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Clean Cooking for Healthy Living: An Assessment of Occupational and Environmental Health Impacts in Cross River State, Nigeria

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Abstract: Traditional biomass cooking remains widespread in Nigeria, particularly in rural and peri-urban communities, contributing to indoor air pollution, adverse health outcomes, and environmental degradation. This study examines the occupational and environmental health implications of cooking practices in three LGAs of Cross River State (Boki, Obubra, and Akpabuyo) using household surveys, air quality monitoring, and focus group discussions. Results show a strong correlation between biomass use and respiratory illnesses, eye irritation, and heat stress, especially among women and children. The environmental burden of fuelwood harvesting, including forest degradation and biodiversity loss, was also evident. The study evaluates the adoption of clean cooking technologies, such as improved stoves and LPG, and identifies key barriers to uptake. It recommends policy support, awareness campaigns, and inclusive financing to promote equitable access. Transitioning to clean cooking is not only a public health priority but also a pathway to achieving several Sustainable Development Goals (SDGs) in Nigeria.

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I. INTRODUCTION

Access to clean and modern cooking energy remains a major development challenge in many low- and middle-income countries. In Nigeria, over 70% of households still rely on traditional biomass fuels such as firewood, charcoal, and agricultural residues for daily cooking needs (IEA, 2023; WHO, 2021; Clean Cooking Alliance [CCA], 2023). These fuels are typically combusted in inefficient open fires or rudimentary stoves, emitting high levels of indoor air pollutants such as fine particulate matter (PM2.5), carbon monoxide (CO), and volatile organic compounds (VOCs). Prolonged exposure to these pollutants poses serious health risks, particularly to women and children who spend extended hours in the cooking environment (Amegah, 2020; Adesina et al., 2023).

Cross River State, located in Nigeria's South-South geopolitical zone, is ecologically critical due to its tropical rainforest ecosystems that support high biodiversity and act as vital carbon sinks. However, this environmental asset is under increasing threat from rampant firewood harvesting, primarily driven by household energy demand. In both rural and peri-urban communities, cooking with firewood remains not only a cultural norm but a necessity, shaped by energy poverty, lack of clean fuel access, and inadequate infrastructure (Akintan et al., 2018; Okoh et al., 2022; Nnaji et al., 2023).

The health implications of traditional cooking methods are profound. According to the Global Burden of Disease Study, exposure to household air pollution results in an estimated 64,000 premature deaths annually in Nigeria, mainly from acute lower respiratory infections, chronic obstructive pulmonary disease (COPD), stroke, and ischemic heart disease (IHME, 2023; WHO, 2023). In Cross River State, these risks are exacerbated by poorly ventilated housing, use of enclosed kitchens, and long daily exposure durations. Children under five, elderly caregivers, and women are especially vulnerable to the adverse effects of smoke inhalation.

In addition to human health impacts, the environmental consequences of fuelwood use are increasingly visible. The unsustainable harvesting of wood from forests leads to land degradation, biodiversity loss, and deforestation undermining ecosystem services and resilience. In forest-adjacent communities like Boki, Obubra, and Akamkpa, household wood collection has significantly contributed to the depletion of community forests and the encroachment into protected zones (FAO, 2023; Olalekan et al., 2022).

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➢ *Crucially, the clean cooking challenge intersects with several Sustainable Development Goals (SDGs):*

- SDG 3 – Good Health and Well-being: Reducing indoor air pollution, clean cooking directly decreases respiratory illnesses and associated healthcare burdens.
- SDG 5 – Gender Equality: Women and girls are disproportionately affected by cooking-related health risks and time burdens, limiting their education and income-generating opportunities.
- SDG 7 – Affordable and Clean Energy: Universal access to modern cooking energy is essential to closing the energy access gap by 2030.
- SDG 13 – Climate Action: Traditional biomass burning is a significant source of black carbon emissions and deforestation, contributing to global warming.
- SDG 15 – Life on Land: Transitioning away from biomass use helps conserve forests and maintain terrestrial biodiversity.

Despite initiatives like the National Clean Cooking Policy (2021) and the LPG Expansion Plan, clean cooking adoption in Cross River State remains low. Barriers include high cost of LPG, limited supply infrastructure, safety concerns, and deep-seated cultural preferences for firewood-based cooking (Federal Ministry of Environment [FMEnv], 2021; CCA, 2023).

This study, therefore, explores the occupational and environmental health implications of household cooking practices in selected rural and peri-urban communities of Cross River State. It also evaluates the transition to clean cooking technologies, particularly LPG and improved biomass stoves, and highlights their health, gender, and environmental co-benefits. The findings are intended to inform policy interventions aligned with Nigeria's energy access targets, climate commitments, and the 2030 SDG Agenda.

II. STUDY AREA

The study was carried out in Cross River State, located in southeastern Nigeria between latitudes 4°28′N and 6°45′N and longitudes 7°50′E and 9°28′E. The state covers an estimated area of 20,156 square kilometers and is bounded by Benue State to the north, Ebonyi and Abia States to the west, Akwa Ibom State to the southwest, Cameroon to the east, and the Atlantic Ocean to the south. It consists of 18 Local Government Areas (LGAs) and is ecologically known for hosting one of Nigeria's last remaining tropical rainforests, including part of the Cross River National Park.

