ASHOKA UNIVERSITY

CENTRE FOR A
People-centric
Energy Transition

Cooking with Coal in *Rajhara*:
Can Clean Energy Compete?

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PREFACE

The Ashoka Centre for a People-centric Energy Transition (ACPET) launched the Trans-Mine project to address the livelihood and environmental challenges faced by communities impacted by coal mine closures in India. With over 100,000 hectares of abandoned mining land and millions affected by job losses, ACPET aims to develop people-centric solutions that promote economic resilience and land rehabilitation. In Rajhara, Jharkhand, ACPET piloted three on-ground interventions—solar-based lift irrigation, Farmer Producer Organizations, and clean cooking practices—to support sustainable livelihoods and catalyze a just transition for coal-dependent communities. This case elaborates on the Clean Cooking Initiative.

1. INTRODUCTION

"Our house fills with smoke. We feel dizzy. We tell our children to go out," recalls a Self-Help Group (SHG) member from *Rajhara* village in Jharkhand. Another echoes, *"We have to go out after using the chulha. It's hard to breathe, and our eyes burn."* These women speak not just of inconvenience, but of a daily health hazard, one that shapes how they cook, care for their children and manage their lives.

Cooking fuel choices are more than a matter of convenience–they shape public health, environmental resilience, and the daily lived experiences of millions. Over 750 million people in India still rely on solid fuels such as firewood, cow dung, and coal for cooking (Gould et al., 2020). Globally, solid fuel use contributes to 4 million deaths per year, and India accounts for a large share of this burden (Pillarisetti et al., 2017). Solid fuel use is linked to a significantly higher risk of respiratory diseases like tuberculosis (TB), chronic obstructive pulmonary disease (COPD), and bronchial asthma, especially in rural areas and among marginalized groups (Faizan & Thakur, 2019). In coal-mining- affected regions such as *Rajhara*, Jharkhand, households predominantly rely on solid biomass fuels, including coal, wood, and dung cakes, for cooking. While these fuels are affordable and easily accessible, their combustion contributes to indoor or household air pollution (IAP/HAP) a leading cause of respiratory diseases, cardiovascular conditions, and environmental degradation (Smith et al., 2014). Given the direct link between traditional fuel use and adverse health effects, transitioning to clean energy alternatives is an urgent necessity in such communities.

Family near traditional chulha (stove) in their house

The Problem of Indoor Air Pollution in Mining-Affected Areas

The burning of solid fuels releases harmful pollutants such as particulate matter (PM2.5), carbon monoxide (CO), and polycyclic aromatic hydrocarbons (PAHs), all of which pose severe risks to human health (Balakrishnan et al., 2013). In mining regions like *Rajhara*, the problem is exacerbated by pre-existing environmental degradation, poor ventilation in homes, and socio-economic constraints that limit access to cleaner fuels (Guttikunda et al., 2014). Women and children, who spend more time indoors, are disproportionately affected by household air pollution, suffering from COPD, asthma, and increased infant mortality rates (Chowdhury et al., 2019). The World Health Organization (WHO) estimates that approximately 2.1 billion people worldwide rely on polluting cooking fuels, with India accounting for a significant portion of this burden. In 2020, household air pollution contributed to approximately 3.2 million deaths annually, including more than 237,000 fatalities among children younger than five years old (WHO, 2024).

Global and National Efforts for Clean Cooking Transition

Recognizing the health, economic, and environmental consequences of household air pollution, global initiatives have been launched to promote the adoption of clean cooking technologies. The United Nations Sustainable Development Goal (SDG) 7 emphasizes universal access to affordable, reliable, and modern energy, pushing for increased adoption of liquefied petroleum gas (LPG), electric stoves, and biogas (IEA, 2022). Similarly, the Clean Cooking Alliance (CCA), supported by international organizations, focuses on developing scalable clean energy interventions in low- and middle-income countries (CCA, 2023).

India has also taken proactive measures to facilitate the transition from traditional to modern cooking fuels. The Pradhan Mantri Ujjwala Yojana (PMUY), launched in 2016, has been instrumental in subsidizing LPG connections for below-poverty-line households (MoPNG, n.d.). However, despite initial success, challenges such as refill affordability, supply chain limitations, and socio-cultural resistance have hindered sustained adoption in some regions (Kumar, 2024). In coal-mining-affected regions, where coal is often a free or low-cost alternative, interventions must be context-specific and community-driven to ensure long-term behavioral change.

The Need for Sustainable Solutions in Mining Communities

In mining-affected regions like *Rajhara*, the shift to clean cooking fuels presents not just an energy choice—but a critical decision point for public health, gender equity, and local livelihoods. Policymakers must now ask: *How can we design interventions that are not only sustainable, but also affordable, culturally accepted, and economically empowering?*

Emerging research highlights that bundling clean energy access with livelihood-enhancing initiatives such as biogas generation from agricultural waste or decentralized solar cookers can improve adoption rates and build economic resilience among rural households (Ravindra et al., 2019). This moment presents a pivotal opportunity to move beyond subsidy-led models toward community-anchored solutions that drive long-term health and development gains.

