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Value Chain Mapping of the Ceramic Cookstove Industry: A Case Study in Murang'a and Nyeri counties, Kenya.

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Abstract— This study mapped and analyzed the ceramic cookstove value chain in Murang'a and Nyeri counties, Kenya, with the objective of identifying key stakeholders, operational dynamics, systemic challenges, and opportunities for enhancing sectoral sustainability. Utilizing qualitative research methods, including site visits, interviews, focus group discussions, narrative analysis, and value chain mapping, the study examined raw material sourcing, production processes, market linkages, and governance structures within the largely informal artisanal cookstove sector. Findings revealed a dynamic but constrained value chain characterized by manual, labor-intensive production, significant gendered labor patterns, weak financial and market structures, and environmental and occupational risks. Women were found to play a dominant role in both production and trade, highlighting the need for gender-sensitive interventions. Despite these challenges, emerging opportunities include technological upgrading, cooperative market development, carbon financing engagement, and alignment with SDG 7(affordable and clean energy) initiatives. The study concludes with actionable recommendations for policy, financing, and institutional reforms aimed at formalizing and scaling up the sector's contribution to clean energy transitions and rural livelihoods in Kenya.

Keywords: Ceramic cookstoves; clean cooking technologies; value chain analysis; energy poverty; biomass fuels

1 Introduction

Globally, the urgent need to address climate change has intensified efforts to transition toward sustainable energy solutions, improve energy efficiency, and reduce carbon emissions through innovations in material use, efficient designs, and renewable energy adoption. Among the essential human energy needs, cooking remains a critical and persistent demand, particularly in low- and middle-income countries where access to modern energy services is limited (Boafo-Mensah et al., 2020).

In African countries, over 82% of the population continues to rely on solid biomass fuels such as firewood and charcoal for their primary cooking needs, while only 11% access clean cooking fuels like electricity and liquefied petroleum gas (LPG) (Boafo-Mensah et al., 2020; Mutua, 2022). This widespread reliance on biomass, combined with the use of traditional and inefficient cookstoves, has far-reaching

health, environmental, and climate consequences. Biomass harvesting contributes to deforestation, land degradation, and biodiversity loss, while household biomass combustion emits pollutants such as black carbon and carbon dioxide, exacerbating both indoor air pollution and global climate change (Otieno et al., 2022; Kaputo et al., 2023).

Recognizing these challenges, the international community has emphasized the importance of clean cooking solutions in achieving global sustainability goals. Sustainable Development Goal (SDG) target 7.1 specifically calls for universal access to affordable, reliable, and modern energy services by 2030, identifying clean cooking technologies as essential for reducing environmental degradation, improving public health, and advancing climate action and socio-economic development (Dagnachew et al., 2020; Nzengya et al., 2021).

In Kenya, efforts to promote Improved Cooked Stoves (ICS) date back to the 1980s, supported by organizations such as USAID (United States Agency for International Development), Practical Action (formerly GTZ), and government-led initiatives (Nyankone, 2018). Among the locally available clean cooking solutions, artisanal ceramic cookstoves have gained traction due to their affordability, fuel efficiency, and compatibility with traditional cooking practices (Tigabu, 2017) despite operating informally, with limited integration into national clean cooking strategies and energy policy frameworks (Ochieng et al., 2020).

Access to affordable, clean, and efficient cooking technologies remains a major development priority in Kenya, but over 70% of rural households rely on biomass fuels, predominantly firewood and charcoal, for cooking (Mutua, 2022; Clean Cooking Alliance, 2021). The substantial proportion of the country's rural population continued dependence to wood fuel for cooking despite the longstanding interventions and innovation raises a concern on low adoption of ICS. Existing literature on clean cooking in Kenya predominantly focuses on large-scale LPG distribution, improved biomass stoves from formal manufacturers, or urban charcoal value chains (Nzengya et al., 2021; Kirimi et al., 2023).

There is little empirical evidence on the opportunities for technological upgrading, cooperative market development, and integration into carbon finance markets for artisanal producers, a proven pathway for enhancing clean cooking sector sustainability elsewhere in East Africa (Bailis et al., 2015; Clean Cooking Alliance, 2021). This reveals a critical knowledge gap regarding the operational dynamics, labor structures, stakeholder relationships, and governance challenges within rural artisanal cookstove value chains, particularly in production hubs.

