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CLEAN COOKSTOVES:
IMPACT AND DETERMINANTS OF ADOPTION AND MARKET SUCCESS

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EXECUTIVE SUMMARY

This study contributes to the sector's understanding of the impact and business conditions for investing in clean cooking solutions, presenting results from a systematic literature review complemented by primary qualitative and quantitative information to answer two research questions:

1. What is the impact of the adoption of efficient cookstoves on health, economic, and environmental outcomes?
2. How do policy, market, and household characteristics affect the success of clean cookstove businesses?

Insights emerging from the study can be used by FMO, government funds managed on behalf of the Dutch government (e.g., MASSIF, AEF), and impact investors in deciding future investments in efficient cookstoves across different countries and geographies.

Three billion people across the world rely on solid fuels for their daily cooking needs. The negative effects of traditional cooking methods on health, environmental, and socio-economic conditions, especially of women, have been well-documented, and clean cookstoves provide a promising solution to these issues.

The impact of clean cooking is explored through three dimensions: socio-economic, health, and environmental outcomes. Research shows that the adoption and continued use of improved cookstoves has a **positive impact on household savings** and can enhance economic wellbeing at the community level, when cookstoves are locally produced. Evidence also shows that the adoption of clean and improved cookstoves reduces time spent gathering fuel and cooking. This leads to **women having more time to spend on leisure or productive activities.**

The negative effects of traditional cookstoves on health are well-documented. However, the evidence of the positive effects of clean cookstoves on health is mixed. **Studies show that the health impacts of clean cookstoves are conditional on the design of the cookstove itself, especially the amount of particulate matter generated from its use, and the regularity with which the cookstove is used.** Practices like "stacking", that is, the continued use of traditional cooking methods alongside clean cookstoves, undermine their health benefits.

The use of traditional cookstoves is also associated with negative environmental effects. Due to inefficient fuel combustion, these cookstoves use large quantities of firewood and solid fuel, leading to deforestation and exploitation of natural resources as well as air pollution. However, **rigorous evidence of the positive impact of clean cookstoves on the environment is limited.** Many factors as well as local and global trends contribute to environmental degradation, which makes disentangling and measuring the impact of clean cookstoves on this outcome, complex.

Knowing the impact of clean cookstoves is essential to guide and inform investments in this sector and **development finance institutions (DFIs) have the resources, motivation, and leverage to promote the generation of such evidence, by creating incentives for multi-disciplinary research in the different domains they invest in.** However, this evidence needs to be complemented by a robust understanding of the policy and market conditions, as well as household demand, which determine the success of a cookstove business. **Challenges in accessing cost-effective and timely finance affect both the demand and supply side of the cookstove industry.** Formal financial institutions are wary of providing credit to cookstove companies, especially early-stage enterprises. **Grant-based financing is, therefore, often the only avenue through which cookstove companies can access finance.** Carbon credits are gaining popularity, but they are considered risky due to market

value fluctuations. **Governments and large institutional donors that invest in clean cooking must focus on building their investees' ability to access formal finance, which depends on their ability to demonstrate their profitability in both the short and long term.** In practice, this translates into building the sector's understanding of best business practices, as well as supporting initiatives that increase the efficiency and market access of clean cookstoves businesses. In addition, national governments, as well as multilateral organizations, should focus on promoting alternate forms of formal finance, both on the supply side (ex: start-up grants for green enterprises) and on the demand side (ex: asset financing via MFIs, fintech firms, etc.).

The choice of business models, distribution channels and marketing strategies are also important determinants of success for cookstove companies. However, **evidence about the effectiveness of the various business strategies and models that cookstoves companies can adopt is extremely limited. DFIs have the interest and means to play a key role in this regard, facilitating the development of best-case practices, as well as investing in rigorous monitoring and evaluation of different models** of production, distribution, and marketing across different economies and consumer groups, with the objective of generating adaptable evidence.

On the demand side, low awareness about the benefits of adopting clean cookstoves, as well as high initial investment costs and limited access to formal credit, act as barriers to consumer demand. Regarding the latter, even though the **evidence on the effectiveness of asset-based financing is limited, it emerges as a more promising approach to meet the financial needs of end-users.** Understanding household behaviours, preferences, and norms is essential to develop business models and strategies that respond to the needs and priorities of potential customers. Evidence suggests that habits leading to the usage of traditional cookstoves are hard to break and that owning a clean cookstove does not necessarily translate into sustained and regular usage. By definition, **understanding local norms and preferences requires contextual and targeted research.** In this report, we provide an example of the importance of conducting such studies, presenting results from a case study in India that analysed the relationship between individual and household socio-economic characteristics and the use of clean or non-clean cookstoves. While some findings were intuitive, others did not align with the prevalent literature on the sector. For example, research has shown that smaller households more commonly adopt clean cookstoves, as they are normally smaller than traditional ones. However, results from this specific survey show an opposite trend, demonstrating that localized research provides essential information for cookstove companies, financial institutions and local governments to design targeted strategies to increase the adoption of clean cookstoves.

Finally, the country-level analysis highlights the key role that governments play in fostering an enabling environment for the growth of the cookstove industry. In countries like India and Kenya, the government, through a combination of subsidies and industry-friendly policies, has been instrumental in increasing the adoption of clean cooking methods. In other countries, the success of government initiatives has been mixed and highly dependent on other factors such as infrastructure development, market access, and the availability of cookstoves tailored to local cooking styles. In the absence of strong government commitments, social enterprises and local cookstove businesses, often backed by international investments, have been successful and show promise, although their scalability is yet to be demonstrated.

In conclusion, and considering the evidence reviewed in this report, it is recommended that DFIs abide by the following six principles when investing in clean cookstoves businesses:

1. **Leverage local policy to guide investments:** Considering whether policy makers are prioritizing one type of cookstove or fuel over another (through regulations, directives, and adequate budget allocations) can provide important guidance to predict whether an investment has the potential to succeed or not. For instance, the Indian government has been heavily promoting and subsidizing the adoption of LPG-based cookstoves, effectively rendering investments in other types of

cookstoves unviable. Additionally, it is recommended to consider the political cycle[1] as well as past policy decisions, weighing for how long certain policies have been in place (as a way to gauge political commitment) and how effectively they have been implemented.

2. **Be explicit about priority outcomes:** Clean cookstoves use a variety of fuels and designs to produce heat, which leads to different outcomes. For instance, an LPG cookstove emits very low levels of particulate matter, which makes it very healthy. However, as it relies on the extraction of natural gas, its environmental impact is negative. On the other hand, improved cookstoves using biomass might have a minimal impact on the environment. However, they still emit harmful particulate matter, though how much depends on the design of each type of cookstove. Similarly, some cookstoves are more fuel-efficient than others, thus having different impacts on savings both in economic terms and time. One single type of cookstove that maximizes impact across all dimensions (e.g., economic, social, health, environmental outcomes) is practically non-existent. Thus, before making any investment, it is essential to understand which outcome is the most important for the investor and select a cookstove design that focuses on achieving that.
3. **Invest in cookstoves that have been created with a Human-Centric Design approach:** The impact of cookstoves is conditional on their correct, continuous, and exclusive use. Ensuring that cooks use the clean cookstove that they have bought or received, with minimal assistance, guidance, and incentives is essential and hinges, for the greater part, on the cookstove being designed to fit the needs, behaviour, and preferences of the users or, in other words, using Human-Centric Design. In practice (and following human-centric design principles), this means investing time and resources in engaging with users, prototyping, and piloting solutions before scale-up.
4. **Consider local financial markets:** The sustainability of an investment in this sector depends on the possibility of the investee to access additional sources of finance as well, which will depend on the development, vitality, and rules of the local financial market. In many low and middle-income countries, it is difficult for clean cookstoves businesses to receive funding from traditional lenders. Therefore, it is important to determine whether an investment is worthwhile if the chances of a business to raise additional funds are low, as well as considering whether financial-sustainability conditions should be tied to the various instalments of the investment (e.g., a payment tranche could be linked to demonstrating profitability and/or raising funds from other sources).
5. **Focus on opportunities that demonstrate mastery of the local context:** It is essential to ensure that investments demonstrate an understanding of and account for local social norms, financial markets, and policies, as highlighted above. However, that is not enough, as the local infrastructure (e.g., road network, power supply, etc.), productive capacity, supply chain (e.g., access to fuel, components, etc.), and market (e.g., competitors, costs, affordability of the proposed product) need to be accounted for as well.
6. **Embed knowledge generation activities:** This report shows that there are some gaps in the literature both in terms of the impact of cookstoves on certain outcomes (especially health and environment), but especially on the effectiveness of different products, marketing, and distribution strategies. Embedding knowledge generation activities to future investments in clean cookstoves (e.g., impact and process evaluations, cost-benefit analysis, etc.) will grow the sector's understanding of what works and what does not and will make future investment decisions easier and more impactful.

[1] i.e., considering when the next elections are going to be held, what are the stated policy intentions of the various candidates on this topic, etc.

1. BACKGROUND AND MOTIVATION

This study contributes to the sector's understanding of the case for investing in clean cooking solutions and their related challenges. Insights from this study can help FMO, government funds managed on behalf of the Dutch government (e.g., MASSIF, AEF), and impact investors guide future investments in efficient cookstoves across different countries and geographies. This is achieved through a systematic review of the literature on the impact and business case for clean cooking, aimed at analysing and summarizing evidence on two key research questions:

1. What is the impact of the adoption of efficient cookstoves on health, economic, and environmental outcomes?
2. How do policy, market, and household characteristics affect the success of clean cookstoves businesses?


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The report also takes a deep dive into the clean cookstove market of six countries: India, Vietnam, Burkina Faso, Ghana, Ethiopia and Kenya. The clean cookstoves market of each of these countries is analysed through policy, social, and market lenses to determine success factors and limitations and draw generalizable conclusions. The report draws on secondary information from a systematic literature review, supplemented by primary quantitative and qualitative data. The quantitative data comes from a survey conducted in 2018 in the state of Karnataka, India, among potential clean cookstoves users, while the qualitative data stems from key-informant interviews conducted as part of this study. Overall, this report provides an updated and consolidated review of the current literature on the impact of clean cookstoves. Unlike other reviews of this type, it also looks into distribution and financing processes and policies. Finally, it also provides recommendations for DFI investors.

The document is organised as follows: the broad rationale and need for clean cookstoves are presented in the introduction (Section 2), which also provides an overview of different types of cookstoves. Section 3 furnishes a comprehensive review of the evidence on the impact of cookstoves on health, environmental, and economic outcomes, and Section 4 presents insights on the socio-demographic and market factors that determine the success of investments in efficient cookstoves. This section also summarizes results emerging from the survey mentioned above in the form of a case study aimed at supplementing the socio-demographic conclusions of the section. Section 5 provides an overview of clean cookstoves markets in six countries, namely India, Vietnam, Ghana, Burkina Faso, Ethiopia, and Kenya. Section 6 concludes with key findings from the study and highlights implications for future programs and research efforts.

2. INTRODUCTION

Three billion people globally rely on burning solid fuel, including biomass, agricultural residues, and charcoal, for their daily cooking needs (Venkata Ramana et al., 2015). Traditional cooking methods in low and middle-income countries involve the combustion of these solid biomass fuels over an open fire on a stone, mud, or metal platform. Although the performance of these traditional cookstoves – in terms of fuel efficiency and emissions released – depends on the nature and quality of materials used, cooking over an open fire has been found to have an overall detrimental effect on health and the environment (Ekoueva, Freeman, and Soni, 2014). Indoor air pollution causes 1.6 million deaths every year and ranks as the fourth risk factor contributing to disease and death in developing countries (WHO, 2020). Clean cookstoves are seen as a valuable tool to combat this issue and directly contribute to the achievement of a number of Sustainable Development Goals (SDG), most especially SDG 3 – ensure healthy lives and promote well-being for all at all ages - and SDG 7 – ensure access to affordable, reliable, sustainable and modern energy for all. Specific relevant targets and indicators are reported in Table 1 below.

TABLE 1: SUSTAINABLE DEVELOPMENT GOALS AND CLEAN COOKSTOVES

Sustainable Development Goals and Clean Cookstoves	
Goal	3. Ensure healthy lives and promote well-being for all at all ages
Target	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
Indicator	3.9.1 Mortality rate Attributed to **household** and ambient air Pollution
Goal	7. Ensure access to affordable, reliable, sustainable and modern energy for all
Target	7.1 By 2030, ensure universal access to affordable, reliable and modern energy services
Indicator	7.1.2 Proportion of population with primary reliance on clean fuels and technology

Against this backdrop, the global movement and advocacy for the adoption of clean cookstoves aim to mitigate the adverse effects of traditional cooking methods by improving fuel efficiency and/or reducing emissions levels (Clean Cooking Alliance, n.d.). The next subsection provides a brief introduction to clean cooking practices that are common in low and middle-income countries and presents an overview of the different types of cookstoves, cooking fuels and their classifications.

A primer on clean cooking

Clean cookstoves is a blanket term that refers to modern cookstoves which are designed to be less harmful to human health and the environment than traditional cookstoves, both by employing cleaner, less polluting fuels, as well as altering conventional designs to address specific issues. Such modifications can improve energy efficiency, reduce emissions levels or improve fuel savings and are normally defined in the literature as Improved Cookstoves or ICs (World Bank, 2011).

Mapping the various traditional and clean cooking alternatives available to low-income households is important for developing a nuanced understanding of different country and region contexts and building user-centric solutions that address both demand and supply-side barriers.

Classification of cookstoves

The Clean Cookstove Alliance's Clean Cooking Catalogue identifies 427 different kinds of cookstoves that are used in household cooking (Clean Cooking Alliance (b) n.d.). Across the literature, cookstoves are categorised along a number of dimensions, such as the degree of modification, standards of performance (in terms of efficiency and emissions), and the type of fuel used.

For example, Venkata Ramana et al. (2015) classify cookstove solutions in terms of their level of modification: baseline traditional cookstoves are considered 'legacy' stoves, while modified cookstoves are defined as "Improved Cookstoves" "Improved Cookstoves" (ICs). The latter group is further catalogued into *Basic, Intermediate and Advanced* ICs depending on the functional features of the stove. For example, legacy cookstoves fitted with chimneys are considered Basic ICs, improved designs focused on fuel efficiency (such as the rocket stove mentioned in Figure 1) are considered Intermediate ICs and vented stoves with high fuel and combustion efficiency are considered Advanced ICs.

Other classifications of clean cookstoves are based on whether the fuel used is modern (LPG,[2] electric, natural gas, kerosene) or renewable (biogas, ethanol, or solar) (World Bank 2014).

Cookstoves have also been categorized according to tiered standards of performance set by the International Organization for Standardization's (ISO) International Workshop Agreement (IWA). This framework evaluates cookstove performance on the basis of fuel efficiency, emissions levels (of $PM_{2.5}$ and CO) and safety, as determined in laboratory tests. The ISO system classifies cookstoves on the basis of laboratory tests - with Tier 0 representing the worst-performing cookstoves and Tier 4 the best (ISO 2018).

The popularity of individual cookstove models varies across regions, and is influenced by their build, cost, material, appearance, and resemblance to the traditional stoves of the region. For instance, LPG is the most common clean cooking fuel in India. However, in Ethiopia, it is rarer, and the consumption of electricity[3] has grown much faster. Some of the models of improved cookstoves available in Ethiopia include the Lakech stove, Tikikil stove and the Mirt stove.[4] **The global market is fragmented by the needs and preferences of each local context, and as such, market leaders also exist and operate by region.**

Figure 2 uses data from the GIZ HERA Cooking Compendium (GIZ, 2013) to classify a selection of cookstoves,[5] described in the table below, according to three parameters: the type of fuel used (indicated within the circles), combustion efficiency (vertical axis), and emissions released (horizontal axis). Interestingly, several of these models, such as the rocket or the gasifier, may be fitted with additional chimneys or vents to reduce emissions further, providing a clear example of how difficult it can be to classify different types of clean cookstoves.

[2] While LPG is indeed cleaner than most fuels, it is still a fossil fuel and as such its adoption is not supported by the Dutch Ministry of Foreign Affairs.

[3] It is worth highlighting that electric cookstoves, while indubitably better for the health of those in the kitchen, are not necessarily "clean" as that depends on how the electricity has been generated.

[4] Merchaye and Lakech stoves are made from clay and sheet metal while the traditional stove is made from only sheet metal. Mirt stoves are improved stoves made with concrete.

[5] Cookstoves presented in the compendium cover a wide array of typologies and have been identified on the basis of GIZ's experience in implementing clean cooking projects.

FIGURE 1: TYPES OF COOKSTOVES AVAILABLE TO HOUSEHOLDS IN LOW- AND MIDDLE-INCOME COUNTRIES

1

Traditional Stoves

These range from open fires to stoves made of brick, stone, ceramic and clay with a fire enclosed within. The performance of the stove depends on the quality of materials used.

2

Chulha

Chulha is a traditional u-shaped clay stove with an apron in front to hold fuel (and ash after combustion).

3

Griddle/Plancha

A griddle stove has a hot flat surface made of metal or stone, with the flame held within an enclosed space underneath and directing hot flue gases to heat the surface, and a chimney to discard emissions.

4

Rocket/Side-Feed

Rocket stoves have an insulated, L-shaped combustion chamber that causes almost complete fuel combustion inside the stove before the heat reaches the pot or griddle. They may be fitted with a vertical chimney to release emissions.

5

Gasifier/Top-Lift Updraft

Gasifier stoves convert solid biomass into gas, and force it into the flame until complete combustion occurs, leading to low emissions.

6

Alcohol Burning Stoves

Ethanol stoves provide heat immediately upon ignition of fuel and provide a higher heat flux than simple biomass, with no soot or smoke emitted.

7

Gas Stoves

Gas stoves have a pipe running from the fuel source to the burner. The amount of fuel released can be regulated.

8

Solar Cookers*

These can be panel cookers with a clamshell shape, box cookers that fully enclose the pot, parabolic cookers that resemble a satellite dish, or vacuum tube cookers that work like greenhouses.

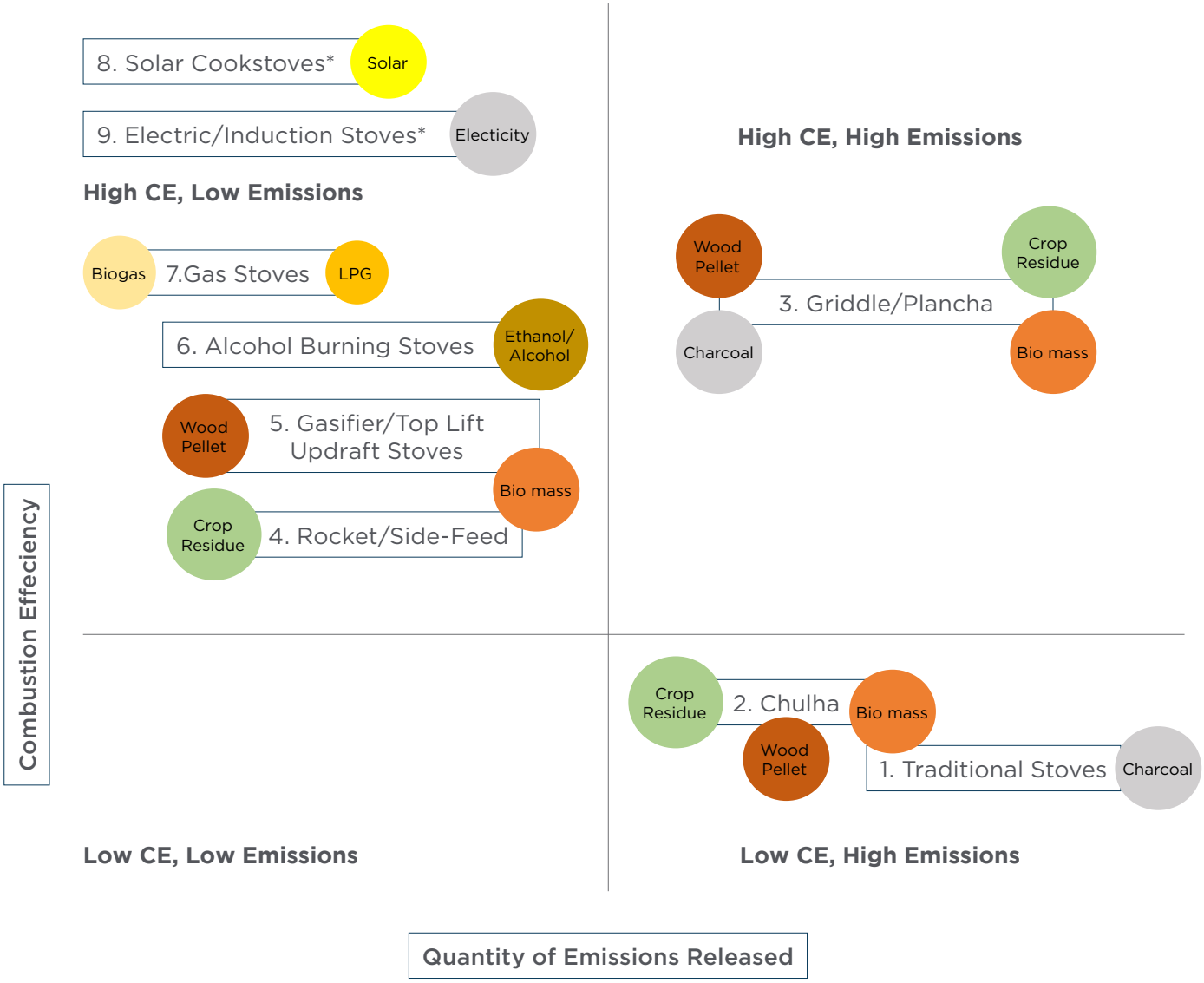
9

Electric/Induction Stoves*

Electric stoves convert electrical energy into heat for cooking. Induction stoves are a type of electric stove that produces heat when a high-frequency magnetic field comes into contact with compatible cookware, with no flames or emissions.

