Beyond Smoke: Behavioural Change Pathways for Clean Cooking in Dar es Salaam, Tanzania

Giorgia Festa-Bianchet, Joshua Sze, Myria Schröder, Sia Chami

Summative Collective Essay

PB403 Societal and Environmental Psychology

Group 7

January 2026

Course Conveners: Frederic Basso and Saadi Lahlou

London School of Economics and Political Science

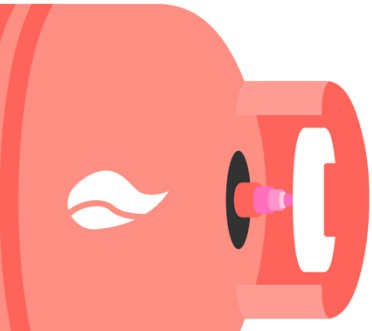




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1 Introduction

As of 2025, approximately 2.1 billion people still rely on traditional biomass for cooking their daily meals. This means households use charcoal, firewood, and kerosene (IEA et al., 2025; Olabisi et al., 2019) for cooking as opposed to using cleaner cooking energy sources such as liquified petroleum gas (LPG), electricity, ethanol, or biogas (Rosenthal et al, 2018). The air pollution from cooking with traditional biomass represents both a human and planetary challenge, with low to middle-income countries disproportionally affected (WHO, 2025).

Cooking with traditional biomass has a significant negative impact on the environment, emitting nearly half of all global anthropocentric black carbon emissions (CCAC, 2025), driving deforestation, biodiversity loss and forest degradation (Odoi-Yorke, 2024). The practice has a severely negative impact on health outcomes and reinforces gender inequalities. It has been estimated that around 2.9 million deaths yearly result from indoor air pollution exposure through diseases such as ischemic heart disease, strokes, respiratory infection, chronic obstructive pulmonary diseases, and lung cancer (WHO, 2025). Women and children are especially affected, as the former are often responsible for household chores such as cooking (IEA et al., 2025). In Africa, women account for approximately 60% of premature deaths based on cooking- related air pollution (IEA, 2023). Additionally, collecting and cooking with traditional biomass is time consuming, reinforcing inequalities by reducing women and children's time for education and income generating activities (Njenga et al., 2021). While some countries have been able to drive large scale reforms to transition households into cleaner cooking fuels, a wide gap still remains, especially in Sub-Saharan Africa where only 23% of the population has access to clean cooking (IEA, 2025).

In this paper, we analyse clean cooking choices from a behavioural perspective, leveraging Dar es Salaam, Tanzania as a case study to craft a clean cooking intervention. We first provide context to some existing clean cooking interventions and provide our rationale for selecting our study site, Dar es Salaam. We then provide a detailed overview of key stakeholders in the cooking fuel ecosystem on both demand and supply side, and their role in the cooking fuel transition. Grounding the cooking crisis in scientific context, we apply installation theory to the process of choosing a cooking fuel, mapping out pain points deterring the selection of clean cooking fuels. We then highlight our proposed intervention and communication framework,

finalising the study with a discussion of the proposal's limitations and reflections on how to achieve long term clean cooking transitions.

2 Background and Context

2.1 Overview of Existing Clean Cooking Interventions

Between 2000 and 2015, the number of people cooking with biomass increased by 400 million, mainly due to population growth in sub-Saharan Africa (IEA, 2017). Despite efforts to transition towards cleaner cooking fuels, the continuation of this crisis indicates deep-rooted and structural barriers that are limiting the complete success of interventions.

A primary solution seen throughout the literature to this cooking crisis is the development of improved biomass cookstoves that employ advanced combustion techniques to increase thermal efficiency and reduce the release of harmful pollutants when burning traditional fuels (Kshirsagar and Kalamkar, 2014). China and India have both used this approach in large-scale national programs where they each distributed over 100 million improved stoves. These stoves help households use less fuel thanks to more efficient combustion, which also lowers their fuel costs (Wright et al., 2020). The idea behind improved biomass cookstoves is simple: reduce fuel emissions without changing supply chains or making households pay high upfront costs.

However, research shows that these improved cookstoves do not provide significant health benefits (Wright et al., 2020). The relationship between air pollution exposure and health risk is non-linear: improved stoves can reduce emissions, but they do not reduce health risks in proportion (Bruce et al., 2015; Thakur et al., 2018). Biomass stoves, therefore, are intrinsically harmful to health regardless of their design and thus cannot be a sustainable solution to this ongoing crisis. Additionally, in India, these stoves failed to fully be integrated into households due to practical and technical problems, leaving suppliers with excess inventory (Urmee & Gyamfi, 2014).

The limited success of improved cookstove programmes reflects deeper systemic barriers that technology alone cannot fix. Clean cooking systems require system-level change to be successful. LPG and electricity rely on infrastructure investment and reliable distribution networks while, traditional fuels like charcoal are already easy to access through existing informal markets with low upfront costs (Wright et al., 2020; Putti et al., 2015).

Recent research has shifted focus from stove improvements to the adoption of LPG as the main cooking fuel. LPG is considered to be a clean cooking solution because it substantially releases

less emissions than solid biomass (Wright et al., 2020). In Brazil, government subsidies allowed for a large transition to LPG (Lucon et al., 2004). Similarly, in Indonesia, 50 million households transitioned from kerosene to LPG within five years due to supply chain development and government subsidies (IEA, 2006; Thoday et al., 2018). While LPG is perceived to having high upfront costs, its adoption is more likely than natural gas or electricity because it does not require as high of comparable large scale infrastructure investments (Wright et al., 2020). These examples illustrate that systemic change depends on developing context appropriate distribution infrastructure and aligning costs with household affordability, making LPG often the first step in moving away from traditional fuels.

2.2 Clean Cooking Intervention Case Studies

Assessing successful and unsuccessful interventions in other parts of the world offer us a better understanding of what has worked to scale clean cooking transitions and what has not. We explored interventions in China, Kenya and Brazil to identify lessons learned before crafting our solution.

China: *Living Facility Improvement (LFI) programs promoting the transition from biomass to LPG and natural gas in China*

China provides a successful case study of national-scale transition from biomass- and coal-based cooking to cleaner energy sources such as LPG and natural gas. Such transition evolved incrementally from earlier interventions such as the National Improved Stove Program, which initially focused on improving biomass cooking by distributing improved stoves to enhance combustion efficiency (Smith et al., 1993). While health benefits and measurable benefits were demonstrated, household's reliance on biomass or solid fuels retained within the existing cooking systems (Carter et al., 2019). Subsequently, the Living Facility Improvement (LFI) programme was implemented, and was accounted for 33.4% transition to clean cooking energy among rural households (Zhu et al., 2025). The programme involved financial investment in energy infrastructure in regions previously reliant on coal or biomass. This included the expansion of natural gas pipeline to rural villages and establishment of over 106 LPG distribution points where grid connection was not feasible (China Gas Holdings, 2023). The programmes also invested in transport infrastructure increasing the access to paved road to 99.6%, thus indirectly improving clean cooking by strengthening energy supply chain and household income opportunities (Lee et al., 2020; McLean et al., 2019; Zhu et al., 2025).

Meanwhile reduced costs and improved access to clean energy lowered the upfront cost of adopting clean cooking (Zhu et al., 2025).

Despite recorded progress, fuel stacking (i.e. using multiple fuel sources) persisted, particularly in western rural counties with lower socioeconomic status (Shen et al., 2022). Rural households are estimated to utilise 2.8 different energy types on average, with only 4.2% relying on a single fuel source. Reliance on traditional fuels is associated with slow transition pace of space heating, where up to 70% household primarily relied on coal or biomass for home heating (Shen et al., 2022). The persistence was attributed to lower upfront cost and convenience (Shen et al., 2022). The LFI programmes therefore demonstrate how a coordinated based solution combining investment in energy infrastructure, housing quality, and connectivity can enable improve condition for the transition to clean cooking (Zhu et al., 2025).

Kenya: *Pay-as-you-go Liquefied Petroleum Gas: the transition of clean cooking in Kenyan urban household (Shupler et al., 2021*)

The introduction of pay-as-you-go (PAYG) LPG systems in Kenya illustrates how perceived high upfront costs can be addressed. Evidence has demonstrated full LPG cylinders present a major barrier for adoption due to the high upfront cost which forced households to rely on biomass or kerosene whilst acknowledging the health benefits of LPG (Shupler et al., 2021). PAYG schemes offered households to purchase fuel credits via mobile banking and home delivery services, thereby allowing flexible payments and reducing the geographical access constraints (Shupler et al., 2021; M-Gas, 2025). Additionally, installation of smart metres for PAYG reduced risks associated with illegal refilling. Empirical data indicated that fuel stacking behaviours and behaviours and reversion to biomass cooking were significantly lower among PAYG users when compared to full cylinder users, meanwhile the reversion to biomass cooking were significantly lower among PAYG users when compared to full cylinder users (Shupler et al., 2021). Notably, participants reported that LPG adoption would not have been possible without the PAYG options due to financial factors such as insecure income. The PAYG scheme in Kenya addressed how affordability, payment flexibility, and supply consistency are essential to improve the adoption and sustained usage of clean cooking fuels in urban settings.

