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Households' Clean Cooking Fuel Poverty: Testing the Energy-Ladder Hypothesis in the Case of Bangladesh

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ABSTRACT

The study explores clean cooking fuel poverty in Bangladeshi households based on the energy ladder hypothesis stating that as income increases, households switch towards cleaner cooking fuels. Data from the Bangladesh Demographic and Household Survey (BDHS) 2017-18 reveals that 20.45% of households use advanced or cleaner cooking fuels, while a majority (79.23%) still rely on primitive or traditional cooking fuels. Electricity is used by a very small percentage (0.57%), while LPG is used by a slightly higher proportion (6.96%). Biogas usage is minimal (0.11%), and a small percentage (0.03%) still relies on kerosene. Wood is the dominant fuel (46.25%), and other minor sources include charcoal (0.10%), straw/shrubs/grass (0.63%), agricultural crop residues (25.96%), and animal dung (6.39%). The results reveal that only a small proportion of households (20.45%) are classified as "clean cooking fuel non-poor," indicating a limited adoption of cleaner cooking technologies in Bangladesh. Further analysis indicates a gradual increase in clean cooking fuel usage as wealth status improves. Only 0.25% of the poorest households use clean fuels, while the percentage increases to 0.68% in the "poorer" category, 3.92% in the "middle" wealth category, and 24.51% in the "richer" category. Among the wealthiest households, 70.64% use clean cooking fuels. The study highlights the urgent need for policymakers in Bangladesh to address clean cooking fuel poverty by implementing measures like subsidies, awareness campaigns, and infrastructure development to promote cleaner cooking technologies, thereby improving public health and environmental sustainability.

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1. Introduction

Energy is a fundamental component of economic and social development, playing a critical role in the provision of health and education services as well as meeting basic human needs such as food and shelter (IEA, 2010). Energy is mostly obtained either from primitive or traditional or from modern or advanced sources. The sources of energy like, firewood, charcoal, crop residues, and animal waste, (are obtained from the natural environment) hence, are also recognized as biomass. On the other hand, the energy sources, like, kerosene oil, liquified petroleum gas (LPG), and electricity, are together classified as modern or industrial or commercial sources of energy (Leach, 1987). The production and productivity outcome of modern energy services is not unsubstantial, because consumption of energy leads toward to lifestyle changes, technological advancements, and better social services relating to modern education and to basic healthcare.

Furthermore, the lives of rural women and children (who typically spend a significant amount of time gathering straw, dung, and firewood to cook meals and heat their rooms) could greatly be improved by increasing access to modern fuels (particularly to gas). Significant contribution to carbon emissions due to the indiscriminate use of firewood as a cooking fuel is very well known (Bailis, Chatellier, & Ghilardi, 2012). Similarly, the detrimental impact of traditional fuels on human and environmental health also signify the importance of using advanced fuels to improve health, protect the environment, and to progress socio-economic development. Households' energy use, (in qualitative terms), has association with sustainable development (AGECC, 2010). Inadequate, unreliable access to, and high cost of clean fuel stand as the main reasons behind the extensive use of traditional fuels in developing countries, with richer households tend to use electricity and LPG, while low-income families using fuelwood, dung, and crop residue (Behera, Jeetendra, & Ali, 2015).

The energy ladder model suggests households' transition from the use of solid fuels to clean fuels (such as natural gas and electricity) in response to higher income and other factors (Leach, 1975). Households' transition from the use of traditional (non-clean) fuels to modern (clean) fuels is mainly triggered through income and by fuel prices (Rahut, Ali, & Behera, 2017). A rise in income is also associated to change in the type of fuel consumed, preferably switching to the clean fuels (Hills, 1994). Households with low income are tend to use non-clean fuels that are detrimental to the health of the individuals as well as to that of the environment (Holdren et al., 2000; Rehfuess, Mehta, & Prüss-Üstün, 2006). The households tend to switch to cleaner fuels as a results of rising income level (Masera, Saatkamp, & Kammen, 2000; Nansaior, Patanothai, Rambo, & Simaraks, 2011).

Bank (2000) has identified the major factors impacting the energy demand. Households' energy utilization is a function of the socio-demographic factors, such as the size and income of the household incentivize or disincentivize for the use of energy (Biesiot & Noorman, 1999; Gatersleben, Steg, & Vlek, 2002; Moll et al., 2005; Vringer & Blok, 1995).