* Solar and Electric/Induction stoves function without the need for any combustion and thus do not contribute to indoor pollution and their contribution to overall emissions depends on their production and, in the case of the latter type of cookstoves, on the electric grid on which they are used.

FIGURE 2: COMBUSTION EFFICIENCY AND EMISSIONS BY TYPE OF COOKSTOVE



Linking Figure 2 with some of the classifications described earlier, it is interesting to see that stoves 2 (Chula), 3 (Griddle), 4 (Rocket), and 5 (Gasifier) are all, technically, 'Improved Cookstoves' since they all use traditional biomass fuels.[6] Thanks to their improved design, they produce fewer emissions and have greater combustion efficiency than traditional stoves, but their scores along these dimensions are highly variable, which lends further evidence to the importance of the stove's design with respect to emission and efficiency outcomes.

An illustrative example can be found in the bottom-right quadrant of Figure 2. Both traditional stoves and chulhas release high amounts of smoke and have a low combustion efficiency. While chulhas can use crop residue and wood pellets (or briquettes) as fuel, and traditional stoves use charcoal, both chulhas and traditional stoves can use biomass. Chulhas, on the other hand, can have slightly improved combustion efficiency and release fewer emissions if they are modified by changing the material of combustion or attaching a chimney.

[6] Traditional biomass fuels include wood, charcoal, leaves, agricultural waste, animal/human waste, etc. (Karekezi, 2004)

3. THE IMPACT OF COOKSTOVES

This section summarizes evidence on the impact of efficient cookstoves on economic, social, and environmental impacts.

This section develops a Theory of Change (ToC) that explains the logic and assumptions linking clean cooking to socio-economic, health, and environmental outcomes. It also presents evidence on the impact of clean cookstoves on these outcomes. In summary, it appears that the impact of clean cookstoves is uneven and highly dependent on local contextual factors, including policy and social norms, as well as the design of the cookstoves themselves. This suggests that any investment in clean cookstoves should be preceded and informed by a thorough and independent review of the local policy and market conditions, as well as an analysis of the preferences, habits, and norms of the intended customers.

Theory of change

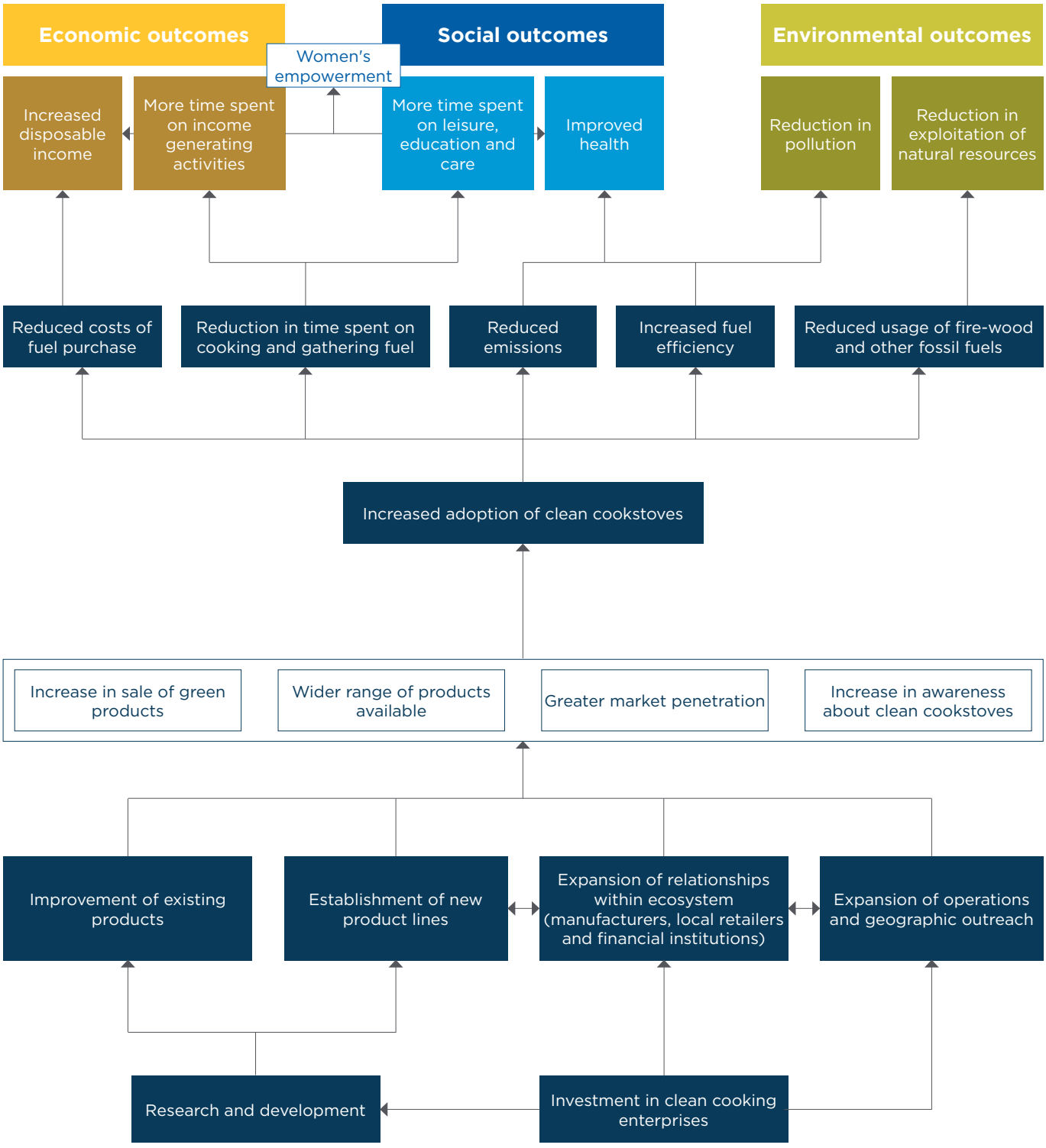
The adoption of clean cookstoves has the potential to lead to several positive development outcomes that can be classified along economic, environmental, and social dimensions. For instance, the adoption of clean cookstoves reduces indoor air pollution, thus leading to improved health of household members. Similarly, there is evidence to support the hypothesis that adoption of clean cookstoves results in savings and reduces the time spent cooking or gathering fuel,[7] which improves individual or economic wellbeing granting more time to spend either on leisure or income-generating activities. Finally, switching to fuel-efficient cookstoves or cookstoves that do not use wood, charcoal, or fossil fuels, reduces the exploitation of natural resources.

While it is important to remember that the impact of clean cookstoves is highly dependent on local contextual factors, trends emerge from the review of the literature. Details will be provided in the following subsections, but, in summary, the literature shows that:

- At the household level, the main measurable economic benefit of the adoption of clean cookstoves is savings from increased fuel efficiency.
- The design of the cookstove is pivotal for its health impacts. Cookstoves causing lower particulate matter, if used correctly and consistently, lead to better health outcomes.
- Empirical evidence consistently suggests that the adoption of clean cookstoves reduces the amount of time needed to collect firewood and cook, which are tasks that are normally borne by women and children.
- There is ample evidence of the negative effects of traditional cookstoves on emissions and deforestation. However, there is no measurable impact of the positive environmental effects of clean cookstoves, arguably due to their limited take-up.

[7] In this report "savings" refer to cash savings, unless it is explicitly mentioned that it has been referred to time savings.

FIGURE 3: THEORY OF CHANGE



Economic outcomes

Key takeaways:

- Multiple studies suggest that the main economic benefit of the adoption of clean cookstoves stems from savings due to increased fuel-efficiency. Since the current evidence is still very localized, future research should focus on ensuring greater comparability of results and/or conducting studies on broader geographies.
- In some contexts, the adoption of locally produced cookstoves has led to improved economic outcomes at the community-level. Arguably, this highlights the importance of designing cookstoves that can be manufactured locally.

Existing evidence suggests that the adoption of clean cookstoves reduces the time spent by households in collecting firewood as well as their fuel expenditures. A study conducted in Mexico by Berrueta et al. (2008) found that households that exclusively used fuelwood for traditional cookstoves, after the adoption of a more efficient wood-burning cookstove saved an average of 846 kg of fuelwood per adult per year (67% reduction), leading to considerable savings. Another study by Bailis et al. (2007) showed that the adoption of clean cookstoves can reduce the daily per capita fuel consumption by a factor ranging between 19 and 67 percent compared to those households that used traditional stoves in India and Mexico. Furthermore, García-Frapolli et al. (2010) undertake a cost-benefit analysis of the Patsari cookstove, an improved biomass cookstove, in the Purépecha region of Mexico. The study finds that this type of cookstove brought significant economic benefits to poor households, mostly through savings from a decreased need for fuelwood and an improvement in health conditions. ACCESS (2015) estimates that traditional cookstoves used by educational institutions in Kenya require large sums of money to buy fuelwood for cooking meals, averaging from USD 128 to USD 148 per month (ACCES, 2015). As mentioned above, there is significant evidence that the adoption of improved cookstoves improves fuel efficiency. Karanja and Gasparatos (2019) posit that schools could use savings coming from the adoption of clean cookstoves to improve the nutritional value of the meals served to their students, which may in turn encourage families to send children to schools (Karanja & Gasparatos, 2019).

The economic benefits from the adoption of clean cookstoves can come from different channels as well, aside from savings. Wiedmer et al. (2015) studied the socio-economic impacts of the Uganda Commercialisation Program, which produced fuel-efficient stoves locally and sold them to households through vendors. Apart from reducing household expenditures on charcoal and energy, they found that the main local economic benefit of this program was the creation of full-time long-term jobs. Clearly, the realization of such community benefits is highly contingent on the design of the cookstoves themselves, which will need to be able to be manufactured using inputs (physical, human, and financial) available in target communities. In conclusion, clean cookstoves have been proven to improve economic outcomes, mostly through increased savings due to fuel-efficiency and by creating local employment and business opportunities if the cookstoves are produced locally.

Social outcomes

The adoption of clean and efficient cookstoves has the potential to improve social and health outcomes. Proponents of the adoption of ICs, such as the Global Alliance for Clean Cookstoves, posit that the adoption of clean cookstoves or fuels reduces the time and effort spent collecting fuel and cooking. In turn, this allows people, and especially women, to spend more time on income-generating activities, education or training and rest (Global Alliance for Clean Cookstoves 2016; Clancy et al. 2012), thus contributing to enhancing women's social and economic empowerment (SDG 5). However, there is still limited empirical evidence of such impacts.

Health

Key takeaways:

- While the evidence of the health impacts of clean cookstoves is mixed, it appears that it is highly contingent on the level of particulate matter emitted by the cookstoves themselves, which varies from cookstove to cookstove, and on whether households use them consistently and correctly.

Beginning from health-related outcomes, smoke from the combustion of solid fuels has a direct impact on health, causing respiratory diseases. The World Health Organization (2020) estimates that, every year, close to 1.6 million deaths worldwide are attributable to indoor air pollution.

While the detrimental effects of traditional cookstoves on health outcomes are acknowledged and supported by evidence, current evaluations of existing programs of the impact of clean cookstoves on health yield mixed results (Quansah et al. 2017; Hanna, Duflo, and Greenstone 2016). In particular, Hanna et al (2016) show that health impacts are highly dependent on the continued and consistent use of cookstoves over time. However, while Jeuland and Pattanayak (2012) find insufficient evidence of the impact of cookstoves on asthma, lung cancer, and cardiovascular diseases, they observe a reduction in morbidity and mortality due to acute respiratory illnesses. The FRESH AIR study (van Gemert, De Jong, et al. 2019) notes that self-reported respiratory symptoms and chest infections diminish significantly for cookstove adopters in Uganda and Kyrgyzstan after 12 months. The findings of the RESPIRE study also suggest that the improved stove intervention of a chimney-fitted plancha was responsible for improvements in cardiovascular health outcomes. **Across studies, the likelihood of improved health outcomes was correlated with the level of emissions, and, more interestingly, it was contingent on the extent of adoption.** As a result, investors and practitioners alike might want to ensure that households are well-informed and guided to properly utilise and maintain their clean cookstoves in order to maximize health impacts. In summary, health outcomes are highly dependent on the type of cookstove employed (and its particulate matters emissions), as well as their correct, continuous, and exclusive usage.

Women's empowerment, time use, and education

Key takeaways:

- Empirical evidence consistently suggests that the adoption of clean cookstoves reduces the amount of time needed to collect firewood and cook. Women use this time for a variety of purposes, including leisure, participation in women's groups, and income-generating activities. Cookstoves' design in terms of perceived safety and ease of use, can hamper or support these results.
- Children are also often involved in collecting fuel for traditional cookstoves and the adoption of clean cookstoves has been linked to improved school attendance and time spent reading.

As noted in the Theory of Change, it is often assumed that the adoption of clean cookstoves helps reduce the time spent by household members, especially women, on cooking[8] and gathering fuel. Chandar et al. (2004) noted that in the Lag Valley, Himachal Pradesh (India), access to LPG led to more men and boys contributing to cooking tasks, leading to a fairer distribution of household tasks between men and women, also setting a virtuous example for younger generations. Another study also conducted in Himachal

[8] According to Miller and Mobarak (2013), women spend, on average, 4 hours a day cooking using traditional cookstoves.

Pradesh (Parikh, 2011), shows that as the quality of the fuel required to operate cookstoves improves, men become more likely to participate in their procurement, alleviating the burden carried by women.[9] Similar results are observed in East Africa as well. A study conducted in Kenya monitored the use of both traditional and improved cookstoves (Jogoe et al 2020) and concluded that usage of clean cookstoves led to a reduction in both cooking time and time spent on collecting fuel. Moreover, women that adopted clean cookstoves felt more confident having other household members cook while they completed other chores, which gave them a sense of freedom and flexibility, highlighting, again, the importance of designing improved cookstoves that are considered to be safe and easy to use. The study showed that time previously spent in collecting firewood was now used for income-generating activities – either working on their own farms or selling their produce. A study by (Bloomfield et al, 2014) also reported that women using clean cookstoves have more free time that they use to participate in community meetings and self-help groups. This gives them access to support networks and income generation activities, but the study did not observe a statistically significant increase in women's financial decision-making power in the household as a consequence of the adoption of clean cookstoves.

It is also possible that the adoption of certain types of cookstoves has unintended negative effects on women's well-being. As highlighted by Green (2003), women tend to socialize and interact with household members when cooking. The adoption of solar cookstoves forced them outdoors while the family continued to socialize indoors. This weakened their influence on the family and, ultimately, their decision-making power.

Aside from the effects on women's empowerment, the use of traditional cookstoves has been negatively correlated with school attendance. A study by Gebru and Bezu (2012) reports that children in Northern Ethiopia spend about seven hours collecting firewood and that a 50 percent increase in hours spent collecting firewood is likely to lead to a decrease in children's school attendance by 12 percent. **School children from households that adopted ICs reported having utilized the time they used to spend collecting fuelwood for doing their homework or reading (Glynn, 2020).** Overall, the adoption of clean cookstoves appears to have a positive effect on women's empowerment, mainly by freeing up their time to either pursue income generating activities, or spend more time on leisure, education, or rest. Either way, both lead to an improvement in their wellbeing.

Environmental outcomes

Emissions and deforestation

The incomplete combustion of biomass fuels during cooking contributes to Indoor Air Pollution (or IAP). Evidence from field studies shows that clean cookstoves designed to allow for more complete combustion and venting of smoke produce fewer emissions as compared to traditional cookstoves. Among stoves that do not use biomass as their primary fuel, gas stoves, electric stoves and solar cookers generate the highest particulate matter reductions (90-99 percent), followed by ethanol stoves. In comparison, only well-performing fan gasifiers and natural draft gasifiers were able to approach the emission reduction levels of gas stoves (van Gemert, de Jong, et

Key takeaways:

- There is ample evidence of the negative effects of traditional cookstoves on emissions and deforestation. Clean cookstoves can, in theory, mitigate the impact of cooking on both, but empirical evidence of this topic is scant, arguably due to insufficient availability of both micro and macro data, the limited scale of the adoption of clean cookstoves, and the effects of a large number of other confounding factors.

[9] While unrelated to cookstoves, a study from South Africa (Anneke, 2005) found that with improved access to electricity, men were more likely to pick up cooking-related tasks, suggesting that men tend to contribute more to such household tasks as the drudgery related to them reduces.

al. 2019). Findings consistently show that clean cookstoves lead, on average, to fewer emissions than traditional cookstoves contingently on the design of the cookstove itself, the type of fuel used and other factors, such as being used properly. More results strengthening this evidence are summarised in the appendix.

Energy-efficient modifications for biomass cookstoves lead to the consumption of less fuel, which should lead to less exploitation of natural resources and especially a reduction in deforestation. While there is ample evidence that excessive reliance on wood and charcoal for household cooking can lead to large-scale degradation of forests (Rosenthal et al., 2018; Specht et al., 2015), and continuous harvesting may result in mudslides, watershed damage, and desertification (Simon et al. 2014; Hutton, Rehfuess, and Tediosi 2007), the environmental benefits of switching to clean cooking can be difficult to measure. Currently, studies that attempt to measure the environmental costs and benefits of clean cookstoves consider as a proxy measure for deforestation and land degradation the cost of re-planting trees (Hutton, Rehfuess, and Tediosi 2007; Jeuland and Pattanayak 2012). Other studies looking at the sustainability of using woody biomass in clean cookstoves find that results are heavily context-specific, where certain regions have enough forest forest-stock so that judicious use of wood-fuelled cookstoves can be sustainable, while others do not (Openshaw, 2011; Simon et al., 2014; Nkambwe and Sekhwela 2006). Overall, given the currently available evidence on this topic, it is not possible to state that clean cookstoves contribute to achieving environmental objectives.

The World Bank Group/flickr

Summary of results

The table below summarises results presented in the review of the impact literature, connecting it to the various outcomes outlined in the Theory of Change.

TABLE 2: SUMMARY OF RESULTS

Outcome	Evidence
Increased disposable income	**Positive** Impact pathways: • Savings, due to fuel-efficiency and, thus, lower expenditures on fuel. • Local production of cookstoves creates local employment and economic benefits (conditional on promoting cookstoves that can be produced domestically, depending on local capacity, access to supplies, and production facilities)
Women's empowerment: More time spent • **on income-generating activities** • **leisure, education, and care**	**Positive** Impact pathways: • Using improved cookstoves or better fuels leads to men taking more responsibilities in cooking tasks, leading to time savings due to improved fuel efficiency (less time collecting fuel) » How women spend this additional time depends on contextual factors, individual preferences, etc. Either way, whether women decide to spend more time on income-generating activities or on leisure, rest, education, or care, this is still an improvement in their wellbeing. *Caution: in traditional contexts, cooking plays a significant role in women's social lives. Altering these dynamics in a few cases, it has shown that it led to greater isolation. This depends on the type of cookstove employed as, for example, this problem has been noted with solar cookstoves, which require the women to spend time outside the house cooking.*
Improved health	**Positive, but weak** Impact pathways: • Positive health outcomes are highly contingent on the design of the stove (different stove emit different levels of particulate matters) and their consistent, prolonged, and exclusive use (if a clean cookstove is used alongside a traditional one in the same kitchen it is evident that its health benefits from reduced indoor pollution are reduced).
Reduction in pollution	**Inconclusive**
Indicator reduction in pollution	• Empirical evidence of this topic is limited due to insufficient data, uneven and limited adoption of clean cookstoves, and the presence of a large number of other confounding factors.

3. FACTORS DETERMINING THE ECONOMIC SUCCESS OF COOKSTOVE BUSINESSES

Understanding the conditions that determine the economic success of different clean cookstove business models is essential to guide investments in this sector. The literature reveals that rigorous evidence on the effectiveness of different business and financing models is limited, highlighting a substantial knowledge gap in the sector. Research on production, distribution, and marketing models is particularly sparse. This issue could be addressed through systematically conducting process evaluations, alongside impact evaluations.

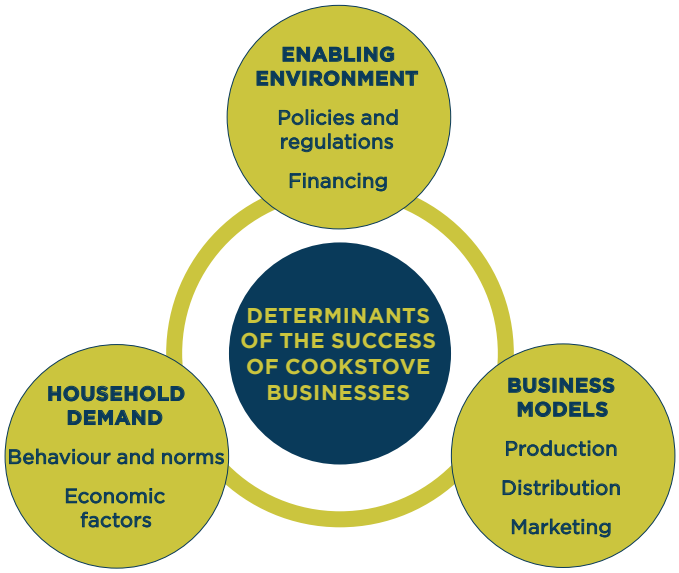
On the financing side, **access to formal finance for SMEs in low and middle-income countries is limited. Financial institutions in these contexts are reluctant to provide credit to clean cookstoves businesses** as cookstoves are not income-generating assets, nor require recurring purchases from the customer's side. Under these conditions, **grants and equity financing seem to be the only viable option.** Many of such grants come from Development Finance Institutions (DFI). However, the investment priorities of these actors might change due to policy or political shifts, raising concerns about the sustainability of this strategy. Alternatively, carbon credits are becoming increasingly popular, but are often considered risky due to market prices fluctuations.

On the policy side, clearer results emerge. **Shifting fuel subsidies from polluting to clean fuels has been demonstrated to lead to a substantial reduction in the use of harmful fuels, although phasing out such policies is difficult.** On the other hand, selling clean cookstoves at heavily subsidised rates does not appear to lead to a significant increase in the adoption of cookstoves themselves.