Brazil: *LPG in Brazil: Lessons* and Challenges (Lucon, et al., 2004)

Brazil offers a compelling example of a partially successful subsidy-dependent transition from traditional biomass to LPG for household cooking. Domestic LPG use began after the 1950s,

when the Brazilian government began subsidizing LPG, making it an affordable and accessible cleaner cooking fuel. Domestic supply increased, and LPG containers were standardized to 13-kg cylinders nationwide, thereby facilitating nationwide distribution. LPG prices were then set at a uniform rate, while profits from other petroleum products were used to cover the additional costs of rural distribution. The distribution of LPGs was established through "primary supply bases" to enable an "automatic delivery" system that delivers cylinders to all municipalities at fixed intervals based on predicted demand. By 2002, 42 million households had access to LPG, which was used by 150 million people and provided 350,000 direct jobs (Lucon, et al., 2004). Price subsidies reached around USD 100 million annually by 2000, leading to an over-reliance on this funding rather than on infrastructure development (Lucon et al., 2004). Price controls hid the reality of supply limitations and dependence on imports, which in turn reinforced households' dependence on ongoing government support.

In January 2002, market liberalisation led to the removal of subsidies, causing the retail price of LPG to rise from R$21.9 to R$26.3 per unit, a 20% increase. Overall, LPG's prices increased as much as 190% between 1987 and 2002 (Lucon et al., 2004). In response, the government introduced targeted programs such as Auxílio-Gás, which gave R$15 every two months to around 9 million families earning less than half the minimum wage. Still, this response failed to keep pace with price volatility. The oligopolistic nature of the market: five companies controlled about 83% of the LPG market, leading to little competition to drive prices down and making the fuel less affordable for consumers. The case highlights that system-level investment is needed rather than blanket subsidy solutions with no time-boundness; market structures must be properly set up, and governments must invest in systems that reduce costs and improve efficiency. Without these systems, they will fail when financial support is removed.

2.3 Dar es Salaam, Tanzania's Intervention Gap

The aforementioned case studies would be an ideal mechanism of scaling clean cooking across multiple countries, however their replicability cannot be guaranteed due to different situated environments. Contextualising Tanzania's clean cooking landscape is a necessary pre-requisite to understanding why Dar es Salaam was selected as a model case study to understand factors slowing down the clean cooking transition and propose interventions.

Tanzania, like other Sub-Saharan African countries, relies heavily on charcoal in cities, with demand rising as more people move to urban areas. The charcoal industry generated USD 650 million in 2009, almost six times more than coffee and tea exports combined (Zulu &

Richardson, 2013), illustrating its important economic role. In Dar es Salaam, the largest city and commercial centre, most households still use charcoal, even though modern fuels are available within urban areas and 74% of Tanzanian households expressed their readiness to transition to cleaner energy sources (Alananga & Igangula, 2022; Lokina & Mapunda, 2015). Despite a booming market for modern fuels, many households remain caught in a "dirty energy trap," where households continue to use biomass fuels despite increased access to cleaner alternatives, making the transition up the *energy ladder* inconsistent (Alananga & Igangula, 2022).

The Dar es Salaam context challenges the *energy ladder theory* which states that increased income and improved living standards should drive a linear shift toward more sustainable energy use. Evidence shows that households across income levels tend to shift from firewood and animal waste to charcoal rather than directly adopting cleaner fuels (Choumert-Nkolo et al., 2019; Peng et al., 2010). Households in Dar es Salaam are more likely to use multiple fuels at the same time (**Figure 1**) instead of fully transitioning to modern alternatives, resulting in what is known as “fuel stacking” (Choumert-Nkolo et al., 2019; Kulindwa et al., 2018, Ntiyakunze & Stage, 2025). This pattern indicates that the *energy ladder theory* does not fully explain household energy choices in Tanzania, and that broader systemic, social and psychological barriers may also influence decision-making.

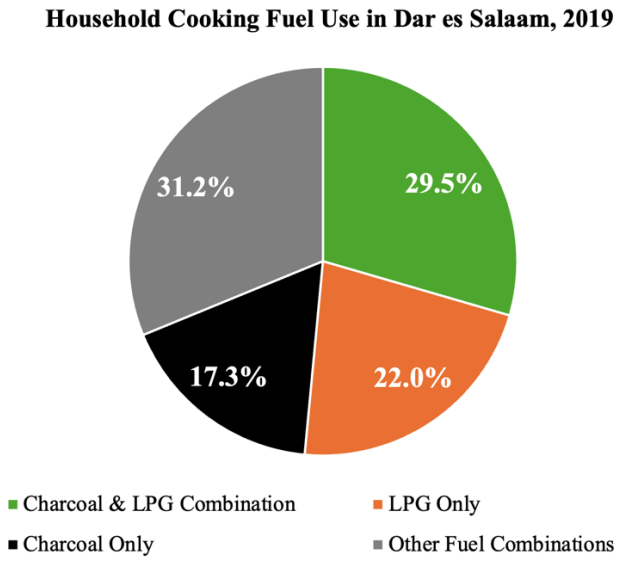


Figure 1: Household Cooking Fuel Use in Dar es Salaam. Ntiyakunze & Stage, (2025).

The fuel stacking framework provides a more accurate explanation for why stated preferences for clean energy do not consistently translate into adoption. This gap is commonly influenced by market liquidity: LPG and electricity require significant upfront investments in cylinders or grid connections, whilst charcoal remains accessible in small and affordable quantities through informal and familiar local markets (Alananga & Igangula, 2022). Additionally, psychological barriers can also impede the transition: the perception that charcoal is easier to use than modern alternatives decrease the probability of switching to cleaner fuels by 83% (Lokina & Mapunda, 2015). Cultural food preferences further reinforce this pattern, as staple Tanzanian dishes such as ugali, beans, and matoke require long cooking times and specific heat profiles, making charcoal both cost-effective and well-suited to local cooking practices (Alananga & Igangula, 2022; Lokina & Mapunda, 2015; Shankar et al., 2020).

Beyond sociocultural factors, infrastructural and institutional barriers further limit the transition to cleaner energy. Unreliable and limited electricity supply reduces household confidence in relying solely on modern energy sources (Choumert-Nkolo et al., 2019; Lokina & Mapunda, 2015). While LPG markets have expanded, their growth is restricted by inconsistent availability (Alananga & Igangula, 2022). Adoption of modern appliances is also hindered by high upfront costs, limited financing mechanisms, lack of user familiarity, and ongoing safety concerns related to gas use (D'Agostino et al., 2015; Choumert-Nkolo et al., 2019; Hollada et al., 2017; Shankar et al., 2020). Households often require multiple appliances to meet diverse cooking needs, which increases both complexity and cost (D'Agostino et al., 2015; Labriet & Alfaro, 2015). As a result, charcoal remains a practical fallback, reinforcing long-term fuel stacking in cities like Dar es Salaam.

Previous clean cooking interventions have already been tried in Dar es Salaam. In 2019, the UN created the "Promotion of "Bio-Ethanol as Alternative Clean Fuel for Cooking in the United Republic of Tanzania" program to distribute and produce biogas stoves across Dar es Salaam. Although households valued the ethanol stove for its speed and cleanliness, adoption rates remained significantly below Phase I targets (Benka-Coker et al., 2025). The programme was unable to compete with the established charcoal market, which remained accessible and convenient through informal networks, while ethanol fuel suffered from limited retail coverage and unreliable distribution. Many households that initially adopted the stove reverted to charcoal due to inconsistent fuel access. The project's market-based approach assumed that consumer demand would drive the development of the supply chain.

However, this project was unable to scale because there was not enough investment in fuel infrastructure and collective community involvement in ensuring demand and education.

These examples show that previous interventions in Dar es Salaam have focused on technology provision rather than systemic change. We intend to examine what other factors influence sustained adoption that might be overlooked in the context of urban households in Dar es salaam? How can clean cooking initiatives move beyond isolated pilot projects and address the broader socio-economic context?