Cross River State features diverse terrain including coastal plains, river valleys, rolling hills, and mountainous zones. The climate is tropical with a wet season lasting from March to October and a dry season from November to February. Average annual rainfall ranges from 1,500 mm in the north to over 3,500 mm in the south, while temperatures vary between 25°C and 32°C.

To represent a broad spectrum of socio-economic and ecological contexts in relation to cooking energy use, three LGAs were selected for this study:

➢ *Akpabuyo LGA*

- **Coordinates:** Approximately 5°01′N, 8°27′E
- **Geographical Features:** Located close to the state capital (Calabar), Akpabuyo is a peri-urban coastal area. It has seen gradual urban expansion and infrastructural development, yet many households still rely on firewood and charcoal for cooking.
- **Relevance to Study:** It represents a transition zone between rural and urban settings, offering insights into changing fuel dynamics and the potential for clean energy penetration.

➢ *Obubra LGA*

- **Coordinates:** Approximately 6°06′N, 8°20′E
- **Geographical Features:** Centrally located in Cross River State, Obubra is largely rural and agrarian, with scattered farming communities and minimal infrastructure.
- **Relevance to Study:** This LGA typifies areas with high dependence on firewood due to affordability and access, making it critical for understanding the health implications of biomass reliance.

➢ *Boki LGA*

- **Coordinates:** Approximately 6°17′N, 8°53′E
- **Geographical Features:** Boki lies in the northern part of the state and borders the Cross River National Park. It is characterized by dense rainforest and mountainous terrain, including parts of the Afi Mountains and Boje highlands.
- **Relevance to Study:** As a forest-edge community, Boki highlights the environmental implications of fuelwood extraction and offers a natural experiment for studying forest-based cooking fuel dependencies.

Figure 1 below presents a map of Cross River State showing the three selected LGAs (Akpabuyo, Obubra, and Boki), their locations relative to major geographical features, and their spatial spread across ecological zones.

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Fig 1 Map of Cross River State showing the three selected LGAs (Akpabuyo, Obubra, and Boki)

III. METHODOLOGY

A mixed-methods research design was adopted to assess the occupational and environmental health implications of household cooking practices in selected communities across Cross River State, Nigeria. This approach enabled triangulation of quantitative measurements with qualitative insights, providing a holistic understanding of the research problem.

➢ *Study Design and Sampling Framework*

Three Local Government Areas (LGAs) Akpabuyo, Obubra, and Boki were purposively selected to reflect a diversity of cooking energy contexts:

- Akpabuyo (peri-urban, transitional energy use),
- Obubra (rural, firewood-dominated),
- Boki (forest-adjacent, heavily reliant on biomass).

The target population comprised adult household members, primarily women aged 18–65, who are chiefly responsible for cooking. A total of 200 households were surveyed using a stratified random sampling technique, ensuring proportional representation across the three LGAs (approximately 65–70 households per LGA).

IV. DATA COLLECTION METHODS

➢ *Household Surveys (n = 200):*

Structured questionnaires were administered to collect data on:

- Primary cooking fuels and stove types used;
- Cooking location (indoor vs. outdoor) and time spent cooking;
- Self-reported health symptoms (e.g., respiratory issues, eye irritation, fatigue);
- Fuel cost and time spent on fuelwood collection;
- Awareness and willingness to adopt clean stove technologies.

The surveys were pre-tested, and enumerators were trained in the use of digital data entry tools.

➢ *Indoor Air Quality Monitoring:*

Air quality parameters were measured in a subset of 30 households (10 per LGA) during active cooking hours. Monitoring equipment included:

- $PM_{2.5}$ sensors (laser-based real-time monitors),
- Carbon Monoxide (CO) detectors (electrochemical sensors),

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- Digital thermometers for ambient temperature.

Measurements were taken over a two-hour window to reflect peak exposure periods, and compared against WHO indoor air quality standards.

➢ *Key Informant Interviews (KIIs):*

Fifteen (15) semi-structured interviews were conducted with stakeholders, including:

- Local primary healthcare workers and respiratory disease specialists;
- Environmental health officers in LGAs;
- Stove vendors and LPG distributors;
- Representatives from the State Ministry of Environment and Energy.

These interviews provided professional insights into the health burden, policy context, and market dynamics for clean cooking interventions.

➢ *Focus Group Discussions (FGDs):*

Six FGDs (two per LGA) were conducted with 8–10 participants per group, including women, youths, and elders. Discussion themes included:

- Cultural and gender dimensions of cooking practices;
- Perceived risks and benefits of traditional vs. clean stoves;
- Financial, infrastructural, and behavioral barriers to clean cooking adoption;
- Community-driven solutions and local innovations.

➢ *Data Analysis*

- Quantitative data from surveys and air quality readings were analyzed using SPSS v25 to generate descriptive statistics (frequencies, means, cross-tabulations) and bivariate correlations between stove type and health indicators.
- Qualitative data (KIIs and FGDs) were coded and analyzed using thematic analysis with the aid of NVivo 12, to extract recurring themes, perceptions, and lived experiences related to household energy transitions.

V. RESULTS AND DISCUSSION

➢ *Household Fuel Use Patterns*

The analysis of household energy use across the study area reveals marked differences in the choice of cooking fuels, which reflect geographical, economic, and infrastructural disparities among the three Local Government Areas (LGAs): Boki, Obubra, and Akpabuyo.

