Sustainable Scaling: Meeting the Clean Cooking Challenge in Africa

MECS Modern Energy Cooking Services

AFRICAN UNION AFREC ENERGY
African Energy Commission
Commission Africaine de l'Energie

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Preface

This report had its origins in a series of discussions that took place between MECS and AFREC colleagues at the margins of the 28th COP meeting held in Dubai in December of 2023. That COP represented the latest step in a marked upturn in the attention paid to clean cooking across the international community during 2023. The UN's 'ACHIEVING UNIVERSAL ACCESS AND NET-ZERO EMISSIONS BY 2050: A Global Roadmap for Just and Inclusive Clean Cooking Transition' (which drew heavily on the extensive analysis carried out by MECS and our partners in the State of Access to MECS report published in September 2020) was prepared in support of the SDG7 review at the High-level Political Forum 2023 and will continue to guide the approach taken towards clean cooking adopted by the UN, the WHO and the World Bank. 2023 also saw the first major publications focusing entirely on clean cooking from the IEA and IRENA. COP 28 then saw the first ever main stage discussion of clean cooking issues via the launching of the Global Electric Cooking Coalition (GeCCo), as well as the announcing of a major new initiative, the Africa Clean Cooking Consortium (ACCC) by the African Development Bank (AfDB), the International Energy Agency (IEA), and the Clean Cooking Alliance (CCA). Since COP, the IEA has followed up on this announcement by organising a Summit on Clean Cooking in Africa designed "to make 2024 a turning point for progress on ensuring clean cooking access for all."

One of the most important issues that we discussed was the need for the drive to tackle clean cooking in Africa to be built upon the commitments of African governments and delivered by African institutions in partnership with their international partners. It must also be built upon a clear understanding of the dynamics of each individual African nation and its complex patterns of resource endowments, cooking cultures, institutional environments, economic circumstances and global relationships. There is no magic bullet. This report is, then, a response to this growing international interest in clean cooking. It offers a comprehensive overview of the current state of knowledge about the sector, the importance of the significant differences that exist between African states and the various interpretations of how resources raised to support tackling the issue should best be targeted and the evidence which they rely upon.

The Report will:

- Outline the scale of the clean cooking challenge in Africa (distilling the insights provided by the recent global-level publications mentioned above);
- Present a state-of-the-art summary of the different data sources, the energy system models and the focused clean cooking models currently available (and in development) and their ability to provide guidance for the development of effective long-term sustainable clean cooking strategy development and cost implications;
- Outline the key factors affecting the supply, infrastructural development, likely price movements, financing needs and affordability of key modern energy cooking fuels and technologies and their applicability to the African context.
- Apply a widely applicable clean cooking decision matrix, and accompanying indicators, to scalable country-level case studies and implementation pathways
- Provide a series of key recommendations for effective national clean cooking strategy development for all options of fuels, as well as how effective delivery can best be orchestrated.

Executive Summary

(To be developed after final consulation)

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1. The Role of Clean Cooking in Economic Growth

"The African Union has ambition" (AUC and OECD 2022). Under Agenda 2063, African governments are seeking to achieve at least 7% growth per year to catch up with the rest of the world, create jobs and reduce inequalities. Real GDP growth is thought to have returned to 3.7% in 2023, the second highest rate in the world after developing Asia (AUC and OECD 2023). However, the task is daunting, with the latest estimate being that Africa's sustainable financing gap until 2030 is about **US$ 1.6 trillion**. On the positive side of the balance sheet the analysis goes on to note that natural resources represent key assets for African economies (Natural capital accounts for 19% of Africa's total wealth) and domestic government revenues amounted to USD 466 billion in 2021, equivalent to 17% of GDP. On the negative side they note high average inflation, 8 countries that are in debt distress, and that the cost of capital has become higher than other regions.

Against this backdrop of ambition an often-neglected contributor to a healthy economy is a healthy population. Inaction on clean cooking results in loss issues in gender equality, health, and climate and turns a domestic opportunity for industry and commerce into a neglect of emerging possibilities and wealth creation. This first section of the report presents the scale of the challenge that the reliance on polluting fuels for cooking represents.

It begins by presenting an assessment of the costs imposed by the current state of access in terms of issues such as gender equality, health, and climate. Whilst circumstances across the whole of Africa are addressed, there is a focus in this section on the Sub-Saharan region—which remains the most challenging both in Africa and the world. This is then followed by the identification of the main barriers to the scaling up of access at a household and consumer level. Finally, an overview of solutions and recommendations on how to overcome the access barriers is provided, including financing mechanisms, regulatory frameworks, and best practices. The key messages are:

- **Out of track on SDG7 Targets** — Data from the World Health Organization and the recent Energy Progress Report (2022) on Sustainable Development Goal 7 (SDG 7) indicates a significant lag in the transition of clean household fuels. Without dramatic acceleration in the coming years, SDG 7 in Africa will be missed by a wide margin.
- **Disproportionate Access** — Between 2010 and 2021, the rate of access to clean cooking fuels and technologies in Africa increased at an average annual rate of 1.76%. While some individual countries have made significant advances, the successes are overshadowed by the alarming slow progress in Sub-Saharan Africa where progress has not even managed to keep up with population growth.
- **The Rural-Urban Divide in Clean Cooking Access** — The access gap between urban and rural areas has widened over the last two decades, with rural areas experiencing only 5.8 percentage point decrease in the use of polluting fuels for cooking (from 86.6% in 2000 to 80.8% in 2021), while significant progress has been made in urban settings although 58.3% still rely on polluting fuels to meet its cooking needs.
- **The Cost of Inaction** — The cost of continuing the current state of access sum up to **US$ 791.4 billion** per year, by negative externalities of gender equality, health, and climate.

Note – Data for this section has been gathered by ESMAP at the World Bank, sources appearing as notes in figures. The methodology used for the Cost of Inaction (Section 1.2) is based on analysis conducted by MECS and their partners, as outlined in the State of Access to MECS report published in September 2020.

1.1. The State of Access to Clean Cooking Services

1.1.1. General overview of the Clean Cooking Challenge.

As part of the Sustainable Development Goals, in 2015, the United Nations (UN) set a target to provide every person access to clean energy including fuels for cooking by 2030 (SDG indicators 7.1.1 and 7.1.2). The actual definition of access used for the UN target is quite vague – "the proportion of population with primary reliance on clean fuels and technology for cooking." Replicating the approach taken in the UN Roadmap, we prefer a definition that takes the widespread practice of fuel-and-stove stacking into account. Drawing on the Multi-Tier Framework (MTF) for cooking, "households can be considered to move out of cooking poverty and have gained access to **cleaner cooking solutions** when they primarily or mainly cook with fuels such as LPG, natural gas, electricity, biogas, ethanol, or very low-emission biomass stoves meeting at least tier 3 of the MTF. Households are considered to have gained access to **Modern Energy Cooking Services** (MECS) when all fuels and technologies in the home are all MTF Tier-4 or above; while those that rely on traditional (polluting) or transitional cooking fuels and technologies (tiers 0-2 of the MTF) are considered in **cooking poverty**." (World Bank, 2020)

However, progress towards these targets has been insufficient with access to clean fuels and technology for cooking remaining a major challenge. According to the latest data, 2.3 billion people globally—nearly one in three individuals—still rely on three-stone open fire and other traditional stoves to cook their meals, using wood, charcoal, kerosene, coal and even animal waste (IEA, 2023) and hence remain in cooking poverty. Globally, the clean cooking challenge is most prevalent in Sub-Saharan African countries, where the access rate to clean fuels and technologies for cooking was only 18% in 2021 (Global Health Observatory, 2023).

Counting with data from 53 African countries, the rate of access to clean cooking fuels and technologies increased at an average annual continent-wide rate of 1.76% between 2010 and 2021. While some countries have made significant advances (e.g. Cabo Verde, Congo Republic, Egypt, Eswatini, Gabon, Ghana, Lesotho, Mauritius and South Africa) the successes are overshadowed by the alarming slow progress in Sub-Saharan Africa, where reliance on polluting fuels for cooking has only dropped from 91% of population in 2000 to 82% in 2021. If current trends persist, projections indicated that by 2030, four out of every five people in Sub-Saharan Africa will still endure the health and socioeconomic burdens associated with cooking poverty (Stoner et al., 2021). Figure 1 depicts the progression of access rates across five Africa regions from 2000 and 2021, with arrows indicating the direction of progress. In some countries, arrows point backward, indicating that population growth has outpaced the annual increase in access to clean cooking fuels.

At a regional scale, the access gap between urban and rural areas has been widening in the last two decades. The percentage of people in rural areas in cooking poverty decreased only by 5.8 percentage points between 2000 (86.6%) and 2021 (80.8%). Conversely, strides have been made in urban settings, where the population of those in cooking poverty appear to have fallen from 69.1% in 2000 to 58.3% in 2021 (REF).