Finally, **affordability remains a necessary condition to ensure and sustain household demand. However, it does not appear to be sufficient, since, even after the purchase, the usage of traditional cookstoves often continues. Households' preferences, habits, and norms are then essential to guarantee the continued usage of clean cookstoves.** However, these characteristics are highly contextual, which means that prior to any investment in clean cookstoves it would be beneficial to conduct an analysis of the local demand, including behavioural and social factors to ensure that cookstoves design fits the needs and preferences of consumers following Human-Centred Design (HCD) principles.

The following subsections will expand the findings summarized above.

FIGURE 4: DETERMINANTS OF THE SUCCESS OF COOKSTOVE BUSINESSES



Enabling environment

Policies and regulations

An enabling policy and regulatory environment is crucial to create the conditions to allow clean cookstoves businesses to grow - building institutional capacity, affecting investment and profitability, fostering market linkages and creating a business-friendly environment. Policies can encourage the manufacture and distribution of clean cookstoves and fuels, but also lower the barriers to purchasing improved cookstoves and fuels by households. This is particularly important since adoption and usage of clean cooking is contingent upon and largely driven by consumers' preferences. It follows that **policies need to be tailored to local economies, culture, and consumer habits in order to influence the success of clean cookstove businesses effectively.** Tangible examples of how the policy environment influences the adoption of clean cookstoves are provided in the country briefs section.

Key takeaways:

- Shifting fuel subsidies from polluting to clean fuels has been demonstrated to lead to a substantial reduction in the use of harmful fuels, although phasing-out of such policies is difficult.
- Selling clean cookstoves at heavily subsidised rates does not appear to lead to a significant increase in the adoption of cookstoves themselves. Indirect subsidies targeted to manufacturers lead to better results.
- The evidence of the impact of tax reductions and rebates on fuels and clean cookstoves components is mixed and highly contingent on market fluctuations.

Pricing, tax and subsidies

Policies that reduce the cost of clean cookstoves and fuels for manufacturers and customers can enable the growth of clean cookstove companies by encouraging sales. The paragraphs below discuss some of the most common types of these policies.

Shifting fuel subsidies from polluting fuels to cleaner alternatives can encourage demand for clean cooking, but the policies need to be targeted towards the most disadvantaged households and safeguards against leakages need to be set up, a good example of which are the direct cash transfers schemes implemented in India and Mexico. Similar policies have been implemented in numerous countries, and existing evidence suggests that they have led to a substantial reduction in the use of heavily polluting fuels for cooking (for instance, see Thoday et al., 2018, for Indonesia; Gould, 2018, for Ecuador; and Ishrat Malek et al., 2015, for Bangladesh). While these policies have been criticized for being costly and difficult to phase out, the evidence provided above shows substantial public benefits in the long run (Lindebjerg et al., 2015)

Subsidies for the purchase of clean and improved cookstoves also aim to improve adoption by under-resourced families. On the demand-side, studies show that when clean cookstoves are offered at competitive prices, adoption increases and is followed by a corresponding decrease in fuelwood collection as well, in line with the results presented in earlier sections of this document (Ekholm, Krey, Pachauri & Riahi, 2010; Ouedrago, 2006). However, errors in targeting hinder the success of these initiatives (Simon et al., 2014) and studies have shown that the beneficiaries of such a strategy are usually middle-and-high income households (Granado, Coady & Gillingham, 2012). Moreover, empirical evidence has shown that providing clean cookstoves at highly subsidized prices, even to the point where they are given away at no cost, does not guarantee increased adoption (Adrianzen, 2013; Lewis & Pattanayak, 2011). Large subsidies for improved stoves can also lead to the perception that they are not products of great value or unworthy of investment in maintenance (Rehfuess, 2014). **Blanket subsidies often do not adequately understand consumers' needs and preferences, which are better directly addressed by cookstoves companies themselves. As a result, policies that use**

indirect subsidies to support R&D, manufacturing, and marketing tend to be more successful in creating sustained adoption (Akbar et al. 2011; Cordes 2011).

Tax incentives and rebates, such as waiving (or reducing) the duties on the import of clean technologies or exempting VAT on sales, have also been implemented in different countries with varying results. For example, Kenya eliminated the tax on cooking gas (LPG) and reduced the import duty on energy-efficient cookstoves in 2016.[10] However, the end-user cost of LPG was still higher than competing fuels in 2018, which impeded adoption. This was mainly due to fluctuations in the international import price, high supply cost, and the high margins retained by dealers, distributors, and retailers.[11]

Financing options

Key takeaways:

- Experts argue that current investments in financing clean cookstoves on both the supply and demand side are insufficient.
- Strong evidence of the success of grants and equity financing in the sector is not available, however, it appears to be the only viable approach at the moment as access to formal finance for SME in low and middle-income countries is limited and financial institutions in these context are reluctant to provide credit to clean cookstoves businesses because cookstoves are not income-generating assets, nor require recurring purchases from the customer's side.
- Carbon credits are an increasingly popular approach in supplier finance but it is considered risky due to market prices fluctuations.
- At present, the sector highly depends on DFI financing. However, the sustainability of this approach is questionable as it is linked to the priorities of national and multilateral donors as well as philanthropic organizations, which are susceptible to changes.
- On the demand side, end-user financing has not demonstrated to significantly increase adoption of cookstoves nor to increase the profitability of microfinance institutions.
- Asset financing appears to be a more promising approach, to consumer finance for the adoption of cookstoves, but evidence on its effectiveness is still limited.

The discussion on financing options for the clean cookstoves sector requires looking into both the supply-side (enterprise finance) and the demand-side (consumer finance). To understand the financing needs and gaps in the sector, this section will first look at what enterprises need financing for, and what are some of the barriers to access to cost-effective and timely finance. Subsequently, the analysis will focus on common financing sources for enterprises and consumers, their advantages and shortcomings, and financing gaps that continue to inhibit the growth of the sector.

The table below summarises the purpose and barriers to finance for different supply-side players as well as consumers as mapped through the Energy Sector Management Assistance Program, ESMAP (Putti et al., 2015).

[10] https://www.cleancookingalliance.org/about/news/06-22-2016-kenya-drops-trade-tax-barriers-to-aid-adoption-of-cleaner-cooking-technologies.html

[11] http://documents1.worldbank.org/curated/en/955741536097520493/pdf/129734-BRI-PUBLIC-VC-LW89-OKR.pdf

TABLE 3: BARRIERS TO FINANCE FOR SUPPLY-SIDE PLAYERS AND CONSUMERS

Actor	Financing needs	Barriers to access
Clean cookstove manufacturers & fuel suppliers	• Asset production. • R&D. • Working Capital.	• High initial capital investment required. • Weak SME financing ecosystems.
Distributors	• Import of cookstoves. • Set up and expansion of distribution networks.	• Lack of collateral. • High interest rates on formal borrowing. • Weak SME financing ecosystem.
Retailers	• Limited stock. • Maintaining a capital position that allows them to operate on credit with end-users.	• Retail microfinance constitutes a big *missing middle,* which refers to the dearth of sources of finance that retailers have access to. • Weak SME financing ecosystem.
End-users/ consumers	• Purchase of Cookstoves.	• Financial products designed in a way that does not facilitate adoption. • Low levels of awareness about ways to access finance for clean energy needs.

These barriers to finance have severely constrained the growth of the clean cookstoves sector. **Estimates from the Clean Cooking Alliance indicate that financing acquired via grants, equity and debt by companies that they track totalled $40 million as of 2017, far below the $4 billion required annually to reach the goal of universal access by 2030.**[12] This brings us to an important question – *what are some of the sources of financing being used by suppliers and consumers?*

Supplier finance

Grants and **equity** have been the prevalent sources of investment capital for the clean cookstoves sector, representative of a market-based approach that has been relied on to boost investment in the sector (Accenture, 2018). The Global Alliance for Clean Cookstoves (GACC) houses several funds ranging from credit-based capital to grant capital and capacity building support to facilitate the growth of enterprises in the sector. As the sector grows in scale and number, clean cookstove enterprises are gaining access to more formal financing. As a result, **debt financing,** which has hitherto received very little traction, is increasingly being used to meet the financing gap.[13]

It is also important to consider what are the risks to lending perceived by financial institutions and investors. From our interviews with clean cooking enterprises, we learned that the perceived risks vary with the stage of the enterprise, and are also influenced by general perceptions of the sector itself. **First, we find that financial institutions are reluctant to lend to early-stage enterprises since the latter have low profit margins, and because of the considerable challenges for cookstove companies creating demand and achieving market penetration. Second, financial institutions tend to associate the capital requirements of more established enterprises with a different set of risks: expansion, be it geographically or in terms of offerings, requires considerable capital. Furthermore, the variance in business models adopted in the sector, with a large number of clean cooking businesses relying on sources like DFIs and subsidies, contribute to a general lack of confidence in the clean cooking sector, which in turn influences the financial institutions' willingness to invest.**

[13] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/549-1.pdf

As discussed previously, **subsidies** constitute one of the most widely relied upon sources of finance for clean cookstoves businesses in developing countries (Gaul, 2009). Subsidy-based business models use them to reduce the cost of their offerings to end-users. Subsidies are a popular financing mechanism in countries in Africa and Latin America with emerging cookstoves markets, such as Ghana, Ethiopia, and Peru. While data on the effectiveness of subsidies for the adoption of cookstoves is mixed, there is evidence about the market distortions and GDP losses that they cause (Pokorski da Cunha et al., 2009).

Carbon financing refers to funding acquired through the sale of carbon credits, originally developed as a financing mechanism to address climate change. In recent years, carbon financing has gained considerable popularity, and is often cited as an effective way to spur greater penetration in the clean cookstoves market (Simon et al., 2012), help increase household adoption (Jeuland & Pattanayak, 2012), and facilitate the growth of the sector (Lambe, Jürisoo, Lee & Johnson, 2015). This enduring popularity can be attributed, at least in part, to the ability of carbon financing to lend financial sustainability to enterprises, since the costs of cookstoves thus produced are not borne entirely by end-users. On the flipside, the primary criticism levied against carbon financing is that it can have pejorative effects on the economy as a whole because it might lead to a crowding-out of the competition in the sector (Simon et al., 2012). The business model of clean cookstoves enterprises that are heavily reliant on carbon financing is often considered too risky due to their susceptibility to market price fluctuations of carbon credit (Shrimali, Slaski, Thurber & Zerriffi, 2011).

Formal credit from financial institutions such as commercial banks and microfinance institutions constitute a crucial alternate source of finance. Formal loans, offered as *enterprise financing,* allow clean cookstove enterprises to sustain their operations, particularly during the initial years, through the provision of credit facilities to manufacturers and distributors.[14] However, financing gaps continue to inhibit the growth of the sector. Micro-credit from MFIs and banks has the potential to be transformative, particularly for start-up enterprises. However, institutions' engagement with customers in these sectors continues to be inadequate because improved cookstoves and clean cookstoves are not income-generating assets (Bailis et al., 2009). Another prominent source of financing comes from development financial institutions (DFIs). While some DFI investments in the sector are in the form of grants, as described above, several multilateral funds like the World Bank (ESMAP),[15] the Multilateral Investment Fund,[16] as well as aid agencies like DFID, USAID, SIDA, and BMZ are known to provide financing to the clean cooking sector through loans and credit facilities.[17] DFIs play a crucial role, particularly in the nascent stages of the sector, as a provider of much-needed grants, often for large projects. DFIs' role in providing credit financing is still limited, but reliance on DFI financing can be precarious, in the event that the funding ends without any alternative lines of financing available.

The role of supply-side financing is to facilitate the growth of clean cookstoves enterprises and the sector as a whole. Consumer finance, on the other hand, is aimed at increasing access to improved cookstoves for end-users by making adoption more affordable. Below are some of the most common consumer finance options currently in use.

Consumer finance

End-user financing refers to the direct provision of credit by financial institutions to end-users for the purchase of Clean Cookstoves. While there is some evidence (Bensch et al. ,2015) that end-

[14] http://ugspace.ug.edu.gh/bitstream/handle/123456789/30616/Sustainable%20Financing%20and%20Business%20Models%20%20in%20the%20Cookstoves%20Sector%20in%20Ghana.pdf?sequence=1

[15] https://www.worldbank.org/en/news/feature/2019/11/04/why-clean-cooking-matters

[16] https://www.cleancookingalliance.org/partners/item/15/193

[17] https://ees.kuleuven.be/klimos/papers/wp14_lietaerand_zaccai_making-clean-cooking-champions.pdf

user financing has been effective in increasing adoption in low-income households, this strategy has generally received criticism for failing to increase adoption (Ablorh, 2019). From the point of view of the financial institution, Allet and Hudon (2015) show that Micro-Finance Institutions that offer microcredit for the purchase of a green product (including cookstoves) are no more (or less) profitable than those that do not. However, they note that more established and "mature" institutions are more capable of providing such offerings. Logically, if it does not lead to additional profits, offering credit to purchase green products is not an appealing strategy for most MFIs, especially considering that it would still require upfront training and development investments.

Another source of consumer finance for the purchase of clean cookstoves is **asset finance,** which is provided by energy companies themselves to their prospective clients. This "one-stop-shop" strategy is implemented either through a *hire purchase* approach, in which customers pay to own their cookstoves at the end of the loan period, or a micro-leasing approach, which functions akin to a fee for a rental service.[18] Currently, published evidence of the effectiveness of these approaches is lacking, and represents a scope for further research and inquiry.

Savings and loans constitute an important means of accessing credit for the unbanked. Operated either as Village Savings and Loans Associations (VSLA), Self-Help Groups (SHGs), or Joint Liability Groups (JLGs), they can facilitate the purchase and the adoption of clean cookstoves either by dipping in the group's savings or through the intervention of a microfinance institution. Technically, other financial institutions (including banks and fintech companies) can also offer a savings product with the end objective of purchasing a clean cookstove. However, evidence directly linked to this kind of financial product is limited.

Despite renewed efforts towards meeting the growth targets of the clean cookstoves sector, a considerable financing gap continues to exist and inhibit progress. In their 2018 report *Financing Growth in the Clean Cookstoves and Fuels Market: An Analysis and Recommendations,* Accenture and the Global Alliance for Clean Cookstoves identify the blind spots in the financing landscape and provide recommendations for future financing. On the supply side, limited potential for recurrent revenue flows is a major disincentive for existing manufacturers and new players alike to substantially invest in the sector. Additionally, the sizeable upfront costs to stimulate demand limits investment into the sector. On the consumers' side, access to credit, low awareness about the benefits of adoption, and prohibitive initial cost limit demand. The report mentioned above calls for location-specific enterprise-focused financing that is aligned with the sector's maturity and financial needs, as well as better strategic engagement with multilateral donors.

Clean-cooking business model

Production

There are three key production methods employed in the clean cookstove industry. These are industrial, semi-industrial, and artisanal. Each production method comprises a series of sub-processes, including raw material purchase, labour, manufacturing, import (if applicable), followed by distribution and retailing. The relative importance of a sub-process in a production cycle depends on the production method employed.

Key takeaways:

- There is no evidence demonstrating that one production model is inherently better to another. However, technical complexity as well as capital (tangible and intangible) requirements vary substantially from one model to another.
- Adopting production models based in local communities in low and middle income countries requires, on average, low capital and technical requirements and contributes to enhance local economic wellbeing.

[18] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/421-1.pdf

a. The **Industrial Model** is characterized by in-house research and development, a high degree of mechanization, large-scale automated component manufacturing. This model often involves cross-regional manufacturing and final assembly, post which it is imported into the countries for final sale (for example, companies such as Philips, BioLite). However, there exist variants of this model wherein "local" industrial production centres for manufacturing and assembly are established within the final country (for example, companies such as Envirofit). **This model is extremely cost-intensive, requiring large-scale initial investment as well as substantial operating capital.**

b. The **Semi-Industrial Model** is less-mechanized compared to the industrial model, and involves workshop-based production, hand assembly using standardized designs, tools, and processes.

c. In the **Artisanal model,** cookstoves are produced locally by small enterprises and artisans. The scale of production is very limited. However, since the producers are part of the communities they service, distribution and after-sale support are easier to carry out. This model is traditionally common in Sub-Saharan Africa, South Asia and South-East Asia.

Distribution channels

Inclusive, effective and sustainable distribution channels form an essential part of the clean cookstove value chain and can have a significant impact on their uptake and usage (Mitchell, 2010). The key objective of selecting a distribution model or combination of models is to maximize the market reach (i.e., customers) while minimizing costs. SNV, Practical Action Consulting, and the Cookstove Alliance (2013) identify three overarching last-mile distribution models that have the potential to significantly improve access to clean cookstoves among the low-income populations in a feasible manner.

Key takeaways:

- A distribution model's effectiveness in creating lasting demand depends on several factors: (1) ensuring a steady supply of clean cookstoves and fuels in local markets; (2) user-friendly product offerings; (3) ensuring access to reliable after-sale services; (4) forging partnerships with local communities, and; (5) improving their products and services by addressing end-user constraints (willingness-to-pay, customer knowledge).
- In practice, successful distribution models are often hybrid. For instance, KokoNetworks in Kenya has found tremendous success developing a model that combines reliance on local grocery stores and their tech-driven proprietary sales network approach.
- While each model, depending on context, has its own advantages and disadvantages, there is no empirical evidence on their effectiveness, scalability, and impact on profitability of enterprises. This highlights a key knowledge gap for future work.

a. The **Village Level Entrepreneur (VLE) Model** employs local resources known as VLE (such as entrepreneurs and artisans) to distribute clean cookstoves and fuels within their communities. **A notable advantage of the VLE model is the low investment costs, and low costs of last-mile distribution in rural areas and communities.**

Furthermore, the VLE model allows enterprises to develop accurate insights into their customers by virtue of their partners' direct knowledge of their communities. In turn, it becomes easier to increase willingness to adopt because the VLEs are known in their communities. **This model is most suitable when there is an existing demand for the cookstoves, as this model has limited scope for control and oversight as well as fewer opportunities for branding or product diversification.** To succeed, this model also requires financial support, including start-up capital and commission to be put in place for the VLEs to build their capital and limit their financial risk. As a result, continuous capacity building of VLEs through marketing, business development training, providing mentors, setting up tiered systems for support and oversight are important factors

affecting the sustainability of this model in a market. This model has been employed by Living Goods in Uganda, where local women are hired as entrepreneurs, the HealthKeepers Network in Ghana, which employs micro-franchisee agents, and Soluciones Comunitarias in Guatemala. VLE models have been similarly adopted in other countries such as Tanzania and Rwanda (ESMAP, 2015), as well as in other sectors[19] (the Common Services Scheme in India uses the VLE model for the provision of public utility and financial services to citizens), studies on their profitability and scalability represent a gap in the literature.

b. The **Piggyback Model** is particularly useful for markets where there is low existing demand for clean cookstoves. In the piggyback model, cookstove companies partner with local organizations (such as supermarkets, MFIs, social organizations, third party dealers) that already have well-established operations in the targeted areas. **Using the established networks of such organizations, cookstove companies can significantly lower their investment costs in last-mile delivery infrastructure as well as reduce the time needed to establish new markets.** On the flipside, the network actors require active engagement by the enterprises, especially since they work with limited oversight. The scope of this model in reaching new customers is also limited to the capacity and market size of the partner institutions. For this model to be effective, it is important to align incentives with partner institutions, ensure partners supervision, and conduct regular training. Examples of companies employing this model include SunnyMoney, a social enterprise that partners with local educational institutions to sell clean cookstoves and other clean energy items across Eastern and Southern Africa. International Lifeline Fund sells cookstoves to vulnerable populations in Uganda through supermarkets and NGOs.

c. A **Proprietary sale network** is a direct-sales model involving the setting up of completely new distribution channels, including transportation, hiring and training of sales personnel as well as building/renting physical infrastructure such as warehouses and stores to access and serve a target customer segment or market. **This model allows for complete control and oversight of the distribution and the option to offer in-house customer finance (such as rent-to-own, different instalment plans) and after-sale services.** However, it is the most expensive model to both establish and run, besides requiring high initial capital investments and a significant amount of time to set up and start yielding profits. The suitability of this model for remote areas, where clean cookstoves could have a significant impact, is doubtful. Despite the high financial risk, it is an effective distribution model to push new products, and offer after-sales services and consumer finance options to boost adoption. It is best suited for urban and semi-urban areas and is often combined with the VLE or Piggyback models to reach rural areas at a lower costs. For example, Ugastove sells clean cookstoves through its own delivery systems in Uganda but also partners with retailers such as supermarkets and hardware stores to reach customers in certain geographies.

Marketing strategies

Clean and improved cookstoves enterprises employ a variety of marketing strategies, depending on the distribution model adopted, to increase awareness about their products, create demand, boost adoption, and sustain demand in order to operate at scale (SNV, 2015). We review some widely used marketing strategies below, and also assess the best fit between these strategies and the distribution models discussed above.

a. Seeking endorsement from influencers: An effective approach to making clean cookstoves more attractive is to identify *influencers* in target markets and acquire their endorsement. In rural and peri-urban areas, this role is often played by village elders or village chiefs, while in urban markets, community leaders, and local celebrities enjoy a large following.

[19] https://csc.gov.in/vle

b. **Creating visibility and manufacturing initial demand:** Often, an effective way to create demand is to give away free product trials and/or samples to influencers, followed by a slew of promotional strategies aimed at creating visibility. This includes public product demonstrations in places with large consumer footfalls, tutorials on how to use clean cookstoves and their benefits and involving early customers in marketing efforts through the provision of incentives like free add-on services. However, as noted in the Financing Options section, relying on subsidized rates alone has not been proven to be an effective strategy to improve adoption.