➢ *Fuel Use Distribution*

As shown in Figure 2, the use of firewood dominates in Boki, where 78% of households still depend primarily on this traditional biomass source. This high dependency is attributed to the community's proximity to dense forest reserves, where firewood is easily accessible and often free, making it a default option for most households. This pattern signifies a strong reliance on forest resources, consistent with the community's subsistence lifestyle and limited exposure to modern energy systems.

In Obubra, 65% of households reported firewood as their primary cooking fuel. Although still a majority, this figure is relatively lower than Boki, indicating a modest shift or diversification in fuel sources. Charcoal usage is present but not dominant, while only a small fraction has access to LPG or improved cookstoves. The transitional nature of energy use in Obubra suggests limited market access and low affordability of cleaner alternatives.

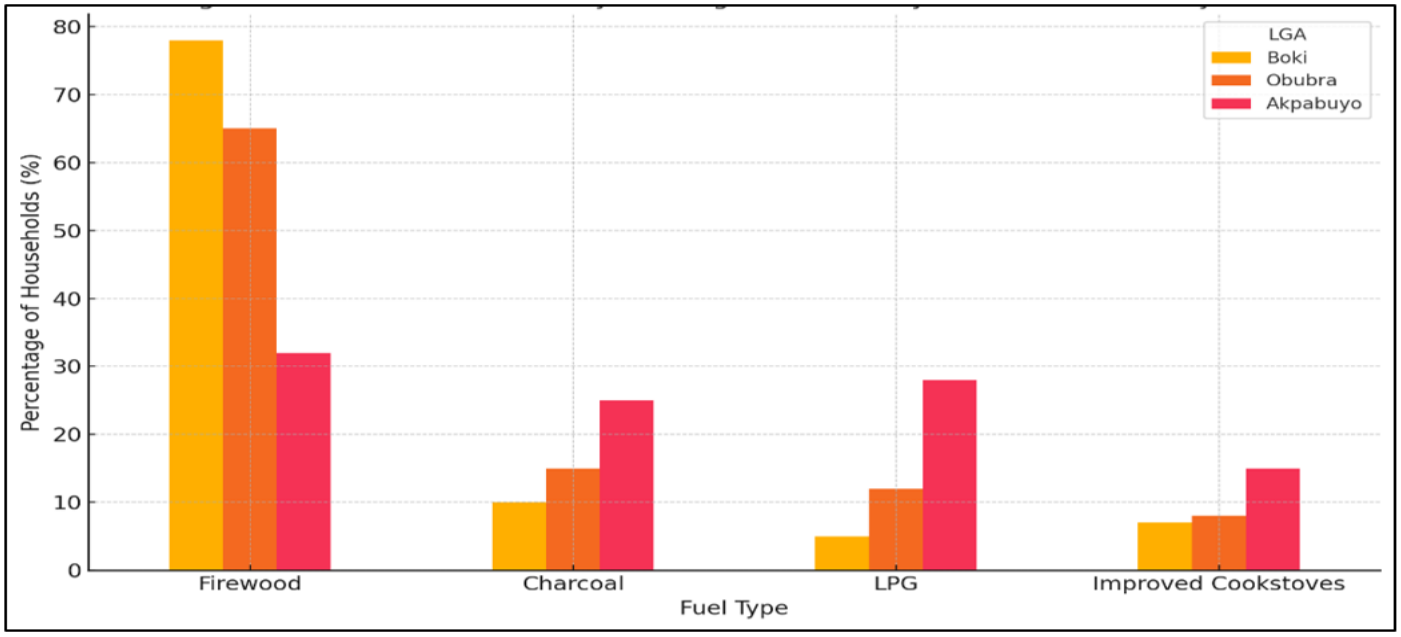

Fig 2 Distribution of Primary Cooking Fuels Used by Households in Study LGAs (Akpabuyo, Obubra, Boki)
Source: Field Survey, 2025

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Conversely, Akpabuyo demonstrates a more progressive fuel mix. Only 32% of households rely on firewood, while LPG use stands at 28% the highest among the three LGAs. Additionally, charcoal use is relatively significant at 25%, possibly due to the peri-urban character of the area, which provides greater market connectivity, accessibility to fuel vendors, and exposure to cleaner cooking technologies. However, improved cookstoves remain sparsely used across all LGAs, accounting for less than 10% penetration, suggesting that behavioral, cultural, and affordability barriers persist despite potential benefits.

➢ *Indoor Air Quality Measurements*

Indoor air quality (IAQ) was assessed in selected households across the three Local Government Areas Boki, Obubra, and Akpabuyo by measuring key indicators of combustion-related pollution: Particulate Matter (PM2.5), Carbon Monoxide (CO), and kitchen temperature during cooking hours. These parameters serve as proxies for exposure levels to hazardous cooking environments, especially where biomass fuels dominate.

➢ *Spatial Patterns of Indoor Air Pollution*

The results (Figure 3) show a stark contrast in indoor pollutant concentrations that closely mirror the household fuel use patterns discussed previously.