3 Stakeholder Analysis

We examine the cooking fuel stakeholder landscape as a starting point for our intervention design. Stakeholders can be categorised into demand side actors, supply side actors and regulators. An effective intervention requires examining both individual motives across the different stakeholder groups, understanding how direct and indirect interactions between actors shape cooking fuel choices, and identify areas of fragmentation across stakeholder groups that systemically and psychologically impede energy transition efforts at the household level. For the purpose of this paper, our main stakeholder is the household cook (**Figure 2**), and we will examine the clean cooking transition through the lens of their activity of selecting their choice of fuel.

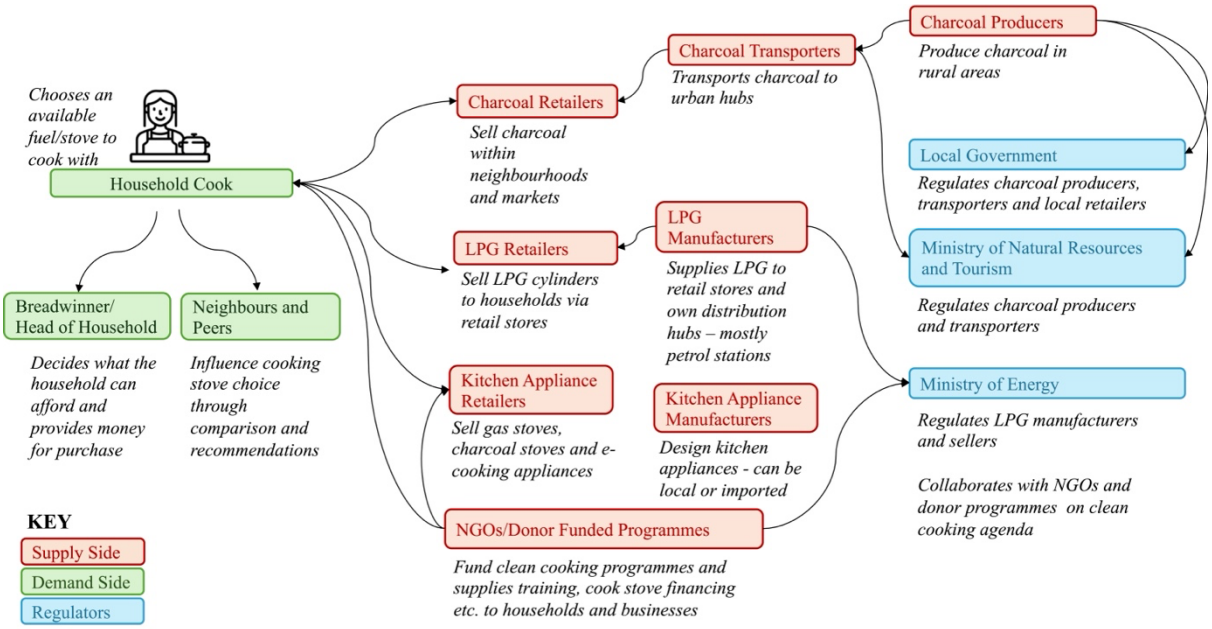


Figure 2: Cooking Fuel Stakeholder Map.

3.1 Demand Side Stakeholders

The locus of cooking fuel demand is the household. Household dynamics, particularly financial capacity and community/neighbour influence stove and fuel choice. Three players are identified as demand side stakeholders for our analysis:

3.1.1 Household Cook

As the member of the household responsible for daily meal preparation, the cook physically produces cooking fuel and must also possess the embodied competencies required to use the cooking technologies available. The fuel choice in Dar es Salaam is influenced by economic, social and cultural factors, but is also highly sensitive to whether the cook has prior experience using the chosen cooking fuel (Ntiyakunze & Stage, 2025). For the purpose of this paper's theoretical analysis, we will use Activity Theory to create a behavioural sequence that maps the cook's fuel choice as a series of steps with different sub-goals to achieve an ultimate motive (Lahlou, 2017). The ultimate motive is to satisfy family hunger, however the means to achieve this motive may vary by household (**Figure 3**). As selecting cooking fuel is a sub-goal within the cook's greater goal of cooking a meal, identifying constraints that channel their fuel choices will reveal relevant points of intervention across the activity.

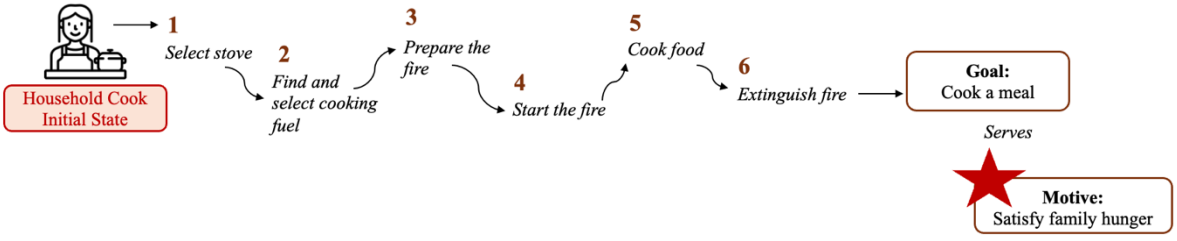


Figure 3: Cooking Process Activity Map

3.1.2 Breadwinner/Head of Household

Breadwinners maintain substantial influence over the choice in fuel as primary financial decision makers and controllers of the household's resource allocation. Male-headed households tend to spend less on energy than female-headed counterparts (Ntiyakunze & Stage, 2025), whereas when households have female heads the likelihood of adopting clean cooking solutions increases (Ntegwa, 2024).

3.1.3 Neighbours and Peers

While the neighbours are not direct consumers of the household's cooking fuel, they have a positive influence on the sustained use of clean cooking fuels (Katutsi et al, 2023). Peers socially regulate fuel choice through their own fuel choices, for example, households that had friends who did not use charcoal were also more likely to not use charcoal themselves (Strong & Silva, 2023).

3.2 Supply Side Stakeholders

Tanzania's supply-side stakeholders play a significant role in upholding or changing existing clean cooking practices, through their role in creating constraints for choice making such as affordability, accessibility, awareness and perceptions. Four key supply side stakeholders have been identified:

3.2.1 Charcoal Producers, Transporters and Retailers

The charcoal value chain comprises of production, transportation and retail segments before consumption, with each segment contributing to charcoal's dominance in urban Dar es Salaam. Employing almost two million people across the entire value chain in Tanzania (Marandu et al, 2024), charcoal is produced in rural and peri-urban regions and transported to urban markets where retailers sell charcoal to consumers from small shops close to residential areas (**Figure 4**). The charcoal is sold in small bags, tins or buckets and sold at highly variable prices across different neighbourhoods and weather seasons (Doggart et al, 2020). The immediate availability and single use affordability of charcoal in urban areas magnifies charcoal's preference amongst households, despite higher price instability.



Figure 4: Charcoal Retail Location, Dar es Salaam. Photographed by author.

3.2.2 LPG Manufacturers and Retailers

While LPG is a fossil fuel, it still presents a critical gateway to cleaner cooking, particularly in districts where electricity is unreliable. The IEA projects that one in three households will gain access to clean cooking through LPG, compared to one in eight through electricity (IEA, 2023). LPG manufacturers influence adoption through physical affordances such as cylinder size, user design and affordability whereas retailer distribution networks determine LPG physical proximity to households (**Figure 5**). The buy-in, involvement and engagement of this stakeholder group is essential to increasing the uptake of LPG as a transitory clean cooking fuel in urban Dar es Salaam.



Figure 5: LPG Retail Outlet. Source: Kupatana.com, 2022

3.2.3 Kitchen Appliance Manufacturers and Retailers

This stakeholder category is responsible for designing and selling stoves, appliances and related equipment compatible with clean cooking fuels. Technical barriers to clean cooking adoption include a user's perceptions of whether the appliances are safe to use and if its suitable for their household's needs (Ngusa, 2025). Clean cooking energy adoption is therefore contingent not only upon the fuel used, but the appliances used with it. Despite this interdependency, there is notable fragmentation between cooking fuel suppliers and cookstove/appliance suppliers. Fuels and stoves are procured through separate retailers and distribution channels, limiting opportunities for bundled, affordable solutions or integrating the customer experience to include comprehensive training on how to use the fuel and cookstove effectively.

3.2.4 NGOs and Donor Funded Programmes

NGOs and donor funded programmes exercise a significant level of agenda setting power in Tanzania's clean cooking landscape, through financial and institutional support. Financially, as a de-risker of private sector investments in the sector, they play a role in determining which clean cooking technologies receive financing for scale-up, while others remain undercapitalised. Historically resources have been channelled towards support for improved cookstoves, a solution criticised by some scholars who have highlighted that these technologies still use biomass fuels and their sustained adoption over decades has not been realised (Perros

et al, 2024). NGOs conceptualise and implement clean cooking programmes at the household level but have limited coordination of efforts with other stakeholders in the ecosystem (Ngusa, 2025). This stakeholder group plays an indirect but significant role in the ecosystem, selectively funding clean cooking technologies and developing programs that target households for adoption.

