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Review Paper-Clean Development Mechanism And Traditional Fuel Use In India

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Abstract

In rural India, household activities account for a significant portion of total energy consumption. The most commonly used fuels, typically in small-scale applications, include wood, biogas, micro-hydro, solar, wind, and various types of biomass. Due to their free availability and lack of direct financial cost, conventional sources still account for the majority of cooking energy, despite the growing availability of cleaner fuels. Another important factor in fuel selection is social and cultural preferences. Continuous use of inefficient fuels releases carbon monoxide, sulfur dioxide, nitrogen dioxide, and particulate matter, that worsens indoor air pollution. Long-term exposure to these pollutants causes eye, cardiovascular, and respiratory diseases.

Keywords: Energy, Health, Pollution, Socio-cultural influences, Environment, Traditional fuels.

Introduction

In India, consumers and policymakers have long been concerned about cooking energy. Due to its extensive effects on public health, environmental sustainability, and climate change mitigation, domestic energy usage is not only a fundamental need but also a crucial policy problem. Government-led initiatives promoted a slow transition to greener cooking options in rural areas between 2016 and 2019. However, almost 80% of rural households still rely heavily on conventional, inefficient solid fuels including coal, agricultural residue, animal dung, and firewood (Roy, 2024). Inadequate access to and availability of contemporary fuels continue to risk social equality, productivity, and health outcomes, even though many families also use kerosene, LPG, or a combination of fuels.

Traditional biomass use has serious environmental impacts, especially due to incomplete combustion's greenhouse gas emissions(“Bansal *et. al*., 2013; Pachauri *et. al*., 2013;

Bhattacharyya and Das, 2016; Ranjan and Singh, 2017"). The "International Energy Agency (IEA, 2023)" found that energy use and the pace of a nation's shift to greener sources affect economic growth. In the Indian context, however, rural households remain a weak point in this transition, with adoption patterns that are often non-linear and inconsistent (Sovacool, 2016; Goswami *et. al.,* 2023).Globally, the challenge of meeting household cooking energy needs is intensifying, driven by population growth and the depletion of conventional energy resources. This makes the demand for affordable, efficient, environmentally friendly, and culturally acceptable fuels in rural areas even more urgent. The present review seeks to offer a comprehensive analysis of the current rural energy scenario in India, highlighting the potential for integrating clean development mechanism (CDM) technologies to address environmental degradation, health hazards, and energy shortages. Such integration could also enhance gender equity and support long-term sustainability by reducing the burden on rural women, who are often the primary providers of household fuel.

Fuel Choices And Energy Consumption

Any region's social and economic growth is greatly influenced by its energy resources. Over 70% of Indians live in rural areas, where biomass-based energy sources, mainly used for cooking, provide over two-thirds of their entire energy needs. Biomass as a renewable resource has drawn increasing interest due to the gradual depletion of fossil fuel stocks, both for domestic consumption and to support small and medium-sized businesses. Despite this, the majority of rural homes still use antiquated, ineffective heating and cooking equipment, which contributes to a major environmental burden and speeds up the depletion of local resources. ("Ramchandra *et. al.,* 2007; Shukla, 2009; TERI-TEDDY, 2014").

The rural energy mix in India is heavily skewed toward firewood (62.5%), followed by crop residues (12.3%), LPG (11.4%), and dung cakes (10.9%). Other minor sources include wood chips and charcoal. In Rajasthan, the figure is less than 30%, with rural households showing high dependence on free or low-cost sources like firewood (61.8%) and crop residue (11%) (Chitlangia, 2024).

Proximity to forests often encourages the continued use of fuelwood, which is collected either daily or seasonally (Ranjan *et.al.* 2017; TERI-TEDDY, 2010). However, the absence of CDM-based, energy-efficient technologies remains a major gap. Agricultural residue burning, such as crop stubble burning, is another significant contributor to GHG emissions, with an estimated 92

million tonnes of crop waste burned annually in India (Chanda *et. al.*, 2021). Furthermore, an estimated 200 million tonnes of biomass are still used each year in rudimentary cookstoves, emitting substantial quantities of pollutants (Earth Watch Institute, 2011; Singh and Singh, 2012).