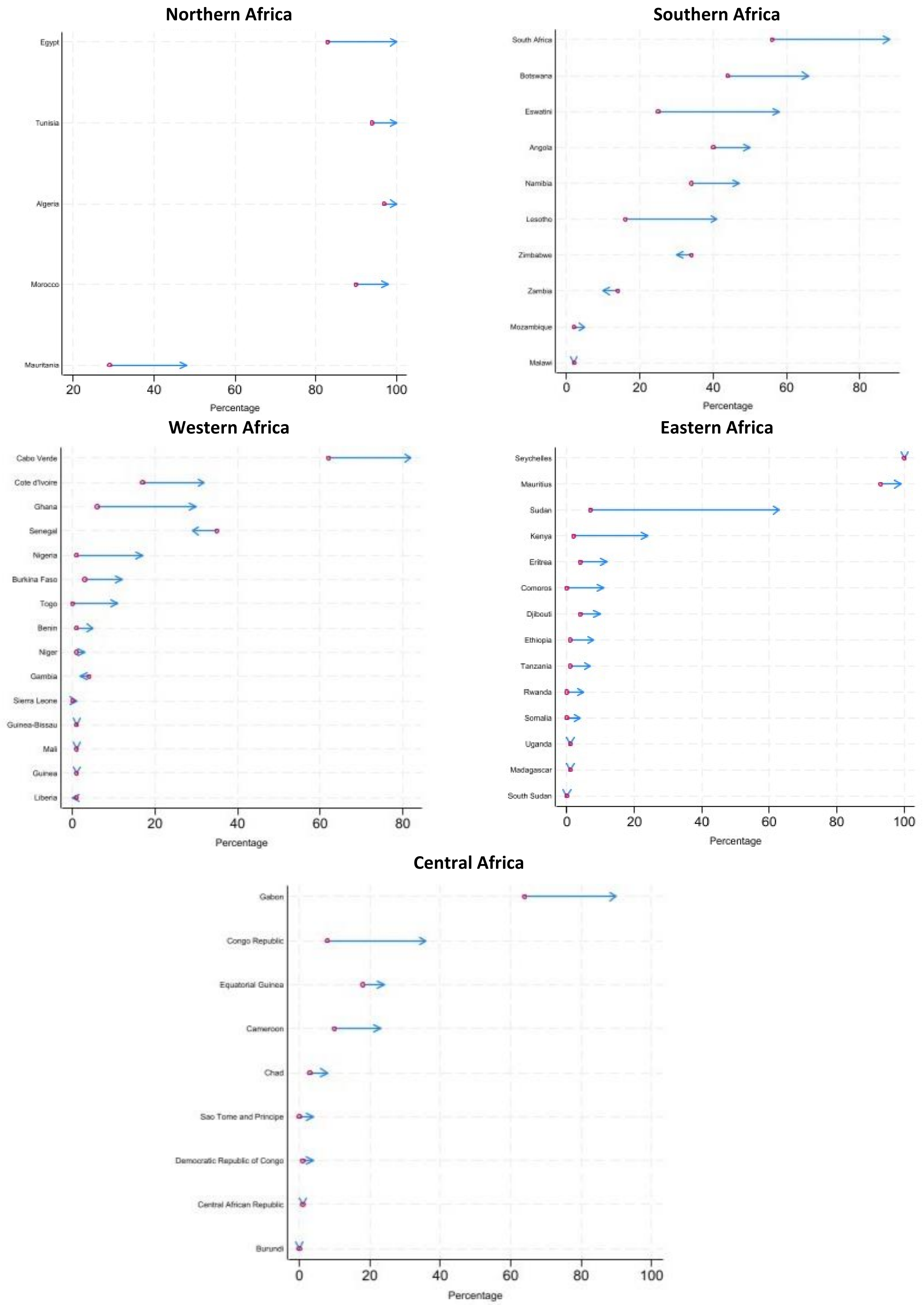


Figure 1. Access rate to Clean Fuels and Technology for Cooking, 2000-2021. (Author's own elaboration based on World Health Organization, Global Health Observatory. The figure uses AU regions and associated country classification.)

The graphs in Figure One also illustrate the diversity of experience across Africa, with some countries already enjoying high levels of access (mainly LPG or LNG based) at the start of the period (e.g. most North African states, Capo Verde, the Seychelles, Mauritius and Gabon). Elsewhere, increases in the use of clean fuels as the primary cooking fuel appears to be principally attributed to a considerable decrease in the use of unprocessed biomass and a shift to LPG, driven by the growth of LPG programs in some countries (e.g. Ghana, Cameroon). However, the primarily reliance on charcoal persists and is increasing in urban areas of Sub-Saharan Africa, where it was used by 30 percent of people in 2021 (IEA, 2023b).

Transitioning to clean cooking delivers immense benefits by saving lives, time, and financial resources, in addition to the positive impact on the environment. Poor air quality from traditional cooking indoors is a major contributor to premature deaths, women and children disproportionately bear the consequences of a lack of clean cooking, forgoing opportunities to pursue schooling, employment, and economic freedom as well as the health consequences. A lack of clean cooking also contributes to deforestation, environmental degradation and greenhouse gases (IEA, 2023). For these reasons, progress in guaranteeing clean cooking access is recognized as a critical cross-sectoral development issue.

More than 78% of the world's people lacking access to clean cooking are found in 20 countries, with 10 of them located in Africa (see Figure 2). Noticeably, access rates remain under 10% in seven of these countries: Democratic Republic of the Congo, Ethiopia, Madagascar, Mozambique, Niger, Uganda, and the United Republic of Tanzania. The situation seems difficult to reverse in those countries, as the average increase in access rates between 2017 and 2021 was less than 0.8 percentage points per year.

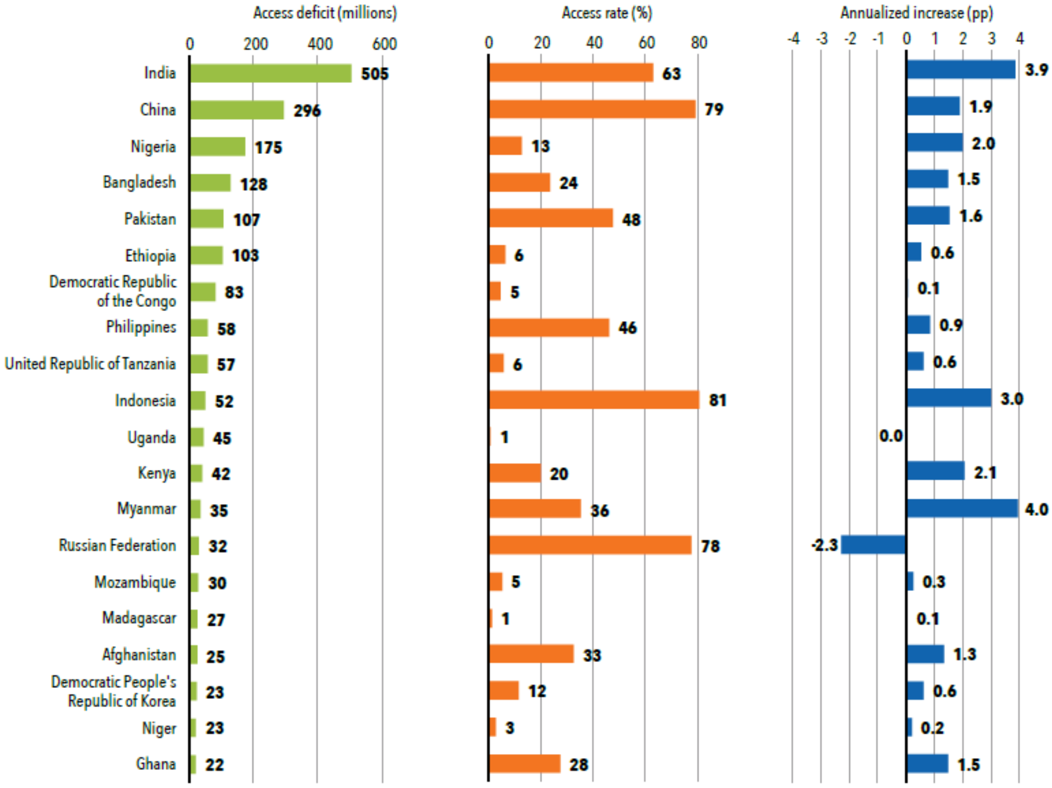


Figure 2: Countries with the largest number of people lacking access to clean fuels and technologies (IEA, 2023)

1.2. Estimating the Cost of Inaction:

1.2.1. Measuring Modern Energy Cooking Services (MECS) access using the Multi-Tier Framework.

In crafting policies aimed at accelerating access to cooking solutions, it is crucial to recognize the intricate dynamics behind cooking practices. Binary metrics, such as clean versus polluting or solid versus non-solid solutions and accompanying services, often oversimplify these complexities and have proven inadequate for capturing the multifaceted reality of household cooking needs. This type of approaches often presumes that all non-solid fuels are clean and efficient while all solid fuels are harmful, overlooking other broader aspects that are inherent to cooking such as convenience, time and effort required for collecting and preparing cooking fuels, as well as safety considerations, availability, and affordability of the resources (ESMAP, 2020).