3.3 Government Regulators

3.3.1 Local Government

District and municipal governments regulate charcoal trade at the local level, responsible for collecting forestry royalties and taxes from production and trade. The revenue collection remains inconsistent, with compliance assumed to be as low as 10% (Doggart et al, 2020). Due to the substantial levels of employment and revenue the charcoal industry generates, reform efforts at the local level are likely to face resistance, as reductions in charcoal trade volumes may threaten both livelihoods and local government budgets.

3.3.2 Ministry of Tourism and Natural Resources

The Ministry of Natural Resources and Tourism is responsible for forest management and the regulation of wood fuel supplies, under the Forestry and Beekeeping Division and the Tanzania Forest Services Agency. The ministry oversees charcoal related policy development, trade oversight and collection of forestry royalties alongside local government. Despite studies noting that some wholesale traders generate annual turnovers of up to £250,000 (MNRT, 2019), the ministry considers charcoal trade as part of the informal sector category and does not subject the sector to value added tax (VAT), further increasing its price competitiveness.

3.3.3 Ministry of Energy

The Ministry of Energy owns the national clean cooking agenda, and is responsible for licencing, pricing and safety standards of energies including electricity and LPG through its Energy and Water Utilities Regulatory Authority (EWURA). The Ministry's current Energy Policy 2015 lacks interventions that address charcoal regulation, despite acknowledging charcoal's significant consumption and obstruction towards clean cooking transition efforts. The regulatory fragmentation between clean cooking housed in one ministry and charcoal housed in another impedes coordinated policy and behavioural interventions to fast-track cooking fuel transitions.

4 Theoretical Concept Application

4.1 Installation Theory

The paper adopts the Installation Theory (Lahlou, 2017) to provide structured examination in how cooking behaviours are shaped and sustained in Dar es Salaam. An installation "conceives" behaviour as being funnelled through interactions consisting of three interdependent layers: material and physical affordances, embodied competence, and social regulation (**Figure 6**) (Lahlou, 2024). Installations are specific, localised, and societal setting in which human behaviours appear predictable. In lieu of attributing behaviour exclusively to decision and motivation on an individual level, Installation Theory emphasis how everyday practices are stabilised or reproduce derived from the cooperation between the three layers.

We utilise Installation theory an analytical framework to illustrate household cooking practices in Dar es Salaam as an installation, identifying the structural and psychosocial conditions that enable the reliance on biomass usage for cooking. In addition, installation theory provides the framework for evaluating proposed behavioural intervention to the extent which addresses all three components of the installation, thus facilitate the promotion of adopting clean cooking techniques/ technologies.

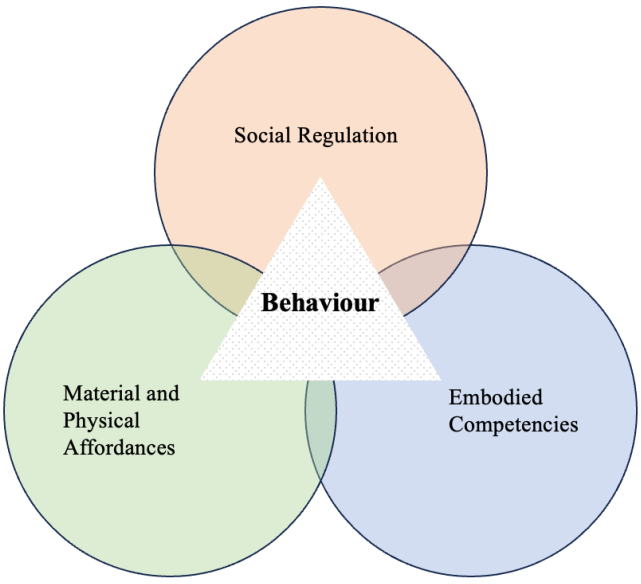


Figure 6: The three layer components of Installation Theory (Lahlou, 2024, p.53)

In the cooking installation, material and physical affordances refer to the physical articles, infrastructures, or technologies with a purposeful use within an environment (Lahlou, 2024). This includes stove availability, fuel supply chains, the physical kitchen layout, labour, and cost or maintenances of equipment. Embodied competence includes the beliefs, habitual practices, skills, values, and mental capacity in relation to perceptions of food quality, knowledge and trust in using new technologies, risk perceptions, personal identity, traditions that an individual possesses (Lahlou, 2024). Social Regulation describes the influence of gendered roles, social norms, household decision making structure, and power dynamics that shapes expectations around cooking practices (Lahlou, 2024).

It is critical to view the entire cooking process as the installation, and not just the point of fuel procurement and selection to understand how fuel choices are made. The cook's competencies help them anticipate physical affordances and social regulations that are expected to materialise in the future steps of the cooking process e.g. fear of turning a gas stove off at the end of the cooking process can influence stove selection in the beginning.

Under the installation theory framework, cooking behaviours with biomass are not derived from individual preference alone, instead the alignment of the three components of the status quo installation foster (unsustainable) practices. The introduction of new technologies/ clean cooking techniques (such as LPG or electric) would be conceived as a misalignment to the (current) installation (ecosystem) if corresponding components of the installation are also not adjusted accordingly.

By applying Installation Theory alongside Activity Theory, we can identify critical constraints and possible leverage points within everyday cooking practice. Building on the Activity Theory framework outlined in **Section 3.1.1**, **Figure 7** integrates both theories combined, to illustrate the cooking process for an urban housewife preparing family's meal. The figure maps each sub-goal and pairs the corresponding components of Installation Theory within these sub-goals. Observation entails how housewives is channelled to select the fuel of choice (in this case, charcoal) with the main goal of cooking a meal.

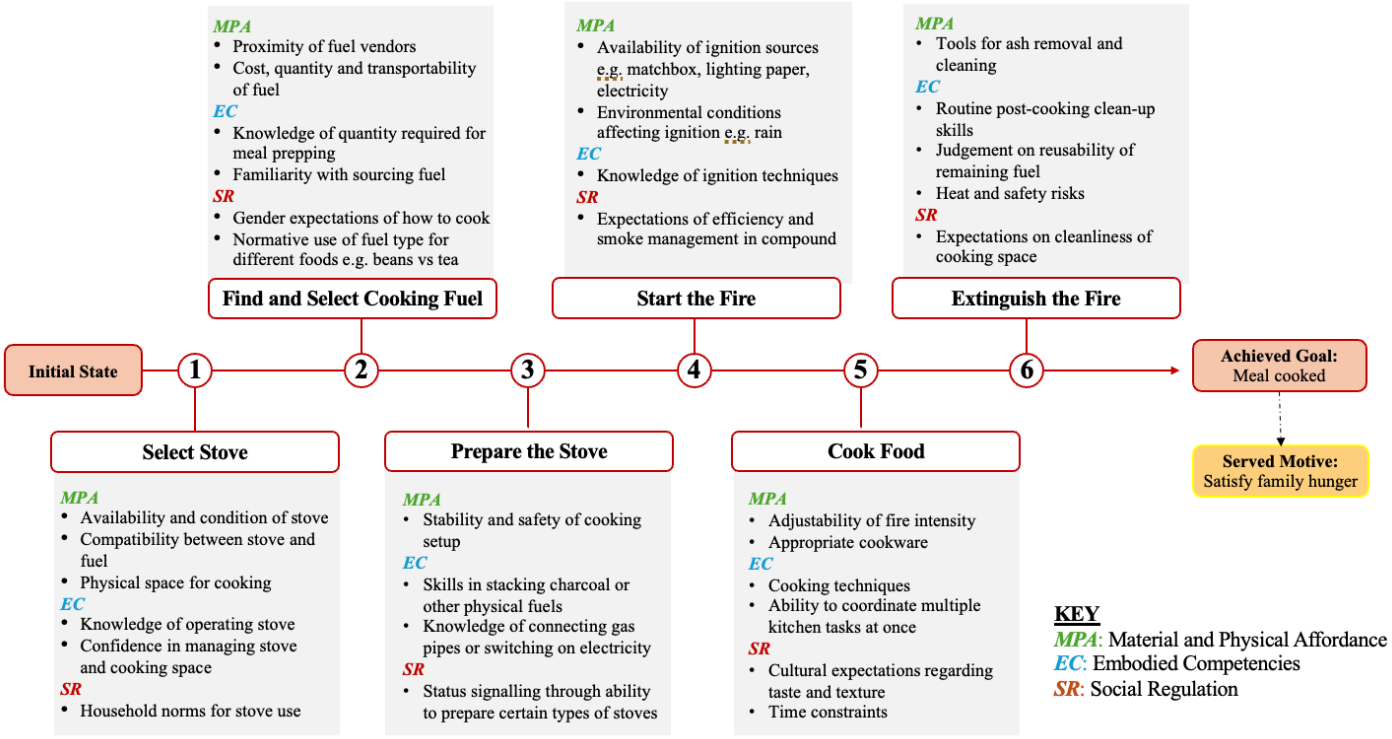


Figure 7: Illustration of Installation layers across cooking activity

4.2 Mapping Pain Points

Analysing the cooking process, from selecting the stove to extinguishing the fire, sheds light on potential pain points that influence choice of fuel. An outline of the activity map with pain points will be presented in the following section; and a detailed overview can be consulted in Table 1.