Given the unique challenges experienced by coal-mining communities, a multi-sectoral approach involving government agencies, NGOs, and local stakeholders is essential to achieve long-term change. The case study will explore the socio- economic and health impacts of existing cooking fuel choices in *Rajhara*, evaluate barriers to clean energy adoption, and propose policy recommendations for an inclusive and sustainable energy transition.

2. PROBLEM STATEMENT

Reliance on traditional cooking fuels such as wood, dung, coal, and *goliya* remains widespread in *Rajhara*, a coal-mining-affected region in India. Economic barriers, cultural resistance, accessibility issues, and policy gaps continue to hinder the sustained adoption of clean cooking technologies. Additionally, the availability of low-cost or free coal in mining areas creates an added disincentive to shift towards cleaner alternatives (Chanchani & Oskarsson, 2021).

Economic Barriers to Clean Fuel Adoption

The primary obstacle preventing households from transitioning to cleaner fuels is economic constraints. While PMUY has provided subsidized LPG connections, many families in coal-mining communities struggle to afford LPG refills, forcing them to revert to biomass fuels (Chanchani & Oskarsson, 2021). Research indicates that even in households with LPG connections, solid fuels continue to be used as a backup due to cost-related concerns (Kumar, 2024). This economic burden disproportionately affects women and marginalized groups, who bear the brunt of household energy collection and exposure to indoor air pollution (Bagri, Garg, & Agarwal, 2021).

Cultural and Behavioral Resistance

Cultural norms and long-standing cooking habits also contribute to resistance towards LPG adoption. Many households in coal-rich areas prefer traditional fuels for cooking certain types of food, such as roti and dal, believing that these fuels provide better taste and texture compared to modern alternatives (Chatterjee, 2006). Additionally, there is a deep-seated perception that LPG is unsafe, especially in households unfamiliar with handling gas cylinders (Kumar et al., 2020). Social influence plays a significant role, as people are often reluctant to shift from fuels that have been used for generations (Bagri et al., 2021).

Accessibility Challenges in Rural and Mining-Affected Areas

The accessibility of clean fuels remains a major hurdle in remote and mining-dense regions like *Rajhara*. Households that do wish to transition often face logistical difficulties in obtaining regular LPG refills due to long distances from distribution centers and unreliable supply chains (Montrone, Ohlendorf, & Chandra, 2021). In contrast, coal is easily available and sometimes provided at low or no cost by informal sources, further discouraging the shift to LPG or electric cooking (Saxena, 2023). The government's energy distribution network has not fully addressed these supply-side challenges, leading to unequal access to clean cooking solutions (Spencer et al., 2017).

Policy and Governance Gaps Affecting Clean Cooking Adoption

While PMUY and other clean energy programs have helped increase access to LPG, policy implementation gaps persist. The focus has been on initial adoption rather than long-term sustainability, with insufficient financial support for refills and stove maintenance (Saxena, 2023). Additionally, coal-mining policies continue to support household coal use, creating a policy contradiction between mining expansion and clean energy promotion (Tongia, Sehgal, & Kamboj, 2020). Without integrated policies that address both energy affordability and behavioral change, clean cooking interventions will struggle to achieve long-term success (Carter et al., 2020).

Challenges Unique to Coal-Mining Regions

Coal is not only an energy source but also a livelihood for many households, making its usage deeply embedded in local economies (Chanchani & Oskarsson, 2021). Workers in informal coal mining sectors often receive free or subsidized coal as part of their compensation, further reducing the incentive to invest in LPG or electric alternatives (Bagri et al., 2021). Additionally, the environmental degradation caused by mining leads to poor air quality, exacerbating the already severe indoor air pollution in households dependent on solid fuels (Saxena, 2023).

The transition to clean cooking fuels in coal-mining-affected regions is fraught with economic, cultural, accessibility, and policy barriers. Despite government interventions, such as PMUY, long-term affordability, behavioral change, and structural policy reforms are necessary for sustained adoption. Addressing these issues requires a multi-stakeholder approach, involving government agencies, energy providers, and local communities to create viable, long-term solutions for energy access.

3. CURRENT LANDSCAPE OF COOKING PRACTICE

Household Fuel Use Patterns in Coal-Mining Communities

The general cooking fuel landscape in coal-mining-affected region in India, is characterized by a mix of traditional and modern fuel sources. Studies show that hybrid cooking models–where LPG is used intermittently along with wood, dung cakes, and coal (fuel stacking)–are common in low-income and rural households (Gould et al., 2020).

This hybrid approach arises due to multiple socio-economic factors, including the affordability of LPG refills, the availability of locally sourced solid fuels, and cultural cooking preferences (Balakrishnan et al., 2013). The practice of fuel stacking, where households alternate between different energy sources based on economic and seasonal conditions, is a persistent trend in India's rural energy landscape (Guttikunda et al., 2014).