A more complete and multidimensional perspective is needed to drive progress towards universal access and develop clean cooking infrastructure, fuels, appliances, and services which fit local contexts. To facilitate this shift, initiatives like the Multi-Tier Framework (MTF), developed by the World Bank's ESMAP, in collaboration with Loughborough University, offer a valuable analytical framework to guide progress toward the SDG 7.1 target. The Multi-Tier Framework considers broader contexts in which people cook by defining six technical and contextual attributes of the cooking experience.[1] Using the MTF we can measure the percentage of households with access to Modern Energy Cooking Services (MECS). MECS refers to households that have achieved at least Tier 4 access across all six measurement attributes. Conversely, households relying on traditional stoves, typically biomass-reliant but also encompassing kerosene, which are inefficient and unsafe, emit substantial amounts of particulate matter within poorly ventilated cooking locations, are relatively expensive to use, and have inconvenient fuel access points, cannot be considered to have gained access to MECS and are classified as traditional. Typically, these types of households score below Tier 2 across MTF attributes, and this is where significant strides can be made towards ensuring that all individuals have access to a basket of clean, safe and environmentally sustainable cooking fuels, appliances, and services driven by effective integrated energy planning practices.

In Sub-Saharan Africa, more than two thirds of households score below Tier 2, indicating a lack of access to modern energy cooking access. On the other hand, only 12 % of households have access to MECS, reaching Tier 4 or above, as depicted in Figure 3. It's important to note that households meeting at least Tier 2 MTF standards across all six attributes, but not all for Tier 4, are considered households in transition. In this case, 19% of households have access to these improved cooking services and are nearing the MECS access bar. Understanding how these six attributes interact and determine the degrees of access will prove essential to effective household cooking interventions.

[1] MTF's six technical and contextual attributes are: i) exposure, ii) efficiency, iii) convenience, iv) safety, v) affordability and vi) fuel availability. These six attributes are integrated into the MTF to capture detailed, indicator-level data for tracking stepwise progress across tiers of access. See Annex 2 of ESMAP (2023)

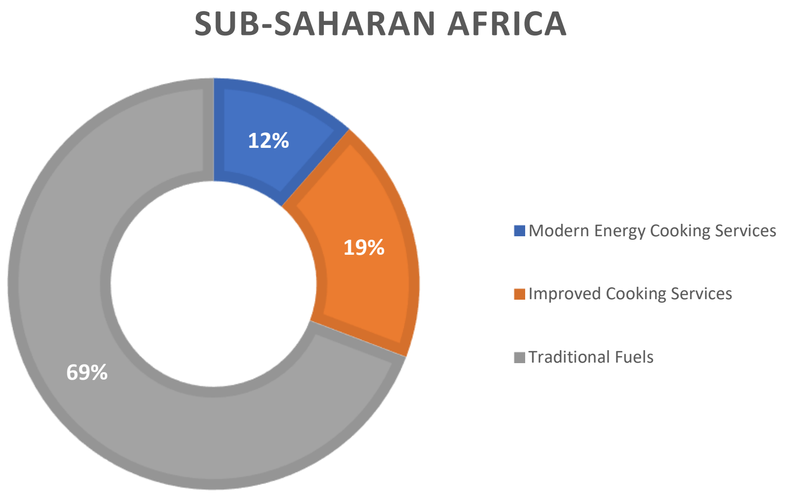


Figure 3: Sub-Saharan MECS Access using the Multi-Tier Framework (Author's own analysis derived from ESMAP's methodology (2023)).

1.2.2. Calculating the Cost of Inaction of sustaining the status quo: Health/Gender/ Climate.

In order to demonstrate to policymakers why they should be investing in effective clean cooking transitions, a number of international agencies have developed methodologies for calculating the costs of inaction on tackling the issue. Research conducted by ESMAP in collaboration with the WHO, calculates that maintaining the current state of access incurs an ongoing cost of US$ 791.4 billion per year, driven by negative externalities of health, economy, and climate. Reliance on polluting fuels for household cooking needs is a primary contributor to indoor air pollution, leading to substantial morbidity from respiratory and cardiovascular diseases and resulting in millions of deaths regionwide. Women and children, who traditionally spend more time in proximity to cooking areas, are particularly the most vulnerable. The health impact of this total sum is estimated at US$ 526.3 billion per year, calculated by quantifying the deaths and disability-adjusted life years (DALYs) linked to household air pollution produced by stoves and fuels.

The absence of access to clean cooking services also has economic impacts and exacerbates gender inequality in different spheres, since women also bear the burden of unpaid labour activities like fuel collection and cooking. The economic cost from these elements is estimated at US$225.8 billion annually, reflecting the time women spend daily on cooking-related tasks, including fuel collection, cooking, and stove cleaning.

Furthermore, the environmental impact of continued reliance on polluting cooking fuels is significant, calculated at US$39.3 billion per year. The release of greenhouse gases and other pollutants exacerbates climate change and its associated consequences. The dollar value of the climate impact is driven by carbon prices and the social cost of carbon[2]

[2] See Annex 2 of ESMAP (2023) The State of Access for cost calculations.

The staggering costs linked to the lack of clean cooking solutions and services emphasize the pressing need for coordinated efforts at both national and regional levels to assist households lacking modern energy cooking services in advancing to high tiers of access. Enhancing efforts towards clean cooking can positively impact other development goals such as poverty and hunger eradication, as well as land restoration, as gender equality, public health and mitigation of climate change effects are examples of the benefits of addressing the cost of inaction.

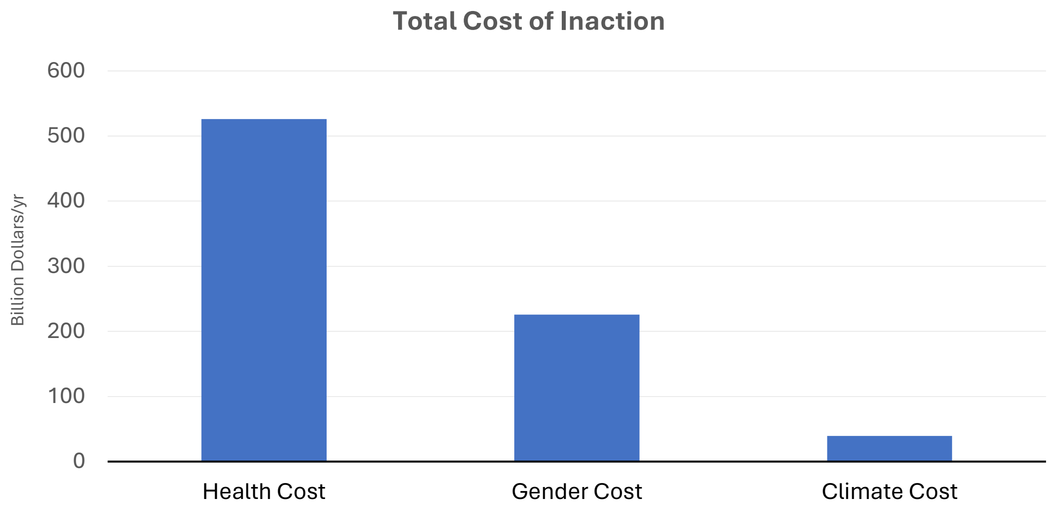


Figure 4: Sub-Saharan Cost of Inaction: Health, Gender, and Climate (Author's own analysis derived from ESMAP's methodology (2023))

BOX. 1 Calculating the Cost of Inaction: Methodological note

The cost-of-inaction estimates in this report rely on three separate calculations aimed at quantifying the annual financial impact of maintaining current cooking practices based on the latest available household fuel mix. These calculations address health, gender and climate considerations and are derived from ESMAP (2023)'s methodology.

Health: The calculation for health costs follows a top-down methodology. It takes country-specific values for deaths and disability-adjusted life years (DALYs) due to Household Air Pollution, which are multiplied by a gross domestic product per capita figure. Finally, this value is multiplied by a cost multiple specific to DALYs or deaths.

Gender: The gender calculation follows a bottom-up approach. It involves applying a multiple factor analysis for annual time spent on fuel collection, cooking and stove cleaning to each country's primary-fuel proportion, using the latest household-fuel mix data. Each factor varies by fuel type. This aggregate value of time is then multiplied by a conservative value of the cost of woman's time.

Climate: The climate calculation relies on the application of a fixed social cost of carbon to the estimate of the carbon footprint of the current cooking fuel mix. The estimation of the carbon footprint of the current cooking-fuel mix (tons of CO2eq per year) follows a bottom-up analysis. The carbon footprint of each country is multiplied by a social cost of carbon of US$45.92. This cost value is sourced from the United States Government Interagency Working Group and the New York University School of Law.

1.3. The Challenge of the modern economy:- awareness, credit, coordination and integration.

1.3.1. Household and Consumer Barriers.

Despite the potential impact of clean technologies to enhance health and wellbeing, adoption rates over the last 20 years remained surprisingly low in many countries. Understanding the nature of these constraints more comprehensively will help facilitate the design and adoption of more efficient policies and solutions, especially where elements of a modern economy (digitalisation, innovative credit and finance pathways, improved policy framing) offer new possibilities for overcoming traditional barriers.