Before the cooking process can begin, selecting a stove is necessary. This will likely happen only every few years, so the actor takes great care when selecting the stove to prepare their future food. Stove selection is determined by the availability of stoves to buy, what the actor can afford to buy, what is possible in terms of space and potential outlets, the actors competencies, familiarity and experiences with a particular stove, the typical cooking method of planned meals, what kind of stove other family members like the husband prefer and what is common to buy in the social circle of the actor. ***Key pain points are here: physical access to a cooking stove, affordability, and knowledge on how to handle appliances available.***

In preparation for a meal, the heat source needs to be obtained. The choice of cooking fuel is determined by the stove and available fuel, which in turn is influenced by the proximity of relevant stores and the preference of the buyer and their family. For the latter, the ease of

carrying, fuel price, and money available for a particular day might determine preference. Buying fuel is also influenced by the knowledge of the location of the fuel seller, the fuel price, and possible safety concerns. Neighbours might influence the choice of fuel seller. ***Three key pain points regarding the choice of fuel are the proximity of the seller, what type of fuel the seller sells, and whether the fuel can be bought, even though stoves requiring LPG / electricity might require a higher upfront cost.***

To start cooking, the fireplace or stove needs to be prepared. For traditional fireplaces, this might require stacking the fuel to successfully start the ignition. Competencies for this step in the cooking process include knowledge of how to start the fire or the appliance and an estimation of how much time the ignition and cooking time will take. ***The key pain point here is the competency in how to start the fire using a specific appliance, which determines whether fuel can effectively be used for the cooking process.***

During the cooking process, sufficient cooking fuel needs to be available to complete the process. Additionally, the fuel used determines the amount of attention required to cook. While electric/LPG stoves might require less attention as the food can 'simmer', the pot's distance to the fire or the fire's intensity of a charcoal-powered fire might need to be constantly adjusted. ***Pain points here include the heat intensity regulation and the suitability of utensils.***

The end of the cooking process is strongly influenced by the choice of stove and fuel. While a fire might require letting the fire slowly burn down and extinguish it with sand, cooking with an electric stove might require switching off the stove. Both require knowledge of how to appropriately switch out the chosen heat source. ***Pain points here include the time and skills required to turn off the heat source and potentially a fear that the heat source has not been properly extinguished.*** For this essay, we decided to focus on **proximity, cost, and knowledge** as the priority pain points, narrowing down on actors who are already familiar with clean cooking fuel but are deterred by distance of retail availability, up-front cost and use technicalities.

Table 1: Activity Grid with Pain Points. Modified from Lahlou, 2024

Task	**Actor's Motives and Goals**	**Contribution from Actor**	**Actor's Reward**	**Physical Affordances**	**Embodied Competencies**	**Social Regulation**	**Pain Points**
Select stove	Have a stove to start cooking meal with	Identify the right appliances for use based on planned meal	Has right stove to cook with Social validation	Appliances need to be available	Knowledge on what stove is required for planned meal Knowledge on how to handle the appliance	Family and social expectations Which appliance is usually used for the meal planned in the family	Unaffordability of clean energy stoves Limited knowledge of how to handle LPG or electric appliances available LPG perceived as difficult to cook certain foods
Find and select cooking fuel	Finding a source of heat for cooking	*For solid fuels and LPG:* Locate seller, queue for fuel, select fuel, pay, carry home *For electricity:* Ensure power availability and bring out required appliances	Has a heat source to connect to the stove	Proximity of desired fuel shops What can be carried and stored Financial resources available	Know the seller's location Money available and understanding of fuel price per meal limits choices Knowledge of which Fuel choice based on type of food being cooked Perceptions of which fuel is safest to handle	Fuel trader normally visited by neighbours / friends / the cook Social norms – cooking with what everyone else uses in the neighbourhood	Estimation of price per meal is difficult with LPG or electricity, even though it is cheaper per unit LPG sellers are further away than charcoal sellers Limited visibility of alternative options as cooking happens in private homes

Prepare stove	Ensure stove and fuel source are connected	For solid fuels: Prepare physical spot for fire Stack fuel (charcoal or firewood) on stove For electricity/LPG: Ensure heat source connectivity to stove	Stove is ready for ignition	Space available to start fire	Knowledge on how to connect fuel to stove e.g. gas connection, electric switch or stacking charcoal in stove	Gender expectations to know how to set up a traditional stove	Fear of making mistakes with gas connectivity or connecting electric kitchen appliances
Start the fire	Turn the source of heat on to start cooking	For solid fuels: Lightning of match/kindling Blow/fan fire For electricity/LPG: Ignite with match, switch or knob	Fire is lit Can start cooking process	Matches, electricity, airflow required	Knowledge on how to start the fire/ heat source Knowledge on when to start lighting the fire	Manage smoke to not affect other family rooms or neighbours Neighbours can be relied on for kindling or match sharing	Charcoal has a higher preparation time, and fire needs to be started long before the cooking begins
Cook food	Fully cooked meal for the family	Stirring, adding seasons, adjusting the intensity of the fire/heat source	Delicious meal Social validation Satisfied family	Sufficient fuel to cook the meal Correct amount of time available to cook the food and pay attention to the task	Knowledge on how to regulate heat Recipe and cooking knowledge	Cooking norms and practices Desire for social approval Desire to feed family	Hard to control heat intensity with charcoal Not all cooking utensils are suitable for different stoves
Extinguish fire	Stop the flow of heat and end the cooking process	For solid fuels: Let fire die down or stop ventilation For electricity/LPG: Turn off switch	Happiness that the process is done	Tools and time available to extinguish the fire	Knowledge on how to put out the fire safely	Safety for all	Takes time to put out charcoal fire Fear that gas is not fully turned off with gas stoves

5 Proposed Intervention

5.1 Intervention: Decentralised Pay-By-Weight Refill Stations

To address the chosen key pain points of **proximity, cost and knowledge,** our proposed intervention will develop **decentralised "pay by weight" LPG refill stations** as a new retail distribution channel in Dar es Salaam neighbourhoods. We focus on the transition to LPG rather than electricity, as LPG is a more scalable gateway to clean cooking transition in Tanzania as the nation faces constraints of unreliable electricity supply (Choumert-Nkolo et al., 2019).

The solution will be implemented by LPG supplier companies in Tanzania, as champions whose business interests align with efforts to transition away from traditional biofuels. For this paper, we have identified one existing LPG distributor, Oryx Energies, as an ideal representative company to implement the solution. Oryx holds a significant share of Tanzania's LPG market, has a track record of pursuing clean cooking innovations, and has established commitments to transition 6 million Tanzanian households to clean cooking by 2034 (Oryx Energies, 2024). Subsequent sections of this chapter elaborate how the intervention will be designed and critical success factors that address other layers of the installation of cooking fuel choice.

5.1.1 LPG Refill Stations

To improve proximity to neighbourhoods and enhance affordability, refill stations will be established in local retail hubs and designed to dispense LPG by weight, rather than provide full-cylinder exchanges. LPG pumps refill cylinders based on amount desired, similar to petrol station pumps, instead of filling the cylinders fully. As many low-income households purchase goods in smaller quantities based on immediate need or available funds, including other cooking fuels such as charcoal, this transforms LPG from a bulk purchase commodity to a pay-as-you-go (PAYG) product that is more compatible with their spending patterns.

Each refill station will include a master LPG storage tank (100 - 200 kg capacity) with dispensing valves and digital weighing scales for cylinder weight measurement. Customers can purchase small sized cylinders from these stations and refill them with the quantity of gas they can afford (**Figure 8**). Customers specify their budget, and the cylinder is filled to the corresponding weight. (e.g. a customer will request for gas worth TZS 2000). Refill station signage will include information on how much the purchased LPG fuel will last, based on hours of use or average number of meals that can be cooked, to help customers gauge how long their fuel will last and compare cost savings with charcoal use.