Value chain mapping offers an effective analytical framework for unpacking the structure, governance, and performance of production and distribution systems in informal economies (Kaplinsky & Morris, 2001; Lamb & Jooste, 2022). It enables identification of key actors, operational linkages, power asymmetries, and value distribution within sectors, while revealing operational bottlenecks and market constraints that inhibit growth. While this approach has been successfully applied in Kenya's formal agricultural and handicraft value chains (Musyoka et al., 2021), its application within the informal clean cooking

sector, specifically in artisanal ceramic cookstove production, remains underexplored.

Addressing the barriers to ICS adoption requires innovations that engage stakeholders through participatory design, inclusive decision-making processes, and comprehensive monitoring and evaluation frameworks (Tigabu, 2017). Moreover, opportunities linked to SDG 7 (affordable and clean energy) offer strategic pathways to scale up the adoption of cleaner, affordable, and sustainable cooking technologies (Nzengya et al., 2021).

This study addresses this knowledge and policy gap by undertaking a systematic value chain mapping of the ceramic cookstove industry in Murang'a and Nyeri counties, Kenya. It aims to document the socio-economic dynamics of raw material sourcing, production, marketing, and distribution of ceramic cookstoves in the whole value chain. In doing so, it contributes to Kenya's clean cooking policy evidence base and offers practical insights for policymakers, development agencies, and financial institutions supporting informal

2 Material and Methods

2.1 Study areas

The study was conducted in Murang'a and Nyeri counties, Kenya. Murang'a county lies within lies on a latitude of -0.7167 (0° 43' South) and longitude of 37.1500 (37° 8' East) while Nyeri county lies within latitude of -0.4167° (0° 25′ South) and longitude of 36.9500° (36° 57′ East). Both Murang'a and Nyeri counties ware selected due to prevailing climatic and hydrographic conditions that favor a small-scale ceramic cookstove producers through rain water and large forest coverage which provides readily available firewood that aid them in the production process. Nyeri and Muranga counties also have close proximity to raw materials necessary for ceramic cookstove such as clay and sand along river banks. Furthermore, Muranga County is one of the two largest counties producing ceramic cookstoves in Kenya other than Kisumu due to its abundant supply of clay deposits (Silk et al., 2012)

2.2 Research design

This study utilized the data obtained from the Value Chain Mapping of the Ceramic Cook stove Industry in Maragua (Murang'a County) and Mukurwein (Nyeri County) (2025) conducted by The Kenya Industrial Research and Development Institute (KIRDI) under the Green and Digital Innovation Hub (gDIH) consortium funded by GIZ. The study was purely qualitative, with site visits and interviews conducted to map the value chain, analyze stakeholder dynamics, identify systemic challenges, and highlight strategic opportunities within the ceramic cookstove sector in Murang'a and Nyeri counties. The sampling units were households participating in ceramic cookstove value chains with a total of 36 participants.

The sampling procedure adopted purposive and snowballing techniques, where the mapped respondents selected other people in the value chain to be interviewed. This helped in identifying individual cookstoves producers, traders, and input suppliers along ceramic cookstove value chain in each production unit. Before data collection, participants provided informed consent and were assured of anonymity (Singh et al., 2014). The study then employed narrative analysis to capture the lived experiences of ceramic cookstove value chain actors in Murang'a and Nyeri, focusing on contextual, relational, and gendered dimensions (Ochieng et al., 2020).

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Rich personal accounts from seasoned producers to women traders and new entrants were selected to reflect diverse perspectives. Analysis involved breaking down stories into key elements, structuring them chronologically, interpreting meaning, and identifying recurring patterns such as resilience, gendered barriers, informal networks, and aspirations (Riessman, 2008). To humanize findings, anonymized narrative vignettes were integrated into the final report (Ridder, 2014).

2.3 Value Chain Mapping

A descriptive analysis was employed to construct a comprehensive value chain map of the ceramic cookstove industry in both counties. The mapping process illustrated the flow of materials, information, and financial resources from raw material sourcing to the end-user. Value chain actors, their roles, inter-linkages, and supporting institutions were visually represented using flow diagrams and stakeholder network maps developed using Lucidchart (Bellù, 2013).