Hybrid Cooking Models: Mixing LPG with Coal, Wood, and Other Biomass

Many households ration LPG usage, opting for coal, firewood, or dung cakes for everyday cooking (Chowdhury et al., 2019). LPG is often reserved for quick cooking or when higher efficiency is required, such as for boiling water or preparing tea (Smith, et. al., 2014). The frequency of LPG refills varies significantly depending on household income, with some families using a single cylinder for two to three months, while others deplete it within a few weeks (Cabiyo, Ray, & Levine, 2020).

The seasonal variations in fuel use also play a crucial role. During winter and monsoon seasons, the use of wood and dung cakes increases, as they provide the additional benefit of heating. In contrast, in summer months, LPG use tends to be slightly higher due to the difficulty of cooking with solid fuels in extreme heat (Ravindra et al., 2019).

Cow dung cakes laid out to dry

The Role of *Goliya* (Coal-Dung Mix) as an Alternative Cooking Fuel

A significant feature of fuel usage in coal-mining regions is the prevalence of *goliya*, a mixture of coal dust, local soil and dung cakes used as an affordable cooking alternative (Gould et al., 2020). *Goliya* is favored for its affordability, high calorific value, and slow-burning properties, making it particularly useful for long-duration cooking (Chanchani & Oskarsson, 2021).

While *goliya* is widely used, it poses severe health and environmental risks. The burning of coal-based mixtures produces high levels of particulate matter (PM2.5), sulfur dioxide (SO_2), and carbon monoxide (CO), leading to increased respiratory diseases and indoor air pollution (Kumar, 2024). Despite these dangers, economic constraints force many households to continue its usage, as cleaner alternatives remain financially out of reach (Saxena, 2023).

Cow dung cakes stacked outside the home

4. CLEAN COOKING FUEL ADOPTION IN *RAJHARA*: INSIGHTS FROM THE FIELD

4.1 Socio-Economic Profile of Respondents

A survey was undertaken of 258 women respondents in *Rajhara* , from 19 to 80 years with an average age of 38. Most respondents belonged to marginalized social groups, with 52.7% identifying as Other Backward Classes (OBC) and 31.8% as Scheduled Caste (SC). Housing conditions varied, with 43.4% living in kutcha houses, emphasizing the socio-economic challenges faced by the community.

Educational and Economic Background

- Education: 43% of the respondents reported no formal education, highlighting significant barriers to accessing information about clean energy solutions.
- Income: The average monthly household income was ₹10,925, primarily derived from non-agricultural daily wage labor (61.6%).

Current Cooking Practices & Fuel Usage in *Rajhara*

- Cooking Habits: The majority of respondents cook two meals per day, spending an average of 162 minutes on cooking activities, predominantly inside their homes. This extensive indoor cooking contributes significantly to indoor air pollution due to the use of traditional fuels.
- Fuel Usage Patterns: Traditional fuels dominate, with 56.6% of households relying on wood, dung, coal, and *goliya*. About 31.4% use a combination of traditional and clean fuels, while only 12% exclusively use clean fuels like LPG.
- Traditional Cooking Fuels:
  - Wood: The primary traditional fuel, used by 62.6% of households, often collected from distances up to 5 km, imposing a significant time burden, particularly on women.
  - Cow Dung and *Goliya*: Used by 47.6% and 31.7% of households respectively, these fuels are often prepared manually, adding to the physical labor burden of women.

> WE HAVE TO GET WOOD FROM AT LEAST 1.5 TO 2 KM AWAY. IT IS VERY FAR.
>
> — SHG MEMBER, PANDWA VILLAGE

Collected firewood stacked near homestead

4.2 Health Impact of Traditional Cooking Fuels

Exposure to smoke from traditional fuels like wood and dung significantly impacts women's and children's health, primarily causing respiratory issues and eye irritation.

- Respiratory Illnesses: A reported 10.1% of households had experienced respiratory issues, with treatment costs averaging ₹10,725, highlighting the economic burden of health care on these families.
- Eye Irritation: Reported by 10.9% of households, with over half not seeking medical treatment due to the high costs involved.
- High awareness of the health risks associated with traditional fuels was reported, with 84.5% recognizing the adverse health impacts.

> IF WE START BUYING EVERYTHING, THEN WE WON'T BE ABLE TO MANAGE OUR OTHER ESSENTIAL HOUSEHOLD EXPENSES. WE RESORT TO MAKING *GOLIYA* BECAUSE COAL IS TOO EXPENSIVE TO USE IN ITS RAW FORM.
>
> – SHG MEMBER, *RAJHARA* VILLAGE

Community Readiness for Transition to Clean Cooking

While there is a strong community willingness to transition to cleaner cooking options, significant barriers remain. 92.2% identified high costs as the primary barrier to using clean fuels regularly. While some cultural preferences for traditional fuels exist, the primary barrier to adopting cleaner fuels remains their high cost.