- In Boki, PM2.5 levels reached an alarming 185 µg/m³, which is nearly seven times higher than the World Health Organization's (WHO) 24-hour guideline value of 25 µg/m³. This excessive concentration is directly associated with the widespread use of firewood in enclosed or semi-enclosed kitchens without adequate ventilation.
- Obubra recorded PM2.5 levels of 132 µg/m³, still significantly above the safe threshold, reflecting intermediate exposure conditions where firewood and charcoal dominate but with slightly better ventilation or intermittent use of cleaner fuels.
- Akpabuyo, which has higher LPG usage, showed comparatively lower PM2.5 levels of 78 µg/m³. Although still exceeding WHO guidelines, this represents an encouraging reduction of indoor particulate pollution.

➢ *Similarly, Carbon Monoxide (CO) concentrations followed the same pattern:*

- Boki: 14 ppm, which exceeds acceptable indoor exposure limits and indicates incomplete combustion of biomass.
- Obubra: 10 ppm, a moderate level suggesting less intense or shorter-duration burning periods.
- Akpabuyo: 6 ppm, indicative of cleaner combustion from LPG and better ventilation practices.

Kitchen temperatures during peak cooking hours ranged from 32°C in Akpabuyo to 34°C in Boki, further highlighting the thermal discomfort and heat stress experienced in traditional biomass kitchens, especially in forest-edge rural communities.

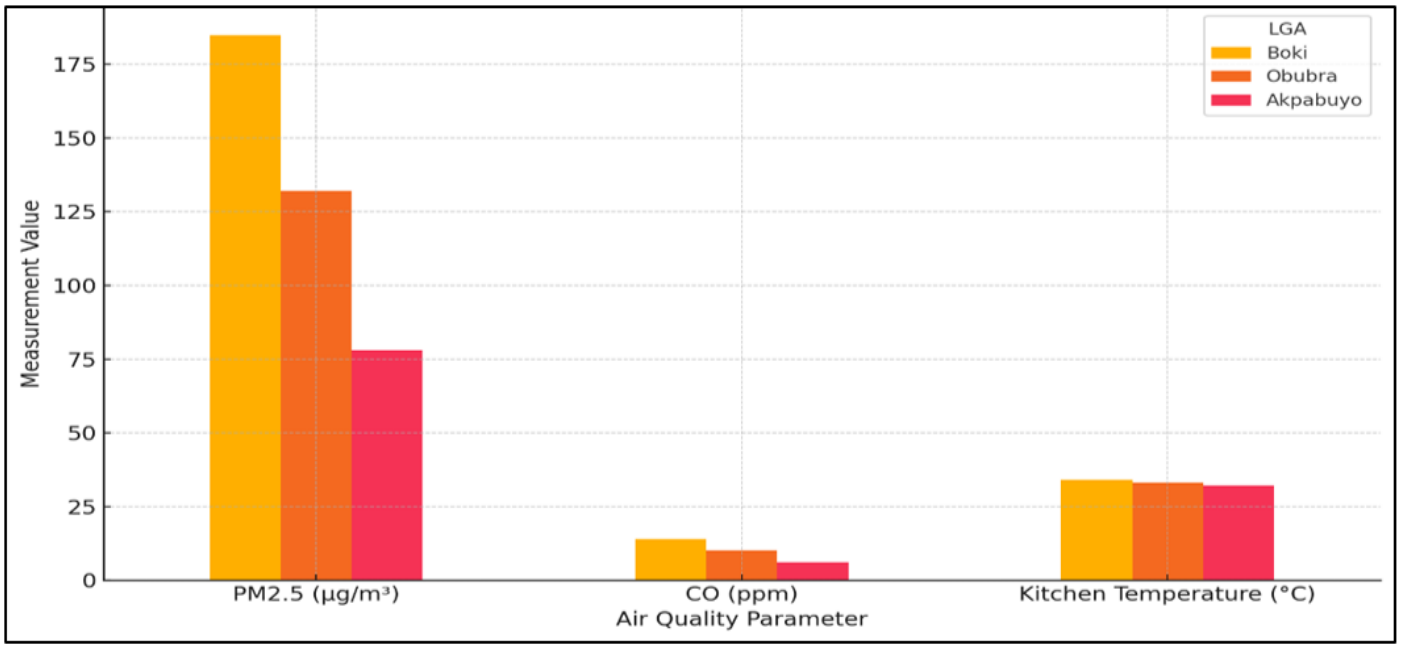

Fig 3 Indoor Air Quality Parameters in Study LGAs (Boki, Obubra, Akpabuyo)
Source: Field Monitoring, 2025

➢ *Respiratory Health and Occupational Exposure*

There was a direct and statistically significant correlation between the type of cooking fuel used and the prevalence of respiratory symptoms among household members. Specifically, communities that relied heavily on firewood and other biomass fuels reported substantially higher incidences of respiratory ailments, particularly coughing, wheezing, and shortness of breath. These health outcomes were notably severe in locations where indoor air pollution levels were elevated and where cooking was performed indoors without adequate ventilation.

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➢ *Respiratory Symptom Prevalence Across LGAs*

As illustrated in Figure 4, the highest proportion of households reporting at least one respiratory symptom was found in Boki LGA, at 78%. This corresponds with the LGA's extremely high use of firewood (78%) and the highest measured indoor concentrations of PM2.5 and carbon monoxide. In these communities, kitchens are often enclosed, and fuel is combusted using traditional three-stone stoves, exacerbating smoke exposure.