Key takeaways:

- The literature suggest that the efficacy and cost-efficiency of different marketing strategies depend on the distribution model on which they build.
  - » Generally, Below-The-Line marketing and seeking influencer endorsements tend to be effective and low-cost are better suited to VLE and Piggyback distribution models.
  - » Above-The-Line strategies, after-sales support services, and investing in creating visibility and manufacturing initial demand are more expensive and become cost-effective only in large markets. They are better suited to proprietary sale network distribution models.

c. **After-sales support:** After-sales support can be used as an extremely effective strategy by Clean Cookstoves enterprises for customer retention to build and consolidate their brand, and even to further boost demand. Extending product guarantees and quality assurances can help increase word-of-mouth publicity by consumers in their networks. Providing access to user assistance, through a user kiosk, for example, in the communities where products are distributed, can be an effective way to pique the interest of new customers. Similarly, easy access to after-sales product servicing can help with customer retention and can be combined with branding exercises and to promote new products.

d. **Above-the-line (ATL) marketing:** ATL marketing is a branding activity that uses indirect marketing exercises, such as advertisements on radio and television, to expose a wide audience to a product (SNV, 2015). Such an approach is typically effective in market segments in urban areas, where the concentration of customers that consume content through such media is higher. ATL marketing, while expensive, can be valuable as a tool to increase general awareness about a product, potentially translating into wider acceptability. While it is difficult to draw a line connecting ATL marketing to a specific distribution model,

e. **Below-the-line (BTL) marketing.** BTL marketing, on the other hand, employs direct communication with target segments to increase awareness about a product (SNV, 2015). BTL techniques, such as word-of-mouth publicity, leverages peer connections and extended consumer networks to increase demand. Using below-the-line marketing can be particularly effective for clean cookstove companies as it allows them to customize their marketing and branding activities to the unique local contexts of their target segments, as well as package their offerings with incentives and after-sales services to make them more attractive.

After-sale support systems

After-sales services constitute an important function for clean cookstoves enterprises, due to the different aspects they assist with. They are useful as a marketing strategy and brand identity, helping companies retain existing customers and attract new ones. After-sales support systems are a means to engage the customer base, and even push new products. The absence of a well-functioning after-sales support system, particularly when aggregated at the sector-level, acts as a barrier to the use and further adoption of improved and clean cookstoves.

Despite their importance, the literature on their role in the clean cooking industry is sparse. Furthermore, we learn from our interviews that while enterprises acknowledge the importance of after-sales services in customer retention, they are seldom put in place or prioritized, particularly by early and mid-stage enterprises. One of the main reasons for the absence of these systems is cost. **With the general lack of access to suitable and timely financing, clean cooking companies tend to pick trade-offs such as expenditure on advertising and marketing, or on expanding distribution over after-sales support.** In other words, the opportunity cost of setting up and maintaining an efficient after-sales support system is considered lower relative to competing expenses like marketing. **The persistence of these choices is likely linked to there being limited empirical evidence on the benefits of such systems.** However, we also learned from our interviews with CC enterprises that a streamlined after-sales support system can be a distinguishing factor between successful and failed enterprises in the long run.

Household demand

Programs that seek to introduce cookstove interventions often emphasize the programmatic health and environmental benefits of clean cooking. However, these may not be sufficient to change deeply entrenched cooking practices. A pilot study conducted by ESMAP in 2017 across 12 countries found that low uptake of clean cookstoves was often due to a divergence between programmatic concerns (reduction of Indoor Air Pollution) and consumer preferences (RISE, 2017). In fact, the primary drivers of household choices regarding the adoption of cooking technologies depend on cost, habit, and availability of products and fuels. This section details some of the constraints and factors that influence household decision making.

Behavioural drivers and economic factors

Key takeaways:

- Household behaviours are difficult to change as the usage of traditional cookstoves has been observed to continue alongside clean cookstoves.
- Even though affordability is an important determinant for the adoption of cookstove, understanding what motivates households' choices (e.g., preferences regarding health or costs) can help shape strategies to both promote the purchase of clean cookstoves, but also support their continued usage and transition away from traditional ones.

The initial take-up of cookstoves does not necessarily lead to their continued use. Understanding the behavioural determinants that motivate households to purchase and utilize clean cookstoves is required to devise strategies to overcome this gap. Employing, for example, a human-centric design approach could yield valuable insights and recommendations in developing both a cookstove that fits the needs and preferences of its intended users as well as processes to support their adoption. At the household level, the drivers that influence individual behaviour in the uptake of the cookstoves include:

- Availability of financial incentives;
- Perceived influence of adoption of cookstove on social status;
- Level of financial autonomy of the women within the household;
- Degree of user influence on the design of the cookstoves.

Heterogeneity in preference and attitudes towards cookstoves plays a significant role in determining the purchasing of cookstoves. Jeuland et al. (2020) classified households based on their interest in clean cookstoves, before any intervention was undertaken:

- Class 1: showed low interest in clean cookstoves.
- Class 2: reported high interest in clean cookstoves.
- Class 3: displayed no interest in purchasing or using clean cookstoves.

Unsurprisingly, Class 3 was the least responsive to incentives and sales visits. Class 1 and 2, on the other hand, consisted of households that placed significant importance on the reduction of smoke emissions and were more likely to adopt electric ICs when given a choice between biomass and electric ICs. This study, thus, demonstrated the need for considering the preferences and priorities of individual households before prescribing technical fixes that may or may not align with household demands.

In general, the value that households place on clean cookstoves can be measured by their continued use and maintenance (Hanna, Duflo, and Greenstone, 2016). A study carried out in Delhi, India, tracked the usage patterns of clean cookstoves against traditional cookstoves using a data-logging thermometer. It was found that, over time, the usage of clean cookstoves dropped from 111 minutes daily in the first month to an average of 75 minutes daily by the end of three months. By the 200th day of monitoring, the average use of clean cookstoves plummeted to 50 minutes daily while the use of traditional cookstoves remained at 150 minutes (Pillarisetti et al., 2014). This[20] indicates that even when clean cookstoves are brought into a household, the employment of traditional cookstoves remains unchanged,[21] and the usage of clean alternatives peters out over time. Asides from designing better cookstoves tailored to the needs and preferences of target households, behavioural change techniques and strategies might be employed to sustain the continued use of clean cookstoves.

Jürisoo, Lambe, and Osborne (2018) use a CCI[22] behaviour change framework to analyse the user journeys of women who have adopted cookstoves in Kenya and Zambia. The framework uses opportunities (*Can individuals acquire and use advanced cookstoves?*), abilities (*Does the user know how to use the cookstove?*) and motivations (*Does the Individual want to use the cookstove?*) to understand the different behaviour change techniques that can be applied at different stages of the user journey and for different categories of users. For instance, women, for whom convenience is the largest motivational factor for the adoption of the cookstove, expect an immediate improvement after acquiring the cookstove and require continuous support to ensure continued use of cookstove. However, women who are motivated by expected financial savings, require technical information on how to use the stove correctly and how not to waste fuel.

When evaluating demand for different cooking systems, it is important to take factors like household time use, credit constraints and cooking preferences into consideration. While direct costs in terms of price are easier to estimate, market prices of fuel-cookstove systems can vary across regions.

Efficient fuel sources like LPG and biogas may have underdeveloped markets due to factors like high transportation costs (LPG) and low trading value (biogas). Polluting fuels like firewood and dung, on the other hand, are preferred as they do not require direct cash expenditures and can be sourced from farmland and livestock to which the household already tends.

Affordability is also a key barrier to the adoption of clean cookstoves (Jürisoo, Lambe, and Osborne, 2018; Hanna, Duflo, and Greenstone, 2016). High upfront investment costs might discourage

[20] In interpreting their results, the authors believe that one of the limitations of their study was that the stoves were given to the participants free of charge and this may have an impact on perception of value. However, this hypothesis was not explored further.

[21] The continued usage of traditional cookstoves alongside clean ones could also explain why in a few studies cited earlier researchers were unable to detect a significant improvement in health outcomes following the adoption of clean cookstoves

[22] Cleaner Cooking Intervention framework expounded by Goodwin et al.

households from switching to clean cookstoves, even if, in the long run, they might be cheaper. Further, maintenance and fuel costs may hinder sustained affordability. Bensch et al. (2015) find that subsidies that help mitigate these costs increase adoption rates.

Case study: Adoption of clean cookstoves among ESAF customers (2018) - an analysis of socio-economic and demographic characteristics

This case study demonstrates the importance of conducting research on socio-economic conditions and preferences of potential clean cookstoves adopters. Results show how such **studies can inform the development of business plans as well as revealing local trends that might diverge from typical patterns observed in the literature.** Specifically, this survey was conducted in 2018 in the Mysore district in the state of Karnataka, India, by Evidence for Policy Design (EPoD) India, with the support of FMO and LEAD at Krea University, with 2,341 clients of ESAF Small Finance Bank, an Indian financial institution. It was the intention of ESAF to offer this population a targeted loan to purchase green products[23] (including clean cookstoves). An immediate and clear result from the survey is that **the vast majority of the respondents already owned and operated an LPG stove,** subsidized by the state, which significantly reduces the market potential of clean non-LPG cookstoves from the beginning. The survey also collected in-depth socio-demographic data, health information as well as data on the adoption and preferences for lighting/illumination sources (such as grid-power, solar lighting system, kerosene lamps), adoption and patterns of usage of cooking systems (LPG, traditional cookstoves, other improved cookstoves) and cooking fuels. An analysis of this information reveals both expected and unexpected trends. Richer and more educated households are more likely to adopt clean cooking solutions, which is in line with the literature. On the other hand, the survey reveals that, in this specific context, large and male-led households tend to own and use clean cookstoves. These results diverge with normal trends observed in the sector, where larger households are typically more likely to use traditional cookstoves since they are, simply, bigger than the average clean cookstove. At the same time, since males are less likely to take up cooking tasks, the literature suggests that women-led households are more likely to transition to clean cookstoves that emit, for example, less smoke in the kitchen. These findings confirm that **behavioural and household demand characteristics are highly contextual, which means that localized research is necessary to maximize the likelihood of success of investments in clean cookstoves.** The following subsections will present detailed results from the case study.

Respondent demographics

The sample is mostly composed of low-education and low-income female respondents, most of whom were married at 16 (earlier than the state median[24]). 60 percent of the respondents are employed, with a significant number (38 percent) identifying themselves as being self-employed or owning a business or being employed in a household business. The mean annual income of the respondents is around INR 50,000, which is equivalent to

Key takeaways:

- Most respondents use an LPG cookstove to meet their cooking needs, probably due to the introduction of the 2016 Ujjwala scheme, which promoted and subsidized the adoption of this kind of cookstoves.
- The case study throws light on the importance of conducting market research before entering the market. As a majority of the respondents have adopted and use LPG cookstoves (largely spurred on by government subsidy and easy access), it would be difficult for other clean/efficient cookstove companies penetrate this market.

[23] The green product offerings included solar lamps, energy efficient firewood stoves, and water purifiers.

[24] National Family Health Survey – 4 (2015/2016)

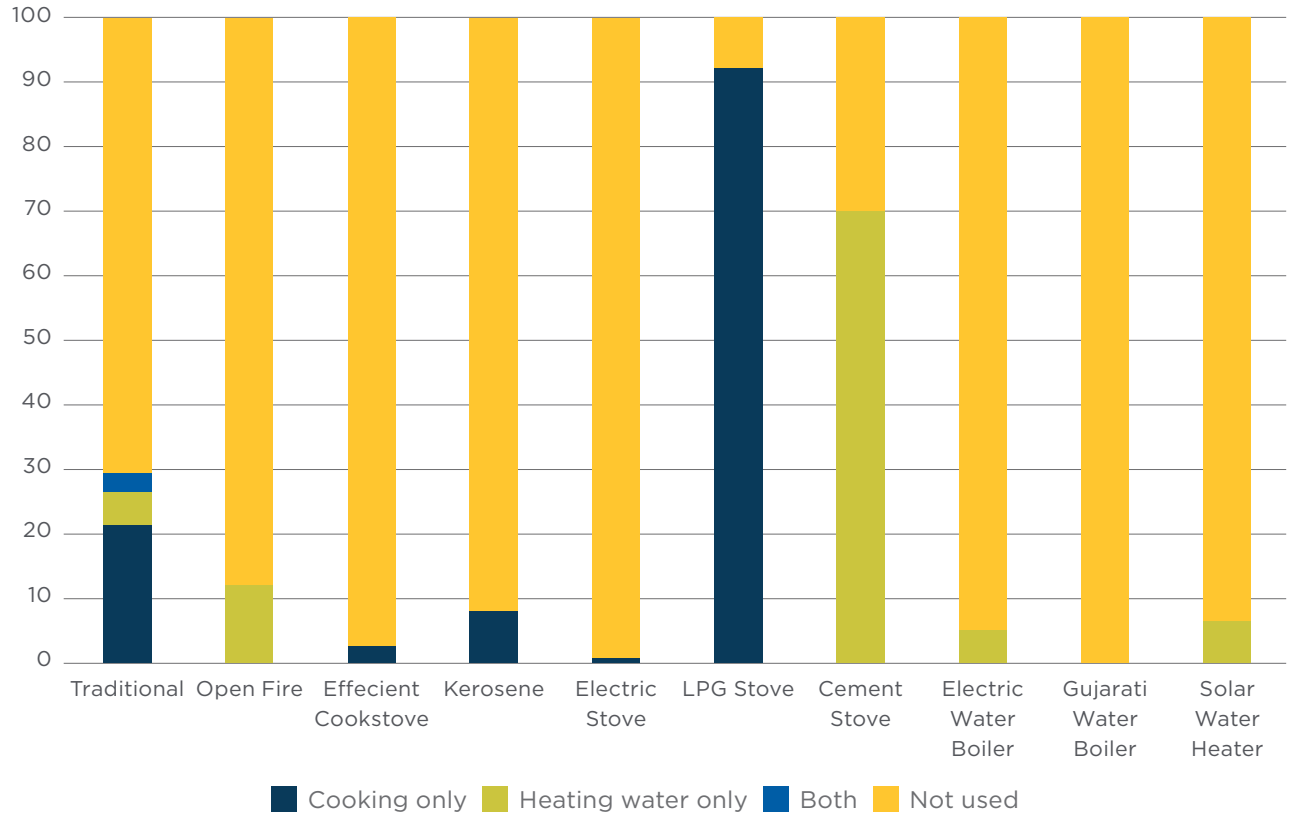
approximately USD 682. The average monthly household income is approximately INR 15,000, which is equivalent to USD 204, showing that most households in the sample can be characterised as being low-income, although above, on average, the poverty line.[25] Average household size is consistent with national values (4 members), with only a small fraction of people contributing to overall household income (1.6 on average).

TABLE 4: RESPONDENT DEMOGRAPHICS

	Frequency	Mean	S.D
Age	2341	38.58	9.43
Marital Status			
Married, living with spouse	1946	0.83	0.37
Married, not living with spouse	29	0.01	0.11
Seperated/divorced	22	0.01	0.10
Spouse/partner died	302	0.13	0.34
Never married	42	0.02	0.13
Marriage Age	2220	16.65	3.63
Level of Education			
Never attended/Did not complete Class 1	955	0.41	0.49
Class 1	27	0.01	0.11
Class 2	47	0.02	0.14
Class 3	65	0.03	0.16
Class 4	80	0.03	0.18
Class 5	128	0.05	0.23
Class 6	71	0.03	0.17
Class 7	203	0.09	0.28
Class 8	112	0.05	0.21
Class 9	169	0.07	0.26
Class 10	279	0.12	0.32
Class 11	39	0.02	0.13
Class 12	108	0.05	0.21
Graduate and above	58	0.02	0.16
Employment Status			
Not Employed	942	0.40	0.49
Employed	1399	0.60	0.49
Type of Employment			
Ownbusiness/Household business/ Self Employed	541	0.23	0.42
Work for a wage	327	0.14	0.36
Casual labor	531	0.23	0.42
Not Employed	942	0.40	0.49
Respondent Income	1386	4992.78	4895.56

[25] Households earning less than INR 120,000 per annum (INR 10,000 per month) are classified as living below the poverty line. The average household income for the sample is slightly above this cut-off. (https://www.deccanherald.com/city/life-on-the-poverty-line-at-rs-15000-a-month-337135.html)

FIGURE 5: STOVE USE – BY STOVE TYPE AND PURPOSE



Interestingly, most of the sampled households (92 percent) use LPG stoves for cooking, while only 21% use traditional cookstoves. Cement stoves, on the other hand, are used by 70 percent of the sample for the sole purpose of heating water, with the second most popular stove for this purpose being an open fire. Although 98 percent of the households in the sample have access to grid electricity, only 5 percent of the respondents use an electric water boiler to heat water.

It can be assumed that the almost complete coverage of the sample by LPG stoves can be explained by the introduction of India's *Ujjwala* scheme, launched in 2016 to supply LPG connections to women from families living below the poverty lines. As one would expect, the introduction of this distribution campaign and subsidy creates a difficult market for non-LPG cookstoves to penetrate.

Data analysis

Using chi-square tests, it is possible to explore whether there are significant differences in usage of different types of cookstoves (Clean vs Non-clean[26]) across a range of socio-economic and demographic groups. While these tests were performed for a range of variables, the sub-sections below present statistically significant results.

Key takeaways:

- Respondents that are younger, more educated, richer, and employed in stable occupations are more likely to adopt clean cookstoves.
- Larger households, headed by males, and that spend proportionally more on education, electricity, and health are more likely to adopt clean cookstoves.

[26] Households that adopt clean cookstoves make use of LPG and Electric stoves. Households that use non-clean cookstoves make use of traditional, open fire, etc.

TABLE 5: INDIVIDUAL SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

Individual Socio-Economic and Demographic Characteristics	
Age	Users of clean cookstoves are, on average, younger than those who use polluting cookstoves (mean age of the first group is one year lower than that of the latter)
Education	Users of clean cookstoves are more educated. The percentage of respondents who have no education that uses non-clean cookstoves is higher than that of those with higher levels of education
Occupation	Respondents working in salaried occupations or as an entrepreneur (or in the family business) are more likely to use clean cookstoves than those working in casual labour. Results for this analysis are presented in Table 2 below
Income	Higher income is linked to using clean cookstoves: the mean income of the respondents who use clean cookstoves is INR 1,300 higher than those respondents who use non-clean cookstoves.

TABLE 6: CHI-SQUARE TEST BETWEEN TYPE OF WORK AND USAGE OF CLEAN STOVE

	Does not use clean stove	Uses clean stove	Total
Own business/ Household business/ Self employed	32.35	39.17	38.67
Work for a wage	8.82	24.52	23.37
Casual labour	58.82	36.31	37.96
Total	100.00	100.00	100.00
Pearson's chi-square value	23.72***		
p-value	0.000		
No. of observations	1399		
*p<0.1 **p<0.05 ***p<0.01			

TABLE 7: HOUSEHOLD CHARACTERISTICS

Head of the Household	It is observed that households headed by males are more likely to use clean cookstoves than those headed by women, as shown in Table 8.
Household Size	The mean size of households using clean cookstoves is slightly higher than those using non-clean cookstoves.
Preferences on the Allocation of Expenditures	Households using clean cookstoves are more likely to spend more on electricity (71 percent more) as well as education and health (55 percent more) than those using other types of cookstoves. Following the latter finding, it would be coherent with the existing literature to hypothesize that households that care more about health are more likely to adopt clean cookstoves.

TABLE 8: CHI-SQUARE TEST BETWEEN GENDER OF HH HEAD AND USAGE OF CLEAN STOVE

	Does not use clean stove	Uses clean stove	Total
Female	52.67	39.37	40.11
Male	47.33	60.63	59.89
Total	100.00	100.00	100.00
Pearson's chi-square value	9.11***		
p-value	0.003		
No. of observations	2341		
*p<0.1 **p<0.05 ***p<0.01			

The results from the analysis also highlight the importance of carrying out micro-market research studies to gain a more nuanced understanding of the demands of the local community. As seen from the results, the mean size of the households using clean cookstoves is slightly higher than those using non-clean cookstoves. However, literature (for example, Bielecki et al., 2014) suggests that clean cookstoves are often perceived as being too small to accommodate the cooking needs of large households (an intuition also confirmed in qualitative interviews). Arguably this difference could be due to the type and design of clean cookstoves offered in a particular geography, thus confirming the importance of tailoring cookstoves offerings to the needs of the target market. Similarly, gender trends observed in this case study diverge from patterns traditionally observed in the literature. Normally women are expected to lead the adoption of clean cookstoves since they spend more time in the kitchen and are set to gain the most from transitioning to clean cooking methods emitting, for example, less smoke and or taking less of their time. However, in this sample, we observe that male-headed households are more likely to have transitioned to clean cookstoves than female-headed households. This demonstrates that local characteristics and behaviours might differ from those typically observed in the literature and that, thus, contextual research is useful to maximize the impact and likelihood of success of investments in clean cookstoves.

Ashwini Chaudhary-Unsplash

5. COUNTRY BRIEFS

This section provides an overview of the cookstove sector in six low- and middle-income countries: India, Vietnam, Burkina Faso, Ghana, Ethiopia, and Kenya. The countries were selected to be geographically diverse and cover South Asia, South-East Asia, West Africa, and East Africa. Similarly, both low- and middle-income countries have been selected in the analysis.

Overall, the country briefs show that government policies (subsidies, incentives, etc.) have the potential to rapidly promote the adoption of clean cooking methods, especially when the commitment is sustained over time, backed by significant budgetary pledges, and implemented by higher capacity governments, as in the case of India and Kenya. However, in other countries, the success of government efforts has been mixed. Factors such as infrastructure development, access to markets, and the availability of cookstove models tailored to local cooking styles play a major role in determining the success or failure of government policies. In the absence of significant government commitments, social enterprises and local cookstove businesses have emerged, often supported by international investments, to address the needs of the cleaning cooking industry.