Figure 8: Sample LPG Refill Station. Signage says "We sell LPG by the Kilogram" (Generated by Google Gemini AI)

Refill stations will be placed in high-traffic locations of the neighbourhood, ideally close to where charcoal sellers and other neighbourhood shops are located. It is estimated that the walking distance to the nearest charcoal market in Dar es Salaam is 4 minutes, compared to 17 minutes to the nearest LPG gas dealer (Alem, 2017). It is therefore important to ensure selected retail spots bridge the walking distance gap and have adequate space for safe LPG handling. The refill model is further depicted in **Figure 15** in APPENDIX II of this document.

While PAYG smart meters have been effective in Kenya as aforementioned in Section 2.2, we chose to not prioritise smart meters in this intervention, as the smart meter adds more complex competencies users will need to embody, such as the ability to understand and manage the new digital meter, as well as using mobile money payments to pay for gas. While Tanzania has made progress in adopting mobile payments for consumer purchases, the level of adoption in Kenya is significantly higher (Horne et al, 2015), enabling the smart meter's success in Kenya, as households regularly use mobile money to make purchases. In Tanzania on the other hand, cash still remains in high demand, and a majority of households still make payments with cash (Kombe et al, 2020). These two constraints – additional technical capacity required and the need to leverage cashless payments to top up on gas – shaped the decision to design an alternative solution that while less technically sophisticated, is able to address the key identified

pain points in the installation. In following iterations of the solution, as competencies are strengthened and cashless payments become more prevalent, refill stations can also sell and install PAYG smart meters as an alternative to the pay-by-weight option.

5.1.2 Community Based Refill Agents

To establish new social contracts in this new installation, existing community members will be recruited and trained as agents to own and operate refill stations. Borrowing from successful localised solutions such as Jibu Inc[1], that capitalises and trains local entrepreneurs to purify and distribute drinking water locally under a franchise model, capital financing and training will be offered to local entrepreneurs to recruit them as Oryx-branded gas refill agents. Charcoal sellers and members of village community banks (VICOBA) will be particularly targeted and supported to become LPG refill agents due to their already established social relations in the community, and pre-existing understanding of the neighbourhood's household consumption habits.

Why charcoal sellers as agents: Multiple attempts to ban charcoal production and trade in Tanzania have been met with significant resistance (Doggart et al, 2020), and without alternative economic opportunities available, top-down efforts to minimize charcoal trade will be fruitless. Capitalising charcoal sellers to transition to act as LPG refill hub operators may provide a stronger incentive to abandon the charcoal trade, rather than displacing them from the ecosystem entirely. They are well positioned to convince households to transition to LPG as retail agents and better inform future transition efforts through their understanding of the cooking fuel supply ecosystem.

Why VICOBA members as agents: In Tanzania, community savings and credit schemes referred to as VICOBA are predominantly women-run, and where women often gain opportunities to earn social capital, access credit and uncover new sources of income (Seitz-McCarthy & Krause, 2024). VICOBAs are an efficient channel to identify women entrepreneurs who can be recruited as refill agents to champion clean energy transition while simultaneously empowering themselves economically, and VICOBA members can be offered

[1] Jibu Inc is a social enterprise that uses a franchise model for local entrepreneurs to operate water filtration systems and bottle and distribute the filtered water within local neighbourhoods. The model targets increasing drinking water accessibility in urban areas across East and Central Africa.

discounts in their local LPG refill sites. As women play a significant role in cooking choices due to gender norms, engagement through collective groups such as VICOBAs could also drive collective cooking energy transitions. The role of community participation and VICOBAs for successful adoption is further elaborated in Section 5.1.4.

5.1.3 Supply Chain Considerations

Oryx will schedule deliveries every 2-4 weeks to refill the master storage tanks at refill stations. Retailers must be taught how to track their inventories effectively to prevent stockouts of fuel, and have access on-demand delivery from the lead distributors when needed. Over time, Oryx can use predictive technologies installed in tanks to improve supply planning and conduct delivery rotations on a predictive basis. Refill station data will also help the ecosystem better understand LPG consumption patterns at a household level, based on average refill quantities, and how long it takes for master tanks to be depleted at different retail sites.

5.1.4 Critical Success Factors

The intervention alone is insufficient to address all components of the new installation design. A number of critical success factors are elaborated below to further scaffold household choices towards cleaner cooking fuels.

Community Validation Meetings: Before the intervention is implemented, community stakeholder meetings will be organised in key targeted neighbourhoods for intervention. To drive multi-actor engagement (Boateng, 2025), Oryx will first engage locally based clean cooking NGOs and the local government to assist with identifying and assembling local stakeholders, based on pre-existing knowledge of community members. Local institutions such as local government can be gatekeepers of change, hence leveraging their support for community buy-in is critical for success.

The local government, charcoal sellers, LPG sellers, VICOBA members and other community members will be collectively welcomed to validate assumptions about the identified pain points and align on whether the proposed solution will offer relief in terms of improving LPG accessibility**.** This stage is essential to participatory decision making, to ensure solution uptake and interest across both supply side and demand side stakeholders.

Procure Smaller Sized LPG Cylinders: The standard LPG cylinder sizes in Tanzania are typically between 6 - 15kg, requiring substantial upfront cost and sometimes transport costs due to bulk size and weight. Oryx must procure and introduce smaller cylinder options of 2kg,

3kg and 5kg capacities into the market, ideally with removable cooker tops attached (bundling the gas with the cooker directly). This can reduce the initial cost barrier while still maintaining per energy unit cost efficiency compared to charcoal.

Community-Led LPG Financing and Training: The availability and affordability of clean cooking technology does not always translate into meaningful use (Boateng et al, 2023). With this in mind, refill station launches will be coupled with community-led financing, installation support and cooking demonstrations. Oryx will develop partnerships with VICOBA and any other community groups available to develop credit plans for cookstove and cylinder purchase for their members, provide LPG installation training and host community cooking demonstrations. A case study from Kilimanjaro, Tanzania indicated that organised groups scale adoption of clean cooking solutions through trust, structure and financial access (MECS, 2025), noting the role of interpersonal influence and collective group change in driving the transition. VICOBA communities can become social regulators and educators to develop new embodied competencies and financial affordances that support the clean cooking transition. Through their structured but still communal platforms, VICOBAs can host cooking demonstrations to build user confidence and provide credit for LPG or e-cooking devices.

As training and competency strengthening is essential to installation design (Lahlou, 2024), it is essential that refill stations include female refill assistants and technicians, trained to support in-home LPG installations and troubleshoot concerns within the neighbourhood. Learning environments regulated and supported by other women through practical instruction may allow for what Kurt Lewin's Change Model describes as "refreezing" of change (Lewin, 1951), making the preference for cleaner cooking fuels permanent.

Regulatory Support and Policy Reinforcements: Impact evaluations on LPG and efficient cookstove provision have emphasised that single interventions reliant on a singular policy lever are insufficient to scale household energy transitions (Das et al., 2022). The proposed solution must be coupled with supportive, integrated and consistent policy implementation from government stakeholders. In particular, the success off refill stations in supporting the clean energy transition will be enhanced through the strict enforcement of charcoal levies at the local and central government level, the removal of marketing levies for clean cooking related advertisements, and enhanced tax subsidies for other kitchen appliances across the value chain.

5.2 Communications Framework

Clean cooking technology is still only as effective as its user's competencies and beliefs. Inspired by Meadow's leverage points for intervening in a system, the final component of the intervention is communications. Our communication framework targets the leverage points of goals and mindset (Meadows, 1999), and prioritises using the community's existing intent and values to frame messaging around transitioning away from charcoal into LPG stoves. Clean cooking is still being marketed to households with its value being attributed to its equipment modernity or environmental benefits, but is not being marketed as a valuable tool for improved health and economic justice. For the installation to work, its communications must align with community values, addressing the mindset or paradigm out of which the choice of cooking fuel arises' (Meadows, 1999). The communication strategy will; 1) install new social regulations through advertising campaigns that align with community values and desired benefits, and 2) address embodied competencies through cooking demonstrations and guides easing the use of LPG refill stations.

5.2.1 Communications for Social Regulation

5.2.1.1 Marketing campaigns targeting actor values

Social relations and belief systems can play a role in driving uptake, filling the gap where rational calculations of cost-benefit analysis cannot. When aiming to influence the actor's choice of which cooking fuel to buy, marketing campaigns could target value-based motivations of the actor such family health. Though cooking with charcoal can have negative health impacts on unborn children, developing children and adult family members (Amegah et al., 2014; Kaulu et al., 2025), this is not often communicated in marketing campaigns.

Fear of health risks motivates family members to make safer choices and has the potential to introduce long-lasting behaviour change (Baiocchi-Wagner et al., 2013). For example, local prenatal clinics could be given posters or leaflets informing expectant parents about the risk of cooking with charcoal to the unborn baby (**Figure 9**). Working with local government and NGO stakeholders, public health officials can be encouraged to include cooking with charcoal as a risk factor, explained to the expectant mother orally.