Gill-Wiehl et al. (2024) highlight as barriers the affordability, unreliable supply, social acceptability, household socio-economic and demographic characteristics and low perceived benefits of transitioning to modern cooking technologies. Although the reasons explaining the low adoption rates have been the subject of debate, one of the most common arguments suggest that the main barrier is the lack of awareness about the harms of traditional biomass cooking and the availability of alternatives among households in many developing countries (Clean Cooking Alliance, 2011). This factor clearly affects the purchase rates of cleaner products (particularly the more expensive solutions) and raises the bar for new entrants wishing to sell clean cookstoves in sufficient quantities in order to be profitable. . Whilst awareness is clearly a major issue, other studies have identified that affordability and credit constraints are significant determinants of household choices over cooking fuels and appliances (Gil-Wiehl et al., 2021).

In addition to the affordability issues, Gill-Wiehl et al (2021) highlight as additional barriers the unreliable supply, levels of social acceptability, household socio-economic and demographic characteristics and the frequently low perceived benefits of transitioning to modern cooking technologies. Household-level data confirms that cooking is the main energy service for the poor and the very poor. Utilizing harmonized household surveys by the Global Monitoring Database of the World Bank, we estimate an energy budget detailing all expenses on fuels incurred by households. We observe that households in the first quintile spend three times as much on traditional fuels as those in the top quintile, primarily to cover cooking needs. In Togo, for example, the bottom 20 percent of households allocate nearly 90% of their energy expenditures on polluting fuels whereas the top 20 percent of households spent one-third of their expenditures. ~~This responds to the low rate of access on clean cooking fuels~~ (11% of access in 2021). In Senegal, where access rates to clean cooking fuels has been decreasing, the first quintile of households allocate almost 80% of their energy budget on traditional fuels while the fifth quintile only allocate a little more than 30%. This is a pattern consistent across regions, so one of the main goals for an effective clean cooking strategy is to decrease the financial costs for the poorest quintiles and develop innovative financial mechanisms that can permit a larger technological uptake.

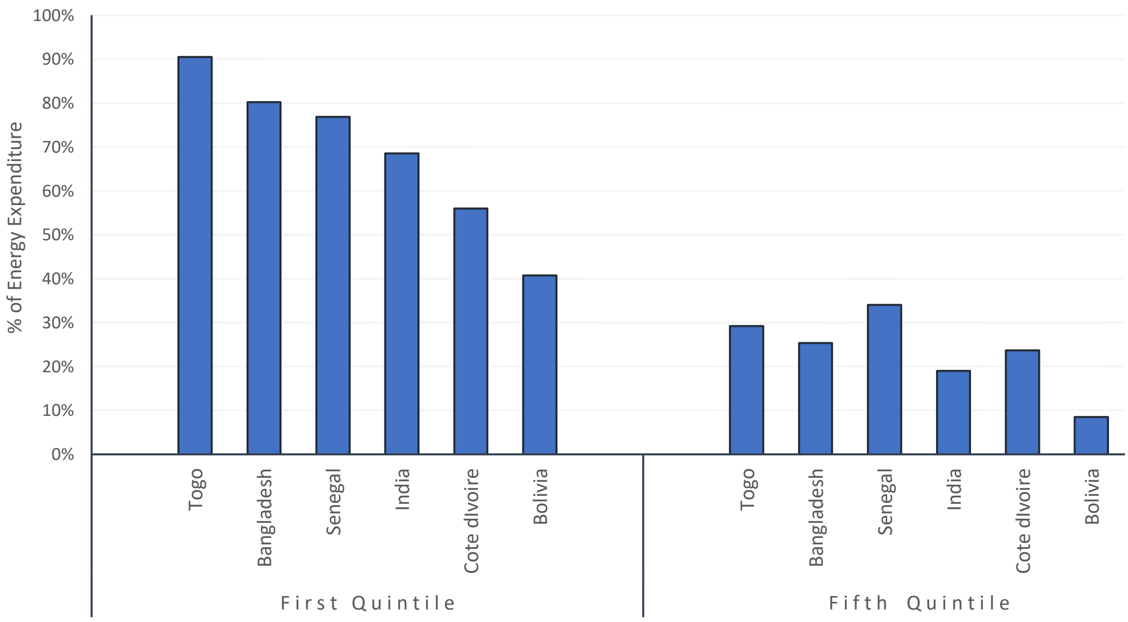


Figure 5: Household expenditures on traditional cooking fuels as % of energy expenditures (Author's elaboration based on harmonized household-level survey data extracted from World Bank's Global Monitoring Database (GMD))

Further illustrating the key salience of affordability to take-up, results from a marketing experiment in Uganda showed that in no instances did the use of marketing messages demonstrating how fuel-efficient cookstoves can improve health or save time and money lead to an increased willingness to pay amongst Ugandan consumers. On the other hand, willingness to pay increased by 40% when a scheme for paying by instalments was introduced, suggesting that at least in this case economic barriers are more important than informational barriers (Beltramo et al., 2015). Similar findings came from another experimental study in Uganda where Levine et al (2018) offered two different fuel-efficient cookstoves at local market prices, but experimentally varied the terms of sales offered in two different settings. In urban settings, they observed high demand for charcoal efficient burning stoves when they were offered as a combination of a one-week free trial followed by four equal weekly payment instalments (46% uptake). In rural settings, they found a similar uptake of wood-burning fuel-efficient stoves when marketed with the same type of offer (57% uptake). This reinforces the need to overcome important barriers, such as liquidity constraints, to unlock the potential demand for environmental, efficient, and health-enhancing technologies.

Berkouwer and Dean (2022) also suggest that opportunities for low-income countries to lower emissions and simultaneously generate welfare gains for households frequently remain unexploited due to the presence of credit constraints or a lack of financing mechanisms. Reporting on an experiment in Kenya, where households were offered a loan to buy a fuel-efficient charcoal, they found that this doubled their willingness-to-pay for it. A similar model has been followed under the "Bottled Gas For Better Life" programme in Cameroon and Kenya which has provided loans (around $100) to poorer households to purchase LPG start-up kits. Research by Liverpool University on the two phases of the programme found that a strong majority of loans had been repaid and LPG usage per household had grown significantly (The Global LPG Partnership, 2019). This suggests that a first-best policy to adopt efficient and less polluted technologies would be to address affordability constraints, especially for the very poor.

1.3.2. Market Barriers: Distribution and Supply Chain Issues.

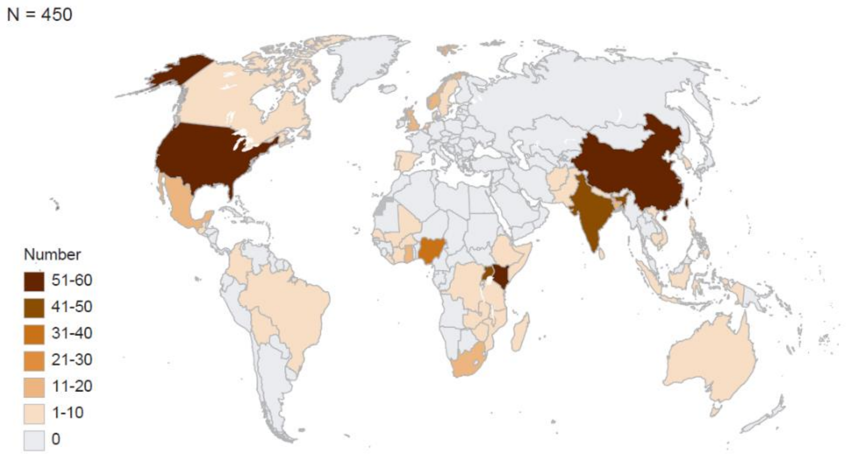
In well-functioning markets, even individuals with limited financial resources would opt to invest in fuel-efficient cookstoves if the savings on fuel expenses outweighed the initial cost of the stove in a short period. However, as Rahut et al. (2016) demonstrate using evidence drawn from across Sub-Saharan Africa, that households unsurprisingly tend to rely more on traditional and solid fuels the farther they are from those supplying alternatives..

Shankar et al. (2020) reviewed eleven clean cooking programs in low- and middle-income countries. The list of programs includes five LPG interventions, two programs on Ethanol, two on Biogas and two on compressed biomass pellets. Supply shortages, distance to refill, and supply and logistical barriers were identified as some of the primary reasons behind continued stacking behaviour with solid fuels regardless of the type of clean fuel intervention. Underscoring the need for investment in clean energy infrastructure and access points for sustained use.

The presence of better developed supply markets for fuels in these locations functions as an important driver for most types of cookstove adoption (in the case of electric cooking we can make a similar point about the reliability of electricity supply). Van der Kroon et al. (2014) discuss how the supply chain of modern energy cooking services has made significant strides in recent years. Innovations in products and business models are enhancing the convenience and safety of cooking with innovative fuel-and-stove combinations. These supply chain innovations encompass various stakeholders, including cooking service providers and energy infrastructure players, such as electric utilities and fuel distributors. ESMAP (2023) with data from the CCA partner database provide a comprehensive description of the global landscape of manufacturers and distributors. Looking at distributors and retailers (Figure 6b), it can be seen that the most active companies operate across Africa and Asia whilst the headquarters of most designers and manufacturers are concentrated in China, India, Kenya, the United Kingdom and the United States (see Figure 6b). As explored below in section 4, there may be significant infrastructure, transition, and service opportunities for African organizations to engage more effectively with the design and manufacture of clean cooking solutions. Many of these companies utilize stove and fuel technologies classified as tier 4 within the multi-tier framework. However, these companies face challenges in expanding their activities due to fragmented energy planning approaches that do not adequately prioritize clean cooking solutions.