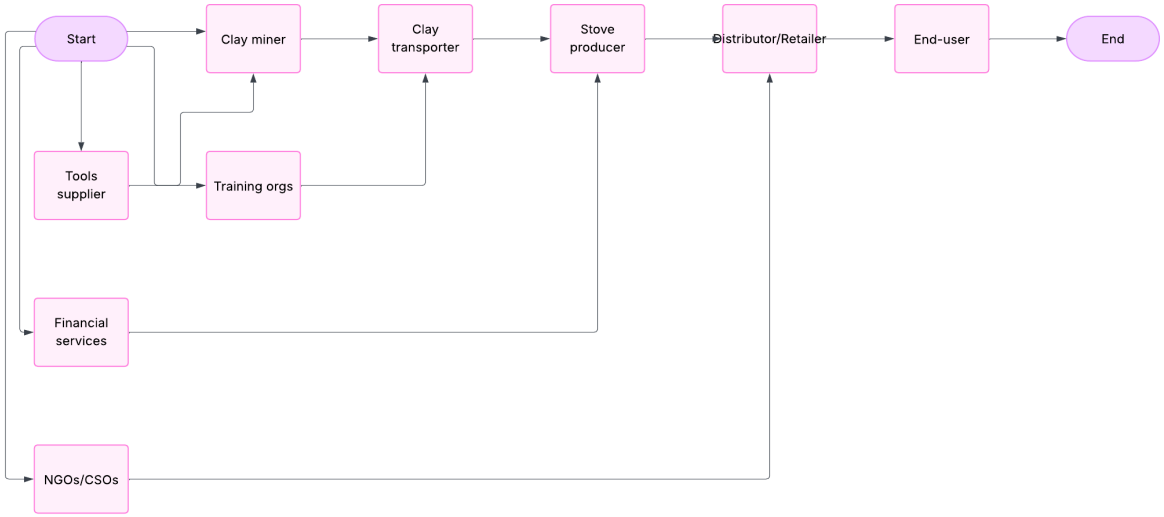

Figure 1—Value chain flow chart.

2.4 Stakeholder Analysis

A stakeholder influence–interest matrix was used to categorize actors in the ceramic cookstove value chain by their relative power and engagement levels. This classification highlighted key partners, guided advocacy approaches, and helped prioritize stakeholder engagement strategies (Golsorkhi et al., 2010).

2.5 SWOT Analysis

A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted to assess the internal and external factors influencing the ceramic cookstove sector in the study areas. This strategic tool helped contextualize the sector's position, highlighting areas for intervention and opportunities for sectoral growth in alignment with Sustainable Development Goal 7 (SDG 7) on affordable and clean energy access (Gurl, 2017).

3 Results

3.1 Raw Material Sourcing and Production

Production operations in the ceramic cookstove sector remain largely manual and labor-intensive. The absence of mechanized equipment such as clay moulders, pottery sand mixers, and mechanized kilns was widely reported by stakeholders. Stakeholders indicated that the average rate of liner breakages was 10 units out of

550 units per firing cycle in kilns as shown in Table 1.

Table 1—Summary of Raw Material Sourcing and Production Data

Parameter	Value/Description
Clay mining location	Kiriaini, Maragua Sub-county
Pottery sand source	Within Maragua
Rice husks source	Mwea Irrigation Scheme
Clay mining depth	~20 ft
Mining rate (Clay)	28 tons / 2 months
Mining rate (Pottery sand)	14 tons / 2 months
Rice husk supply	2 sacks / 2 months
14-ton lorry (Sand cost)	KES 17,000
7-ton lorry (Sand cost)	KES 11,000
7-ton lorry (Pot clay cost)	KES 11,000
7-ton lorry (Jiko clay cost)	KES 8,000 – 9,000
Clay transport (per trip)	KES 10
Clay mining labor (per worker/day)	KES 500
Average liner breakage	10 out of 550 per kiln cycle (1.8%)

3.2 Gender Distribution and Roles in the Ceramic Cookstove Value Chain

The findings from the study showed a clear gendered division of labor within the ceramic cookstove value chain. Women, mostly over 30, are engaged in low-paid, informal transport work, while men dominate higher-paying mining roles. This highlights both occupational segregation and wage disparities based on gender as shown in Table 2.