Discrepancies are there between high and low-income groups within a country and across countries regarding the use of household resources (Pachauri, Mueller, Kemmler, & Spreng, 2004). The traditional energy ladder hypothesis narrates that with increasing income and awareness, the households gradually transit from non-clean fuels to cleaner fuels (Leach, 1975, 1992). Empirically, a number of studies have validated the changing fuel type associated with the changing income levels (Behera & Ali, 2016; Daioglou, Van Ruijven, & Van Vuuren, 2012; Khandker, Barnes, & Samad, 2012; Rao & Reddy, 2007).

However, some studies have also confirmed the non-validity of the energy ladder hypothesis (Huang, 2015; Masera et al., 2000; Nansaior et al., 2011). Wealth or assets have a vital place (as a variable) in the energy choice model, it is because that some studies have evidenced the role of wealth in the clean energy choice decisions of the households (Heltberg, 2004; Mensah & Adu, 2015; Rahut et al., 2017). The effect of wealth in the clean energy choice decisions of the households lies in fact in its role in increasing affordability. A following table summarizes the reviews of some previously conducted studies.

Table 1
Literature Review Matrix

Study	Economy understudy	Dependent variable	Independent variable	Research Findings
Mekonnen and Köhlin (2009)	Seven major cities of Ethiopia	Energy fuel sources	Price, income, expenditure, family size, and education	Households continue to turn to different fuel-use (fuel stacking) approaches as their income rises
Das, De Groote, and Behera (2014)	Bhutan	Energy choices	Age, education, gender, household size, distance to market	Better-educated households with higher incomes and urban households are at a greater risk of switching to modern energy and traditional fuels are highly used among poorer.
Assa, Maonga, and Gebremariam (2015)	Malawi	Choice of fuel for cooking	Location of residence, education, income, age	Rural residents have the largest influence on firewood use and are the least likely to have a beneficial effect of using modern fuels for cooking
Behera and Ali (2016)	sub-Saharan Africa	Fuels for cooking	Gender, area, education, wealth	A substantial portion of households use traditional fuel for heating, and a small amount of their households use modern fuel instead.
Zou and Luo (2019)	China	Energy consumption	Age, gender, education, household size, area, health	The strong economic position of rural households helps reduce the intake of biomass
Punyu and Jamir (2018)	Nagaland	Energy consumption	Age, income, gender, education, household size, income, occupation	Households have a combination of several fuel products, which means that access to modern fuels has not replaced traditional fuels
Ali, Mottaleb, and Aryal (2019)	Pakistan	Cooking-fuel use	Education, income, physical and financial assets	Households with more human, physical, and financial capital are more agreeing to use clean fuels and are less willing to use traditional fuels for cooking

The existing literature on clean cooking fuel poverty has provided valuable insights into the prevalence of the issue and its association with household wealth status. However, there remains a research gap in several critical areas:

- limited exploration of clean cooking fuel poverty within Bangladesh, which could provide a more nuanced understanding of the unique challenges faced by country
- insufficient investigation into the specific drivers influencing households' decisions to adopt cleaner cooking technologies
- insufficient analysis of the affordability and accessibility of clean cooking technologies for low-income households
- scarcity of research on the effect of households' socioeconomic variations on transitioning to cleaner cooking fuels

The study explores clean cooking fuel poverty in Bangladeshi households based on the energy ladder hypothesis, which posits that as income increases, households transition towards cleaner cooking fuels. By addressing the above given research gaps, the current study can contribute to a more comprehensive understanding of clean cooking fuel poverty in Bangladesh and inform evidence-based policies and interventions to improve the overall well-being of households, public health, and environmental sustainability. Hence, the current study intends to bridge the research gap with respect to the above given points.

2. Theoretical Framework

2.1 Households' Cooking Fuel Theory

Fuel accessibility, affordability and convenience strongly influence a household's fuel choice, along with the economic and technical choices of a household coupled with the social and cultural realities (Sepp, 2014). For instance, in many households, cooking with fuelwood is so deeply rooted in culture that other fuels have little appeal, although they might provide recognizable health and economic benefits.