SHGs have the potential to act as catalysts for change, with members expressing readiness to lead awareness and training initiatives if supported with resources and training.

The transition to clean cooking fuels in *Rajhara* is confronted with deeply entrenched socio-economic and structural challenges that necessitate a multifaceted approach to solution implementation. The demographic profile of the community, characterized by low educational attainment, reliance on unstable daily wages, and non-durable housing, underscores a heightened vulnerability to health risks associated with traditional cooking practices. These traditional methods, dominated by the use of wood, dung, and locally produced *goliya*, are not just a matter of cultural preference but are primarily dictated by economic constraints and accessibility issues.

FGD with Self Help Group (SHG) members

Health implications from continuous exposure to smoke from traditional fuels are significant, affecting primarily women and children within these households. The data reveals a clear awareness among the community of the adverse health impacts, yet economic barriers and limited access to cleaner alternatives like LPG constrain their ability to transition to safer cooking methods. The average cost of clean fuel, which is notably higher than what most families can afford, compounds this challenge, making sustainability and regular use difficult.

Community readiness to embrace clean cooking solutions is evident, with a considerable number of households expressing willingness to transition if affordable solutions are provided. Self-Help Groups (SHGs) within the community are pivotal in this transition, showcasing potential as grassroots catalysts who can drive awareness, facilitate behavior change, and support the adoption of clean cooking technologies. Leveraging these networks to educate and empower women can act as a springboard for broader community engagement and adoption.

To foster a successful transition, it is essential to integrate economic, educational, and infrastructural strategies. Subsidizing the cost of clean fuels, simplifying access to these resources, and ensuring that women are at the forefront of the transition efforts are critical steps. Moreover, a collaborative approach involving local governance, health agencies, and community organizations is crucial to address the multifaceted challenges of transitioning to clean cooking fuels in *Rajhara*.

> WE WILL HELP. JUST GIVE US THE TRAINING, AND WE'LL SHARE IT WITH OTHER WOMEN AS WELL. "EVERYONE LISTENS TO US WHEN WE APPROACH THEM.
>
> – SHG MEMBER FROM *RAJHARA* VILLAGE

The path forward involves not just providing access to technology but also building a supportive ecosystem that addresses the economic and informational barriers that these communities face. This holistic approach will not only improve health outcomes but also enhance the overall quality of life for the residents of *Rajhara*, making clean cooking a reachable and sustainable goal.

4.3 Data Insights and Projections

Transitioning to clean cooking fuels in Rajhara has the potential to deliver substantial health, economic, and environmental benefits.

Health Benefits

- Reduction in Disease Burden: Households that rely on solid biomass fuels have a significantly higher probability of reporting illnesses and more frequent health facility visits compared to those using clean fuels (Martey, 2021).
- Reduced Risk of Visual Impairments: Exposure to biomass smoke is linked to an increased risk of partial blindness, emphasizing the ocular health risks associated with traditional cooking fuels (Mishra, Retherford, & Smith, 1999).
- Women's Health Improvements: Women experience measurable improvements in health outcomes after switching to clean fuels, including enhancements in self-rated and externally rated health metrics (Wu, 2021).

Economic Benefits

- Lower Healthcare Costs: Shifting to clean fuels reduces the financial burden associated with treating illnesses caused by indoor air pollution, representing significant potential savings for low-income households (Martey, 2021).
- Increased Productivity: The transition also alleviates the time burden of collecting traditional biomass fuels, especially for women, which can be redirected toward income-generating activities (Paudel, Jeuland, & Lohani, 2020).

Environmental Benefits

- Reduction in Air Pollutant Emissions: Switching to clean fuels like LPG or carbonized biomass products significantly reduces household emissions of PM2.5 and other harmful pollutants (Li et al., 2019).
- Climate Change Mitigation: The use of cleaner fuels can also lead to substantial reductions in CO_2-equivalent emissions at the household level (Kaur-Sidhu et al., 2020).

Woman gathering cow dung cakes

Extrapolations Table: Potential Benefits of Clean Cooking Transition in *Rajhara*

Impact Area	Data Insight	*Rajhara*-Specific Projection	Source
Respiratory Disease Reduction	25% higher illness risk with biomass fuel use	Up to 25% reduction in respiratory illness burden if households shift to clean fuels	(Martey, 2021)
Women's Health Improvement	9% improvement in self-rated health post-switch	8-9% increase in women's reported health well-being scores	(Wu, 2021)
Blindness Risk Reduction	32% higher risk of partial blindness with biomass smoke	Adult blindness cases are preventable	(Mishra, Retherford, & Smith, 1999)
Healthcare Cost Savings	Average respiratory treatment costs ₹10,725 per household	Savings of ₹10,000–₹12,000 per household per year	(Martey, 2021)
Time Savings for Women	2–3 hours/day saved from wood collection	Additional ₹10,000–₹12,000 annual income potential per household	(Paudel, Jeuland, & Lohani, 2020)
PM2.5 Emission Reduction	80–97% reduction in particulate matter with clean fuels	Up to 90% reduction in household air pollution	(Li et al., 2019)
CO_2-Equivalent Emission Reduction	559 kg CO_2-equivalent emissions mitigated per LPG-using household/year	>72 metric tons of CO_2 savings annually if 50% of households transition	(Kaur-Sidhu et al., 2020)