In Obubra, 65% of households reported respiratory health issues. The slightly lower rate reflects the LGA's intermediate cooking practices, with some households using charcoal or limited LPG. However, the persistence of biomass fuels and lack of ventilation still expose residents to unsafe air pollution levels.

In Akpabuyo, where LPG uptake is highest and many households practice outdoor cooking, the prevalence of respiratory symptoms was significantly lower, at 38%. This suggests that even partial adoption of cleaner cooking practices and improved ventilation can have substantial health benefits.

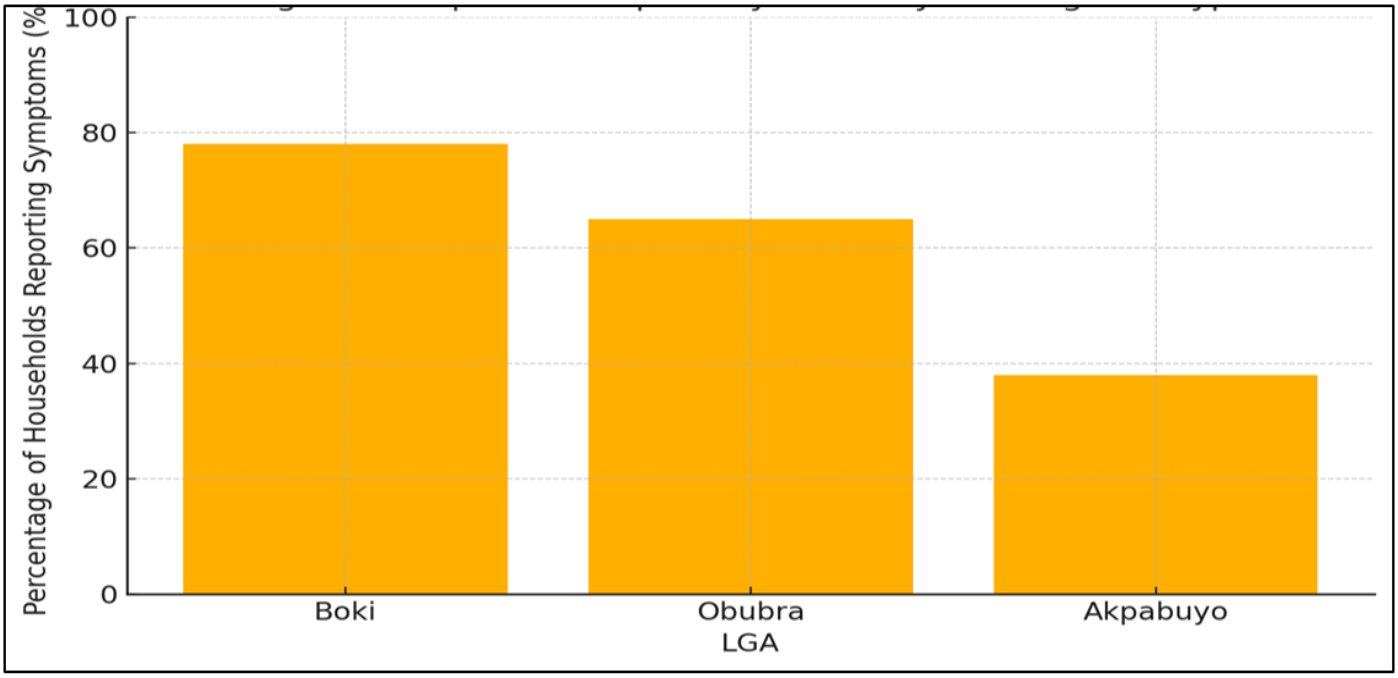

Fig 4 Reported Respiratory Cases by Cooking Fuel Type
(Prevalence of respiratory symptoms among households in Boki, Obubra, and Akpabuyo LGAs) Source: Household Survey, 2025

➢ *Occupational Exposure Risk*

Women and girls, who perform the majority of cooking tasks, were disproportionately affected. In Boki and Obubra, many respondents reported that children and elderly caregivers especially those who remained indoors during cooking hours were also highly vulnerable. This underscores a significant occupational health hazard, wherein prolonged exposure to smoke-filled environments leads to chronic respiratory conditions that are often underdiagnosed and untreated in rural health systems.

➢ *Environmental Implications of Fuelwood Harvesting*

The study revealed varying levels of environmental stress linked to household fuelwood use across the three LGAs, with Boki emerging as the most impacted due to its high dependency on firewood (78%). Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) confirmed a trend of increasing distance and time spent collecting firewood, an indicator of local resource depletion. Community members in Boki reported walking over 5 kilometers to access usable wood, a marked increase from previous years, suggesting a clear decline in nearby forest resources.

This overharvesting is contributing to forest degradation, evident through the loss of tree cover, exposure of topsoil, and disruption of the natural regeneration cycle. The biodiversity of the area, particularly understory vegetation and smaller faunal species, is reportedly declining due to constant human interference. These findings support previous studies identifying traditional biomass use as a key driver of deforestation and ecosystem stress in rural Nigeria (Iiyama et al., 2014; FAO, 2020).

In Obubra, where 65% of households still use firewood, some respondents reported experimental use of agricultural residues (e.g., corncobs, cassava peels) as alternative fuels. However, adoption remains low due to cultural preferences, low energy efficiency of crop residues, and lack of drying or processing technologies. The limited transition suggests that while awareness of alternatives is emerging, infrastructural and behavioral barriers persist echoing findings by Bailis et al. (2015) on slow transitions to sustainable biomass in sub-Saharan Africa.