2.2 A Classification of Energy Sources for Cooking

Generally, energy sources are classified as primitive or traditional or non-clean and as advanced or modern or clean fuels. Non-clean fuels are in raw form, while clean fuels are technologically processed (Smith, Rogers, & Cowlin, 2005). Conventional fuel sources, such as firewood, plant residues, and animal dung, are typically solid and biomass in nature. The selection of conventional domestic fuel is contingent upon the context of interest, culture, geography, and environment. In comparison with the clean fuels (such as electricity, kerosene, and LPG), the non-clean fuels (including charcoal briquettes, animal dung, firewood, and plant residues) are responsible for more harmful gaseous emissions (Fischer, 2001). Modern or clean fuels are considered safer, more efficient, and more sustainable in comparison to non-clear or traditional fuels (Birol, 2007; Goldemberg & Coelho, 2004). Although kerosene oil, liquified petroleum gas, electricity, are considered as clean or modern fuels (Barnes, Singh, & Shi, 2010) but these fuels are more costly than the traditional fuels.

Many traditional fuels, such as wood and animal dung, are freely obtained from nature (Hosier & Dowd, 1987). Typical use of the non-clean fuels are by the economically disadvantaged (Arnold, Köhlin, & Persson, 2006). Conversely, those who are more affluent can purchase any type of fuel, despite the higher costs. The wealth people are not constrained by the cost of energy sources as they have greater financial resources. However, as household income increases, society becomes more reliant on modern fuels and less reliant on traditional fuels (Arnold et al., 2006; Hosier & Dowd, 1987). The rising cost of modern fuels, which are typically commercially sold, impacts the consumption of these fuels (Aweto, 1995). Clearly, financial income is one factor that impacts a household's ability to afford energy (Karekezi & Majoro, 2002; Suliman, 2010).

2.3 Classification of Energy Sources for Cooking

Table 2

Categories of cooking fuel	**Sub-categories of cooking fuel**
Advanced Fuels	*Electricity* *LPG* *Natural gas* *Biogas*
Transition Fuels	*Kerosene* *Charcoal*
Primitive Fuels	*Wood* *Straw/shrubs/grass* *Agricultural crop* *Animal dung*

2.4 The Energy Ladder Model

The model of the energy ladder postulates that households replicate the behavior of a utility that maximizes neoclassical customers, signifying that they will transition to more advanced energy carriers as their income rises in order to maximize their utility (Hosier & Dowd, 1987). During the energy transition process, fuel switching is a pivotal concept, which refers to the substitution of one fuel with another. Similarly, transitioning to a new fuel implies a move away from the previously employed fuel (Heltberg, 2005). The fuels on the energy ladder are arranged based on physical characteristics such as cleanliness, ease of use, speed of cooking, and efficiency, in accordance with household preferences (Hiemstra-Van der Horst & Hovorka, 2008). As families attain socioeconomic status, they relinquish inefficient, less costly, and more polluting technologies and make the shift from universal reliance on biomass fuels to second-phase transition fuels such as kerosene, coal, and charcoal. In the final phase, households convert to fuels like LPG and electricity (Heltberg, 2004).

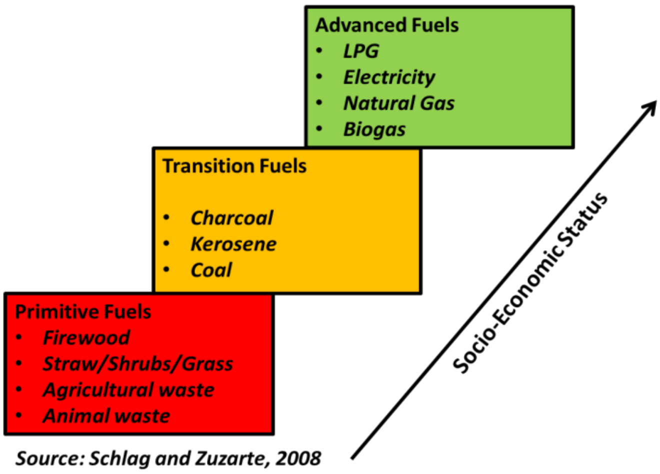

Figure 1: The Energy Ladder Model

The diagram (figure 1) displays the energy ladder hypothesis, (see the left-hand side in Figure) which indicates that as the income increase, people move toward the cleaner source of energy for the purpose of cooking. Traditional fuel is less expensive, even freely collected from nature; meanwhile, modern fuel is commercial energy. Consequently, low income households tend to use wood, dung and other biomass instead of LPG and electricity (Reddy & Srinivas, 2009).