5. HEALTH AND ECONOMIC IMPACT OF TRADITIONAL COOKING FUELS

5.1 Health Consequences of Traditional Cooking Fuels

The reliance on solid biomass fuels (wood, coal, dung cakes, and crop residues) for cooking has severe health consequences for individuals in coal-mining-affected communities like Rajhara. These fuels emit high levels of particulate matter (PM2.5), carbon monoxide (CO), and volatile organic compounds (VOCs), which are directly linked to respiratory and cardiovascular diseases (Balakrishnan et al., 2013). Women and children, who spend more time indoors near cooking areas, are disproportionately affected by household air pollution (HAP) (Kaur-Sidhu, Ravindra, & Mor, 2019).

1. Chronic Obstructive Pulmonary Disease (COPD) and Asthma
Studies indicate that prolonged exposure to biomass smoke increases the risk of COPD and asthma (Faizan & Thakur, 2019). Inhalation of fine particulate matter and toxic gases leads to lung inflammation and reduced pulmonary function (Simkovich, Goodman, & Roa, 2019). Women in rural households with traditional stoves are found to have 40–60% higher rates of COPD than those using clean fuels (Bisui et al., 2024).

2. Tuberculosis and Respiratory Infections
Indoor air pollution compromises lung immunity, increasing susceptibility to tuberculosis and respiratory infections. A study in North India found that women exposed to solid fuel emissions were significantly more likely to develop pulmonary TB compared to LPG users (Chakrabarti, Khan, & Kishore, 2019). Children in biomass-burning households are also at a higher risk of pneumonia and acute respiratory infections (ARI), contributing to increased infant mortality (Laxmi et al., 2003).

3. Eye Irritation and Cardiovascular Diseases
Constant exposure to coal and biomass smoke leads to severe eye irritation, cataracts, and corneal damage. The high levels of carbon monoxide emitted from inefficient stoves also increase the risk of hypertension, stroke, and ischemic heart disease among long-term users (Puzzolo, Fleeman, & Lorenzetti, 2024).

5.2 Economic Burden of Traditional Cooking Fuels

The use of traditional cooking fuels imposes a significant economic burden on households, both in terms of direct medical expenses and indirect costs such as fuel collection time and lost productivity.

1. Medical Costs from Pollution-Related Diseases
Households using traditional fuels spend more on healthcare due to the high prevalence of respiratory illnesses (Faizan & Thakur, 2019). According to a 2019 study, families in rural India spend 10–15% of their annual income on treating respiratory diseases caused by biomass smoke (Kaur-Sidhu et al., 2019). The financial burden is further exacerbated in coal-mining communities where environmental pollution increases the risk of chronic illnesses.

2. Opportunity Costs: Time Spent Collecting Fuel
Women in rural households spend up to 20 hours per week collecting firewood and dung cakes (Laxmi et al., 2003). This time could otherwise be used for income-generating activities, education, or childcare, highlighting the gendered economic cost of fuel collection (Simkovich et al., 2019).

3. Household Expenditure on Fuel
While coal and wood are often cheaper than LPG, the hidden costs—including health expenses, lost working days, and fuel shortages—result in higher long-term expenses (Staton & Harding, 1998). A study in West Bengal found that families using traditional fuels spent 30–40% more on total energy expenses annually than those using LPG due to low combustion efficiency (Bisui et al., 2024).

In the case of *Rajhara*, 30 KG of coal costs approximately 300 Rs and is consumed in 15 days. Whereas, the average monthly expenditure on LPG was ₹915, with a minimum of ₹860 and a maximum of ₹1,200, making it a significant financial burden for low-income households.

5.3 Emission Testing Data and Coal Dependency

Recent emission studies have reinforced the case for reducing coal dependency in household cooking. Laboratory analysis of cooking fuel samples from rural households shows that:

- Coal and dung mixtures (*goliya*) emit 5–10 times more PM2.5 than LPG (Balakrishnan et al., 2013).
- CO emissions from biomass stoves exceed WHO air quality guidelines by 300–400% (Chakrabarti et al., 2019).
- Sulfur dioxide (SO_2) and benzene levels from coal combustion are associated with increased lung cancer risks (Simkovich et al., 2019).