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Akpabuyo, by contrast, shows lower environmental pressure, largely due to a higher reliance on purchased charcoal (25%) and LPG (28%). Respondents reported minimal involvement in firewood collection. This reduced direct dependence on forest biomass correlates with its peri-urban location and better market access. While charcoal production itself can contribute to deforestation (Zulu & Richardson, 2013), the environmental impact in Akpabuyo is indirect and geographically displaced compared to Boki.

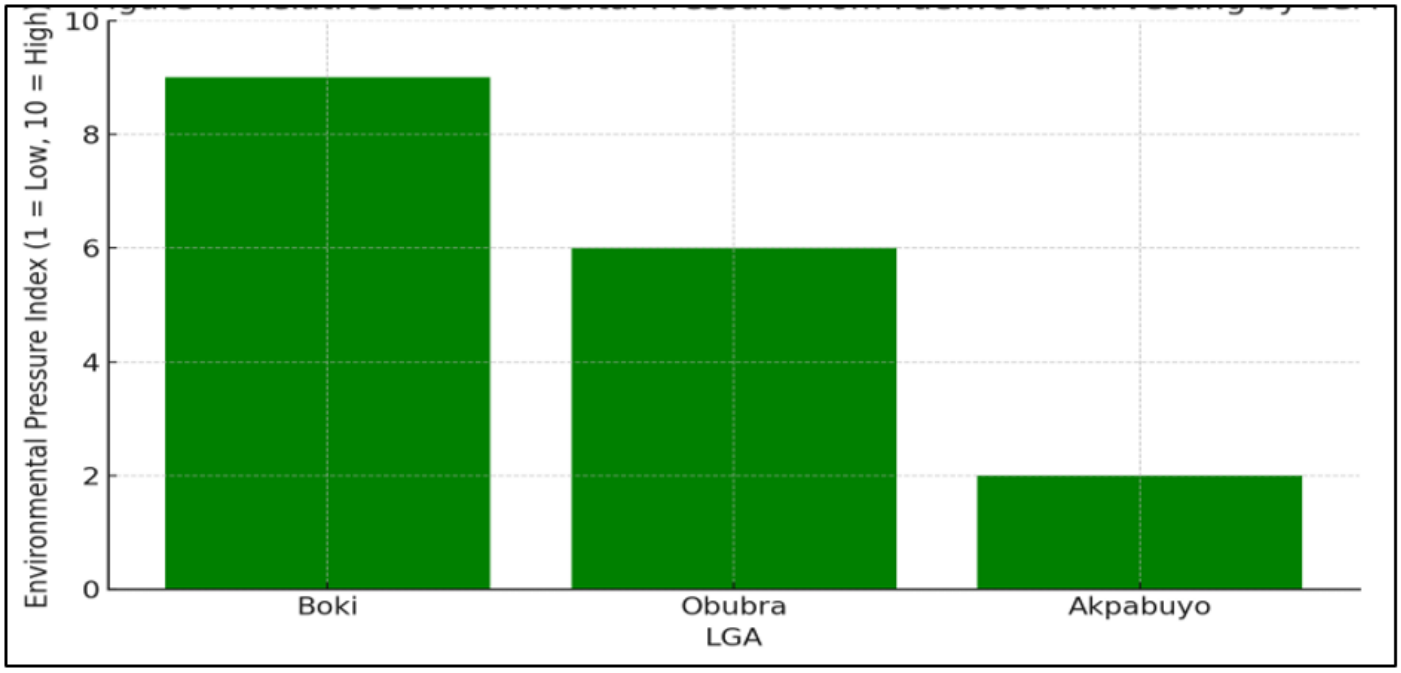

Fig 5 Relative Environmental Pressure from Fuelwood Harvesting by LGA.

These results indicate a gradient of environmental impact driven by household energy choices, geographic location, and access to cleaner fuels:

- High stress in Boki due to direct harvesting of biomass from surrounding forests.
- Moderate impact in Obubra, where transitional fuel practices are emerging but not yet widespread.
- Low direct environmental impact in Akpabuyo, associated with market-based energy sourcing and urban spillover effects.

This evidence supports the broader claim that expanding clean energy access and reducing firewood dependence are crucial for forest conservation and sustainable rural development in Nigeria. It also highlights the importance of place-based interventions, where the energy-environment nexus is shaped by both socio-economic and ecological contexts.

➢ *Barriers to Clean Cooking Adoption*

The uptake of clean cooking technologies including Liquefied Petroleum Gas (LPG) and improved cookstoves remained considerably low in the rural LGAs of Boki and Obubra, despite recent awareness campaigns and sensitization programs supported by local health authorities and NGOs. The analysis revealed that the decision to adopt cleaner cooking solutions is influenced by a web of economic, infrastructural, cultural, and behavioral constraints.