Additionally, parents could be informed of the risk of cooking with charcoal to their children's health in kindergartens, schools and community centres through leaflets. Whenever there is a personal contact with parental figures, educators could be encouraged to enquire whether

traditional cooking methods are used at home or otherwise inform about the risk, raising awareness and contributing to a shift in social norms and social acceptance.

One must not forget to ask, "Who is the gatekeeper and what is his psychology?" (Lewin, 1948). The family's breadwinner cannot be overlooked in installation design. As they influence daily resource allocation, communications lending towards their personal values and priorities will also be critical, for example, highlighting financial savings, time savings and social status.



Figure 9: Information leaflets on the risk of cooking with charcoal on foetal health in English and translated to Swahili (Generated by ChatGPT and Gemini).

5.2.1.2 Information campaigns clarifying benefits

Given the many tasks a housewife has in a day, e.g. purchasing and cooking food, preparing children for school, cleaning etc., time savings of LPG cooking could serve as an effective marketing strategy. Posters incorporating these benefits (**Figure 10**) could be hung in places where women typically carry their fuel (e.g. along frequented roads) or at the fuel shops. Additionally, marketing posters can indicate amount of money saved through the use of cleaner cooking energies compared to charcoal (**Figure 11**).



Figure 10: Poster promoting time saved by cooking with LPG in English and Swahili.



Figure 11: Poster marketing money saved through LPG in English and Swahili. (Generated with Gemini).

5.2.1.3 Information campaigns showing proof of concept and social identity

Community leaders such as local government leaders and religious leaders can offer social validation to the community by using their platforms to offer special recognition of families or collective groups during community events, offering them the platform to highlight the impact clean cooking has had in their lives.

Oryx and community leaders can also establish "charcoal free" community pacts, to encourage social groups or neighbourhoods to become certified as "charcoal free" (**Figure 12**). This not only shows other community members that cooking without charcoal is possible and realistic, but also a new social identity can be constructed around identifying as a "charcoal free" VICOBA or neighbourhood.



Figure 12: "Charcoal Free" SignPost. Generated by Google Gemini

Groups can develop their own collective plans to attain a "charcoal free" status and label, encouraging all of their members to transition to cleaner cooking technologies. Upon target achievement, Oryx will offer certificates or rewards to the group. Sample of certification is depicted in Figure 16 within APPENDIX III.

5.2.2 Communications to Improve Competencies

5.2.2.1 Cooking Demonstrations

As mentioned in Section 5.1 VICOBAs and other community groups will be encouraged and sponsored by Oryx and other LPG suppliers to host demonstration classes on how to use LPG stoves. A proposed standard curriculum for skill sessions will be developed by the Oryx marketing department to lower the efforts to organize such skill sessions and increase the likelihood of the courses taking place. Videos will also be used to teach how to connect gas cylinders to stoves effectively, and disseminated through key social media platforms such as WhatsApp, Facebook and Instagram, with Swahili as the language of communication. Additionally, flyers in Swahili explaining how to connect LPG tanks will be distributed (**Figure 13**).



Figure 13: Information leaflet on using LPG for cooking. (Generated with ChatGPT).

5.2.2.2 Guides at refill stations

With affordability as a key pain point, communication strategies must address the price advantage of using LPG cooking compared to traditional cooking methods. A main problem here is that clean cooking methods might require higher upfront costs compared to traditional cooking. To communicate the price per meal clearly, a screen above a tappable gas container in the fuel shop could clearly show the price per meal to strengthen understanding of costs per unit (**Figure 14**).



Figure 14: Underlining the price-meal connection at an LPG filling station in English and Swahili. (Generated by ChatGPT and Gemini).

6 Intervention Limitations

We acknowledge that the proposed solution is heavily reliant on marketplace actors (LPG suppliers, charcoal traders etc.) to drive clean cooking transition at household level. The solution is dependent upon Oryx's willingness to make significant investments in small scale refill stations, marketing efforts and incorporate a new distribution channel into existing business models. The solution's success is also dependent upon the influence and role of charcoal producers and wholesale sellers, whose psychological factors have not been addressed in this study.

The study also does not address how government stakeholders will improve regulation efforts, to increase barriers to charcoal trade and decrease barriers to clean energy trade. Without the buy-in of government leaders across different levels, this intervention may remain uncompetitive against the prevalent supply of unregulated, untaxed biomass fuels. At an individual behaviour level, the paper does not address taste preferences for foods cooked with biomass fuels, however studies indicate this to be only a marginally prevalent reason for selecting biomass fuels over clean energies (Ministry of Energy, 2022).

7 Discussion

Individualistic interventions are not sufficient for clean cooking transitions

Our solution attempts to address a broad environmental challenge that, while perceived as an individual household choice, cannot be addressed solely through individualistic interventions. Households are social actors and are not responding to individual preferences alone when choosing clean cooking fuels. Their trajectories are channelled through the cooking installation through group dynamics, infrastructure and policies that maintain the status quo.

Our intervention is constructed through a group-level analysis of behaviour change (*g-frame)*, using the VICOBA group-level identity to harness the power of social systems to produce change. By crafting a new social identity tied to clean cooking transition e.g. “charcoal free” community labelling, we are able to “recruit people’s energies” into the clean cooking campaign (Bingley et al, 2023). Leveraging local community members as refill station agents and trainers serves to democratise the behaviour change process, acknowledging the importance of framing interventions as community-focused (c-frame) bridging the gap between individual-focused (*i-frame*) or system-focused (*s-frame*) interventions (Caggiano et al., 2023).

As mentioned in the paper, solely implementing a systemic level (*s-frame)* intervention, such as a government initiated charcoal ban or subsidies would not effectively change cooking fuel choice. Regulatory interventions must be coupled with engagement from different stakeholder groups while addressing psychosocial pain points across the installation layers. Future looking policies must be designed to move households towards cleaner technologies such as e-cooking solutions. Left to market-based stakeholders alone, LPG distributors are unlikely to propose and advance clean cooking policies that would negatively impact their business, and therefore must not be considered permanent partners, rather interim solution providers as incremental shifts towards clean cooking are made.

Incremental shifts and fuel stacking are inevitable

The proposed intervention follows an incremental shift to a full clean cooking transition, instead of leapfrogging from charcoal to more environmentally preferred clean energies, such as electricity. Across reviewed case studies (see **2.2**), effective clean cooking transitions are fundamental long-term processes which require sustained gradual policy commitment and large-scale infrastructural shifts. Evidence from China demonstrates how national progress was

achieved through incremental policy implementation and with the coordination of infrastructure investments, allowing households to adapt to new technologies and (Zhu et al., 2025) over time. As interventions unfold gradually, an immediate or abrupt transition to clean cooking exclusively is unlikely. Instead, fuel stacking behaviours as seen in all examples including Dar es Salaam should be understood as an adaptive household response to possible constraints rather than policy failure. Habit transformation is not linear, and food practices including cooking are heavily entrenched into existing social practices. With this in mind, the closer a new sustainable practice is to existing social practices and contingencies, the easier it may be for households implement (Wendler, 2024). Fuel stacking and incremental shifts are a manifestation of this philosophy in clean cooking behaviour change in urban Dar es Salaam.

E-cooking remains the long-term priority

This paper focuses on the implementation of LPG as 1) emissions and health risks are lower than for traditional biomass (Puzzolo et al., 2020), 2) it does not necessitate immediate investments in infrastructure (Floess et al., 2023), and 3) it is portable compared to electricity (MECS et al., 2020). Unlike in the Global North, a significant majority of the infrastructure required to support scaled clean cooking e.g. gas pipelines and electric grids has not been built yet, and one in three households gain access to clean cooking through LPG compared to one in eight for electricity (Perros et al, 2024).

In this context we regard LPG as a transitioning fuel towards using electricity for cooking to lower the production of carcinogenic benzene through the combustion of gas (Kashtan et al., 2023; Kashtan et al., 2025) and the risk of pneumonia and chronic pulmonary diseases (Puzzolo et al., 2024). As electricity is up to four times more efficient as cooking with LPG (Scott & Leach, 2023), it remains the long-term priority for future clean cooking interventions. Nevertheless, LPG and the intervention proposed here represents continued steps towards establishing clean cooking for healthier people and a less polluted planet.