Comparative Analysis of Cooking Fuels: Emissions, Health Impacts & Prevalence

Fuel Type	PM2.5 Emissions	CO Emissions	Other Pollutants	Health Hazards	Prevalence in Rural India	Validated References
Coal + Dung *(Goliya)*	5–10× higher than LPG	Exceeds WHO limits by 300–400%	High SO_2, benzene, PAHs	Lung cancer, cardiovascular & respiratory disease	~14% (NFHS-5, 2019-21)	(Tiwari et al., 2015); (Wang et al., 2025); (Raiyani et al., 1993)
Firewood	3–6× higher than LPG	High and variable	PAHs, CO, NO_2	Asthma, eye irritation, low birth weight	~45%	(Tiwari et al., 2016); (Singh, 2016); (Sandaroo & Damayanthi, 2016)
Cow Dung Cakes	Similar to firewood	High, prolonged exposure	Methane, ammonia, VOCs, benzene	Tuberculosis, COPD, eye irritation	~20%	(Park et al., 2013); (Wang et al., 2025); (Tiwari et al., 2015)
LPG	Baseline (low)	Within WHO safety limits	Trace aldehydes, hydrocarbons	Minimal impacts; rare misuse risks	~37% (increasing trend)	(Kaur-Sidhu et al., 2020); (Mawari et al., 2023); (Tiwari et al., 2015)

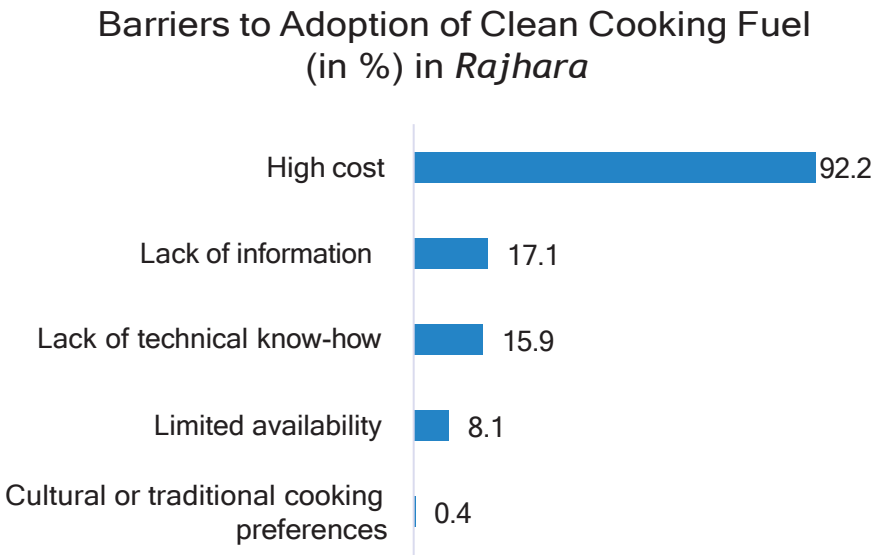
The evidence clearly supports a transition to cleaner cooking fuels to reduce healthcare burdens and improve economic productivity in communities like *Rajhara*.

The health and economic costs of using traditional cooking fuels are disproportionately high, particularly for women and children in rural and mining-affected communities. The prevalence of respiratory diseases increased medical expenses, and lost economic opportunities underscore the urgency of shifting to cleaner alternatives like LPG, electric stoves, and biogas. Strengthening policy initiatives, enhancing financial support for refills, and promoting awareness of health risks will be crucial to accelerating this transition.

6. BARRIERS TO CLEAN COOKING FUEL ADOPTION

Despite the increasing awareness of household air pollution and the availability of clean cooking technologies such as liquefied petroleum gas (LPG) and biogas, many households in coal-mining-affected regions like *Rajhara* continue to rely on traditional biomass fuels. The transition to cleaner alternatives is hindered by a complex interplay of financial, cultural, infrastructural, and policy-related barriers (Malakar, Greig, & van de Fliert, 2018).

Figure 1: Barriers to Clean Cooking Fuel Adoption in Rajhara



1. Financial Constraints

A primary barrier to clean cooking fuel adoption is economic affordability, especially for low-income rural households.

Qualitative insights from SHG discussions in villages around the *Rajhara* mine site confirmed that economic constraints, rather than social norms, remain the primary reason households continue to use polluting fuels.

> WE HAVE GAS, BUT WE CAN'T AFFORD ₹1000 EVERY MONTH. THAT'S WHY WE USE WOOD, COAL AND *GOLIYA*. WE KNOW IT IS HARMFUL TO OUR HEALTH, BUT WHAT CAN WE DO?
>
> – SHG MEMBER FROM PANDWA VILLAGE

Analysis of primary survey data from 258 households in Rajhara revealed a strong association between monthly household income and the type of cooking fuel used. Using a one-way ANOVA, statistically significant differences were found in income across the three cooking fuel categories — traditional fuels, clean fuels, and a combination of both $F(2,255) = 37.43$, $p<.001$. Further post hoc testing using the Games-Howell method (to account for unequal variances) confirmed that households using clean fuels had significantly higher incomes than those using traditional fuels or a combination of both. There was no significant income difference between users of traditional fuels and those using a combination of both fuel types.

These results indicate that higher household income is strongly associated with exclusive use of clean cooking fuels, while those with lower or unstable incomes are more likely to rely on traditional fuels or adopt a mixed-use strategy due to affordability constraints.