As per the Enerdata, 2024, India's total energy consumption was over 40,000 PJ, and its CO2 emissions were 2.22 tCO_2/capita. This represents people's energy access and usage patterns (Census, 2011). Geographic, sociological, educational, and demographic variables affect rural India's energy use(Mottaleb and Rahut, 2021; Mondal *et al*., 2021; Mottaleb *et al*., 2022; Bush, 2024).LPG and electricity are more popular with higher-income and better-educated households than kerosene and firewood.Cleaner fuels are more likely to be selected by female-headed families, particularly when they are readily accessible nearby (Rahut *et al*., 2016). Family size, household wealth, per capita income, homestead area, agricultural land, household heads' age, gender, and education, and power availability also affect household fuel usage (Hassan, 2016).

In addition to limiting energy efficiency, this over-reliance on conventional fuels impedes the achievement of sustainability objectives. Because fossil fuels account for 75% of India's greenhouse gas emissions, a systematic switch to cleaner, renewable energy is needed. (BEE, 2024).

Impact Of Fuels On Human Health

The widespread use of solid biofuels in rural India pollutes indoor air.Firewood, charcoal, crop residues, and animal dung burn to release carbon monoxide, fine particulates, and other hazardous gases. The ineffective use of biomass in conventional cooking methods has major negative health effects, despite the fact that it is frequently seen as a renewable and environmentally friendly alternative (Ranganathan et al., 2020). For many rural Indian families, biomass and other solid fuels are their main cooking source, like in many developing nations(Mishra and Retherford, 2007). Residents are exposed to high levels of indoor air pollution as a result of the ongoing use of these fuels in basic, inefficient stoves. Acute and chronic respiratory conditions, cardiovascular diseases, and skin and eye irritation are among the health effects. Because they spend more time near food preparation areas, women and children are more at risk.

Indoor air pollution is the ninth most important global risk factor, as per the World Health Organization (WHO), and it is considered to be responsible for 2.7% of the global disease

burden.Pollutants emitted from solid fuel combustion—such as $PM_{2.5}$, PM_{10}, sulphur dioxide, nitrogen dioxide, and black carbon—are small enough to penetrate deep into lung tissue, triggering inflammation and impairing respiratory function (Valavanidis, 2023). Financial challenges often exacerbate the situation, as households revert to cheaper but more polluting fuels when modern alternatives are unaffordable.

Long-term exposure to polluted indoor environments increases susceptibility to respiratory diseases, particularly among elderly residents. Documented symptoms among biomass users include persistent dry cough, eye and nasal irritation, shortness of breath, dizziness, headaches, and hypertension (NIOH, 1982; Chakraborty *et. al.*, 2014; Mohapatra *et. al.*, 2018). Researches have also shown a direct correlation between years of cooking exposure and elevated systolic and diastolic blood pressure. Extended biomass smoke exposure during pregnancy has also been linked to low birth weight, neonatal mortality, and acute respiratory illnesses in children under five(Edwards and Langpap, 2012; Epstein *et. al.*, 2013; Shezi *et. al.*, 2021").

Long-term biomass smoke exposure during pregnancy is connected to low birth weight, neonatal mortality, and acute respiratory disorders in children under five. (Ezzati and Kammen, 2002). Women's higher exposure rates are due to their role in cooking, which exposes them to concentrated levels of $PM_{2.5}$, PM_{10}, carbon monoxide, and sulphur dioxide.

Despite programs that involve the Pradhan Mantri Ujjwala Yojana, many rural regions still don't use cleaner options like LPG, natural gas, electricity, biogas, as well as solar power, which can dramatically minimize health issues(Gaikwad *et.al.*,2024). One prominent behavioral issue is "fuel stacking," in which households continue to use a combination of traditional and clean fuels because of cultural cooking customs, perceived flavor advantages, or worries about dependability and pricing. These behavioral and financial challenges must be overcome to promote public health and meet "Sustainable Development Goal 7", that requires universal access to modern, cheap, as well as reliable electricity(SDG, 2015).