Table 2: Gender Distribution and Roles in the Ceramic Cookstove Value Chain

Aspect	Women	Men
Age Group	Majority above 30 years	Minority above 30 years
Primary Role	Transportation of raw materials	Mining and extraction of raw materials
Wage Rate	KES 10 per round trip	KES 500 per day
Nature of Work	Informal, low-paid, labor-intensive	Relatively formalized, higher-paid
Key Observation	Reflects gendered labor division and wage disparity within the value chain	Reflects male dominance in higher-paying, physically intensive tasks

3.3 Operational Challenges

Producers in the ceramic cookstove value chain face several operational challenges, including limited access to mechanized equipment and PPE, financial constraints that restrict investment, and weak marketing and distribution networks. Most rely on manual production methods and informal sales channels, with little collective organization. Additionally, unsafe manual mining practices and a lack of training expose workers to environmental and occupational hazards as summarized in the Table 3.

Table 3—Summary of Key Operational Challenges

Category	Challenge Description
Technology & Equipment	Lack of moulders, mixers, kilns; no PPE
Financial	Inadequate access to capital funding
Marketing	Limited market linkages; no cooperative bargaining structures
Environmental & Occupational	Landslide risks; unskilled labor; manual mining limitations

3.4 Stakeholder Influence Mapping

Stakeholders involved in the ceramic cookstove value chain in Murang'a and Nyeri counties were classified using a Stakeholder Influence-Interest Matrix. This matrix categorized stakeholders into four quadrants based on their relative levels of influence over, and interest in, the cookstove sector's activities and outcomes (Figure 2).

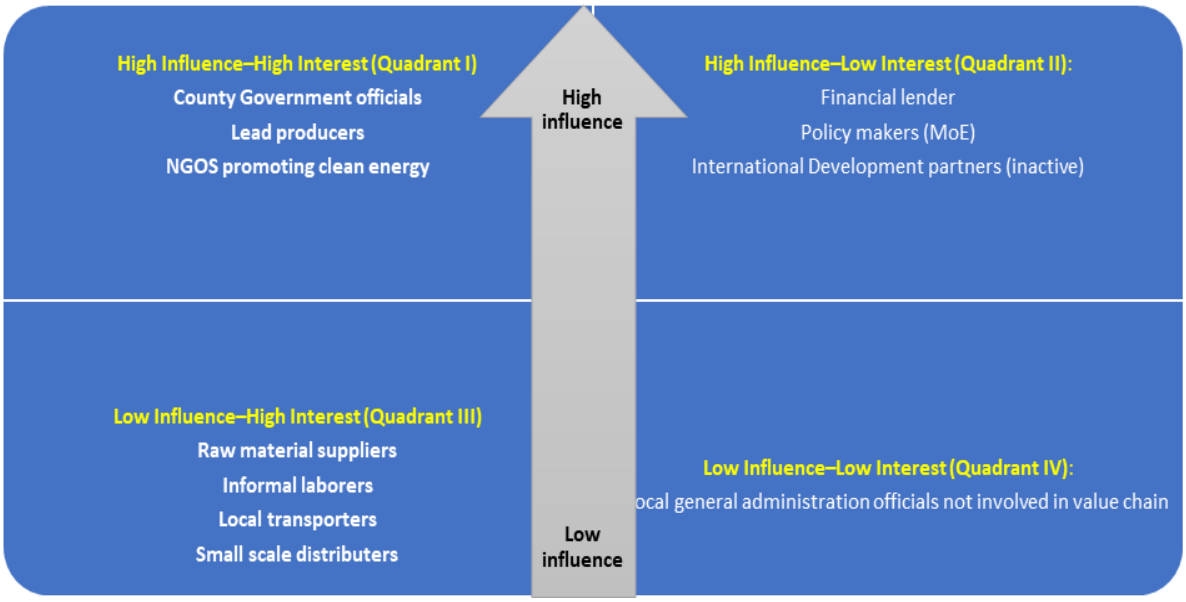

Figure 2—Stakeholder Influence-Interest Matrix

The stakeholders identified included county government officials, NGOs promoting clean energy, lead stove producers, financial institutions, national policymakers, raw material suppliers, informal laborers, local transporters, and general local administrative officials. Key findings from the mapping exercise are summarized in Figure 2.