The absence of institutional coordination and inadequate regulatory frameworks pose ongoing obstacles for suppliers in the cooking industry striving to achieve greater penetration of clean fuels and high-efficiency, low-emissions technologies. Often, the clean cooking mandate sits across multiple ministries of government agencies resulting in disconnected and fragmented approaches, especially in the context of just energy transitions (AFREC, 2022; Lavenda et al., 2021). Energy policies and national expansion plans should acknowledge these realities and incorporate strategies at the design stage to facilitate the transition away from polluting fuels. High taxes and misaligned tariffs codes hinder industry growth and create an unfavourable business environment, ultimately dampening end-user adoption (ESMAP, 2023). These are issues which we return to in the sections below.

6.a. Manufacturers and designers, by headquarters country



6.b. Distributors and retailers, by countries of operation.

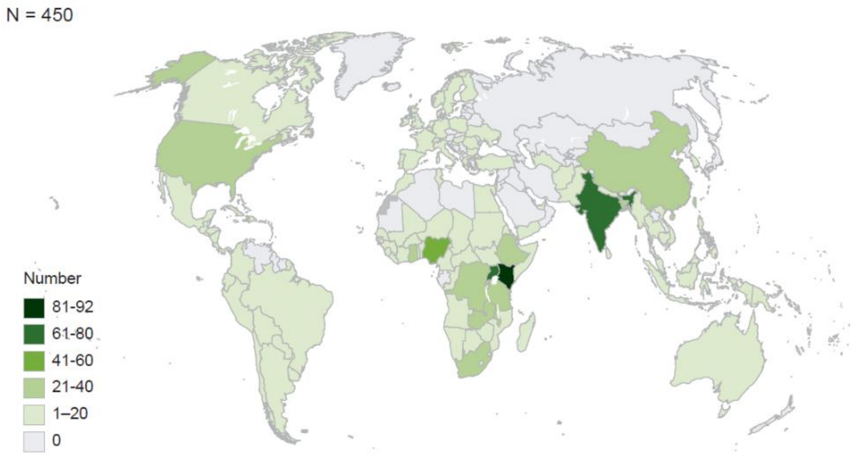


Figure 6: Supply chain of modern energy cooking stove and fuel suppliers (Extracted from Energy Sector Management Assistance Program (ESMAP, 2023))

1.4. Sustainable Scaling: Steps to Meeting the Clean Cooking Challenge in Africa

1.4.1. Understanding current approaches to universal energy access

While SDG 7.1.2 set targets for 'clean cooking', discussed above in this chapter, the intention of SDG7 was an integrated approach to energy and ultimately to ensure that all levels of society had access to sustainable, reliable modern energy for all. This is a prerequisite for healthy households, a balanced natural climate, pathways to gender inclusion, and growing the domestic economy, and the shortfall in the clean cooking sector undermines the whole. As the opening section states, this shortfall sums up to a calculable US$ 791.4 billion per year, by negative externalities of health, gender, and climate, and the impact on these externalities may well have other hidden costs on the general economy. It is therefore vital that the issue of clean cooking be an integral part of all energy planning, and by various innovative financial and policy mechanisms.

1.4.2. Integrating Clean Cooking into Energy Modelling and Planning

As a key step to this universal energy access, we need a refreshed approach to energy modelling and planning. For too long clean cooking has been siloed from wider planning processes. Sometimes seen as a deforestation problem, it becomes isolated from a modernization agenda. With the increased urbanisation of Africa, we nevertheless see an underuse of energy infrastructure, distribution networks and services for the urban population with many urban households and businesses continuing to rely on biomass-based cooking. As electrification reaches out into the rural areas with an increasing cost of connection, the demand for modern energy is limited to lights giving low Average Revenue Per User. Better more holistic energy modelling, utilising the latest in GIS data management, can help integrate clean cooking possibilities into an integrated energy plan. Data reliability also needs to improve to take into account the complexities of the Multi-Tier Framework and Fuel Stacking.

1.4.3. Achieving a Just Energy Transition through Infrastructure Investment and Accompanying Services

To address the needs outlined above, the issue of a just transition must come to the foreground. While clean cooking has traditionally been considered through health and environment lenses, it will be important for the economic growth of Africa to ensure that the integrated energy planning supports the overall economies. This means taking into account the plans for the wider infrastructure and leveraging broader investment scenarios to include the benefits of clean cooking. Services often depend on the road networks, and outreach to rural areas depends on all weather roads. Urban planning needs to take into account actual access, even that brokered through landlords of informal settlements. Policies on the role of the displaced in their host community can easily affect the planning processes. The economic direction of a country may be influenced by its energy security and its reliance on imported fuel – this also needs to shape the fuel mix basket chosen for a Just Transition. In all therefore the basket of choices for a fuel mix are very context dependent and are different for different markets even within the same country.

1.4.4. Multi-Fuel Clean Cooking Roadmaps (Archetypes & Case Studies)

To address the different markets, multiple road maps are required. A single road map for a country will need to unpack the differing agroecological and socio-economic zones. An over reliance on a biofuel could tip the balance of food production. Ignoring the opportunity of biofuels from municipal waste could result in an overdependence on imported fuels. Green grid electrification in regional power pools or Natural gas could open up new solutions for urban conurbations. Credit facilities and pay as you go technology for a fuel delivery service can be applied to multiple fuels. Carbon and climate finance is being agreed globally and opens the way to scalable approaches for integrated energy provision inclusive of clean cooking.

In the following section we outline the progress and role of modern energy cooking solutions, address clean cooking as a climate solution, and consider financing flows both through carbon financing and other co-benefits.

2. Tackling the Challenge of Achieving Universal Access to Clean Cooking

Building on the scale of the clean cooking challenge presented in section 1, this section brings together the key learnings from global statements on clean cooking pathways. This includes drawing on a wide range of flagship reports from across the clean and modern energy cooking sector. The section opens by outlining the progress and role of modern energy cooking solutions, clean cooking as a climate solution, and financing flows both through carbon financing and other co-benefits. We then address the role of public and private sectors in achieving universal access to clean cooking, and close by addressing the key challenges and opportunities in the global clean cooking transition to modern, reliable, and sustainable energy systems and services. The key messages in this section are:

- **Financing Falls Short of the Clean Cooking Challenge** - Recent technology and business model development and innovation are driving the uptake of modern energy cooking solutions and lifting people out of cooking poverty across Africa. However, financial support for the clean and modern cooking energy sector remains insufficient and calls for an urgent scale up of funding and financing to boost both the availability and affordability of Modern Energy Cooking Services (MECS). Estimates suggest that achieving universal access to MECS by 2030 necessitates approximately USD150 billion annually[3] (ESMAP, 2020).
- **Leverage wider investments and resources in Africa –** energy is an integral part of the growing economy, and the trajectory set by African leadership requires a balanced growth – in modern energy, all-weather roads, digital services, industrialization and food security, among other system elements. Clean cooking is not an isolated sector, but requires integrated energy planning, use of new financial services, innovative farm to table paths and a strategic plan to recover what are currently economic losses.
- **Leverage Clean Cooking Co-Benefits** - Given the role extending access to MECS plays in combating climate change, climate finance has emerged as a promising funding stream that can be used for both the demand- and supply-side of MECS. Leveraging clean cooking co-benefits also holds promise in offering additional revenue streams for both the private and public sectors - both of which play a critical role in supporting markets for, and achieving universal access to, MECS in Africa~~SSA~~. Two-thirds of the investment tracked coming into clean cooking enterprises in 2021-2022 went into enterprises that are generating carbon credits or are in the process of certifying a Program of Activities (PoA) with a carbon registry (CCA, 2023).
- **Multi-Stakeholder and Cross-Sectoral Partnerships may hold the Key** - The challenges associated with universal transitions to MECS in Africa call for the creation of multi-stakeholder partnerships and increased support to R&D. As clean cooking is a critical energy service, a tool for climate action and socio-economic development there is an opportunity to galvanize action and commitments from these multi-stakeholder and cross-sectoral partnerships.

2.1. Progress and the role of modern energy cooking solutions

[3] This includes $39 billion from the public sector, $11 billion by the private sector, and the remaining $103 billion comes from household purchases of stoves and fuels.

Given the scale of the challenge outlined in Section 1, over the coming years, and decades, the world will need to significantly accelerate efforts toward transitions to universal clean cooking access globally given the critical role it plays under both the Sustainable Development Goals (SDGs) and climate agendas. Greenhouse gas (GHG) emissions from cooking contribute an estimated 2% of global emissions (Floess et al., 2023). Evidence has shown that universal adoption of electric cooking by 2040 could reduce cooking-related emissions by as much as 40% compared to 2018 levels (ibid.). Based on current power generation mixes across Africa, nearly all countries could reduce their carbon emissions by adopting efficient electric cooking appliances (IRENA, 2023a). Under the *World Energy Transitions Outlook 2021* pathway to limit global temperature rise to 1.5°C, electric cooking accounts for 85% of cooking energy by 2050 (IRENA, 2021). Yet alternative solutions will also be key in unlocking low-carbon, clean cooking access. As postulated by the International Renewable Energy Agency (IRENA) (2023a, 2023b), renewable cooking solutions, including cleaner bioenergy (e.g., biogas and bioethanol) and renewables-based electric cooking, are among those that best align with both the SDG and climate change mitigation objectives.