India

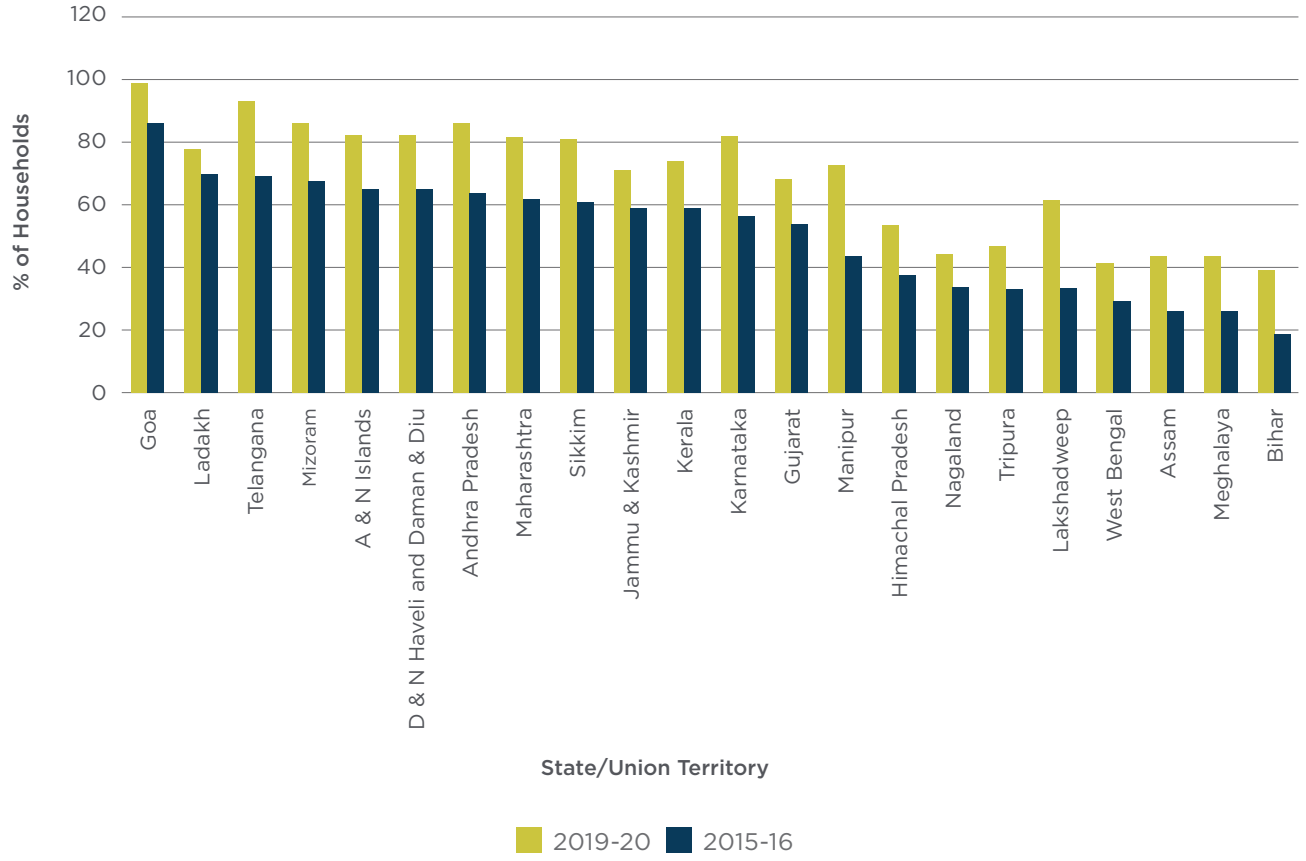
Adoption trends

Traditional cooking practices are still common in India, but a sharp disparity is observed in energy source usage between rural and urban areas. In rural areas, firewood remains the principal fuel source for cooking (85 percent), while LPG has become the most used fuel in urban India (86 percent). **However, the Cooking Energy Access Survey (2020) shows that only half of the households that own LPG use it exclusively, hinting at the continued reliance on stacking cleaner fuels like LPG with dirty fuels and firewood. This is supported by census measures, which report that 34 percent of respondents in urban areas stated using firewood.** Moreover, the data from the National Family Health Survey 2015 indicates that over 98 percent of the households using solid fuels, whether in rural or in urban India, operate traditional cookstoves (open fire/Chulhas). **These figures from different administrative datasets collected**

Key takeaways:

- Access to clean cooking fuels has steadily increased in India in the past two decades, reaching 41.04 percent in 2016.
- Usage of clean cooking fuels varies widely with geography, with central India having the lowest level of access. Urban areas also see a much higher level of usage of clean cooking fuels than rural areas.
- Primarily, the government has encouraged the adoption of clean cooking practices through subsidies.
- Following large government campaigns, LPG has been the most commonly used clean cooking fuel in the country. However, to limit reliance on imports, in recent years there has been a shift from the government to prioritizing PNG, which is produced in-country at a larger scale.
- In general, the Indian case shows the effectiveness of large government-driven campaigns in promoting the adoption of clean cooking solutions, in this case LPG. The success of the scheme is linked to the strong and continued government's commitment to it. The initial budget allocated to the scheme amounted to USD 1.1 billion, which was supplemented year after year with the latest budget allocating an additional USD 400 million to the initiative. India's focus on LPG, however, comes at the cost of creating an unfavourable market for other types of clean cookstoves, which cannot compete with the reach, leverage, and resources that the Indian government can mobilize.

FIGURE 6: STATE-WISE RELIANCE ON CLEAN FUELS FOR COOKING 2015-16 AND 2019-20 (NFHS 4 AND 5) - (% OF HOUSEHOLDS)



in different years indicate the persistence of unfavourable trends like stacking and use of dirty fuels.

Policy and financing landscape

In 2009, the Indian Ministry of New and Renewable Energy (MNRE) started a National Biomass Cookstoves Initiative (NBCI) to support R&D in clean cookstoves. It also included initiatives to use Carbon Financing to reduce prices and increase the affordability of biomass cookstoves as well as revising standard and test protocols for clean cookstoves. While no comprehensive results have been published yet, early results from a *Community Sized Biomass Cookstove* pilot showed a 20-45 percent reduction in solid fuel consumption, a 45-86 percent reduction in emissions, and a reduction in cooking time of 17-43 percent. Similarly, another initiative called the *Unnat Chulha Abhiyan (UCA)* was launched in 2014 with the aim of deploying 2.4 million household-level and 350,000 community-level clean cookstoves by March 2017. However, only 1.3 percent of the objective was met at the target date.[27] This may, in part, be attributed to the introduction of the Pradhan Mantri Ujjwala Yojana (PMUY) in 2016, which resulted in the UCA being sidelined.[28] The PMUY's focus, on the other hand, is on LPG penetration. Despite the scheme's success in this regard, it had a negative externality in the form of a loss in momentum for clean cookstoves not based on fossil fuels.

Currently, LPG is by far the most popular clean cooking fuel in India. While the Indian Government **has been subsidizing LPG since the 1970s,** the distribution of subsidies has been inequitable, with subsidies disproportionately reaching consumers and businesses in more developed states and union territories, presumably due to the politics of fiscal relationships between the federal and state governments. (Clarke, 2014). In recent years, however, a greater emphasis has been put on targeting

[27] Patnaik, Sasmita, Saurabh Tripathi, and Abhishek Jain. 2019. Roadmap for Access to Clean Cooking Energy in India, New Delhi: Council on Energy, Environment and Water.

[28] https://www.downtoearth.org.in/blog/pollution/air-pollution-in-rural-india-ignored-but-not-absent-75341

households below the poverty line, an objective that has been spearheaded by the introduction in 2016 of the PMUY. Moreover, the adoption of Direct Benefit Transfers (DBT) aims to reduce leakages by directly transferring the subsidy to the bank accounts of beneficiaries. The 'Give it up' campaign launched by the Government encourages affluent households to give up their LPG subsidy; as of 2017, 10.5 million households have renounced their LPG subsidies. The government also made the subsidy unavailable to households where the primary consumer or his/her spouse has taxable income of more than INR 1 Million (USD 13,000) per annum.

The increase in the number of domestic LPG connections from 4-10 percent in 2015 to 16 percent in 2017-18 attests to the short-term success of the PMUY. However, India currently imports 50 percent of its domestic LPG consumption, thereby risking vulnerability to global fuel price fluctuations. Furthermore, the scheme does not take away the burden of the cost of fuel from the consumer, and only provides the first cylinder for free.

In an attempt to address these shortcomings, the Government of India has also been promoting the use of Piped Natural Gas (PNG) in urban areas, which is cheaper than LPG since it is sourced domestically. As of October 2016, the distribution of PNG was underway in 45 towns and cities across the country, with pipelines under construction in at least 29 more areas. Nonetheless, according to recent WHO estimates, India still accounts for the largest deficit in access to piped gas in the world (25 percent).[29]

In summary, the Indian public sector displays a deep commitment to ensuring access to clean and affordable cooking via clean cookstoves and fuels. Subsidies lie at the heart of the government's strategy, with a focus on LPG. However, the fiscal and environmental sustainability of this strategy remains unclear. Consequently, the Ministry of New and Renewable Energy has taken other steps such as directing investment in R&D, supporting the establishment of an entrepreneurial ecosystem in clean cooking, and setting up other market-driven financing modalities like carbon credits. However, improving transparency and extending capacity building and financing support to clean cookstove companies will continue to be key determinants of success for India.[30] Currently, cookstove companies in India depend largely on grants from foundations and central/state governments for initial funding. On the other hand, consumer financing options are limited to MFIs and small commercial banks, whose offerings are few and far between. Finally, in recent years, there have been an increasing number of donor and multilateral initiatives from DFIs like USAID, DFID, Shell Foundation, IFC, and GIZ targeting India's cookstove market, the impact of which remains to be seen and represents an important scope for further research.

DFID - UK Department for International Development/flickr

[29] Access to Clean Fuels and Technologies for Cooking, Tracking SDG 7: The Energy Progress Report 2019. https://trackingsdg7.esmap.org/data/files/download-documents/chapter_2_access_to_clean_fuels_and_technologies_for_cooking.pdf

[30] For a country as large as India, the clean cookstoves sector is limited, with only 20 registered manufacturers on the Ministry of New and Renewable Energy approved list.

Vietnam

Adoption trends

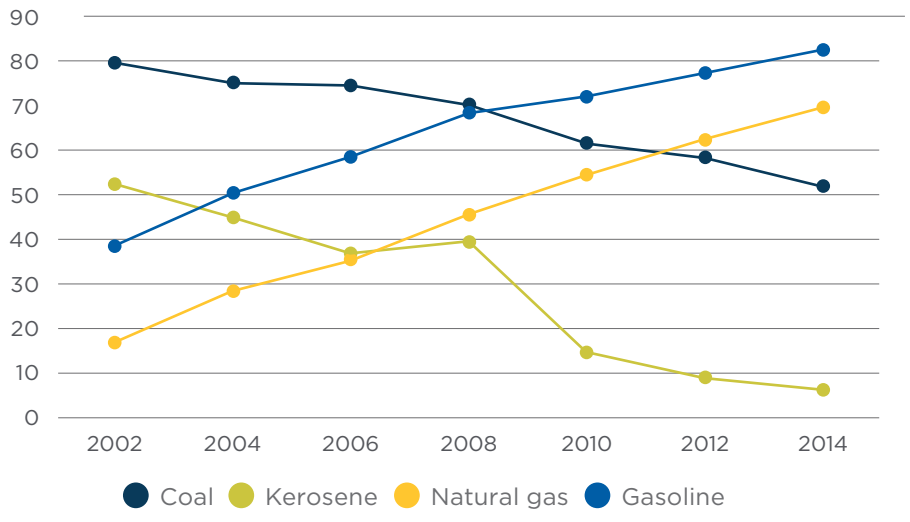
Traditional cooking practices are still common in India, but a sharp disparity is observed in energy Vietnam has made significant progress in terms of economic and human development indicators over the last few decades. With sustained growth in GDP of 18 percent per annum, the country has performed impressively on a number of Sustainable Development Goals. However, 2016 figures show that 28 million people in Vietnam still lacked access to clean cooking solutions.[31] Furthermore, over half of Vietnam reports using firewood for cooking, while only 32 percent of the population uses LPG. This pattern of use differs by geography: while overall LPG usage levels remain low, they constitute the single most widely used fuel for cooking in urban Vietnam.

Key takeaways:

- The share of the population primarily reliant on clean fuels for cooking climbed quickly from 14.4 percent in 2000 to 73.1% in 2018.
- Increased access to clean cooking fuel has been largely due to shifting from coal and kerosene to LPG and gasoline.
- The government issued a number of local and national policies in support of the adoption of clean cookstoves. However, their effectiveness has been mixed.
- The clean cookstoves sector in the country is highly fragmented and is not characterized by a significant number of large scale initiatives.
- Vietnam's progress on the adoption of clean cooking methods is largely driven by the adoption of LPG, which in turn has advanced not due to a large government push like in India, but mostly due to Vietnam's infrastructure and market access. This also explains why LPG usage is mostly limited to urban areas.
- In summary, the evolution of the adoption of clean cookstoves in Vietnam suggests that in the absence of strong clean cookstoves businesses or significant government commitments, the adoption of clean cooking methods is mostly driven by infrastructural development and market conditions.

Figure 7 below shows that the dependence of Vietnamese households on solid fuels and kerosene has declined over the years, as they move to using cleaner sources of energy (Nguyen and Ngo, 2019). Interestingly, the data shows that the speed of the transition from polluting to clean fuels in Vietnam has been faster than the global average.[32]

FIGURE 7: HOUSEHOLD COOKING CONSUMPTION BY SOURCE: 2002 TO 2014 - VIETNAM

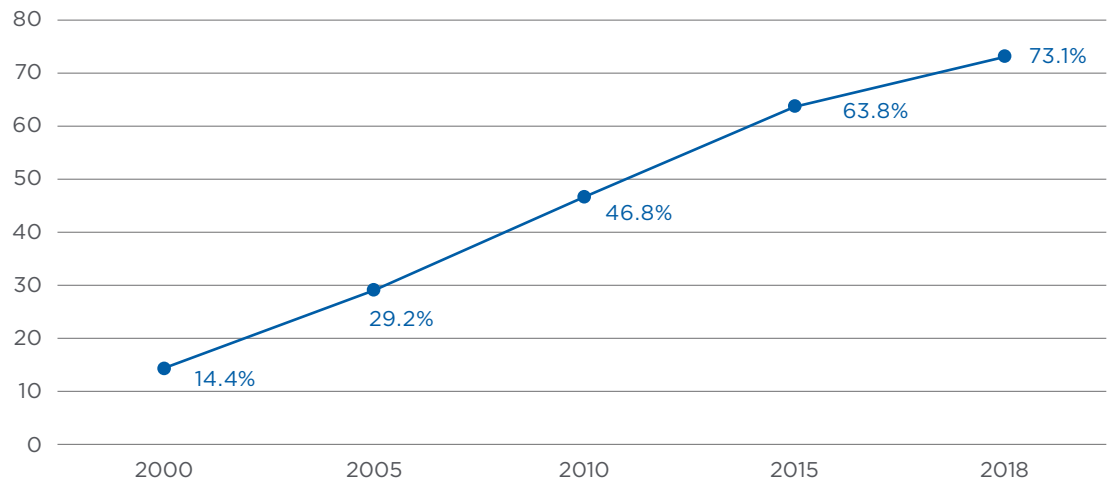


[31] https://trackingsdg7.esmap.org/data/files/download-documents/chapter_3_clean_cooking.pdf

[32] Scott, A (2020), "Access to Affordable, Reliable, Sustainable and Modern Energy for All in Vietnam"

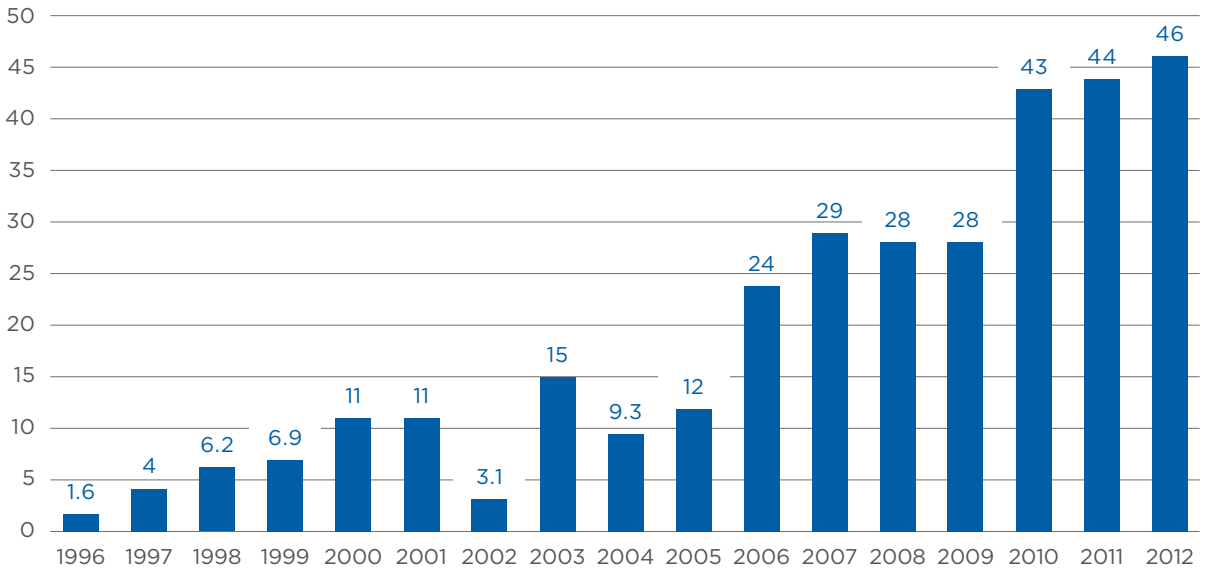
Figure 8 below presents data on the proportion of Vietnamese households primarily reliant on clean fuels for cooking between 2000 and 2018, with this share climbing quickly from 14.4 percent in 2000 to 73.1 percent in 2018.

FIGURE 8: RELIANCE ON CLEAN COOKING FACILITIES – VIETNAM (% OF POPULATION)



Vietnam's progress in furthering its clean cooking agenda may be attributed to its being one of the largest LPG markets in the East Asian region. Estimates from the Global Economy Database show that its current consumption stands at nearly 46 thousand barrels per day, compared to 1,600 barrels per day in 1996. While the use of LPG as their primary source of cooking fuel has increased considerably in recent years, solid fuel consumption and related deaths continue to persist. Scaling up programs to replace traditional stoves with clean cookstoves, like in Hanoi, to the rest of the country, particularly rural areas, should be an important part of their strategy in coming years.

FIGURE 9: CONSUMPTION OF LPG – VIETNAM (THOUSAND BARRELS PER DAY)



Source: Global Economy Database

Policy and financing landscape

In 2007, the Government of Vietnam launched the Scheme on Development of Biofuels, which offers financial incentives like loans and tax relief, and promotion of R&D activities to facilitate the transition from fossil fuels to biofuels. This success is a result of policies at both the national and local levels. Since 2017, the city of Hanoi has been monitoring the cookstoves usage and assessing user demand to improve financial offerings and design interventions aimed at increasing clean cookstove adoption. The city's commitment to eliminating its 50,000 traditional "beehive" coal stoves[33] by 2020, and replace them with safer, clean-fuel stoves, if successful, is estimated to reduce CO2 emissions by 3662 million tons.[34] However, as of 2020, more than 23,000 beehive stoves continue to be in use. The Hanoi municipal administration has extended its timeline till the end of 2021, and instituted penalties on the use of the beehive stoves beyond that.[35]

However, the clean cooking sector in Vietnam is highly fragmented. Neither the government nor the private and civil society sectors have shown much interest in funding end-to-end, full-scale improved cookstove programs. Most ongoing programs are small in scale (40-100 cookstoves) and focus on demonstration and design rather than scalability. The Vietnam's Women's Union rural distribution program, which distributed 29,300 cookstoves in North Vietnam in 2012, is one of the few large-scale programs in the country. Furthermore, enterprises such as SolarServe[36] and organisations such as SNV run projects attempting to make clean cooking products more accessible to low-income customers.[37] SNV's "Market Acceleration of Advanced Clean Cookstoves in the Greater Mekong Sub-region" project employed a results-based finance strategy to sell 120,000 clean cooking devices in Cambodia, Laos and Vietnam between 2015 and 2019, in order to create a market for such products and strengthen the supply chain.[38]

In addition, the growth of Vietnam's carbon market is slow. The European Union previously purchased carbon credits from Vietnam under the Clean Development Mechanism. However, Vietnam stopped being classified as a Least Developed Country in 2012, making it ineligible under the EU Emissions Trading Scheme. In 2015, the Vietnamese government, along with the World Bank, launched a carbon market. However, actual progress on this front has been negligible, and reports suggest that another attempt to draw up a domestic carbon market as of 2020.[39]

World Bank Photo Collection/flickr

[33] Honeycomb briquettes, also known as beehive briquettes, are cheap coal bricks which get their name from the shape of their arrangement which looks like a honeycomb.

[34] https://www.c40.org/case_studies/hanoi-households-emissions-reduction-through-cookstove-conversions

[35] https://vietnamnews.vn/environment/570707/hanoians-still-burn-23000-honeycomb-charcoal-stoves-each-day.html

[36] SolarServe sells innovative low cost solar cookstoves tailored to local needs

[37] https://www.inclusivebusiness.net/ib-voices/solar-serve-clean-cooking-revolution-vietnam

[38] https://snv.org/project/market-acceleration-advanced-clean-cookstoves-greater-mekong-sub-region

[39] https://carbon-pulse.com/11090/#:~:text=The%20%243.6%20million%20plan%2C%20developed,BAU%20levels%20throughout%20the%202020s.&text=Vietnam's%20ambition%20is%20to%20participate,market%20in%20the%20long%20term.