3.5 SWOT Analysis

A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis showed that the ceramic cookstove sector benefits from local raw materials, traditional skills, and strong market demand. However, it faces challenges such as manual production, limited capital, and weak market linkages. Opportunities include tapping into carbon credit markets, supporting SDG 7 goals, and product diversification, while key threats involve environmental degradation, occupational risks, and market instability as shown in (Table 4).

Table 4—SWOT Analysis of the Ceramic Cookstove Value Chain

Strengths	Weaknesses
Availability of local raw materials	Manual, labor-intensive production
Established traditional skills	Limited capital and technology access
Market demand for affordable cookstoves	Weak market and policy linkages
Opportunities	**Threats**
Carbon credit markets; SDG 7 initiatives	Environmental degradation from mining
Product diversification into other wares	Occupational hazards; market volatility

4 Discussion

4.1 Stakeholder Influence-Interest Mapping

4.1.1 High Influence–High Interest Stakeholders

County government officials, NGOs, and lead stove producers, classified in Quadrant I as shown in Figure 2, play critical roles in setting operational standards, promoting clean cooking technologies, and influencing regulatory environments. Their alignment of influence and interest positions them as key drivers of sectoral change. This mirrors patterns observed in other artisanal value chains where decision-making is typically centralized among a few institutional and commercial leaders (Bailis et al., 2015). Given their dual operational and governance functions, these actors are best positioned for leadership roles in sector coordination platforms, clean energy policy advocacy, and market development initiatives.

4.1.2 High Influence–Low Interest Stakeholders

Quadrant II actors such as financial service providers and national policymakers possess considerable capacity to influence sectoral trajectories through financial, regulatory, and policy instruments (Figure 2). However, their limited operational interest represents an underutilized opportunity. Financial institutions' hesitance to engage with informal producers is consistent with previous findings in informal enterprise financing in East Africa (Chemtai, 2023). Similarly, national-level policy priorities have traditionally focused on large-scale solutions like LPG and grid electrification, often overlooking artisanal and community-based clean energy technologies. Targeted advocacy that frames clean cookstove production within the broader national clean energy and climate policy agendas could mobilize these actors' resources and influence (Atela et al., 2021).

4.1.3 Low Influence–High Interest Stakeholders

The mapping revealed that operationally critical stakeholders; raw material suppliers, informal laborers, transporters, and retailers occupy a structurally weak position (Quadrant III) (Figure 2). Despite their high economic and livelihood dependency on the cookstove sector, their limited bargaining power and exclusion from decision-making processes reflect systemic governance inequities typical in informal manufacturing value chains. This result underscores the need for interventions promoting collective action, capacity-building, and advocacy training for these marginalized actors, a recommendation supported by artisanal sector studies across Sub-Saharan Africa (Lamb & Jooste, 2022).

4.1.4 Low Influence–Low Interest Stakeholders

Quadrant IV actors such as local chiefs and assistant chiefs currently have limited operational involvement in clean cookstove promotion (Figure 2). While their administrative authority could support community mobilization, their present disengagement implies they are not a strategic priority for immediate sector interventions. However, engaging them in public awareness campaigns could, over time, build local administrative support for clean cooking initiatives (Otieno, 2019).

4.2 Raw Material Sourcing

4.2.1 Cost Structures and Market Efficiency

The data on material pricing exposes the informal and somewhat unstable market structure characterizing raw material

transactions. Price variations for different types of clay (pot clay at KES 11,000 vs. specialized jiko clay at KES 8,000–9,000 per 7-ton lorry) suggest a lack of standardized market regulation and quality grading systems within the upstream value chain (Table 1). This can have cascading effects on production costs, product pricing, and ultimately the affordability of improved cookstoves for end-users. Moreover, the seasonality of harvesting activities, limited to around eight months annually, highlights the susceptibility of raw material supply to environmental and labor-related constraints. This cyclical availability can result in production bottlenecks, particularly during the rainy season when mining activities are disrupted, as documented in related artisanal mining literature in Kenya (Mutembei et al., 2020).