Recent studies suggest that energy-efficient electric cooking appliances, such as Electric Pressure Cookers (EPCs) with effective electricity infrastructure, challenge the perception that electricity is too expensive for cooking (ESMAP, 2020; MECS & ESMAP, 2020; Sánchez-Jacob et al., 2021). Such appliances significantly reduce energy demand, offering an 80% reduction for "heavy foods" and 50% across all cooked foods compared to electric hotplates. Modern energy cooking fuels and stoves, including electricity and liquid petroleum gas (LPG) cooking stacks, are already cost-competitive with dominant biomass fuels (MECS & ESMAP, 2020). With expanding electricity grids in developing countries and advancements in battery-supported appliances, electric cooking has become accessible even in off-grid areas (Batchelor et al., 2018). In certain urban centres, electric cooking with alternate current (AC) grid electricity is cheaper than charcoal when electricity tariffs are below \$0.35/kWh and charcoal costs exceed \$0.40/kg. For example, an analysis of a scenario for 100% electric cooking in Kenya revealed that transitioning completely from baseline fuels (LPG, charcoal, and electricity) to 100% electric cooking with EPCs, hotplates and air fryers could reduce energy use from 3.68 MJ to 0.41MJ/person per dish (EED Advisory & MECS, 2023). AC electric cooking on national grids or mini-/micro-hydropower is already cost-effective for many, with battery-supported DC electric cooking on Solar Home Systems becoming competitive by 2025 (MECS & ESMAP, 2020).

IRENA (2023a) highlights renewable cooking solutions, such as renewables-based electric cooking and cleaner bioenergy, as essential to include in the clean cooking solutions mix to achieve universal clean cooking access for all and combat climate change. Biofuels such as biogas and biomethane can play a particularly important role in countries with bioenergy targets, such as Indonesia, Malaysia and Thailand, as well as in other parts of the world, including Africa, where these fuels can help fill in both the electricity and clean cooking access gaps and help with waste management challenges, particularly in quickly urbanising regions (IEA, 2020). Innovation in the biofuels space has also been promising to enable faster scale-up. For example, novel technologies for small-scale and low-cost biogas clean-up into biomethane, and compression into small bottles have been shown as promising and suitable to help facilitate access to clean cooking fuel in countries like Ghana and Uganda (Twinomunuji et al., 2020; Black et al., 2021).

The emergence of large-scale bioethanol utilities, most notably in Kenya, has also demonstrated the viability of bioethanol as a cooking fuel (Osiolo, Marwah & Leach, 2023). Significant investments in technology and distribution infrastructure have resulted in bioethanol utilities reaching mass-market adoption within just a few years, serving hundreds of thousands of households (ibid.). Further, an assessment of the feasibility of producing LPG (further discussed below) from renewable feedstocks, known as bioLPG, has also highlighted its potential for scalability in Africa (Chen et al., 2021). Innovative chemical processes utilizing biogas and syngas from municipal and agricultural waste have been shown to selectively produce bioLPG, offering a sustainable alternative for clean cooking transitions (GLPG, 2023).

LPG has already been playing an important role in clean cooking transitions and an alternative modern cooking fuel alongside electricity, with some estimates showing that if universal access to clean cooking is to be reached by 2030, 40% of people without access in 2022 would need to be reached with LPG (IEA, 2022). LPG is often considered as more practical than electricity (as it requires fewer cooking behaviour changes and adaptations), commercially viable and more widely available, and cost-effective (Puzzolo et al., 2019). Its adoption presents various benefits, including GHG emission reductions, health improvements, and time-saving advantages for households (Gould et al., 2018) as well as large-scale cooking contexts, such as schools (Puzzolo et al., 2024). Despite skepticism from some government donors, evidence suggests a latent market demand for LPG, particularly in low-income countries as well as among refugees (Haselip et al., 2022). Several African governments already promote LPG in national energy access policies and planning efforts, further emphasizing its role in achieving inclusive and sustainable energy transitions (KAPSARC & UNESCWA, 2023). LPG is an important transition fuel towards e-cooking and while carbon emission reductions are greater for e-cooking solutions, LPG stoves still represent a decrease in carbon emissions – by as much as 60% as compared to biomass (Acumen, 2023; WLPGA, 2018). For example, Circle Gas – a Pay as You Go (PAYG) LPG solution provider in SSA, became the first LPG-based company to be certified on the Gold Standard platform (Acumen, 2023).

In Section 4, we further address the complexity of choices around infrastructure, transitions, and services when creating a multi-fuel integrated energy strategy which can effectively react to the complex cooking needs outlined in Section 1. Whilst there are examples of progress to universal access to modern fuels, appliances, and services significant efforts are required to overcome the vast nature of this challenge. In following sub-sections we explore various opportunities the clean cooking sector in Africa can tap into or can further leverage to speed up progress towards universal clean cooking access.

2.2. Clean Cooking as a Climate Solution

The adoption of clean cooking technologies holds immense potential as a climate solution, offering a pathway to mitigate GHG emissions while addressing multiple societal challenges. A full transition to clean cooking in Africa could avert as much as 900 million tons of CO2 equivalent annually, playing an important role in Africa's Net Zero ambitions (IEA, 2023).

Interventions promoting clean cooking have emerged as a highly cost-effective measure which offers emissions reductions, as well as health, gender equality, and livelihood improvements (CCA et al., 2022), underscoring the urgency of transitioning to clean cooking solutions. This has been manifested in the growing number of national governments including household energy or clean cooking measures in their Nationally Determined Contributions (NDCs) to the Paris Agreement. As of March 2023, 98 low-middle-income countries (LMICs) already had such NDC targets; of those, 72 included specific clean cooking targets, while the remaining 26 included adjacent goals, such as household energy efficiency, forest conservation, or air quality, which could be partially achieved through clean cooking activities (CCA & ICLEI, 2023).

To maximize the climate, environmental and other co-benefits of clean cooking, concerted efforts are needed from governments and multilateral finance institutions. Recognising clean cooking as a nature-based solution and integrating clean cooking into NDCs, environmental programs like reducing emissions from deforestation and forest degradation in developing countries (REDD+) or park development plans is crucial (CCA, 2023a). Additionally, collaboration between government donors and development finance institutions (DFIs) can leverage international and national private finance through mechanisms like the Paris Agreement's Article 6, enhancing gender, health, and biodiversity outcomes (ibid.).

Clean cooking solutions not only play a pivotal role in safeguarding the climate and natural ecosystems, but are also indispensable in supporting sustainable food systems (CCA, 2023b). By reducing households' reliance on charcoal and fuelwood, these technologies mitigate climate-harming emissions and forest degradation, preserving ecosystems vital for sustainable food production (ibid.).

Addressing air pollution, exacerbated by urbanization and the heavy reliance on polluting fuels for cooking in urban centres, is another vital aspect of climate action. Scaling clean cooking solutions is imperative for mitigating both household and ambient air pollution, improving public health, and building resilience in urban populations (Mackres et al., 2023). As clean cooking becomes central to coordinated efforts to combat air pollution and climate change, its widespread adoption will be indispensable in fostering both healthier and more sustainable communities as well as leveraging the economic benefits of creating conditions for economic growth.

2.3. Financial flows into the clean cooking sector

Financial flows towards clean cooking initiatives reveal both progress and persistent challenges in recent years. Despite significant strides, investments have fallen short of the levels required to ensure universal access to modern cooking solutions by 2030.

Estimates suggest that achieving universal access to MECS by 2030 necessitates approximately USD150 billion annually (ESMAP, 2020). This includes substantial contributions from both the public and private sectors to address affordability gaps and establish essential infrastructure for modern energy cooking markets (ibid.). However, despite the substantial funding requirements, total financing levels remain critically low, largely due to perceived risks associated with clean cooking enterprises. According to SEforALL (2021), high-income countries' (HICs) commitments to clean cooking in LMICs have remained relatively stagnant, hovering around USD 130 million annually between 2015-2019, with a significant drop to USD50 million in 2017. The sector's financing continues to be concentrated in a few large projects across select countries, funded primarily by a limited number of capital providers which inhibits the overall growth of the sector.

Despite the challenges and the continued failure to reach the necessary financial commitments, the sector has seen notable increases in investment in clean cooking enterprises, reaching an all-time high of USD 215 million in 2022 (CCA, 2023a). The increasing number of clean cooking enterprises with well-established revenue reflects the growing momentum in the sector. In 2022, a record number of 11 clean cooking enterprises (most of which operate in Africa) reported revenue exceeding USD 1 million. This diversification of enterprises covering various clean and improved cooking technologies and fuels demonstrates the expanding market for clean cooking solutions. Carbon finance has been instrumental in driving the investment growth, with investments in equity, debt, and grants witnessing an 80% increase compared to previous years. However, investment concentration remains a concern, with a significant portion of funding directed towards LPG enterprises and overall, a handful of the same companies capturing most of the capital (ibid.).

