality. Therefore, the demand side bottleneck in adopting LPG as the primary cooking fuel in rural India and Bihar persists.

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