Determinants Of Energy Consumption

In today's rapidly evolving technological and economic landscape, the demand for energy is rising sharply, while natural resources remain finite. There are a number of socioeconomic, demographic, cultural, and infrastructure aspects that affect the kind and quantity of energy that a household uses. Household size, income, education, the head of the household's age and gender, occupation, kind of habitation, fuel prices, cooking preferences, lifestyle, and cultural customs

are some of these determinants (Zou and Lio, 2019; Son and Yoon, 2020; Tran *et. al.,* 2023, Barik and Padhi, 2024; Mark and Adikaibe, 2025).

Energy preferences are significantly shaped by income. Families typically switch from conventional, inefficient fuels to cleaner, more efficient alternatives like LPG, electricity, or biogas when household income rises(Bansal *et. al.,*2013; Nlom and Karimov, 2014). Long-term biomass smoke exposure during pregnancy has been associated to low birth weight, neonatal mortality, and acute respiratory problems in children under five(Pandey and Chaubal, 2011; Guta, 2012; Gebreegziabher *et. al.,* 2012; Kroon *et. al.,* 2013; Özcan *et. al.,* 2013).

Accessibility and availability of modern fuels are other decisive factors. In areas where LPG refilling stations or electricity connections are scarce, households are more likely to remain dependent on firewood and other biomass fuels. Reducing the time and effort—especially for women—involved in collecting fuelwood increases the likelihood of adopting modern fuels (Peng *et. al.,* 2010; Link *et. al.,* 2012; Merrill, 2017; Muller and Yan, 2016; Lay *et. al.,* 2013; Zhang and Koji, 2012).However, household size can work against the transition to modern fuels. Larger households, which are often less affluent, tend to favour low-cost, traditional energy sources because of the higher total fuel demand (Pandey and Chaubal, 2011; Knight and Rosa, 2012; Zhang and Koji, 2012). Cultural as well as traditional factors, that involve cooking styles, taste preferences, and entrenched beliefs about food preparation, also influence fuel choices and can slow the shift toward cleaner energy (Heinonen and Junnila, 2011; Taylor *et. al.,* 2011; Zhao *et. al.,* 2012; Muratori, 2013).

In summary, the decision to utilize clean energy is affected by various factors, that involve household demographics, fuel accessibility, cultural preferences, educational knowledge, and economic capability. Understanding these determinants can help policymakers design targeted interventions that encourage “fuel switching” from polluting biomass to cleaner, more efficient options—thereby improving health, reducing environmental damage, and advancing long-term sustainability goals.

Conclusion

Due to traditions, social conventions, financial constraints, and inadequate infrastructure, traditional fuels are still widely used in rural India. This reliance has severe environmental and health consequences, including greenhouse gas emissions and respiratory diseases. A holistic approach, incorporating clean fuel availability, awareness, and adoption of clean technologies, is

necessary for a sustained transition to cleaner energy, ultimately improving health outcomes, gender equality, and living standards.The persistent use of traditional fuels in rural India, despite their well-documented environmental and health impacts, is driven by numerous factors beyond cost.The findings demonstrate that cultural practices, social norms, fuel availability, and household demographics all play critical roles in influencing energy choices. Economic constraints and inadequate infrastructure reinforce the dependence on biomass-based fuels, including dung cakes, firewood, and agricultural leftovers.

Recommendations

To accelerate rural India's shift from traditional to clean energy and reduce the health and environmental impacts of biomass use, strategies should include awareness campaigns with technology demonstrations, targeted subsidies and low-interest loans, institutional involvement through pilot villages, and active community participation with feedback systems. Strengthening infrastructure and supply chains for LPG, biogas, and renewable fuels, along with local production for cost reduction and job creation, is essential. Integrating clean energy initiatives with rural development programs, self-help groups, and agricultural services will enhance adoption, empower women, improve livelihoods, and promote a sustainable, healthier future.

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