While grants continue to play a vital role, innovative financing mechanisms such as results-based financing (RBF)[4] programs and specialized investment funds have emerged to incentivize private sector involvement (CCA, 2023). Initiatives like the World Bank's Clean Cooking Fund and the MECS Challenge Fund supporting early-stage research to stimulate innovation in modern-energy cooking

[4] RBF is a mechanism whereby a donor (or implementer) disburses funds to a recipient once a pre-agreed set of results has been achieved and confirmed through independent verification process.

technologies and systems aim to attract private sector financing and stimulate innovation in clean cooking technologies (ESMAP, 2023a). Energising Development (EnDev) and Swedish International Development Agency's (SIDA) RBF, implemented jointly with multiple partners, supported companies in providing access to clean cooking across Africa and South-East Asia (EnDev, 2021). The World Bank's Carbon Initiative for Development (Ci-Dev) Facility and the Netherlands Enterprise Agency's RVO SDG 7 Partnership Facility also aim to attract private-sector financing to deliver MECS or improved (transitional) cooking services. The Clean Cooking Alliance's Cooking Industry Catalyst program provides seed funding and capacity building to increase the pipeline of investment-ready companies that design, manufacture, and sell clean cooking solutions in LMICs around the world. Beyond the traditional cooking space, but critical to accelerating modern energy uptake, the consolidation and expansion of funds focused on climate-change mitigation and renewable-energy access, including the Green Climate Fund and the Africa Climate Change Fund, among others, can help open new avenues for better integration of cooking objectives within broader energy policy (CCA, 2023). Additionally, financial institutions (such as micro-finance institutions (MFIs)) are poised to play a crucial role in providing financing across the value chain, particularly to offset the high upfront costs associated with MECS (MECS & ESMAP, 2020).

However, challenges persist, including unsuitable financial terms, lack of domain expertise, and the need for de-risking measures to attract investment, particularly for early-stage companies and SMEs (IRENA, 2023). Despite these obstacles, the urgent need for investment in clean and modern cooking infrastructure and equipment remains evident, with an estimated annual investment requirement of USD 8 billion over the next decade to reach universal clean cooking for all (IEA, 2023b), and significantly more if universal access to MEC is to be reached (approx. USD 50 billion of public and private sector investment annually) (ESMAP, 2020). Moving away from funding projects on a case-by-case basis and promoting innovative funding mechanisms like investment funds and specialized facilities (e.g. the Spark+ Africa Fund and the Nordic Green Bank's Modern Cooking Facility for Africa) offers promising avenues for mobilizing capital and accelerating progress in the clean cooking sector. Redirecting investments from fossil fuels, increasing aid commitments, introducing structural reforms in international public finance and improving transparency in commitment reporting have all been identified as necessary steps if meaningful progress is to be made over the coming decade (IEA et al., 2023).

2.3.1. Carbon finance – propelling clean cooking transitions

Carbon finance has emerged as an important mechanism propelling the transition to clean cooking, offering a powerful blend of financial incentives and climate action. Carbon financing has transformed the sector. Not only do carbon credits contribute to a reduction in GHG emissions, but they also make cookstoves more affordable, and the companies more profitable (Acumen, 2023). At its core, carbon finance operates as a results-based financing mechanism, linking payments to verified reductions in CO2 emissions (Zhang & van der Vleuten, 2023). For suppliers of clean cookstoves, carbon finance provides a dependable revenue stream, particularly crucial for ventures necessitating significant upfront investments in production and distribution infrastructure. For governments carbon finance can help support safeguarding public health and combat deforestation by transitioning away from biomass fuels for cooking (ibid.).

The uptick of carbon revenue has catalysed investment in clean cooking enterprises, fuelling growth and innovation within the sector over the last few years. Two-thirds of the investment tracked coming into clean cooking enterprises during the past two years went into enterprises that are generating carbon credits or are in the process of certifying a Program of Activities (PoA) with a carbon registry (CCA, 2023).

Yet, challenges around carbon finance persist, with carbon markets experiencing fluctuations and increased scrutiny due to the supply-side problems with over-crediting from some projects (Gill-Wiehl et al., 2024). The average carbon credit spot price for household devices (which includes cookstoves) in 2023 fell to USD 5.90 per tCO 2e, which is 38% below the average price for 2022 (CCA, 2023). Efforts are underway to enhance the quality and credibility of carbon credits generated by clean cooking projects (particularly under the voluntary carbon markets (VCMs)), ensuring carbon credits integrity, improved transparency, fairness, and sustainability in market transactions (Galt et al., 2023). Notable initiatives are the African Carbon Market Initiative (ACMI) – a non-partisan advocate for African carbon credits, providing strategic advisory and convening market actors to catalyse change for African carbon markets; the CCA's Interim Principles for Responsible Carbon Finance (CCA, Climate Focus & SEI, 2023); and the Integrity Council for Voluntary Carbon Markets which should help alleviate the current risks associated with carbon finance, including reputational issues (for clean cooking companies, carbon project developers, governments and financiers alike) and regulatory ambiguity (Zhang & van der Vleuten, 2023).

Carbon finance measures, including Paris Agreement Article 6 market mechanisms and VCMs, can be used as opportunities to expand the deployment of clean cooking at large, with particularly promising (and growing) opportunities for MEC solutions, especially electric cooking solutions (IRENA, 2023). Although there are some uncertainties around how Article 6 market mechanisms will be operationalised (UNFCCC, 2023), electric cooking is a high-potential activity for consideration under the market mechanisms, aligning with global climate goals. The Case Study below illustrates one operationalisation of an Article 6 mechanism for cleaner cooking in Zambia.

Measurement, reporting, and verification (MRV) play a crucial role in ensuring the credibility of emissions reduction programs, enhancing the value of clean cooking initiatives as sources of climate finance (CCA et al., 2022). Advances in the measurement of fuel use, has allowed for new methodologies for calculating carbon emission reductions with greater accuracy. The new Gold Standard (GS) methodology (2022, revised), developed by MECS and Climate Impact Partners) quantifies GHG impacts through the direct metering or measurement of electricity or fuel use, and applies to almost all MEC appliances including LPG, electric, biogas, and bioethanol cookstoves (Bricknell & Leach, 2024). According to recent studies, metered cooking devices offer the most robust evidence demonstrating GHG emission reductions and have the greatest abatement potential and health benefits (Stritzke et al., 2023; Gill-Wiehl et al., 2024). Notable examples of the application of the GS metered methodology in the clean cooking sector are the ATEC 'Cook to Earn' scheme whereby data-backed carbon payments are 100% linked to actual use and can be verified at any point, boosting their transparency. Additionally, a portion of the received carbon credits goes to the end-users as an incentive to encourage continued use and displacement of alternative (largely biomass-based) fuels (Batchelor, 2022).

Despite complexities in quantifying emissions reductions, carbon financing has undeniably transformed the clean cooking sector, making cookstoves more accessible, profitable, and impactful in mitigating GHG emissions. With new technological developments and more robust methodologies, and with concerted efforts to address challenges and uphold integrity, carbon finance holds immense potential in realizing universal access to clean cooking while mitigating the climate crisis.

CASE STUDY – Digital Innovations for Financing Green Technology Infrastructure in Africa

Digital transformation, through leveraging carbon finance to promote financial inclusion and stimulate socio-economic development, can also create opportunities to mobilize and equip digitally-native youth with skills, tools and incentives, which could provide the workforce and promote entrepreneurship for the green economic transition in Africa. The UNICEF-led Youth Opportunities Marketplace (Yoma) is gearing up to provide the digital coordination and financing platform aiming to create new income opportunities for youth in the transition to a green economy.

National governments in Africa have begun to introduce regulations that allow mitigation activities to be funded through Internationally Transferred Mitigation Outcomes under Article 6.2 of the Paris Agreement. As an example, the government of Zambia has authorized the design of a national modern energy cooking mitigation activity that implements digital Measurement, Reporting and Verification (dMRV) to certify Mitigation Outcomes and Carbon Credits. Government-sanctioned Mitigation Outcome Purchase Agreements (MOPAs) between the Mitigation Activity (MA) implementers and counterparty government Acquiring Parties are expected to raise the bar for the quality, price, and predictability of the supply for Mitigation Outcomes – including for carbon credits in the Voluntary Carbon Markets. This should significantly reduce financing risks for private capital to invest in green energy infrastructure projects. Digital MRV provides real-time visibility of MA project performance, which could reduce project execution risks. Generating digitally certified outcomes could increase capital velocity and liquidity in carbon credit markets. Project finance may now be structured using innovative financing instruments that are linked to the proceeds of MOPAs and to forward contracts for digitally certified ITMOs and Carbon Credits in the private sector.

This model of Outcome-based Financing presents a promising approach that could be extended to other areas of sustainable development, such as healthcare and education, potentially transforming funding mechanisms in these sectors and providing opportunities for youth.

2.3.2. Leveraging clean cooking co-benefits

Clean cooking solutions offer more than just environmental advantages; they present significant gender and health benefits that can be harnessed to attract additional funding and financing. Research indicates that achieving universal access to clean cooking could save as many as 3.2 million lives and nearly USD 2.4 trillion every year driven by adverse impacts on health (USD 1.4 trillion), climate (USD 0.2 trillion), and women (USD 0.8 trillion from lost productivity) (ESMAP, 2020). According to the International Energy Agency (IEA) (2023a), thanks to the wide range of clean cooking benefits, there are 2.5 million less premature deaths caused by the fall in air pollution toward 2030, and the average household saves on nearly 1.5 hours a day from the switch.