The upfront cost of biogas plant installation is another deterrent, despite long-term savings on fuel. Households require substantial financial investments for plant construction and maintenance, making it an infeasible option for many rural families (Vigolo, Sallaku, & Testa, 2018).

> WE HAVE TO COOK FOOD ON THE CHULHA FOR CHHATH POOJA." IT IS CONSIDERED AUSPICIOUS.
>
> – SHG MEMBER FROM *RAJHARA* VILLAGE

2. Safety Concerns and Lack of Awareness

Secondary literature suggests that households hesitate to adopt LPG or biogas due to concerns over safety and maintenance. Reports of accidental LPG explosions create fear among rural populations, discouraging them from switching to gas-based cooking (Sharma et al., 2020). Households often perceive biogas plants as high-risk due to concerns about gas leakage and maintenance difficulties (Falcone, 2023). Many users struggle with handling LPG cylinders and biogas digesters, leading to hesitancy in adoption.

Even where subsidies exist, lack of awareness about application procedures, refill logistics, and safe usage practices prevents widespread adoption, especially among women and older residents who are primary users of cookstoves (Rao et al., 2020). The absence of training programs on safe handling and maintenance exacerbates the issue (Kulyal & Jalal, 2022). Many rural households remain unaware of the health benefits of clean cooking, as education and behavioral change programs are insufficient (Luthra et al., 2015).These challenges are compounded in mining-affected areas, where development outreach is often weak and traditional fuels like coal residue are readily available.

3. Supply Chain and Infrastructure Issues

Clean cooking fuel adoption is also hindered by inconsistent LPG supply chains and inadequate biogas support systems. Villages lack regular access to LPG refills, forcing households to revert to biomass and coal. Delays in cylinder delivery and long travel distances to refill centers discourage continued LPG use (Rehfuess, Puzzolo, & Stanistreet, 2014). Households that do install biogas plants face difficulties in maintenance due to the scarcity of skilled technicians and repair services in rural areas (Wright, Sathre, & Buluswar, 2020).

4. Cultural Preferences and Cooking Habits

Traditional cooking methods are deeply embedded in cultural and culinary preferences, making behavioral change a notable challenge. Many rural

households perceive food cooked on wood or coal to have a better taste and aroma compared to LPG or electric stoves (Astuti, Day, & Emery, 2019). The use of clay stoves (chulhas) and open-fire cooking methods is deeply rooted in generational practices, with many families reluctant to switch due to familiarity and perceived efficiency (Malakar et al., 2018).

While the broader primary data from Rajhara shows minimal cultural resistance, one specific religious practice emerged where members noted that during Chhath Puja, traditional stoves are preferred:

Cow dung cakes stored in a narrow corridor

This suggests a ceremonial preference for cooking with wood or dung during festivals, indicating that even LPG-owning households may temporarily revert to traditional fuels for ritual purposes. However, across all other SHGs, respondents explicitly stated that no cultural preferences were preventing them from adopting clean fuels.

5. Policy Gaps in PMUY and Clean Energy Initiatives

Although PMUY has made strides in distributing LPG connections, it lacks sustained financial support mechanisms for refills and long-term usage. PMUY only subsidizes the initial LPG connection but does not provide consistent financial aid for refills, leading to low sustained adoption among low-income groups (Sharma et al., 2020).

Taste preferences surfaced in some SHG discussions in *Rajhara*—particularly among older women who favored the smokier flavour of food cooked on a chulha. Others downplayed this, emphasizing health, convenience, and the need to build new habits. While cultural factors like taste or religious practices may influence individual choices, they are not systemic barriers in *Rajhara*. Instead, economic constraints and limited exposure to clean cooking technologies remain the primary challenges. Supply chain issues and safety concerns, often critical elsewhere, were not reported as significant obstacles in this context.

7. ROADMAP FOR IMPLEMENTATION

The successful transition to clean cooking fuels in coal-mining regions like *Rajhara* requires an integrated approach that addresses financial, logistical, and behavioral barriers. While programs such as the *Pradhan Mantri Ujjwala Yojana* (PMUY) have improved LPG access, ensuring sustained adoption requires a combination of financial solutions, supply chain interventions, and behavioral change strategies (Kumar, Dhand, Tabak, & Brownson, 2017).

7.1 Program/Project Level Recommendations

PHASE 1: ENHANCING AFFORDABILITY THROUGH FINANCIAL MODELS

STRENGTHENING PMUY WITH REFILL SUBSIDIES

Direct Benefit Transfers (DBT) can provide targeted LPG refill subsidies to vulnerable groups (Kar, 2019). Implement tiered pricing models, where lower-income households receive higher subsidies, while wealthier consumers pay market rates (Lewis & Pattanayak, 2012).