Burkina Faso

Adoption trends

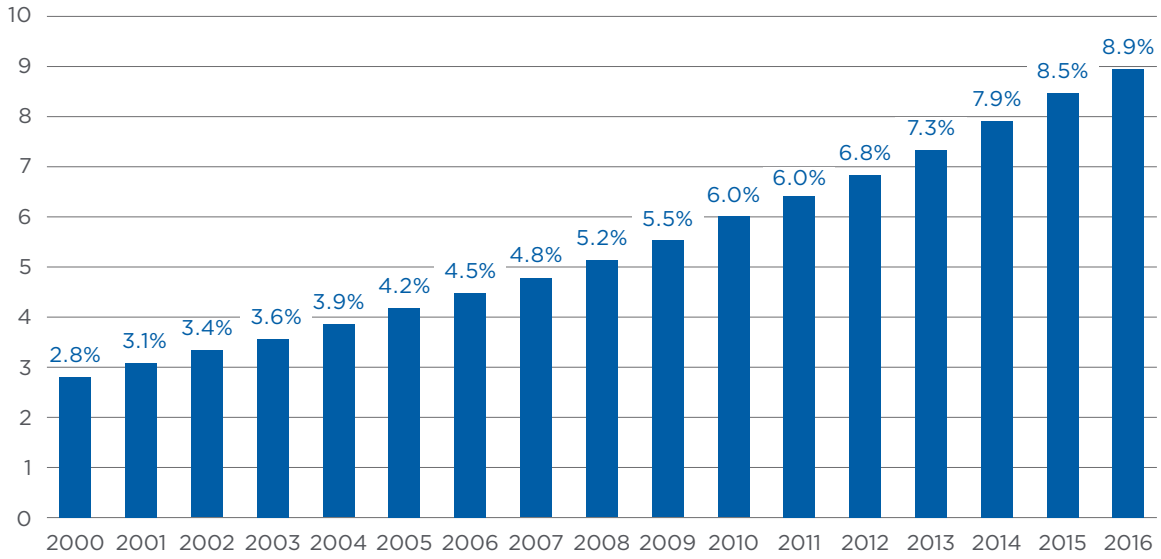
Almost the entirety of Burkina Faso's population (93 percent) uses solid fuels for cooking, including 89 percent using wood, and 4.3 percent using charcoal. This has contributed to a deforestation rate of over 100,000 hectares per year, in a region that is already arid,[40] leading to serious environmental and health consequences related to emitted smoke. According to WHO, in Burkina Faso 16,500 people die every year due indoor air pollution stemming from biomass-based cooking fuels (WHO 2009).

Key takeaways:

- Adoption of clean cooking practices has slowly increased in Burkina Faso, but it was still only at 8.9% of the population in 2016. However, even among those who own clean cookstoves, usage is not very frequent.
- Due to its geographic location and its industrial capacity, LPG does not appear to be a reliable alternative to traditional cooking methods. Thus, clean cooking practices have been mostly promoted through the encouraging the adoption of improved solid-fuel cookstoves.
- The country has been the target of many multilateral initiatives to promote the adoption of clean cooking practices with mixed results. Interestingly, some of the most successful initiatives relied on the establishment of social enterprises.
- The case of Burkina-Faso highlights the importance of macro and geographical factors to determine available options for a country to transition to clean cooking methods.

Yet, while Burkina Faso has been investing heavily in the development and dissemination of clean cookstoves, most clean cookstoves owners do not use them frequently for cooking. Estimates provided by Bensch et al. (2013) suggest that around 62.5 percent of clean cookstoves owners use it at most once per day, whereas less than 10 percent use it more frequently than twice a day. It is found that the clean cookstoves is only used in case of ceremonies and other exceptional occasions.[41]

FIGURE 10: ACCESS TO CLEAN FUELS AND TECHNOLOGY FOR COOKING – BURKINA FASO (% OF POPULATION)



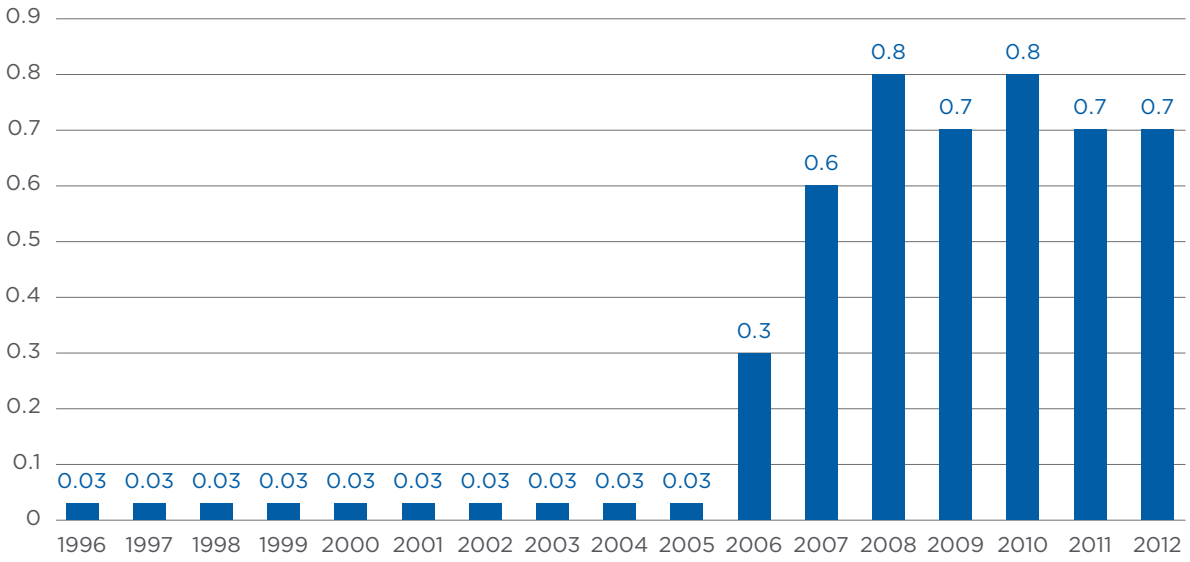
Source: World Bank

[40] http://e4sv.org/clean-energy-crisis-one-burkina-faso-social-business-aims-address/?doing_wp_cron=1609221855.8554530143737792968750

[41] Bensch et al. (2013)

The most used alternative energy for household cooking in Burkina Faso is gas (LPG). Nearly 35 percent of households in big towns and between 10 and 25 percent in smaller towns own LPG equipment.[42] For new customers, the investment cost for the equipment is seen as a disincentive for adoption together with the unreliability of LPG supply. Being a landlocked nation without any energy or refining resources of its own, providing access to LPG is a significant concern in Burkina Faso. As per Global Economy Database estimates, current national consumption stands at nearly 700 barrels per day, which is much higher than 1996, when it was only 30 barrels a day. However, since 2006 consumption has remained more or less stable.[41]

FIGURE 11: CONSUMPTION OF LPG (THOUSAND BARRELS PER DAY) – BURKINA FASO



Source: Global Economy Database

Policy and financing landscape

The Strategy for Accelerated Growth and Sustainable Development (SCADD 2011-2015) recognised that the present energy system was unsustainable and relied heavily on wood fuel use, thus causing a loss in vegetation, and encouraged the government to strengthen alternate, energy-saving techniques and technology programmes.[43] As a part of the Renewable Energy and Energy Efficiency Action Plans, the government has set a target to reach universal access to clean cooking solutions in urban areas, and 65 percent coverage in rural areas by 2030.[44]

In line with the thrust areas of SCADD – 2011-15, the World Bank along with the Ministry of Energy adopted the Energy Sector Budget Support Programme (PASE) in end-2010 with a view to achieving strong, sustained and quality economic growth that has multiplier effects on the improvement of the population's income and living standard, and complies with the principle of sustainable development.[45] The Energy Sector Reform Support Programme (PARSE), a continuation of the earlier Energy Sector Budget Support Programme (PASE), implemented in the form of a multi-tranche sector budget support (SBS) programme covered the 2018 and 2019 financial years. While PASE's success was underwhelming, it brought other donors into the sector, which led to the emergence of social enterprises selling cookstoves, such as the Nafa Naana initiative.[46]

[42] Energypedia-Burkina Faso Energy Situation https://energypedia.info/wiki/Burkina_Faso_Energy_Situation

[43] IMF (2012) "Strategy for Accelerated Growth and Sustainable Development" https://www.imf.org/external/pubs/ft/scr/2012/cr12123.pdf

[44] Sustainable Energy For All https://www.se4all-africa.org/seforall-in-africa/country-data/burkina-faso/#:~:text=The%20Objectives%20envisaged%20by%20the,by%202030%20(without%20biomass)

[45] African Development Fund (2015) "Energy Sector Budget Support Programme" https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Burkina_Faso_AR-_Energy_Sector_Budget_Support_Programme__PASE_.pdf

[46] http://e4sv.org/clean-energy-crisis-one-burkina-faso-social-business-aims-address/

The improved cookstoves sector in Burkina Faso relied almost exclusively on subsidies for over three decades. This changed in 2006, with FAFASO, a Dutch-German partnership funded by the Dutch Foreign Ministry and the German Ministry of International Cooperation, introducing a market-based approach to clean cookstoves dissemination. This approach led to a sale of 400,000 stoves, without government subsidies and thereby proved that the subsidy model was constrained by the inactivity of state agents. While the proportion of population reliant on clean cooking is still meagre in the country, the growth in the last decade is encouraging.

In order to support the use of renewable energy for cooking, Burkina Faso's National Programme of Biodigesters (PNB-BF) started operations in 2009 with the aim to initiate and assist large-scale commercial dissemination of domestic biogas to benefit rural households in Burkina Faso as a part of the Africa Biogas Partnership Programme. The programme is being supported by private suppliers in consonance with the World Bank's Carbon Initiative for Development (Ci-Dev). This was also the first Carbon Credit issued in Burkina Faso under the UN's Clean Development Mechanism.[47] Under this programme, in 2018, the government of President Roch Marc Christian Kabore made a commitment to have 40,000 biodigesters installed in the country by 2020 in partnership with SNV and Hivos.

Ghana

Adoption trends

Key takeaways:

- The Ghanaian government has been encouraging people to shift towards LPG consumption, however, progress in this sector has been hampered by infrastructural issues, as well as cultural and behavioural norms.
- On the other hand, Ghana displays a growing market of clean cookstove businesses, dominated by a few actors that developed cooking solutions tailored to local habits and customs.
- The case of Ghana shows the importance of developing clean cookstoves that adapt to local preferences and cooking styles, rather than try to change them.

With a total population of about 24.7 million, Ghana's political stability and growing economy stand out in the West African region. However, Solid fuels remain the main energy source for cooking in Ghana.[48] Access to clean cooking fuels and technologies in Ghana increased sharply from close to 6 percent in 2000 to 21.7 percent in 2016. Currently, the cookstove market is dominated by the locally produced Gyapa Charcoal stove, which is widely used in urban and peri-urban areas and offers some, but not significant reductions in emissions.[49] The specific style of cooking in Ghana requires specific qualities in clean cooking solutions to ensure that they meet the end users' needs. Ghana has a well-developed cookstove market with strong local players across all sectors, including government involvement and international organizations (The stoves common across markets in Ghana can be found in the Annexure). However, some barriers include high import tariffs on foreign cookstoves as well as on raw materials and parts for locally manufactured ones, high interest rates on loans for manufacturers, and the lack of carbon financing.[50]

Figure 12 presents the trend in the proportion of the population being primarily reliant on clean cooking facilities between 2000 and 2018. Clearly, the share rose sharply from less than 6 percent in 2000 to almost 25 percent in 2018, indicating significant progress towards the implementation of SDG 7.1.2. While the proportion of the population reliant on clean cooking is not very sizeable, the growth over the years has been impressive.

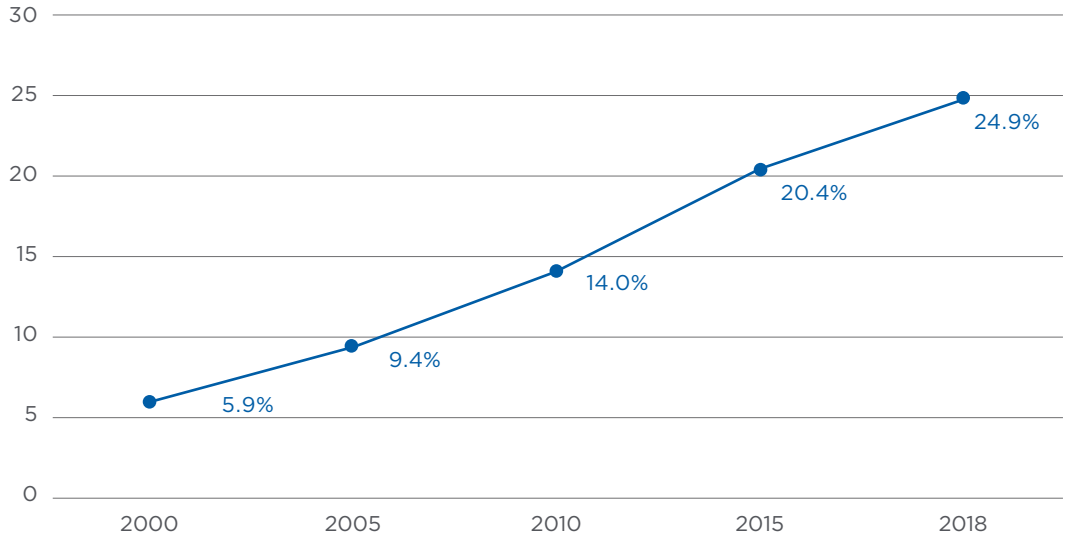
[47] https://www.worldbank.org/en/news/feature/2018/03/06/carbon-credits-serve-up-clean-cooking-options-for-west-african-farmers#:~:text=Some%20households%20in%20Burkina%20Faso,cleaner%20cooking%20in%20rural%20areas

[48] https://www.tandfonline.com/doi/full/10.1080/23311886.2019.1697499

[49] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/334-1.pdf

[50] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/334-1.pdf

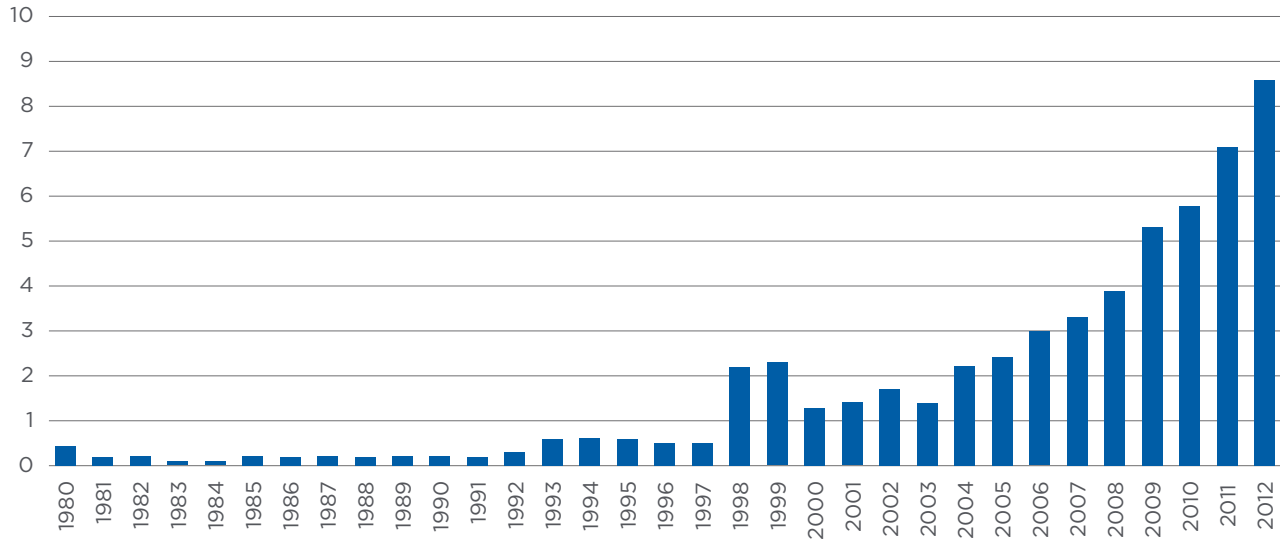
FIGURE 12: PRIMARY RELIANCE ON CLEAN COOKING FACILITIES (% OF POPULATION) – GHANA



Source: International Energy Access

As per the estimates from the Global Economy Database, the current LPG consumption in Ghana stands at nearly 8.6 thousand barrels per day. It has grown rapidly since the early eighties when the consumption stood at merely 420 barrels per day and, today, approximately 24.5 percent of Ghana's population uses LPG as its main cooking fuel. The highest LPG consumption level is observed by the Greater Accra region, with around 54 percent of the population consuming LPG for cooking, followed by the Western, the Central and the Ashanti regions. These estimates are based on a study conducted by the Global LPG Partnership, together with KFW and the European Union in 2018.

FIGURE 13: CONSUMPTION OF LPG (THOUSAND BARRELS PER DAY) - GHANA



Source: Global Economy Database

Policy and financing landscape

The Ministry of Environment, Science, Technology, and Innovation coordinates a Nationally Appropriate Mitigation Actions programme which establishes private sector market-based solutions to expand access to clean energy and financing for consumers. It is estimated that one million more efficient cookstoves and 250,000 LPG cookstoves will reach consumers through this programme.

The Ministry also has an organ called the Environmental Protection Agency, which is coordinating a programme to install 200 biogas digesters in schools, prisons, and hospitals.[51]

The Ghana Alliance for Clean Cooking (GHACCO) has also been active in creating private and public sector partnerships for the adoption of clean cookstoves. A recent project has been signed between GHACCO and ENI Ghana to implement an ENI-World Bank Rural Clean Cooking Project to distribute woodfire stoves in 10 communities. GHACCO has also signed an MoU with the Government of Korea to distribute 500,000 ICs to rural households.[52] An enterprise named CookClean also works to distribute energy-efficient CookMate charcoal stoves, and train local women as distributors.[53]

The Ghanaian government has been pushing to reduce households' dependence on solid fuels and moving towards LPG, with a goal of transitioning at least 50 percent of the population to using LPG as their primary cooking fuel by 2015. As discussed above, just about 22 percent of the population currently use LPG but prefer to use a mix of charcoal and fuelwood along with LPG, with charcoal particularly being cited as offering tastier food.[54]

In 1989 the Ministry of Energy introduced a National LPG Promotion Programme to reduce deforestation and dependence on fuelwood. It worked to provide free LPG to individuals, educational institutions, hospitals, prisons, catering services, etc. and improved the distribution network as well. However, the supply could not keep up with demand, especially after the only domestic LPG refinery ceased to function. The lack of supply caused some consumers to go back to using charcoal. In 2014, the National LPG Promotion Programme was discontinued and replaced with Ghana's Rural LPG Programme. It aimed to popularize LPG use in poorer and rural areas, unlike the earlier programme, which was more focused on urban areas. It was started in the northern district and covered 40 districts by 2016. Though the programme began by subsidizing LPG, this led to the transport sector switching to LPG from petroleum, and hence the subsidy was scrapped. At present, there is no data on the rural household LPG programme.[55]

Ghana currently has two registered Gold Standard cookstove projects and three carbon financing projects pending approval, but carbon financing can only be done on a voluntary basis since the country became a middle-income country.[56] The already mentioned Gyapa cookstoves have been promoted by ClimateCare and Relief International since 2007. The project led to the sale of over 800,000 cookstoves and affected the lives of both manufacturers and consumers.[57] The organizations offer Gold Standard carbon credits to investors, thus ensuring a steady stream of revenue to the project.[58]

The government has committed to increasing local LPG production capacity, but the country's only refinery, the Tema Oil Refinery has been shut since 2017 following an explosion.[59] In 2020 the government pledged to extend LPG access to at least 50 percent of households by 2030, up

[51] Opportunities for transition to clean household energy: application of the Household Energy Assessment Rapid Tool (HEART) in Ghana. Geneva: World Health Organization; 2018, p.20.

[52] https://www.ghanaweb.com/GhanaHomePage/business/GHACCO-lauds-gov-t-on-MOU-with-Korea-to-deploy-500K-improved-cookstoves-to-rural-dwellers-701379

[53] https://climatecare.org/project/cookclean-efficient-cookstoves-in-ghana/

[54] Opportunities for transition to clean household energy: application of the Household Energy Assessment Rapid Tool (HEART) in Ghana. Geneva: World Health Organization; 2018, p. 7.

[55] Opportunities for transition to clean household energy: application of the Household Energy Assessment Rapid Tool (HEART) in Ghana. Geneva: World Health Organization; 2018, p. 14.

[56] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/334-1.pdf

[57] https://climatecare.org/carbon-finance-helps-gyapatm-cookstove-project-break-records/

[58] https://energy-access.gnesd.org/projects/51-gyapa-cookstoves-for-more-efficient-cooking.html

[59] Opportunities for transition to clean household energy: application of the Household Energy Assessment Rapid Tool (HEART) in Ghana. Geneva: World Health Organization; 2018, p. 11.

from the current number of 23 percent. An Agreement was signed between Indian Oil and the National Petroleum Authority of Ghana to assist in this aim, with Indian Oil offering assistance in the development of licensing and policy framework, attainment of Health, Safety, Security and Environment Standards, pricing, and communication structures for plants.[60]

Ethiopia

Key takeaways:

- The adoption of clean cooking fuels and technology is low and has experienced a very sluggish growth, reaching only 3.5 percent of the total population in 2016.
- The government has attempted to encourage the adoption of clean cookstoves through capacity building, improved access to finance, and awareness creation. Recent programs also entail significant investments in equipment. The impact of these initiatives, however, is limited.
- Despite rich endowments of natural resources, LPG is scarcely used by the population for cooking. Arguably this is due to its sourcing and distribution, which is entirely left to the private sector,
- Following major advancements in the electrification of the country, the consumption of electricity has increased at a remarkably high rate and is viewed to be the most likely choice to replace biomass in cooking.
- The Ethiopian case confirms that in the absence of effective government policies to promote the adoption of clean cookstoves market and infrastructure conditions determine which path a country will follow to transition to clean cooking. In this case, a lack of penetration and competitiveness in its supply has hindered the adoption of LPG, while widespread electrification shows promise for the adoption of electric stoves.