4.2.2 Gendered Division of Labor and Employment Structures

One of the most significant findings pertains to the gendered nature of labor in raw material extraction. The study established that women predominantly perform transportation tasks, earning KES 10 per round trip, a modest wage indicative of the informal, low-paid labor arrangements typical of subsistence-level value chains. Conversely, male workers dominate mining operations, receiving KES 500 per day, reflecting both a gender-based division of labor and a wage disparity (Table 2). This pattern is consistent with studies on informal artisanal mining and rural industrial value chains in Kenya and sub-Saharan Africa, where women are often relegated to supportive, labor-intensive, and lower-paying roles (Hinton et al., 2017). Such gendered labor dynamics not only reinforce socio-economic inequalities but also limit the potential for women's economic empowerment within the cookstove sector, a concern that intersects directly with SDG 5 (Gender Equality) and SDG 8 (Decent Work and Economic Growth) (International Energy Agency, 2024)

4.3 Operational Challenges and SWOT Analysis

4.3.1 Technological and Resource Constraints

Stakeholders consistently reported the absence of essential equipment such as clay moulders, pottery sand mixers, and mechanized kilns (Table 3). Consequently, production processes remain manual and labor-intensive, restricting output volumes, introducing variability in product quality, and limiting opportunities for scaling up operations (Table 2). Similar constraints have been widely documented in Kenya's informal MSME sector, where limited access to appropriate production technology perpetuates inefficiencies and impedes competitiveness (Kamau et al., 2018). The situation reflects a broader trend within Kenya's informal manufacturing sector, where occupational safety is poorly regulated, and protective infrastructure remains underdeveloped. Addressing these constraints is critical not only for enhancing production efficiency but also for safeguarding the health and well-being of workers, thereby contributing to SDG 8 (Decent Work and Economic Growth) and SDG 3 (Good Health and Well-being) (Mutembei et al., 2020).

4.3.2 Financial Limitations

Stakeholders reported acute capital constraints that restrict investment in equipment modernization, bulk raw material procurement, and market expansion initiatives (Table 3). This issue mirrors national trends, where financial exclusion among informal MSMEs continues to inhibit enterprise growth, with over 70% of

small businesses in Kenya citing financing as a major operational hurdle (Nafula et al., 2020). The problem is exacerbated by the lack of financial services customized to the unique needs of artisanal producers. Without formal business registration, credit history, or sufficient collateral, most producers are effectively excluded from mainstream banking and microfinance programs. This financial marginalization perpetuates informality and limits the ability of producers to invest in productivity-enhancing technologies, access bulk raw materials, or diversify their markets. Studies have shown that targeted financial instruments, such as asset-based microloans and savings cooperatives, can significantly enhance the resilience and scalability of MSMEs in similar contexts (Alemu et al., 2022). Integrating such financial products within the cookstove sector could help unlock latent entrepreneurial potential and contribute to inclusive rural development.

4.3.3 Marketing and Distribution Challenges

Most producers rely on informal, localized distribution networks, limiting opportunities for market diversification and reducing product visibility beyond their immediate communities (Table 3). This reliance on informal markets is characteristic of small-scale artisanal industries in Kenya, where producers often lack the financial and logistical capacity to access formal retail markets or engage in strategic marketing campaigns (Musyoka et al., 2021). Additionally, the absence of producer cooperatives or collective bargaining structures undermines the negotiating power of individual artisans, particularly in the procurement of raw materials and pricing of finished products. Without cooperative frameworks, producers are unable to pool resources, access bulk discounts, or advocate for supportive policies. Evidence from other artisanal and agricultural value chains in Kenya, such as dairy, horticulture, and coffee, illustrates that well-organized cooperatives can enhance market access, improve incomes, and strengthen value chain governance (Ochieng et al., 2020). Establishing similar cooperative structures within the ceramic cookstove sector would help address current marketing and distribution inefficiencies while enhancing producers' resilience against market shocks.