2.5 Operationalization of Clean Cooking Fuel Poverty

The present study has operationalized the concept of clean cooking fuel poverty in the way as given in the following table 3. The households using advanced or clean sources of fuel were considered as the clean fuel non-poor, while the household using the rest of the sources of fuel for cooking were treated as the clean fuel poor.

Table 3
Measuring Clean Cooking Fuel Poverty

Status of Clean Cooking Fuel Poverty	***Description***
Clean Cooking Fuel Non-Poor	Households are considered clean cooking fuel non-poor if they are using any of the following source as a primary source of fuel for cooking: Electricity, LPG, Natural gas, Biogas
Clean Cooking Fuel Poor	Households are considered clean cooking fuel poor if they are using any of the following source as a primary source of fuel for cooking: Kerosene, Charcoal, Wood, Straw/shrubs/grass, Agricultural crop, Animal dung

3. Results and Discussion

3.1 Advanced, Transition, and Primitive Fuels Use by the Households in Bangladesh

Based on the provided data from the Bangladesh Demographic and Household Survey (BDHS), we can interpret the results regarding the households' clean cooking fuel poverty in Bangladesh. The figure 2 classifies the types of cooking fuels used by households into three categories: Advanced Fuels, Transition Fuels, and Primitive Fuels, along with their respective percentages.

Households that use advanced and cleaner cooking fuels are 20.45%. This percentage indicates that a relatively smaller proportion of households in Bangladesh have adopted cleaner and more efficient cooking technologies. Advanced Fuels may include options like LPG, electricity, biogas, or other clean and modern fuels that contribute to reducing indoor air pollution and environmental impacts.

The Transition fuels category consists of households that are in the process of transitioning from traditional or primitive cooking fuels to cleaner alternatives. This fuel type includes the fuels like, kerosene and charcoal. The low percentage (0.12%) suggests that only a very small number of households are in this transitional phase. Such households might be using slightly cleaner options compared to primitive fuels but have not fully switched to advanced and cleaner cooking fuels yet.

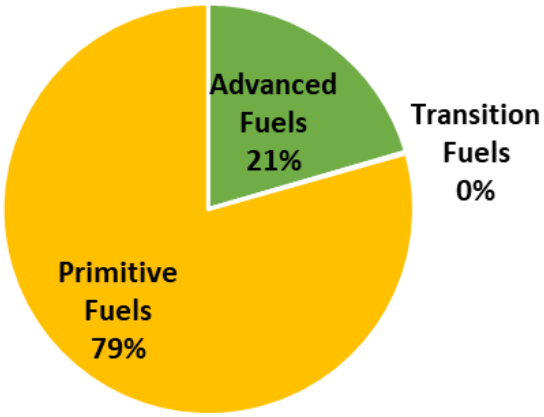

Figure 2: Cooking Fuel Use in Bangladesh by Type of Fuel

A clear majority of households in Bangladesh, (with 79.23%) is using primitive or traditional cooking fuels. Primitive fuels include solid biomass fuels like wood, agricultural crop residues, and animal dung, as well as other traditional options. Reliance on these fuels leads to significant indoor air pollution and environmental degradation.

3.2 Advanced, Transition, and Primitive Fuels Use in Bangladesh: A Further Exploration

Based on the provided data from the Bangladesh Demographic and Household Survey (BDHS), we can interpret the results regarding the households' clean cooking fuel poverty in Bangladesh. The given pie chart (figure 3) further disaggregates the households' use of cooking fuel based on the three already explained categories, i.e., advanced, transition, and primitive fuels use in Bangladesh.