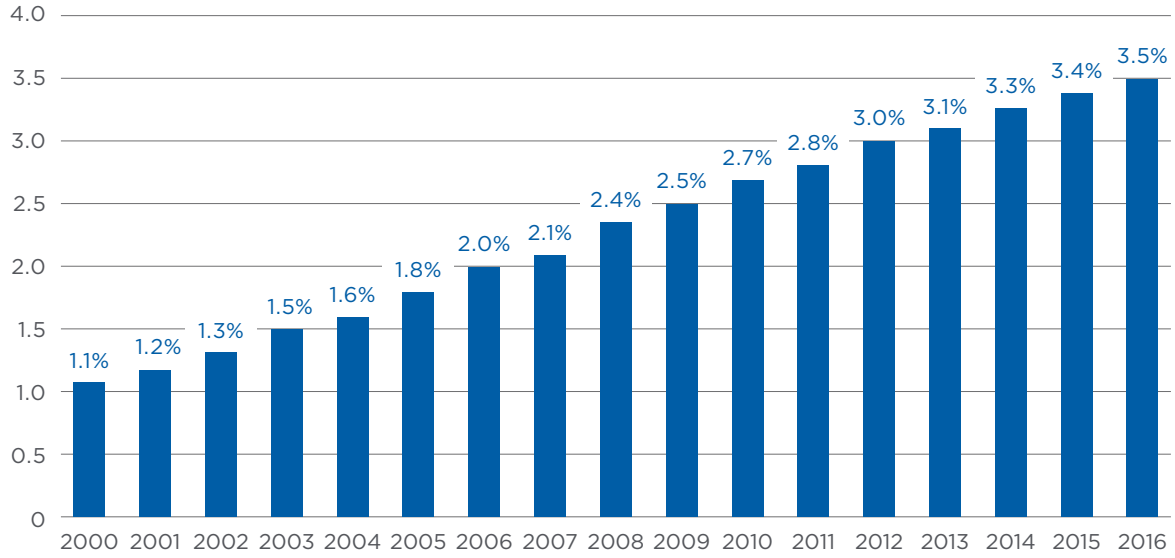
Adoption trends

Solid fuels remain the main energy source for cooking in Ethiopia (95 percent of the total), with firewood being used by 85 percent of the population. On the other hand, a mere 0.1 percent uses LPG as the primary fuel for cooking. Access to clean cooking fuels and technologies in Ethiopia has increased sluggishly from 1.1 percent in 2000 to 3.5 percent in 2016. Clearly, the share of the population with access to clean cooking technology in the country is very low, despite a rich endowment of renewable energy sources.


Ben Grey/flickr

[60] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/334-1.pdf

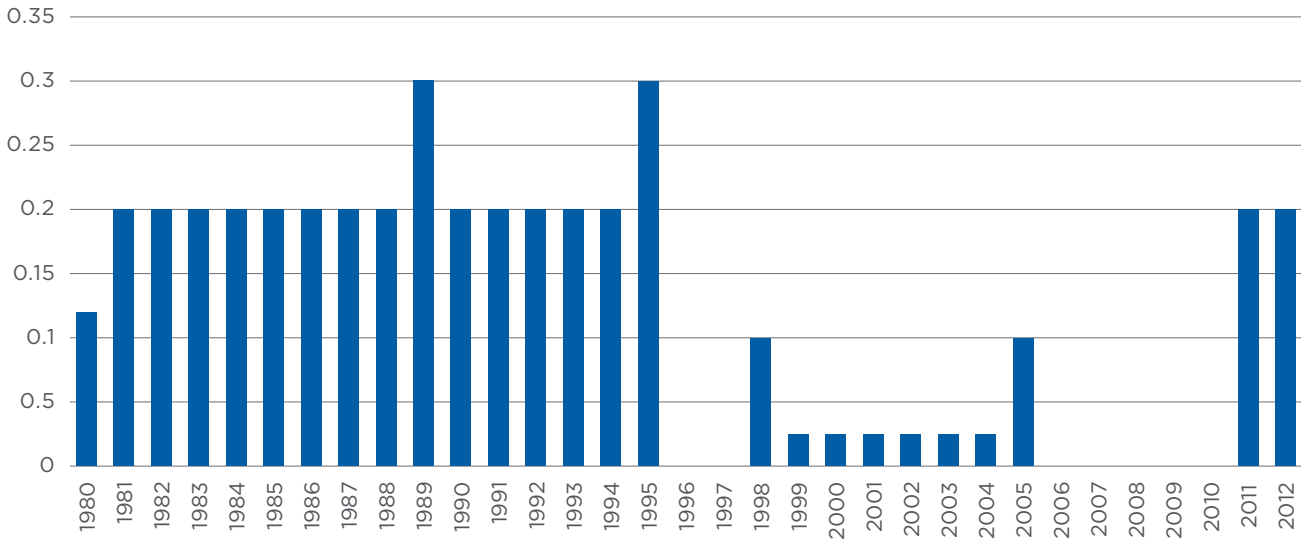
FIGURE 14: ACCESS TO CLEAN FUELS AND TECHNOLOGY FOR COOKING (% OF POPULATION) - ETHIOPIA



Source: World Bank

As per the estimates from the Global Economy Database, the LPG consumption in 2012 in Ethiopia stood at nearly 2 hundred barrels per day. It has remained more-or-less stable since the early eighties, as shown in Figure 15.

FIGURE 15: CONSUMPTION OF LPG (THOUSAND BARRELS PER DAY) – ETHIOPIA



Source: Global Economy Database

Policy and financing landscape

Improvement in energy efficiency for domestic cookstoves has been at the forefront of energy interventions in Ethiopia since the mid-1980s. Slow but continued has been made, particularly in the past two decades in distributing energy-efficient cook stoves in urban and rural areas.[61] The National Improved Cookstoves Programme is Ethiopia's flagship program on clean cookstoves, and it is designed to help with the distribution of clean cookstoves, building the capacity of producers, distributors, and investors, as well as developing credit services for end-users and promoting awareness. The Ministry of Environment, Forest and Climate Change (MEFCC) also has an Improved

[61] ibid

Cookstoves Technology Development and Promotion Directorate which is tasked to support the development and promotion of improved cookstoves.

However, biomass continued to be used as the predominant source of fuel for cooking. Due to the continued and growing dependence of Ethiopian households on biomass for cooking, a Biomass Energy Strategy (BEST) of Ethiopia was initiated in 2013 jointly by GIZ and Ministry of Water, Irrigation and Energy (MOWIE), with support from the EU Energy Initiative Partnership Dialogue Facility (EUEI PDF). The strategy, whose results are not yet published, was aimed at promoting sustainable use of biomass energy for the socio-economic and environmental benefit of citizens.[62]

Another significant initiative is the National Programme for Improved Household Biomass Cookstoves Development and Promotion. A Results-based Aid (RBA) program in Ethiopia aimed to deploy 9 million improved cookstoves by 2018 and 31 million cookstoves by 2030; the program was to be run by the Ministry of Water, Irrigation and Energy, in collaboration with the Environment Protection Authority, Ministry of Finance and Economic Development, Ministry of Agriculture, Ministry of Health, and the Ethiopia Quality and Standards Authority. The progress made under this program against its interim 2018 target has yet to be released.

LPG used to be imported by the government, however, in the last couple of decades, LPG price has not been regulated, and import and distribution have also been left to the private sector. Distribution of the fuel is limited only to major cities, and it faces frequent interruption of supply. (MEFCC/SNV, 2018).[63] Consumption of Electricity has grown much faster than LPG and is believed to have displaced significant amounts of biomass energy used for cooking and baking in urban areas. Considering the goal for universal electrification by the Govt of Ethiopia, electricity appears to be the prioritized choice to replace biomass in cooking.[64]

The Ethiopian Power System Expansion Master Plan Study looks forward to 95 percent grid-based electrification by 2037. The National Electrification Strategy 2016 and the National Electrification Programme 2017 aim to achieve universal electrification by 2025 (65 percent grid-based) and 97 percent grid based electrification by 2030.[65]

The clean and improved cookstoves sector in Ethiopia secures financing from several sources, such as: grant-based financing[66] for enterprises, carbon financing,[67] donor support from international governments and organizations like the World Bank,[68] and funding from formal financial institutions like banks and MFIs (SNV, 2018).

With a view to promoting the use of renewable sources of energy for cooking, the Ethiopia Clean Cooking Biogas Programme[69] was introduced in 2015 and included the distribution of household biogas digester, ethanol cookstoves and improved cookstoves. Additionally, the program seeks to establish an agreement with the Carbon Initiative for Development (Ci-Dev), as per which the World Bank trust fund would buy the carbon credit resulting from the national biogas programme of Ethiopia. Finally, the programme aims to construct 39,178 biogas digesters of an average 10 cubic metre volume each over the period 2015 to 2020. This is expected to reduce CO2 emission by 803, 167 tons between 2015 and 2024.

[62] https://www.worldbank.org/en/news/feature/2018/11/01/green-entrepreneurs-bring-clean-cooking-to-ethiopia

[63] https://www.multiconsultgroup.com/assets/LPG-for-Cooking-in-Developing-Countries_Report-by-Multiconsult.pdf

[64] https://www.multiconsultgroup.com/assets/LPG-for-Cooking-in-Developing-Countries_Report-by-Multiconsult.pdf

[65] https://snv.org/cms/sites/default/files/explore/download/eth-seeccs-review_of_policies_and_strategies_final_report.pdf , pp.14-15.

[66] https://www.worldbank.org/en/news/feature/2018/11/01/green-entrepreneurs-bring-clean-cooking-to-ethiopia

[67] https://fairtradeafrica.net/ethiopian-coffee-farmers-earn-first-ever-carbon-credits-from-clean-cooking/

[68] https://energypedia.info/wiki/Ethiopia_Energy_Situation#Improved_Cookstove_.28ICS.29 and https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/159-1.pdf

[69] Africa Carbon Forum https://www.africacarbonforum.com/sites/default/files/brochures/2016/Day%202-WS7-Yemezwork%20Girefie.pdf

Kenya

Adoption trends

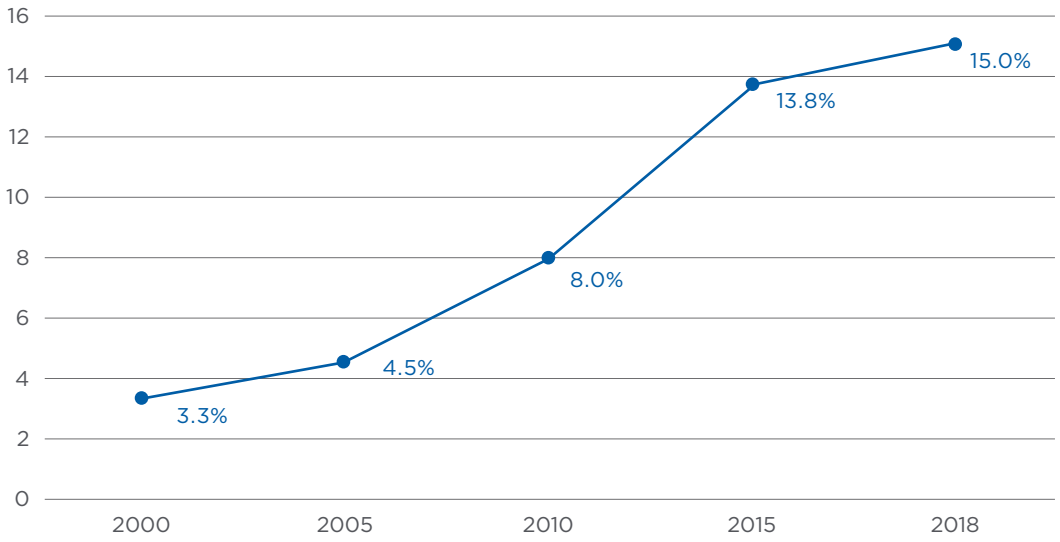
Indoor air pollution causes more than 14 thousand deaths every year in Kenya,[70] with women and children being the most affected categories.[71] Estimates suggest that 82 percent of Kenya's population uses solid fuels as their primary source of cooking, 68 percent uses wood, and 13.8 percent uses kerosene. Only 3.5 percent of the population uses LPG for cooking.

Key takeaways:

- The Government of Kenya has recognized clean cooking as an important issue and has included it in government policies and development plans, attempting to significantly curb and regulate logging and the production of charcoal.
- Supported by several national and international initiatives, the Kenyan clean cookstoves market has grown significantly and access to clean cooking fuels and technologies in Kenya increased from 2 percent in 2000 to 13.4 percent in 2016.
- While usage of LPG is currently limited to urban areas, access to this fuel is expected to continue growing and reach 70 percent of the population by 2030.
- The Kenyan model is interesting for the diversity of actors and strategies involved. Overall, the success of the Kenyan model appears to hinge on the collaboration between government, market, and international actors that have led to a thriving market ecosystem and sustained adoption of clean cookstoves.

While access to clean cooking technology in the country is still low, Kenya has witnessed steady progress in the clean cookstoves and fuels sector, which has resulted in increased investment[72] and, today, it is the leading nation in Sub-Saharan Africa in the development and distribution of clean cookstoves. Access to clean cooking fuels and technologies in Kenya increased sharply from 3.3 percent in 2000 to 15 percent in 2018 as shown in Figure 16 below.

FIGURE 16: PRIMARY RELIANCE ON CLEAN COOKING FACILITIES (% OF POPULATION) - KENYA



Source: International Energy Access

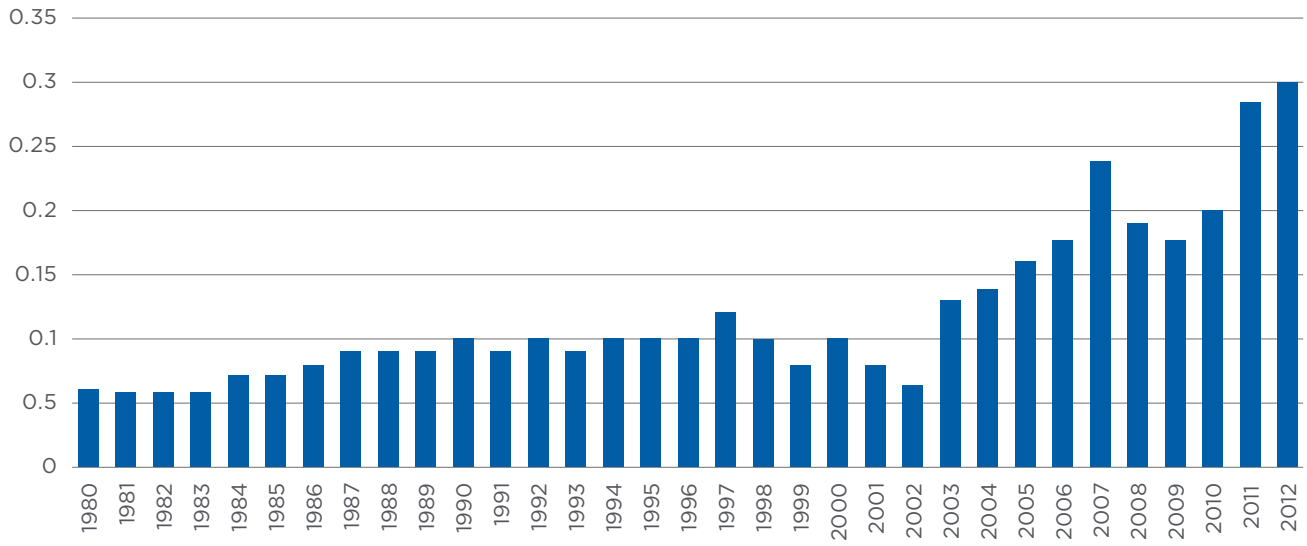
[70] http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A1349162&dswid=528

[71] https://forestsnews.cifor.org/68884/beyond-bans-toward-sustainable-charcoal-production-in-kenya?fnl=en

[72] Clean Cooking Alliance

Kenya is gradually moving away from kerosene towards LPG for cooking. As per the estimates from the Global Economy Database, the current LPG consumption in Kenya stands at nearly 3 thousand barrels per day, growing rapidly since the early eighties, when the consumption stood at 600 barrels per day. Growth in the usage of LPG has mostly been driven by urban areas, mostly Nairobi,[73] and is supported by schemes such as the Gas Yetu Mwananchi Gas Project by the National Oil Corporation of Kenya, which provides low-income households with 6 kilograms of LPG cylinders at a discounted price and a subsidy to purchase an LPG stove. It is expected that with an average annual growth of 14 percent (PIEA 2016) the country will have 70 percent LPG penetration by the year 2030.

FIGURE 17: CONSUMPTION OF LPG – KENYA (THOUSAND BARRELS PER DAY) – KENYA



Source: Global Economy Database

Policy and financing landscape

The Energy Act of 2019 empowers the cabinet secretary to draft rules on renewable energy use, and requires county governments to regulate biomass, biogas and charcoal production and use, which affects the clean cookstoves sector as well.[74] At the same time, the Forest Conservation and Management Act of 2016 provides directions on licensing and regulatory powers given to the Kenya Forestry Services with regards to the collection and use of biomass. This act complements the Forest (Charcoal) Rules of 2009, providing licensing requirements for charcoal producers and distributors with the Kenya Forest Service.[75] However, to combat deforestation and environmental degradation, in February 2018, the government imposed a ban on charcoal production followed by a nationwide ban on logging. Still, the ban has not been enforced strictly and charcoal continues to be widely available in black markets, though it became more expensive.[76]

In recent years, clean, modern fuels have become increasingly available and cost-competitive in Kenya (Dalberg, 2018). Multiple donor-funded projects such as projects by the Clean Cooking Alliance Spark Fund, World Bank Clean Cooking Fund,[77] Netherlands Enterprise Agency,[78] Netherlands Development Organisation,[79] etc. aim to make clean cookstoves accessible to low-income households. Social enterprises such as EcoZoom make low-cost cooking products and provide credit to distributors, as

[74] http://academia-ke.org/library/download/mey-sessional-paper-no-4-of-2004-on-energy/

[75] https://www.epra.go.ke/download/the-energy-act-2019/

[76] https://www.cleancookingalliance.org/country-profiles/focus-countries/4-kenya.html

[77] https://www.worldbank.org/en/news/feature/2019/11/04/why-clean-cooking-matters

[78] https://english.rvo.nl/sites/default/files/2019/10/End%20of%20program%20report%20Clean%20Cooking.pdf

[79] https://snv.org/update/story-change-kenyas-clean-cooking-champions

well as have tie-ups with microfinance institutions, companies offering employee benefits, and other such interested organizations.[80] The K-REP Development Agency, a microfinance organisation, has helped set up Village Banks or Financial Service Associations, which helped poor women access financial products for the purchase of clean energy products.[81] A detailed list of different forms of financing used by these can be found in the annexure.

The Government of Kenya has recognized clean cooking as an important issue and has included it in government policies and development plans such as the National Climate Change Action Plan (2018-2022).[82] The Action Plan develops pathways for low-carbon reliance and reduction of greenhouse gas emissions and encourages the transition to clean cooking. However, under the Finance Act of 2020, the Government of Kenya reinstated a standard rate of 14 percent VAT on various clean cooking products, including stoves, biogas, and LPG.[83] This was a reversal of a 2016 pledge to exempt such taxes on clean cooking technologies and fuels, and may adversely affect their uptake by increasing prices for consumers. However, reports suggest that attempts were being made by the Ministry of Energy to have this decision reconsidered.[84]

At the sub-national level, each county is required to formulate County Integrated Development Plans, which have a five year outlook. Attempts have been made by organisations such as GROOTS working with agencies such as Voice for Change Partnership (V4CP), to advocate for clean cooking initiatives to be considered in the formulation of these policies, particularly in Kitui County, which resulted in government-sponsored training programmes being conducted for villagers to build clean cookstoves known as *jikos.*[85]

DFID - UK Department for International Development/flickr

[80] https://mediamanager.sei.org/documents/Publications/SEI-NCE-DB-2016-Kenya-Clean-Cooking.pdf

[81] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/421-1.pdf , pp.11-12.

[82] https://www.cleancookingalliance.org/country-profiles/focus-countries/4-kenya.html

[83] https://www.businessdailyafrica.com/bd/opinion-analysis/ideas-debate/why-this-is-not-the-time-to-tax-clean cooking - 2292838

[84] https://www.standardmedia.co.ke/business/article/2001388095/government-backtracks-on-taxing-clean-cook-stoves

[85] https://snv.org/update/story-change-kenyas-clean-cooking-champions

6. CONCLUSION

The global clean cooking movement has gained considerable momentum in recent years, as the adverse impacts of solid fuel combustion and the use of traditional cookstoves become more apparent and supported by evidence. Clean cookstoves can address these issues and directly contribute to the achievement of a number of Sustainable Development Goals (SDG), most especially SDG 3 (ensure healthy lives and promote wellbeing for all at all ages) and SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all).