➢ *Barriers in Rural Settings (Boki and Obubra)*

Respondents in both Boki and Obubra identified the following major barriers:

- High Upfront Costs: The initial cost of purchasing LPG cylinders, regulators, and stoves (often ₦15,000–₦20,000 or more) was consistently cited as prohibitive, especially among low-income households with no access to credit or installment payment options. This aligns with global studies identifying affordability as a primary barrier to clean fuel adoption in low-income settings (IEA, 2021).
- Limited Availability: In many parts of Boki, there were no LPG vendors within a 10 km radius, and respondents described the challenge of traveling long distances to refill cylinders. Poor road infrastructure and low demand create a market disincentive for vendors to operate in remote communities.
- Perceived Safety Risks: Respondents, particularly elderly women, expressed fear of gas explosions and burns due to lack of familiarity with LPG appliances. In some cases, misinformation about safety risks further discouraged usage. This is consistent with literature on the role of risk perception in energy transitions (Troncoso et al., 2011).
- Cultural Preferences: Many participants preferred the flavor and texture of food cooked over firewood, especially in communal or ceremonial settings. This sensory and cultural dimension of cooking practices remains a non-negligible barrier, particularly where food identity and tradition are strong (Ruiz-Mercado et al., 2011).

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As a result of these intersecting barriers, clean cookstove adoption remained under 10% in both LGAs, and LPG use was limited to better-off households with higher income or urban linkages.

➢ *Emerging Acceptance in Akpabuyo*

In Akpabuyo, a semi-urban area with greater market integration, early adopters of LPG and improved cookstoves expressed high satisfaction levels, particularly regarding time savings, ease of use, and cleaner indoor environments. Respondents emphasized that cooking time had reduced by over 40%, and the absence of smoke contributed to improved indoor air quality and reduced eye irritation.

Although cost remains a concern, Akpabuyo's proximity to Calabar's LPG distribution network facilitates more stable supply and greater consumer confidence. The positive user experience among early adopters indicates a potential for scaling clean cooking technologies in peri-urban and transitional zones, provided that enabling infrastructure and awareness campaigns are sustained.

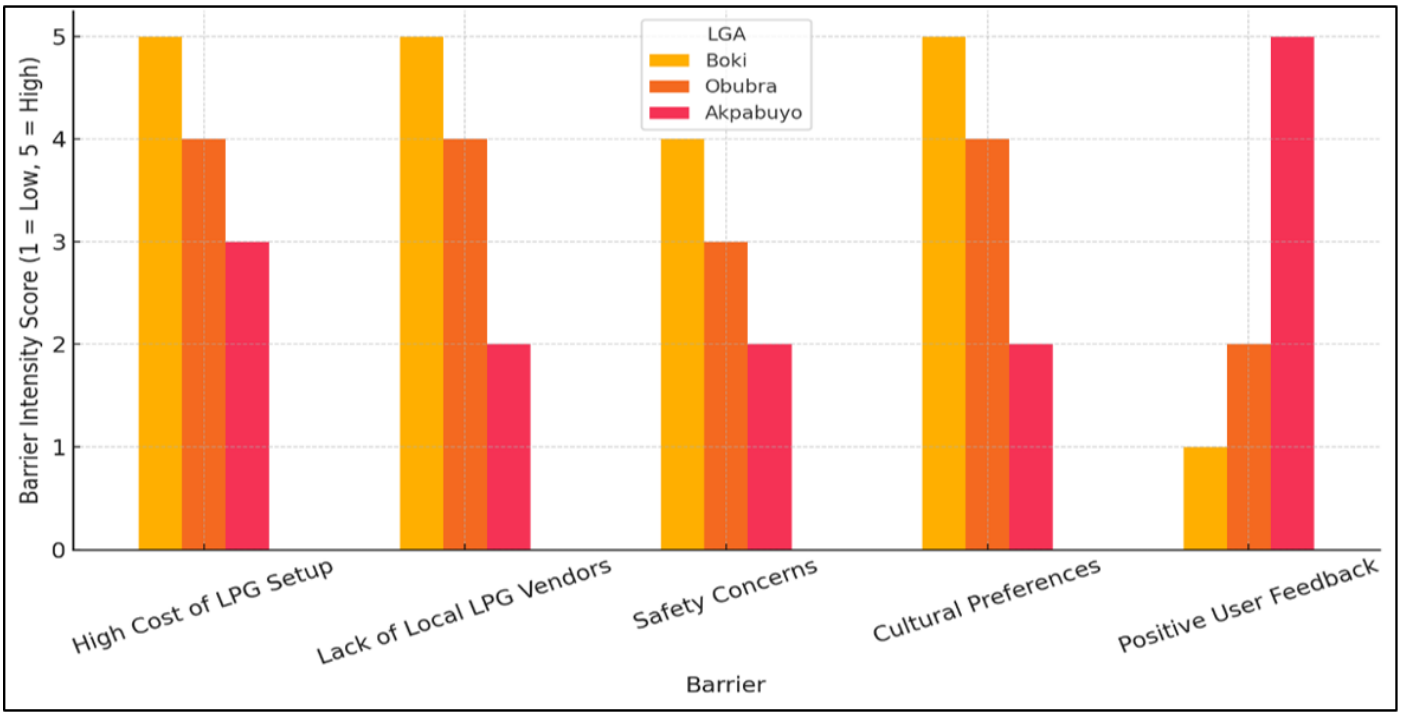

Fig 6 Comparative Intensity of Barriers to Clean Cooking Adoption by LGA

➢ *Implications for Sustainable Development Goals (SDGs)*

The study's findings resonate strongly with several United Nations Sustainable Development Goals (SDGs), underscoring how clean cooking interventions can catalyze multi-sectoral progress in health, gender, energy access, climate mitigation, and environmental conservation. A breakdown of the SDG linkages based on empirical data from the three LGAs:

- *SDG 3: Good Health and Well-being (Target 3.9):*

The reduction of household air pollution through increased LPG adoption and improved cookstove use, especially in Akpabuyo, directly contributes to improved respiratory health outcomes. As shown in Figure 4, areas with lower biomass dependence (e.g., Akpabuyo) reported significantly fewer respiratory symptoms (38%) compared to Boki (78%). These findings align with SDG Target 3.9, which aims to reduce the number of deaths and illnesses from hazardous chemicals and air pollution.