A very small percentage of households (0.57%) rely on electricity as their primary cooking fuel. Electricity is generally considered a clean cooking fuel option, but its low prevalence might be due to factors such as limited access to electricity in certain areas or the relatively higher cost of using electricity for cooking. A small but slightly higher proportion of households (6.96%) use LPG (liquefied petroleum gas) for cooking. LPG is a cleaner alternative to traditional fuels like wood or crop residues, and its use can significantly reduce indoor air pollution and associated health risks. Natural gas usage is relatively more common, with 12.80% of households relying on it for cooking. Natural gas is another clean fuel option that is commonly available in urban areas and some parts of rural regions with gas pipeline infrastructure. Biogas usage is minimal, with only 0.11% of households utilizing this clean cooking fuel source. Biogas is produced from organic waste and can be an environmentally friendly and sustainable option for cooking.

A very small percentage of households (0.03%) still rely on kerosene for cooking. Kerosene is considered a less clean option compared to the alternatives mentioned above and can lead to indoor air pollution and health issues. Similarly, a small proportion of households (0.10%) use charcoal as a cooking fuel. Charcoal is a solid biomass fuel and might contribute to indoor air pollution and deforestation.

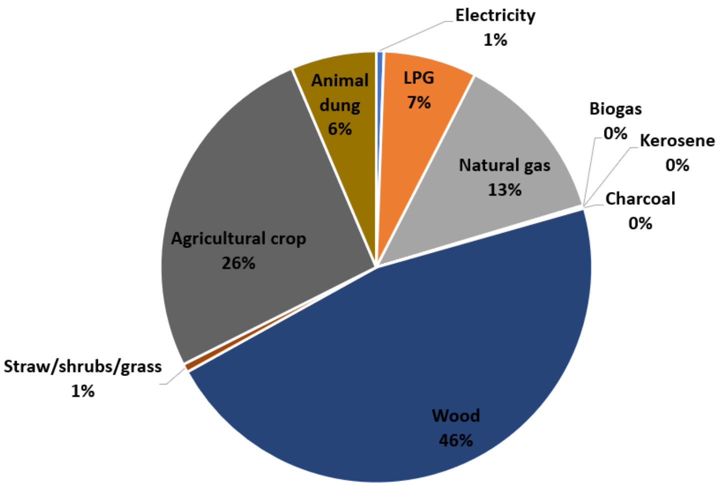

Figure 3: Cooking Fuel Use in Bangladesh by Type of Fuel

Wood is the most dominant cooking fuel source in Bangladesh, with approximately 46.25% of households using it for cooking. The heavy reliance on wood as a primary cooking fuel indicates a significant challenge in transitioning to cleaner and more sustainable cooking options. A small percentage of households (0.63%) use straw, shrubs, or grass as cooking fuel. These are also solid biomass fuels and may have similar environmental and health impacts as wood. A substantial proportion of households (25.96%) use agricultural crops as their primary cooking fuel. These crops are likely used as solid biomass fuels, and their usage contributes to deforestation and indoor air pollution. A significant number of households (6.39%) use animal dung for cooking, which is another form of solid biomass fuel with associated health and environmental concerns.

The data shows that most households in Bangladesh still rely on solid biomass fuels (wood, agricultural crop, animal dung) for cooking, which poses significant challenges in terms of health, environment, and sustainable development. While there are some households using cleaner cooking fuel options like LPG and natural gas, the numbers are relatively low. The high percentage of households using wood and agricultural crops as cooking fuel indicates a pressing need for targeted interventions and policies to promote cleaner cooking options, improve access to clean fuels like LPG, and raise awareness about the health and environmental benefits of adopting clean cooking technologies. Such efforts can help reduce clean cooking fuel poverty, improve indoor air quality, and contribute to sustainable development in Bangladesh.

3.3 Testing the Energy Ladder Hypothesis: Wealth Status Versus Clean Fuel Use

To test the energy ladder hypothesis in the context of Bangladesh, we can analyze the relationship between the wealth status of households and their use of clean or advanced sources of fuel for cooking, as indicated by the bar graph diagram (figure 4).

Among the poorest households, only 0.25% have access to clean or advanced sources of fuel for cooking. This indicates that the vast majority of the poorest households in Bangladesh still rely on primitive or traditional cooking fuels, such as solid biomass (wood, crop residues, and animal dung) or other less clean options like kerosene or charcoal. The percentage of households using clean cooking fuels increases slightly to 0.68% among the "Poorer" category. While the improvement is modest, it suggests that some households in the lower economic strata have started transitioning towards cleaner cooking options. In the "Middle" wealth category, the percentage of households using clean cooking fuels rises significantly to 3.92%. This demonstrates a more substantial shift towards cleaner and more advanced cooking technologies as households move up the economic ladder.