Using clean or improved cookstoves is considered to have several favourable impacts. Multiple studies show that the increased fuel efficiency brought about by the adoption of clean cookstoves has a positive effect on **household savings and women's control over their own time.** However, much of this evidence pertains to specific contexts and these results may not be generalizable. **On the health front, the evidence of the impact of cookstoves is mixed** and appears highly contingent on the type of fuel used by the cookstove as well as its design. Finally, there is abundant evidence on the negative environmental impact of traditional cookstoves, but evidence **on the positive impact of clean cookstoves on the environment is limited.** Therefore, **a continued focus on generating rigorous and comparable evidence is instrumental to furthering the clean cooking agenda and supporting governments, the private sector, development finance institutions, and other institutional investors to inform program design and steer investments.** Additionally, the role of community organizations to support the adoption of clean cookstoves requires further investigation as, for example, women collectives can play a promising role as financing sources and facilitators. Such cross-cutting evidence is relevant not just for the clean cooking movement but also for other areas like social protection and financial inclusion. **Development finance institutions (DFIs) have the resources, motivation, and leverage to promote the generation of such evidence, by creating incentives for multi-disciplinary research in the different domains they invest in.**

Evidence on the impact of cookstoves on economic, health, and environmental outcomes, as well as their adoption and usage, is highly dependent on their design. Furthermore, the evidence also suggests that how clean cookstoves are used have implications for any associated effects on health. This is corroborated by the country-level case studies presented above. For instance, in Ghana, the cookstove market is primarily dominated by the locally produced Gyapa charcoal stove, which is suited to the specific cooking styles and requirements of users. While it is widely used in urban and peri-urban areas, it does not translate into significant reductions in emissions, suggesting room for innovation in product design. **Therefore, cookstove designs and, consequently, production models must be tailored and adapted to the market where they are intended to be deployed with both quality and affordability in mind.**

In Vietnam, while the reliance on LPG as the primary fuel for cooking has increased considerably in recent years, deaths associated with polluting cookstoves continue to be high, as a result of practices like the continued use of firewood alongside clean fuels. **Consequently, programs and policies focussing on clean cookstoves and clean fuels should focus not just on designing and furthering the adoption of clean cookstoves but also on increasing awareness on how to use them. In addition, clean cooking enterprises also have a role to play in facilitating correct methods of use for their customers.**

The six country case studies presented in this report suggest that there is considerable variation in the cookstove market in low and middle-income countries. Accelerating the adoption of clean cookstoves thus requires an improved understanding of the complex demand and supply-side barriers faced by the actors operating in this sector. First, it is evident from an analysis of the current

literature that the most **effective policies are those that are tailored to local economies, culture, and consumer habits.** This has implications for regulations that govern different aspects of clean cooking, such as the design of cookstoves, access to financing, as well as capacity-building support given to enterprises.

An important challenge faced by the clean cooking industry, as emerged in Key Informant Interviews, is access to financing, both by consumers and enterprises. Current levels of access to formal finance are severely inadequate for the sector and its growth targets, a view substantiated by the interviews conducted as part of this study. **As a result, the sector relies on a variety of arguably sub-optimal options, such as a combination of subsidies, grant-based financing, and modalities like carbon credits.** Additionally, qualitative interviews show that the sector's reliance on grant-based funding and subsidies does not reduce the risk of debt or equity financing for formal financial institutions, which is mostly concerned with the profitability of cookstoves businesses net of the grants they received. In addition, they result in the emergence of enterprises with sub-optimal business models, leading to a vicious circle. In summary, the gap in financing is one of the foremost problems faced by clean cooking businesses. **While a short-term solution is not possible for such a systemic challenge, governments and large institutional donors that invest in clean cooking must focus on building their investees' ability to access formal finance, which depends on their ability to demonstrate their profitability in both the short and long term.**[86] In practice, this translates into building the sector's understanding of best business practices, as well as supporting initiatives that increase the efficiency and access to a market of clean cookstoves businesses. In addition, national governments, as well as multilateral organizations, should focus on promoting alternate forms of formal finance, both on the supply-side (ex: start-up grants for green enterprises) and demand-side (ex: asset financing via MFIs, fintech firms, etc.).

Finally, the success of clean cooking enterprises also depends on their choice of business models, distribution channels, and marketing strategies. The paucity of rigorous, context-specific evidence on the success of different models, acts as a barrier to growth for enterprises, particularly in the early stage. Once again, **DFIs have the interest and means to play a key role in this regard, facilitating the development of best-case practices, as well as investing in rigorous monitoring and evaluation of different business models and strategies, with the objective of generating adaptable evidence.** A suitable illustration of this gap is after-sales support systems. Despite their acknowledged importance, supported by qualitative interviews, there is no empirical evidence demonstrating the impact of after-sale support systems or supporting one way or implementing them against the other. As a result, enterprises often prioritize other expenses over setting up after-sales support systems, which may constrain their growth in the longer run.

Last but not least, understanding the behavioural and economic factors that drive adoption are at the heart of furthering the clean cooking agenda. Evidence from literature and the country-level analysis presented in this report show that an increase in reliance on clean fuels for cooking, or an increase in adoption of LPG due to a state-wide regulatory push, does not necessarily result in transformative outcomes like the discontinuation of solid fuels. Behaviours like stacking clean and dirty fuels continue alongside the use of clean cookstoves, which undermine the impact of the clean cooking movement. **Focusing on understanding what motivates household choices and behaviours can help inform the design of targeted interventions that further clean cookstove usage, while reducing the use of solid fuels and traditional stoves.** Overall, the right combination of programs and policies, as well as improved financing options, and targeted cookstove design, is required to further promote the adoption and use of clean cooking.

[86] Naturally, since clean cookstoves can lead to some positive externalities, a case can be made in support of subsidies. However, investors need to go into this kind of arrangement knowing that in that case there could be an issue with sustainability of the investment.

In addition to this, the insights from the case study analysis highlight the importance of gaining a more nuanced household-level understanding of the needs of the end-users. For instance, in the sample, larger households are more likely to be using clean cookstoves. However, evidence in literature showcases that modern clean cookstoves are seen as being unable to cater to the demands of large households. Therefore, in order to increase the take-up and adoption of clean cookstoves, it becomes necessary to carry out more context-specific research. Finally, the analysis of the adoption trends across the six countries brings to light the role played by state and national level governments in pushing the clean-cooking agenda, but also its limitations. The transition to clean cooking practices in India and Kenya has been tremendously supported by government policies (subsidies, incentives, and other industry-friendly policies). However, in other countries, the success of government efforts has been mixed. Factors such as infrastructure development, access to markets, and the availability of cookstove models tailored to local cooking styles play a major role in determining the success or failure of government policies. In the absence of strong government commitments, social enterprises and local cookstove businesses have emerged, often supported by international investments, to address the needs of the cleaning cooking industry.

In conclusion and considering the evidence reviewed so far, it is recommended that DFIs abide by the following six principles when investing in clean cookstoves businesses.

1. **Policy matters.** It is essential to understand national priorities and policies with regards to clean cooking. Considering whether policy makers are prioritizing one type of cookstove or fuel over another (through regulations, directives, and adequate budget allocations) can provide important guidance to predict whether an investment has the potential to succeed or not. This has been clearly demonstrated in the country case studies. For instance, the Indian government has been heavily promoting and subsidizing the adoption of LPG-based cookstoves, effectively rendering investments in other types of cookstoves unviable. Additionally, it is recommended to consider the political cycle[87] as well as past policy decisions, weighing for how long certain policies have been in place (as a way to gauge political commitment) and how effectively they have been implemented.
2. **Be explicit about priority outcomes.** Clean cookstoves use a variety of fuels and designs to produce heat, which lead to different outcomes. For instance, an LPG cookstove emits very low levels of particulate matter, which makes them very healthy. However, relying on the extraction of natural gas, their environmental impact is negative. On the other hand, improved cookstoves using biomass might have a minimal impact on the environment, but they still emit harmful particulate matter, though how much depends on the design of each type of cookstoves. Similarly, some cookstoves are more fuel-efficient than others, thus having different impacts on savings both in economic terms and time. One single type of cookstove that maximizes impact across all dimensions (e.g., economic, social, health, environmental outcomes) is practically non-existent. Thus, before making any investment it is essential to understand which outcome is the most important for the local context and select a cookstove design that focuses on achieving that.
3. **Invest in cookstoves that have been created with a Human-Centric Design approach.** The impact of cookstoves is, obviously, conditional on their correct, continuous, and exclusive use. Ensuring that cooks use the clean cookstove that they have bought or have received with minimal assistance, guidance, and incentives is essential and hinges, for the greater part, on the cookstove being designed to fit the needs, behaviour, and preferences of the users or, in other words, using Human Centric Design. In practice (and following human-centric design principles), this means investing time and resources in engaging with users, prototyping, and piloting solutions before their scale-up.

[87] i.e., considering when the next elections are going to be held, what are the stated policy intentions of the various candidates on this topic, etc.

4. **Consider local financial markets.** The sustainability of an investment in this sector depends on the possibility of the investee to access additional sources of finance as well, which will depend on the development, vitality, and rules of the local financial market. In many low- and middle-income countries, it is difficult for clean cookstoves businesses to receive funding from traditional lenders. Therefore, it is important to determine whether an investment is worthwhile if the chances of a business to raise additional funds are low, as well as considering whether financial-sustainability conditions should be tied to the various instalments of the investment (e.g., a payment tranche could be linked to demonstrating profitability and/or raising funds from other sources).
5. **Focus on opportunities that demonstrate mastery of the local context.** It is essential to ensure that investments demonstrate an understanding and account for local social norms, financial markets, and policies, as already mentioned. However, that is not enough, as the local infrastructure (e.g., road network, power supply, etc.), productive capacity, supply chain (e.g., access to fuel, components, etc.), and market (e.g., competitors, costs, affordability of the proposed product) needs to be accounted for as well.
6. **Embed knowledge generation activities.** The report shows that there are some gaps in the literature both in terms of the impact of cookstoves on certain outcomes (especially health and environment), but especially on the effectiveness of different products, marketing, and distribution strategies. Embedding knowledge generation activities to future investments in clean cookstoves (e.g., impact and process evaluations, cost-benefit analysis, etc.) will grow the sector's understanding of what works and what does not and will make future investment decisions easier and more impactful.

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APPENDIX

Annexure 1: Additional Factors Determining the Economic Success of Cookstove Businesses

Safety Regulation and Standards

Regulations establishing minimal acceptable standards for cookstove performance are critical to reduce safety risks in handling, distribution and usage. Cookstove durability, an indicator of a cookstove's shelf-life and longevity, encompasses multiple aspects such as the performance, safety, value for money, and quality perception. The Global Alliance for Clean Cookstoves, along with the Centre for Energy Development and Health at Colorado State University developed a *Cookstove Durability Protocol* in 2014, aimed at standardizing assessments and claims of cookstove durability in literature.[88] The protocol outlines the tests cookstoves are subjected to, and list four aspects of cookstove quality that the tests are based on:

- Performance - will the cookstove's performance and safety change with time?
- Reliability - will the cookstove continue to perform as expected/promised?
- Durability - will the cookstove last/how long will it last?
- Perceived Quality - will end-users feel like their cookstoves, regardless of actual performance, are good value for money?

Aside from this protocol, the International Organization for Standardization (ISO) is currently the best available international guidelines for cookstoves and fuels. ISO has published an international standard for testing cookstoves under laboratory conditions in 2018.[89] The standard specifies

[88] https://www.cleancookingalliance.org/binary-data/DOCUMENT/file/000/000/89-1.pdf

[89] https://energypedia.info/wiki/Standards_for_Improved_Cookstoves#The_International_Standard_ISO

protocols for conducting tests and reporting findings to measure and evaluate durability, safety, efficiency, and emissions of cookstoves in a lab setting. The Standard Test Sequence is a protocol to measure thermal efficiency, fine particulate matter, carbon monoxide, and optionally black carbon. Additional protocols also outline how to assess safety and durability. It is applicable to stoves used for cooking or water heating in domestic or small-scale enterprise settings. An international standard for the field testing of cookstoves is in the works, which should be valuable in lending uniformity to assessments of cookstove durability.

International standards need to still be modified to the local context. Most of the standards developed by ISO allow for customization while still maintaining harmonization in testing, to cater to local context.[90] However, the performance of any given technology will differ under real-use conditions and is highly influenced by conditions such as usage, local practices. ISO, therefore, recommends field testing of any cookstove to assess performance and impacts. At the same time, high-quality cookstove testing centres (Regional Testing and Knowledge Centers (RTKCs)) are still scarce in the developing countries which impedes the implementation and customization of these regulations.

Research and Development

Traditionally, the proliferation of improved or clean cookstoves for domestic use came about as a consequence of humanitarian aid or official development assistance (ODA). With the global clean cooking movement gaining traction, and the subsequent commercialization of the sector, the emergence of new players has been accompanied by innovation in clean cooking practices and cookstove design (Differ, 2012). While electric cookstoves and clean fuels cookstoves (using solar energy, methane, ethanol, or biogas) are the superior forms of clean cookstoves measured by direct emission, their adoption continues to be cost-prohibitive, on account of factors like poor access to electricity in rural areas, and the massive upfront costs of adoption (Mudombi et al., 2018). Consequently, biomass cookstoves – the least clean among the clean cooking trinity – has emerged as the most viable alternative, and consequently, the one which has enjoyed the most changes in design as with the advent of the commercial clean cooking sector.[91]

On the basis of design typology, biomass cookstoves may be classified as manufactured rocket stoves, which are factory-made and mass produced, or as *improved cookstoves*[92] (ICs). ICs are produced locally, and typically made with locally available build materials like clay or ceramics. Often made by artisans or small enterprises, ICs are the most affordable clean cooking devices for end-users, due to the lower transportation and production costs. Depending on specific design attributes, ranging from smaller ceramic stoves to larger stoves with attachments like chimneys, the prices and durability vary accordingly.

The discussion on cookstove design would be incomplete without paying heed to the consumer perspective. Literature on clean cookstove adoption show that along with reduced cooking times and fuel consumption, the design attributes that are closely linked to consumer satisfaction are a cookstove's *size, usability, and functionality.*[93] These attributes, in turn, are highly contextual to the food habits and kind of domestic cooking common to a region (Goswami et al., 2017). For example, cookstoves that are the wrong size to cook a traditional recipe are unlikely to find a significant buy-in in regions where that dish is a staple. Similarly, build materials that are less effective at handling

[90] ISO has already developed national standards for cookstoves for a few countries such as Indonesia, Bolivia, Peru, Uganda, and Kenya.

[91] https://www.cleancookingalliance.org/resources_files/a-rough-guide-to-clean.pdf

[92] Ibid

[93] Ibid

heat or more difficult to stir or move limits the functionality and usability for the end-user. Clean cookstoves that resemble traditional cookstoves aesthetically have been found to be more readily accepted by consumers (Bensch et al., 2015).

Like any consumer product, the cookstoves industry has also witnessed innovation in recent years. Despite an influx of multinational entrants, there continues to be a noticeable gap between consumers' wants and needs, and a variety of products that cater to these different needs (GACC, 2011). While commercially available cookstoves traverse the gamut of advantages, ranging from efficiency, safety, and affordability, there is a dearth of options that tick all or most of these boxes.[94]

Technological innovation, however, has paid dividends in other aspects. Applications that support cookstoves with additional functionalities are on the rise. For example, some cookstoves whose heat emissions are used to generate electricity, which in turn power fans that make the cookstoves burn with greater efficiency, eliminating the need for a power source or battery.

At the outset, the sector has adopted three different models[95] of research and product development (World Bank, 2015). The models, and each of their advantages and shortcomings are summarized in the table below:

Type of Model	Characteristics	Advantages	Shortcomings
Local Design model	Characterized by local players being at the forefront of R&D. Product development is informed by local context.	Accurately meet the needs of the local market, due to their familiarity with local context and consumer preferences.	Products developed with local markets in mind, and with locally-based resources tend to lack the capacity and access to finance required to produce high quality models.
International Design model	Characterized by the adoption of globally tried and tested designs to local markets. This model lends itself to product uniformity.	Stoves designed this way use materials of superior quality, and provide end-users with greater benefits.	These stoves often fail to cater to the specific preferences of local consumers, and tend to be cost-prohibitive on account of their superior build quality.
Hybrid model	Under the hybrid model, stoves and/or parts are devised in international settings, and adapted in accordance to the specific preferences of local markets.	By combining the favourable aspects of both the local and international models, the hybrid model is, in theory, the most suited to robust R&D.	Adopting this model is difficult in practice, given the challenges in integrating different designs.

As R&D in the clean cookstoves and fuels industries gathers momentum, it is crucial that the aim of such efforts be to develop solutions that customers find useful and attractive in coming years, and not just in the present day. This must be kept in mind as financing is fuelled into the development of advanced cookstoves, producing cleaner fuels, and in promoting end-user participation in cookstove design.

[94] https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/272-1.pdf

[95] https://openknowledge.worldbank.org/bitstream/handle/10986/21878/96499.pdf

Production Models

Different production processes and technologies have differing cost structures, and these vary widely by the cookstove design and local conditions. ESMAP and Clean Cookstove Alliance (2015) interviewed manufacturers in Africa and India to understand how different components in the value chains of these three production processes contribute to the final price paid by a customer. The following is adopted from their findings,

Process	Production Method		
	Industrial	Semi-Industrial	Artisanal
Raw Materials	15-40%	20-40%	30-50%
Labour	5-15%	10-20%	15-25%
Manufacturing Margin	5-15%	10-15%	*
Shipping and Import Duties	0-40%	0%	0%
Taxes	10-15%	10-15%	0%^
Local Transport	5-15%	10-20%	10-25%
Distribution Costs	5-20%	5-15%	10-30%
Price Subsidy	0-50%	0-50%	0%

*Note: *The cost of manufacturing in Artisanal models is included in Labour costs. ^Taxes are 0 because this model lies outside the formal sector.*

In the last few years, due to increased competition and often government intervention, there is downward pressure on prices. To achieve low prices, ESMAP recommends manufacturers to move towards local production and investing in low-cost designs.

Annexure 2: Additional information on country briefs

This section reports information that, while interesting, was not included for consistency and brevity in the main text of the report.

Vietnam and renewable energy

The Vietnam Annual Electricity Report, 2018 records that the country produces around 56% of its energy from fossil fuel based sources, 35% from hydropower, and only 7% from renewables. The country has achieved around 99% electrification, and energy demand is expected to grow by upto 8% per year from 2021 to 2030. In 2001, a Renewable Energy Action Plan (REAP) was created in consonance with the World Bank to formulate a 10-year programme to encourage development of large scale renewable energy to promote rural electrification and grid supply. The Plan had two phases, the first being five years of capacity building and the second being a five year implementation phase.[96] The Electricity Law 2004 which lays out a comprehensive legal framework on electricity generation, distribution, investment, subsidies, etc. also mandates that investment in renewable energy be made a priority in the generation of electricity.[97] In order to increase the share of renewable energy in power generation, National Power Development Master Plan was introduced

[96] https://www.esmap.org/sites/default/files/esmap-files/vietnamesmap25216.pdf

[97] https://policy.asiapacificenergy.org/sites/default/files/ELECTRICITY%20LAW%20%28No.%2028%3A2004%3AQH11%29%20.pdf

in 2016 that aims to increase the share to 7% by 2020 and 10% by 2030 and also reduce the use of imported coal fired electricity.[98]

In 2015, the government adopted a Renewable Energy Development Strategy 2016-2030 with an outlook to 2050, which sets medium and long term goals, with special focus on biomass, wind and solar technology, to reduce carbon emissions by 5% by 2020, 25% by 2030 and 45% by 2050. A Renewable Portfolio Standard would be introduced as a policy means to ensure that power generation companies set targets set for renewable energy capacity.[99] To finance goals set under the Renewable Energy Development Strategy 2016-2030 the government will set up a Sustainable Renewable Energy Fund, using allocations from the state budget and environmental fees on fossil fuels. The strategy also indicates that measures such as net metering, preferential taxation, and land and environmental permits will be laid out for renewable energy projects.[100]

Kenya: Financing options offered by cookstoves companies

Forms of financing offered by individual cookstove companies:[101]

- Results-based financing, such as by SNV's Clean Cookstove Market Acceleration Project.
- Grants or Concessional Loans to entrepreneurs, such as Africa Enterprise Challenge Fund and Green Enterprise Challenge by the Micro Enterprises Support Programme Trust.
- Impact investment in enterprises such as in BURN Manufacturing, BiolLite, PayGo Energy, etc.
- Lay-away Business models, used by organisations such as Koko Networks which encourage customers to put away savings for ethanol fuel and stoves.
- Carbon financing by organisations such as Hivos, which works to install biodigesters.[102]
- MicroEnergy Credits is an organisation which has partnered with a commercial bank in East African called Equity Bank and an asset financing company named Juhudi Kilimo to offer access to microfinance for clean energy solutions in low income households.[103]
- The Livelihoods Hifadhi Project collects carbon funding from private companies like Danone and Michelin to two organisations (EcoAct and ClimatePal) who will arrange for the production, quality control and distribution of clean cookstoves to 600,000 people by 2029. The companies are rewarded with Gold Standard carbon credits.[104] A similar project by Toyola stoves and financed by E+Co also distributes clean cookstoves and makes Gold Standard carbon credits available to investors.[105]

[98] https://www.vietnam-briefing.com/news/vietnams-push-for-renewable-energy.html/#:~:text=The%20PDP%20VII%20plan%20aims,and%20sustainable%20socio%2Deconomic%20development

[99] https://www.iea.org/policies/6095-vietnam-renewable-energy-development-strategy-2016-2030-with-outlook-until-2050-reds

[100] https://www.iea.org/policies/6095-vietnam-renewable-energy-development-strategy-2016-2030-with-outlook-until-2050-reds

[101] https://ccak.or.ke/index.php/resource-centre/ccak-research-papers/send/2-ccak-downloads/12-hand-book-for-sensitization-on-clean-cooking-technologies-for-public-officers

[102] https://hivos.org/program/carbon-finance-program/

[103] https://shiftingparadigms.nl/projects/microfinance-as-the-solution-to-disseminating-efficient-cookstoves-and-solar-lanters-in-kenya/

[104] https://livelihoods.eu/the-livelihoods-carbon-fund-doubles-its-investment-in-an-energy-efficiency-project-to-reach-600000-people-in-kenya/

[105] https://livelihoods.eu/the-livelihoods-carbon-fund-doubles-its-investment-in-an-energy-efficiency-project-to-reach-600000-people-in-kenya/

	Ashanti Region	Brong Ahafo	Central Region	Eastern Region	Greater Accra	Northern Region	Upper East Region	Upper West Region
Traditional Charcol stove (scrap Metal)				■	■	■	■	■
Traditional Charcoal stove (Mild steel/ aluminium cast)	■	■	■	■	■	■	■	■
Tyre Rim Charcoal Stove				■		■	■	■
Improved Charcoal Stove	■	■	■		■	■	■	■
Firewood Stove						■	■	■
Tyre Rim Firewood Stove			■	■		■	■	■
Saw Dust Stove						■	■	■
LPG Stove	■	■	■	■	■	■	■	■

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