MICROFINANCE AND SELF-HELP GROUP (SHG)-LED FINANCING

Microfinance institutions (MFIs) and SHGs can offer low-interest loans for clean fuel adoption (Anjanappa, 2024). SHG-led LPG bulk purchasing models can negotiate discounts and enable installment-based payments (Jeuland & Pattanayak, 2020).

PAY-AS-YOU-GO LPG REFILL MODELS

The pay-as-you-go (PAYG) model enables households to buy LPG in smaller, affordable quantities. Smart meters can support mobile-based micropayments (Schunder & Bagchi-Sen, 2019; Balachandra, 2011).

PHASE 2: ADDRESSING SUPPLY CHAIN CHALLENGES

EXPANDING LPG DISTRIBUTION NETWORKS

Establish mini LPG refilling stations in rural areas and deploy electric cargo vehicles for last-mile delivery (Kumar et al., 2017; Puzzolo, Pope, Stanistreet, & Rehfuess, 2016).

STRENGTHENING BIOGAS INFRASTRUCTURE

Deploy localized biogas service centers and train rural youth in biogas maintenance (Kar, 2019; Vigolo, Sallaku, & Testa, 2018).

PHASE 3: BEHAVIOR CHANGE COMMUNICATION STRATEGIES

OVERCOMING CULTURAL RESISTANCE

Conduct community cooking demonstrations and offer LPG starter kits with traditional-cooking-compatible features (Astuti, Day, & Emery, 2019; Malakar, Greig, & van de Fliert, 2018; Jeuland & Pattanayak, 2020).

ADDRESSING SAFETY MYTHS

Launch safety training programs and establish local repair helplines (Sharma, Ravindra, & Kaur, 2020; Anjanappa, 2024).

LEVERAGING SHGS AND LOCAL GOVERNANCE

Train SHG members as clean cooking ambassadors and integrate clean cooking education into public health campaigns (Schunder & Bagchi-Sen, 2019; Puzzolo et al., 2016).

7.2 Policy Level Recommendations

How can the state convert one-time LPG connections into sustained, clean fuel usage in low-income, coal-affected communities where affordability and accessibility remain key barriers? Without mechanisms for refill subsidies or alternative affordable technologies, households revert to the same polluting fuels that compromise their health, increase their unpaid labour burden, and perpetuate environmental harm.

The following two-phase policy roadmap addresses this dilemma by offering scalable, intersectoral solutions–from strengthening PMUY's financial viability to embedding clean cooking within renewable energy and rural development strategies.

PHASE1: STRENGTHEN PMUY SUPPORT

The Pradhan Mantri Ujjwala Yojana (PMUY) has been a transformative policy in expanding LPG access among marginalized groups, but its current design largely focuses on connection subsidies. Evidence suggests that without sustained refill support, many households revert to traditional fuels due to refill costs (Kumar et al., 2017). Our fieldwork in *Rajhara* also revealed that while many households possess LPG connections, regular refilling is rare. Refills are often reserved for festivals or emergencies due to high refill costs and inconsistent subsidies.

Policy Decision Point: Can LPG subsidies shift from one-time access to sustained affordability?

Proposed Actions:

- Proposal: Extend automatic refill subsidies for 3-5 years after initial connection, particularly for low-income and remote households.
- Additionally, by integrating public-private partnerships (PPPs), the government can share distribution responsibilities with private players to expand LPG access in underserved rural regions, enhancing last-mile delivery efficiency (Lewis & Pattanayak, 2012).

> IF OUR HUSBANDS EARN ONLY ₹20,000 A MONTH, HOW CAN WE SPEND ₹1,200 ON GAS? WE SAVE IT FOR GUESTS
>
> – SHG MEMBER, *RAJHARA*

PHASE 2: INTEGRATE CLEAN COOKING INTO RENEWABLE ENERGY POLICIES
Biogas remains a viable and renewable clean cooking alternative, especially in agriculture-driven rural areas, but it lacks mainstream policy visibility.

Policy Decision Point: Can rural energy policy move beyond LPG and recognise diverse clean fuel options?

Proposed Actions:

- Link biogas promotion with agricultural waste management programs, encouraging the use of crop residues and livestock waste to fuel decentralized digesters (Kar, 2019).
- Further, integrating carbon credit schemes—where households earn benefits for reducing emissions—can provide financial incentives to adopt clean cooking technologies (Anjanappa, 2024). This aligns clean cooking with India's climate goals and rural development objectives, enhancing cross-sectoral policy impact.

The transition to clean cooking fuels in coal-mining regions like *Rajhara* requires a multi-pronged strategy combining financial support, supply chain strengthening, behavior change communication, and policy reforms. Leveraging PMUY with enhanced subsidies, introducing microfinance and SHG-led financing, and improving last-mile LPG distribution will be critical for sustained adoption. Additionally, community-led awareness programs and infrastructure investment in biogas solutions will help accelerate the shift to clean cooking technologies.

These two recommendations together offer a policy bridge that connects short-term adoption incentives with long-term sustainability frameworks, essential for a resilient and inclusive clean cooking transition in India's coal-impacted regions.

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