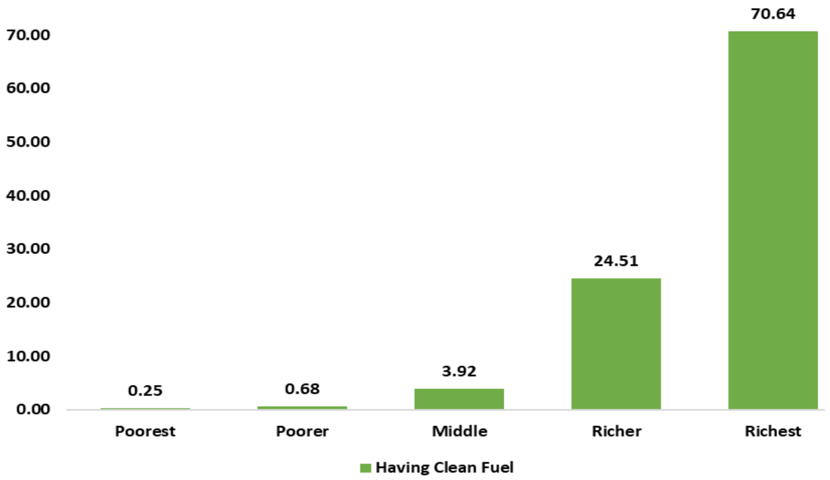

Figure 4: Clean Cooking Fuel Use in Bangladesh by Wealth Status

Among the "Richer" households, the percentage using clean cooking fuels increases significantly to 24.51%. This indicates that a significant proportion of wealthier households have adopted cleaner cooking options, such as LPG, electricity, or biogas, which are more efficient and less polluting. At the highest level of wealth, the "Richest" households show a substantial percentage of 70.64 using clean cooking fuels. This suggests that the majority of the wealthiest households in Bangladesh have transitioned to clean or advanced cooking technologies, representing the highest level of adoption among all wealth categories.

The findings from the bar graph support the energy ladder hypothesis in the context of Bangladesh. As households' wealth status improves, there is a clear trend of transitioning from primitive sources of fuel for cooking towards cleaner and more advanced sources. This shift can be observed through the increasing percentages of households using clean cooking fuels as we move from the poorest to the richest wealth categories. The data suggests that as households become wealthier, they are more likely to have the financial means to invest in and access cleaner cooking technologies like LPG or electricity. Cleaner fuels offer various advantages, including reduced indoor air pollution, better health outcomes, and a lower impact on the environment.

3.4 Testing the Energy Ladder Hypothesis: Wealth Status Versus Non-Clean Fuel Use

The bar graph (figure 5) shows the percentages of households using non-clean fuel at different wealth status levels:

Among the poorest households, 26.31% are using non-clean fuel for cooking. This indicates that a significant proportion of households with low wealth status rely on primitive or traditional cooking fuels like solid biomass (wood, crop residues, and animal dung), kerosene, or charcoal. The percentage of households using non-clean fuel remains relatively high at 24.66% among the "Poorer" category. This suggests that even as households move up slightly in economic status from the poorest category, a substantial number continue to use non-clean fuels for cooking. In the "Middle" wealth category, the percentage of households using non-clean fuel decreases slightly to 22.49%. This indicates a modest reduction in the use of non-clean fuels as households move further up the economic ladder.

Among the "Richer" households, the percentage using non-clean fuel further decreases to 18.23%. This demonstrates a more noticeable shift away from non-clean fuels as households improve their wealth status. At the highest wealth status level, the "Richest" households show the lowest percentage of 8.32% using non-clean fuel. This indicates that the wealthiest households in Bangladesh have made significant progress in transitioning away from non-clean cooking fuels, as per the energy ladder hypothesis.

The bar graph provides some evidence supporting the energy ladder hypothesis in the context of Bangladesh. As households' wealth status improves, there is a general trend towards lower usage of non-clean cooking fuels. This aligns with the energy ladder hypothesis, which suggests that households with higher economic status are more likely to adopt cleaner and more efficient cooking technologies, leading to a decrease in the use of non-clean fuels.