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9 Appendices

APPENDIX I: Mapping Interventions Against Pain Points

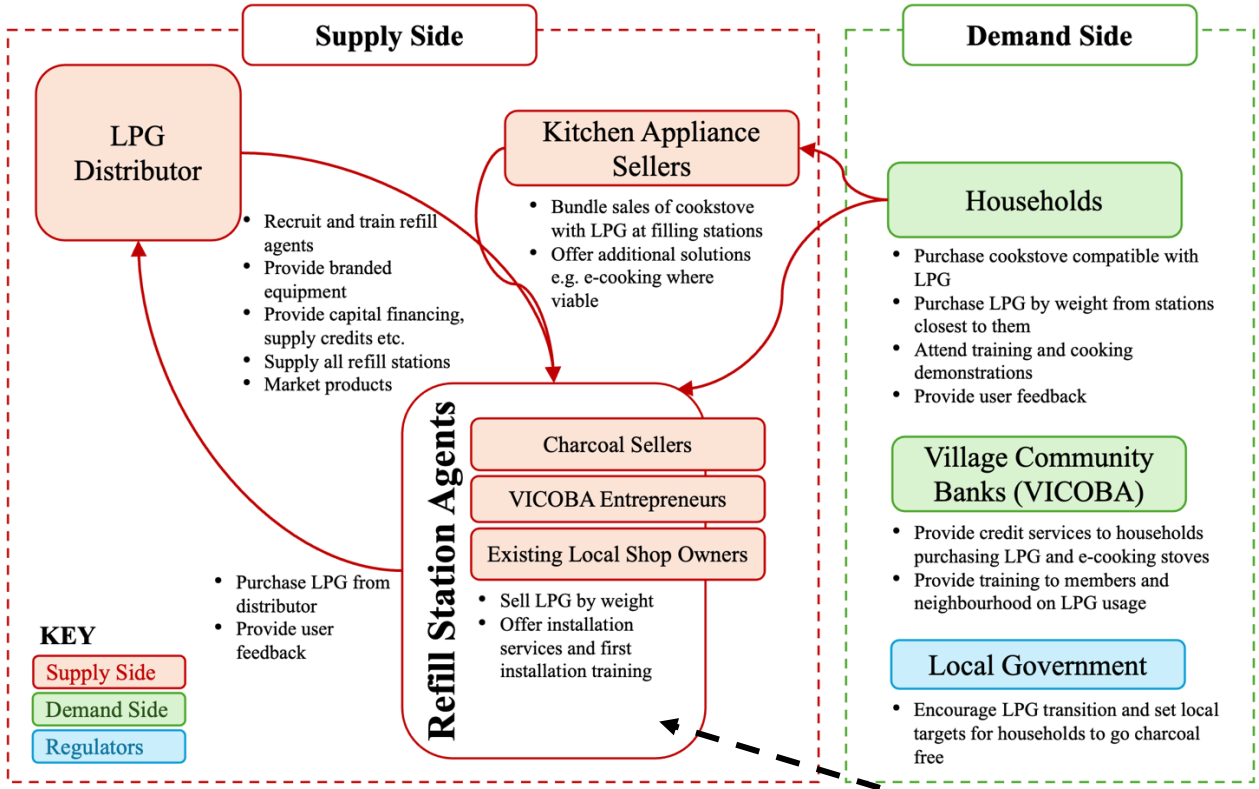
Referencing Table 1 highlighting the cook's activity analysis grid, we validated whether the solution addresses our pain points by mapping elements of the intervention against the pain points identified across the cook's activity process.

Task/ Sub-Goal	**Pain Points**	**How does the Intervention Address Identified Pain Points?**
Select stove	Unaffordability of clean energy stoves	Community savings groups are used to provide in-group financing with discounts from the LPG supplier for VICOBA groups.
	Limited knowledge of how to handle LPG or electric appliances available	Anyone provided with financing is offered free installation and training guidance, conducted by dedicated female trainers who live in the neighbourhood.
	LPG perceived as difficult to cook certain foods	This pain point is a limitation – was not addressed, however can be addressed with transition to e-cooking, where pressure cookers can navigate challenges with ingredients that require longer cooking times.
Find and select cooking fuel	Estimation of price per meal is difficult with LPG or electricity, even though it is cheaper per unit	Estimation of LPG by weight will also include estimations of how long the gas will last in terms of burn time and provide average number of meals each kilogram of LPG can cook. Current cost of Oryx 6KG gas cylinder refill at retail price is TZS 24,000 and can last for 3-4 weeks ~ 28 days for a small family cooking daily. A 1KG refill would cost ~TZS 4000, and last ~ 4.5 days. In comparison, one tin of charcoal can cost TZS 2000 and last for only one day. Therefore, the cost per day for LPG is TZS ~ 890, against TZS 2000 for charcoal.
	LPG sellers are further away than charcoal sellers	By establishing refill stations within neighbourhoods, we reduce distance between neighbourhoods and LPG sellers, and onboarding charcoal sellers to transitioning them to selling LPG instead. Further, smaller cylinder sizes will be introduced to reduce burden of carrying bulky cylinders after purchase.

	Limited visibility of alternative options as cooking happens in private homes	Community groups will go through collecting onboarding and training of what cooking options are available. Further, a revamped marketing campaign focused on the values of the community e.g. health and “charcoal free” neighbourhoods, intends to highlight possible alternatives
Prepare stove	Fear of making mistakes with gas connectivity or connecting electric kitchen appliances	The smaller cylinders are designed to have cooker top attachments, that offer an easier use design for connectivity instead of gas pipes. Free installation services will be made available to households requiring financing for LPG stove. At refill stations retailers will also be trained to teach their customers how to connect the gas cylinders to the stoves.
Start the fire	Charcoal has a higher preparation time, and fire needs to be started long before the cooking begins	Marketing campaigns will focus on the time-saving benefits of cleaner energy
Cook food	Hard to control heat intensity with charcoal	Marketing campaigns and cooking demonstrations will highlight the benefits of heat regulation with cleaner energy stoves
	Not all cooking utensils are suitable for different stoves	Most cooking utensils for charcoal can be used for LPG stoves. Limitations mostly arise when transitioning to e-cooking methods e.g. ovens
Extinguish fire	Takes time to put out charcoal fire	Marketing campaign will highlight safety features and the time saving benefits of cleaner energies.
	Fear that gas is not fully turned off with gas stoves	Community based training and installation support will also be used to ease fears on gas shut off.

Table 2: Mapping intervention against identified pain points

APPENDIX II: Refilling Model



Refill Station (Source: Alibaba)



Figure 15: Refill Station Model

APPENDIX III: Sample Recognition Certificates



Figure 16: Sample "Charcoal Free" Certificates (Developed in PowerPoint).

APPENDIX IV: Large Language Model (LLM) Usage

Item in Paper	Tool Used	Prompts Used
Figure 8	Gemini v.3	a. Please generate a model image of an LPG cylinder refill station based in Dar es Salaam, Tanzania. Please put in next to a shop and have the front branding say TUNAUZA LPG KWA KILO. b. Reference these images as inspiration (attached following link: https://www.ecotecpetroleum.com/Ecotec-Two-Nozzle-LPG-Dispenser-Gas-Pump-LPG-filling-Machine-for-Gas-Station-pd570853968.html)
Figure 9	ChatGPT v.5.2	a. Create an information poster. Context: Promoting clean cooking in Dar es Salaam. The poster should include the caption "Cooking with fire can harm your baby". Depict an embryo, a stove using charcoal and a stove using LPG.
Figure 9	Gemini v.3	a. Recreate the attached images. Replace "Cooking with fire can harm your baby" with "Cooking with charcoal can harm your baby". Keep everything else the same. b. Translate the texts in the attached pictures to Swahili. Keep everything else the same.
Figure 10	ChatGPT v.5.2	a. Create a poster with the heading "Cooking with charcoal wastes so much time". Depict a slim woman carrying charcoal.

Figure 11	Gemini v.3	Create a poster that should focus on promoting clean cooking through LPG highlighting the cost benefits. Include something like "One meal of charcoal will cost you [insert literature based value here] but one meal cooked with LPG will cost you only [insert literature based value here]. So, you could save [insert value].
Figure 12	Gemini v.3	a. Can you please make me a neighbourhood street sign based in Dar es Salaam that says “This neighbourhood is CHARCOAL FREE”. “Tunza Mazingira Yakutunze” b. Please make it look nice and clean it should be a modern sign. And spell neighbourhood correctly
Figure 13	Gemini v.3	c. Create a poster showing the steps involved in LPG cooking.
Figure 14	ChatGPT v.5.2	a. Create an image of a “pay-as-you-go machine” for gas. Give different options regarding the number of meals to pay for. Show coins instead of a card reader. Depict the question “For how many meals do you want to fill?”
Figure 14	Gemini v.3	b. Recreate the attached pictures. Translate them to Swahili.
Bibliography	Claude AI v.4.5. and End Note v.21	Please ensure the following references are in APA. If some of them are not, please amend them to APA format.

Table 3: LLM Tools Used