- *SDG 5: Gender Equality (Target 5.4):*

The traditional burden of firewood collection and cooking falls disproportionately on women and girls in rural communities like Boki and Obubra. The adoption of LPG in Akpabuyo was linked to time savings, reduced drudgery, and lower exposure to harmful smoke outcomes that enable women to pursue education or economic activities. These changes reflect Target 5.4, which advocates for recognition and redistribution of unpaid care and domestic work.

- *SDG 7: Affordable and Clean Energy (Target 7.1):*

The study highlights stark energy poverty in rural LGAs where access to clean cooking fuel is nearly nonexistent. Despite awareness, LPG penetration remained below 15% in Boki and Obubra due to affordability and distribution constraints. This reflects the need for targeted interventions to achieve Target 7.1, which seeks universal access to affordable, reliable, and modern energy services by 2030.

- *SDG 13: Climate Action (Target 13.2):*

Firewood use in Boki and Obubra contributes to black carbon emissions and forest degradation, two major accelerators of climate change. In contrast, LPG adoption reduces emissions significantly, presenting a low-carbon pathway for rural energy transition. The study's findings support Target 13.2, which emphasizes integrating climate change measures into national policies and planning.

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- *SDG 15: Life on Land (Target 15.2):*

The unsustainable harvesting of wood in forest-edge communities like Boki is leading to deforestation and loss of biodiversity, as confirmed through FGDs. Clean cooking adoption has the potential to ease pressure on natural forests, aligning with Target 15.2, which calls for sustainable forest management and halting biodiversity loss.

This intersection of energy access and sustainable development reveals that clean cooking is not merely a technical issue, but a developmental imperative. The study provides empirical evidence that expanding access to clean cooking fuels and technologies is a powerful enabler of multiple SDGs, especially in vulnerable rural and peri-urban settings.

VI. RECOMMENDATIONS

Based on the empirical evidence gathered across Boki, Obubra, and Akpabuyo LGAs, and in light of their implications for health, gender, environment, and energy policy, the following recommendations are proposed:

➢ *Expand Access to Affordable Clean Cooking Solutions*

- Implement targeted subsidy programs or micro-financing schemes (e.g., pay-as-you-cook LPG solutions) for rural households to overcome the high upfront cost of LPG cylinders and accessories.
- Promote locally produced improved cookstoves that retain the cultural cooking style of firewood while reducing emissions.

➢ *Strengthen Last-Mile Distribution Networks*

- Support the development of community-based LPG retail outlets through public-private partnerships to improve rural availability.
- Provide logistical support for periodic mobile LPG refill stations in remote communities.

➢ *Scale Behavioral Change and Safety Campaigns*

- Launch community-wide sensitization programs focusing on the health benefits and safety of clean cooking options.
- Train local women as LPG and cookstove ambassadors, creating employment while fostering trust in new technologies.

➢ *Integrate Clean Cooking into Forest and Climate Policy*

- Incorporate clean cooking access as a strategic component in forest conservation and climate adaptation policies in states like Cross River.
- Align state-level initiatives with Nigeria's NDC (Nationally Determined Contribution) under the Paris Agreement to promote climate-smart household energy.

➢ *Promote Multi-Sectoral Coordination*

- Foster collaboration between ministries of health, women affairs, environment, and energy to mainstream clean cooking into national development planning.
- Encourage data-driven programming by supporting ongoing household energy-use monitoring at the LGA level.

VII. CONCLUSION

This study assessed household fuel use, indoor air quality, health impacts, environmental pressures, and barriers to clean cooking adoption across three diverse LGAs in Cross River State: Boki (forest-dependent), Obubra (semi-rural), and Akpabuyo (peri-urban). The results demonstrate a clear link between energy poverty and adverse outcomes in health, gender equality, environmental sustainability, and rural development.

Boki, with high firewood reliance, faces severe health and ecological consequences. Obubra represents a transitional case with emerging awareness but limited adoption. Akpabuyo, though not without challenges, exemplifies the early benefits of cleaner fuel transitions highlighting the role of infrastructure, awareness, and market access.

The findings illustrate that clean cooking is a critical enabler for achieving SDG 3, 5, 7, 13, and 15. However, barriers such as cost, distribution gaps, cultural preferences, and misinformation continue to hinder progress, particularly in rural zones.

Achieving universal access to clean cooking in Cross River and similar regions in Nigeria will require context-specific, multi-dimensional interventions that address affordability, accessibility, cultural compatibility, and policy integration while prioritizing clean household energy, stakeholders can simultaneously advance public health, environmental resilience, gender equity, and climate action.

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