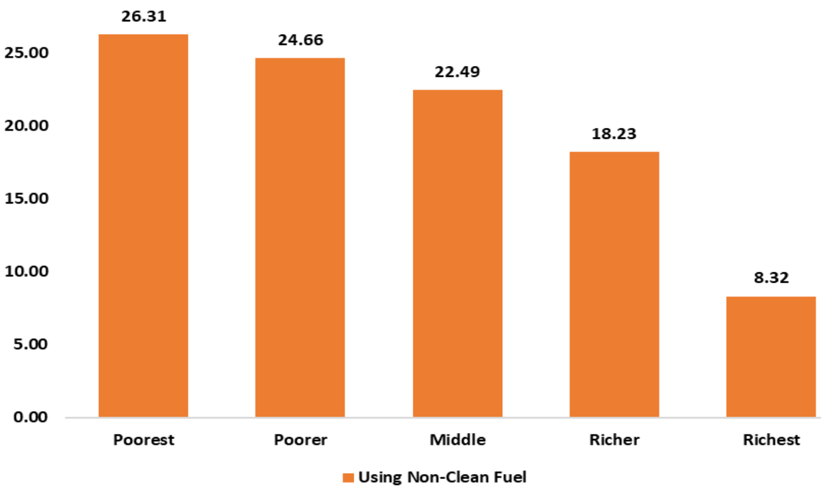

Figure 5: Non-Clean Cooking Fuel Use in Bangladesh by Wealth Status

The findings of the currents study, as discussed in the sections 3.3 and 3.4 of this paper are in line with the findings of (Behera & Ali, 2016; Behera et al., 2015; Biesiot & Noorman, 1999; Daioglou et al., 2012; Gatersleben et al., 2002; Holdren et al., 2000; Khandker et al., 2012; Masera et al., 2000; Moll et al., 2005; Nansaior et al., 2011; Rahut et al., 2017; Rao & Reddy, 2007; Rehfuess et al., 2006; Vringer & Blok, 1995). Such a very nature of the findings of this study could be strongly justified in the context of a developing economy. That is, Bangladesh has a predominantly agrarian fabric of the economy where agriculture, by providing livelihoods to a large portion of the population and by employing about 40% of the labor force and providing a source of income and sustenance to millions of rural households, is playing a crucial role in the country's GDP. Hence, according to the findings obtained by analyzing BDHS 2017-18 (country's representative data set) data, the use of non-clean fuel for cooking by 79% of the households of Bangladesh seems embedded in the large proportion (nearly 63% of the country's total population) of rural population of the country. However, the findings of the current study are in contrast with the findings of some studies (Huang, 2015; Masera et al., 2000; Nansaior et al., 2011).

3.5 Clean Cooking Fuel Poverty in the Context of Bangladesh

Based on the provided table 4, we can interpret the results regarding the clean cooking fuel poverty status in the context of Bangladeshi households.

Fuel Non-Poor: This category represents households that are not experiencing clean cooking fuel poverty, as they are using clean cooking fuels. The percentage (20.45%) indicates that a relatively small proportion of households fall into this category, meaning that only a fraction of the total households surveyed have adopted cleaner cooking technologies like LPG, electricity, biogas, or other advanced fuels.

Table 4

Clean Cooking Fuel Poverty Status	Frequency	Percent
Fuel Non-Poor (Clean Fuel Users)	3978	20.45
Fuel Poor (Non-Clean Fuel Users)	15416	79.23
Total	19394	99.68

Fuel Poor: Most households fall into this category, representing households experiencing clean cooking fuel poverty. The percentage (79.23%) indicates that a significant portion of the households surveyed is still reliant on non-clean cooking fuels, such as solid biomass (wood, crop residues, and animal dung), kerosene, or charcoal. This heavy reliance on non-clean fuels can lead to adverse health effects, indoor air pollution, and environmental degradation.

The results from the table highlight a concerning situation regarding clean cooking fuel poverty in the surveyed households. The majority (approximately 79.23%) of households are classified as "Fuel Poor" because they use non-clean cooking fuels. This implies that a significant portion of the population is still facing challenges related to accessing and adopting cleaner cooking technologies.