4.3.4 Production Losses and Quality Control Gaps

The study documented an average liner breakage rate of 10 out of 550 units per firing cycle, equating to a breakage rate of approximately 1.8% (Table 1). While this rate may appear moderate when compared to artisanal production standards elsewhere in sub-Saharan Africa (commonly ranging from 2%–5%), it still represents a tangible source of production inefficiency and financial loss (Adkins et al., 2010). Each breakage not only results in direct material wastage but also incurs opportunity costs in terms of labor time, fuel (rice husks), and lost sales. Quality variations and production losses also have implications for customer trust and market reputation. Since improved cookstoves are marketed on their durability and fuel-saving capabilities, any compromise in product quality undermines consumer confidence and risks discouraging uptake, a factor that can slow progress towards SDG 7 (affordable and clean energy) targets at the household level (Rosenthal et al., 2018).

4.3.5 Strengths

A key strength of the ceramic cookstove value chain lies in the abundant availability of local raw materials, particularly clay and pottery sand, which ensures sustained supply for

producers at relatively low procurement costs (Table 4). The proximity of clay deposits in Kiria, Maragua Sub-county, and the accessible pottery sand sources within the same region reduce transportation costs and logistical challenges. This natural endowment positions the region favorably as a hub for artisanal ceramic production. Another notable strength is the well-established reservoir of traditional skills within the local communities. Ceramic cookstove production has been passed down through generations, creating a culturally embedded knowledge system that preserves artisanal craftsmanship (Table 3). This indigenous knowledge provides a valuable foundation for clean cooking innovations, as it can be combined with modern production techniques and materials science to enhance cookstove performance (Matsubara, 2024)

4.3.6 Opportunities

One of the most promising avenues is engagement with carbon credit markets, where improved cookstove projects can generate verified carbon offsets by reducing household emissions (Table 4). Linking producers to such climate finance mechanisms could unlock new income streams and incentivize the adoption of higher-efficiency designs. Similar models have been successfully implemented in Kenya's clean cooking sector, particularly through partnerships with carbon offset buyers (Clean Cooking Alliance, 2021). Another emerging opportunity is alignment with Sustainable Development Goal 7 (SDG 7) initiatives, which promote access to affordable, reliable, sustainable, and modern energy for all. Government and donor-backed programs aimed at expanding clean cooking access present prospects for technical assistance, subsidies, and market development support for local producers (Onsongo et al., 2023). Additionally, the sector holds potential for product diversification into other ceramic wares such as water filters, decorative items, and horticultural planters. This diversification could stabilize incomes, reduce dependence on seasonal cookstove demand, and foster innovation in artisanal production.

4.3.7 Threats

A primary concern threat is environmental degradation resulting from unregulated clay mining, which risks damaging local ecosystems, depleting natural resources, and generating land-use conflicts (Table 4). Without proper environmental management plans and regulatory oversight, continued extraction could provoke community resistance or legal restrictions. Occupational hazards represent another significant threat, as most production activities occur in informal, unregulated environments without proper safety equipment or training. Workers, including women and youth, face health and safety risks such as landslides during mining, exposure to dust, and injuries from manual equipment handling (Njoh, 2017).

5 Conclusion

Ultimately, this study underscores the ceramic cookstove sector's dual potential: as a significant contributor to clean energy transitions, rural livelihoods, and climate mitigation, and as a site of entrenched socio-economic inequities and environmental risks that must be carefully managed through inclusive, evidence-based policy and development interventions. The findings serve as a valuable evidence base for policymakers, development partners, financial institutions, and community-based organizations seeking to foster a more sustainable, inclusive, and

competitive clean cooking industry in Kenya and comparable Sub-Saharan African contexts.

6 Limitations of the study

This study faced the following limitations. Firstly, its geographic scope was restricted to Murang'a and Nyeri counties, limiting the generalizability of findings to other regions. Secondly, the informal nature of the ceramic cookstove sector meant much of the data relied on self-reported information, which may have led to reporting biasness (Table 3). Thirdly, the study's short data collection period did not capture seasonal variations in raw material supply and market demand. Additionally, while technological gaps were identified, no technical performance assessments were conducted. Despite these limitations, the study provides an important foundational understanding of value chain dynamics and operational challenges in Kenya's artisanal cookstove sector.

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Author contribution: SO: Conceptualization, Methodology, Formal analysis, Writing of the original draft, review & editing. KO: Data curation, Formal analysis and reviewing. CM, JO, EM, RW- reviewing of the manuscript.

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