4. Conclusion and Policy Suggestions

The energy ladder hypothesis narrates that as the income increase, people move toward the cleaner source of energy for cooking. Based on the data from the Bangladesh Demographic and Household Survey (BDHS), the present study has measured the clean cooking fuel poverty in the households of Bangladesh. The households using advanced or clean sources of fuel are considered as the clean fuel non-poor, whereas the household using the rest of the sources of fuel for cooking are treated as the clean fuel poor.

The study finds that the households using advanced and cleaner cooking fuels are 20.45%. The low percentage (0.12%) suggests that only a very small number of households are in this transitional phase. A clear majority of households in Bangladesh, (with 79.23%) is using primitive or traditional cooking fuels.

A very small percentage of households (0.57%) rely on electricity as their primary cooking fuel. A small but slightly higher proportion of households (6.96%) use LPG (liquefied petroleum gas) for cooking. Biogas usage is minimal, with only 0.11% of households utilizing this clean cooking fuel source. A very small percentage of households (0.03%) still rely on kerosene for cooking. Similarly, a small proportion of households (0.10%) use charcoal as a cooking fuel. Wood is the most dominant cooking fuel source in Bangladesh, with approximately 46.25% of households using it for cooking. A small percentage of households (0.63%) use straw, shrubs, or grass as cooking fuel. A substantial proportion of households (25.96%) use agricultural crops as their primary cooking fuel. A significant number of households (6.39%) use animal dung for cooking, which is another form of solid biomass fuel with associated health and environmental concerns.

Among the poorest households, only 0.25% have access to clean or advanced sources of fuel for cooking. The percentage of households using clean cooking fuels increases slightly to 0.68% among the "poorer" category. In the "middle" wealth category, the percentage of households using clean cooking fuels rises significantly to 3.92%. Among the "richer" households, the percentage using clean cooking fuels increases significantly to 24.51%. At the highest level of wealth, the "richest" households show a substantial percentage of 70.64 using clean cooking fuels.

The current study highlights a concerning situation regarding clean cooking fuel poverty in the surveyed households in Bangladesh. A clear majority, i.e., approximately 79.23% of households are classified as "clean cooking fuel poor" because they use non-clean cooking fuels. This implies that a significant portion of the population is still facing challenges related to accessing and adopting cleaner cooking technologies, which can have detrimental effects on health and the environment.

4.1 Policy Implications

To address clean cooking fuel poverty and promote the use of cleaner cooking technologies, policymakers in Bangladesh could consider implementing the following measures:

- Provide subsidies or financial support to make cleaner cooking fuels more affordable and accessible, particularly for low-income households.
- Conduct targeted awareness campaigns to educate the public about the benefits of clean cooking fuels and the health and environmental risks associated with non-clean options.
- Invest in infrastructure to expand the distribution of clean cooking fuels like LPG and natural gas to rural areas.
- Encourage the use of improved cookstoves that burn solid biomass more efficiently and produce fewer harmful emissions.
- Promote the adoption of biogas technology, which can utilize organic waste to produce clean cooking fuel and reduce the pressure on forests and other natural resources.
- Implement programs and initiatives to uplift the economic status of households, as higher income levels have been correlated with a greater likelihood of adopting clean cooking technologies.

4.2 Limitations and Additional Considerations

The heavy reliance on primitive fuels has several implications for public health, the environment, and sustainable development in Bangladesh. Indoor air pollution resulting from the use of solid biomass and traditional fuels poses health risks, particularly for women and children who spend considerable time in cooking areas. Additionally, the burning of these fuels contributes to deforestation, air pollution, and greenhouse gas emissions, exacerbating climate change and environmental degradation. By addressing the energy needs of households and promoting clean cooking solutions, Bangladesh can improve public health, environmental sustainability, and overall quality of life for its citizens.

While the data suggests a correlation between wealth status and the use of non-clean fuel, it's essential to consider other factors that might influence fuel choice, such as access to infrastructure, availability of clean cooking technologies, cultural preferences, and government policies. Additionally, the data only provides a snapshot of fuel use at a specific point in time, and longitudinal studies would be more suitable to observe changes over time.

Authors Contribution
Tusawar Iftikhar Ahmad: study design, critical revision, incorporation of intellectual content
Kokab Kiran: data analysis, data interpretation, drafting
Amina Alamgir: data collection, literature search, visualization, drafting

Conflict of Interests/Disclosures
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