Recognizing this potential, initiatives like the Clean Impact Bond (CIB)[5] (IFC, 2023) have been developed to provide results-based finance instruments aimed at financing clean cooking solutions that not only reduce carbon emissions but also achieve tangible development impacts such as improving health and empowering women through time-savings and drudgery reduction. In a similar way to how carbon credits are issued for GHG emission reductions, tradable and verifiable health and

[5] A CIB is an RBF instrument that is designed to mobilize finance for small and medium enterprises based on sales of certified health and gender credits in the modern energy cooking sector.

gender credits can be issued to generate additional cash flow for small and medium enterprises that manufacture and distribute clean cooking solutions to improve the livelihoods of the currently underserved communities (ibid.). This approach not only enhances the affordability of clean cooking solutions for low-income consumers but also attracts development funders and impact investors interested in scaling up clean cooking initiatives with measurable social and environmental impacts (Alexander et al., 2023; Floess et al., 2023).

Moreover, the transition to clean energy is expected to generate more than 10 million net new jobs globally by 2030, offsetting the 2.7 million jobs expected to be lost in fossil fuel sectors (CCA & ICLEI, 2023). Promoting access to clean cooking solutions across both rural and urban areas can also pave the way for sustainable and equitable employment opportunities. In Africa, the push to reach universal access to clean cooking could employ nearly 1.5 million people in stove production and sales, fuel delivery, and supporting clean cooking campaigns (IEA, 2023a). By embracing clean cooking initiatives, communities can not only improve public health and environmental sustainability but also foster inclusive economic growth and employment prospects. However, traditional livelihoods, particularly jobs in the charcoal and firewood trade sectors, will inevitably be affected. These jobs, while still needed in 2030, could decline substantially, emphasising the need for a just, people-centred transition, including efforts to formalise these industries and upskill workers, particularly in Africa, where two-thirds of the world's charcoal is produced, playing a vital economic role in regions where urban settlements and forests coexist (CCA & ICLEI, 2023).

However, to fully capitalize on the co-benefits offered by clean cooking, there is a need to develop rigorous methodologies and tools for assessing and quantifying these benefits. While health co-benefits, such as the reduction in particulate matter and averted disability-adjusted life years (aDALYs), are relatively well-understood, there is a need for further development in assessing gender impacts, particularly in terms of time savings and the reduction in activities considered drudgery (ESMAP, 2023b), job creation and economic growth at large.

2.4. The need for cross-sectoral collaborations

According to the IEA (2023a), reaching universal access to clean cooking is not solely a technological challenge but largely hinges on policy implementation and availability of funding. While there are policy solutions that have proven effective, many countries lack the necessary resources and implementation capacity. Less than a third of people without access to clean cooking reside in countries with adequate policies and funding. In particular, Africa faces the most significant constraints as less than a third of clean cooking plans get funded. The recent global energy crisis and the impacts of the Covid-19 pandemic have further exacerbated these challenges, leading to a reduction in incentives and financial support for households (Pachauri et al., 2021; Zhang & Li, 2021).

Noteworthy examples of countries, programmes and initiatives that have made a significant impact on access to clean cooking are China, India and Indonesia who all halved their populations without clean cooking access, to a large extent by providing free stoves and subsidised canisters of LPG (IEA, 2023a). The USD 80 million, clean-cooking component of the China Hebei Air Pollution Prevention and Control Program using the Program-for-Results (PforR) instrument helped 1.22 million households transition from coal stoves to gas (1.09 million) and electric (0.14 million) cooking and heating appliances, exceeding the original target of 0.8 million households (ESMAP, 2023). These efforts, however, would not have been possible without an active part played by both the public and private sectors – both of which are critical in accelerating clean cooking access globally (Zhang, 2022). Below we further discuss the role of the two in the collective and multi-sectoral efforts towards the achievement of universal access to clean and modern cooking.

2.4.1. The role of the public sector

The public sector plays a pivotal role in driving efforts to achieve universal access to MECS ~~by 2030~~. High-profile coalitions of political leaders are needed to prioritize MECS access on both global and national agendas. This involves enacting enabling policies, including results-based incentives, fiscal incentives (e.g., tax reductions or exemptions on clean cooking products; supply or demand side subsidies) and targeted infrastructure investments (e.g., LPG storage facilities; road improvements to ease distribution; electrical connections to expand e-cooking), particularly in rural areas where nascent product and fuel markets are developing (UN, 2023). Behaviour-change campaigns, including demonstration hubs showcasing different MECS, are also crucial for fostering clean and modern cooking solutions adoption and adherence on a systemwide scale (EnDev, 2021; Coony et al., 2021). National governments should also strive to implement policies regarding standards for the deployed clean cooking solutions as standards provide rigorous definitions and goals for stove and fuel performance, safety, durability and quality. For example, the International Organization for Standardization (ISO) has developed clean cooking standards (including laboratory and field-testing guidelines to accurately assess quality, emission reductions, and other indicators) (ISO, 2020). Strategically aligning the public and private sectors, as well as development partners, finance institutions and non-governmental organisations (NGOs) leading or supporting initiatives in the clean cooking sector should also be led by national governments, to ensure complementarity of efforts and an efficient deployment of resources.

National energy planning must formalize cooking energy demand and develop strategies reflecting diverse user needs, local market conditions, and comparative advantages in energy resources. For example, integrating electric cooking solutions into electricity supply and grid modernization projects presents an opportunity to leverage existing finance sources. This integration can be achieved through holistic energy access planning, aligning electric cooking with investments in grid generation, transmission, and distribution (Philibert, 2022; IRENA, 2023a). Clean cooking should also be integrated into national food system transformation pathways and nutrition strategies given the catalytic role it plays in the creation and sustenance of sustainable and climate-resilient food systems (CCA, 2023c).

Moreover, there is a pressing need for a significant increase in funding dedicated to MECS, transitioning from mere millions to tens of billions of dollars, to accelerate progress (ESMAP, 2020; UN, 2023). Furthermore, governments must prioritize clean and modern cooking at the national level, integrating planning and programs across ministries, agencies, and sectors (SEforALL, 2021) and consider establishing lead agencies to coordinate all clean cooking activities, such as the Clean Cooking Delivery Units championed by the CCA (CCA, 2023). They must also ensure affordability of clean and modern cooking solutions by implementing targeted support mechanisms. While switching to cleaner cooking solutions, whether electricity, LPG or other renewable biomass-based solutions, eventually pays for itself through higher efficiencies and reduced expenditure on traditional fuels, ongoing price support may be necessary for some households. This requires balancing affordability support with the risks of ballooning imports and subsidies (IEA, 2023), as well as making polluting fuels less available and less affordable and explaining to the public why they should consider cleaner options when they become available over traditional, mostly inefficient, fuels (Puzzolo et al., 2019). Policymakers should therefore carefully utilise various instruments, such as targeted subsidies, fuel price caps, and tax incentives, to increase distribution and uptake of clean cooking solutions (Das et al., 2022; Alexander et al., 2023). They will also be pivotal in helping private sector providers of clean and modern cooking solutions leverage carbon and social impact finance by putting in place clear guidelines and supporting frameworks (UN, 2023).

Overall, a strategic rethink of the piecemeal approach to clean cooking investment is necessary, with increased targeting of public finance to leverage and de-risk private capital (SEforALL, 2021). Integrating clean cooking into national energy plans as well as national food system transformation pathways and nutrition strategies further underscores the comprehensive role of the public sector in achieving universal access to clean cooking by 2030.

2.4.2. The role of the private sector

Collaboration between the public and private sectors is imperative for developing robust modern-energy markets to achieve universal access to clean and modern energy cooking services (ESMAP, 2020). The private sector, in particular, plays a critical role in driving innovation, financing, and scaling up clean cooking solutions (Zhang, 2022).

One avenue for the private sector to help speed up progress is through the development of business models that are suitable for early-stage start-ups, small and medium-sized enterprises (SMEs), and experienced companies seeking to enter the clean and modern cooking market (IRENA, 2023a). These business models can help attract finance and stimulate investment in various cooking technologies, and should at their core have the goal of boosting affordability and satisfaction for end-users, and the delivery of social and economic impacts, in addition to assisting companies reach profitability (Mukoro et al., 2022). New business models should also be scalable to maximise the potential to extend access to cleaner cooking solutions to millions of households in both rural and urban areas (Hosier et al., 2017).

As postulated by Acumen (2023), clean cooking companies must prioritize selling high-quality appliances at affordable prices to succeed. This necessitates innovative financing mechanisms and close collaboration with customers on product design. Many companies have achieved scale through strategic distribution partnerships, pivoting away from direct sales to customers (e.g. BURN, MimiMoto, KOKO Networks).

As the focus on the interrelationship between nature and climate intensifies, clean cooking companies should consider forging new types of partnerships, such as with conservation organizations, local government stakeholders, and other environmental groups. These partnerships can leverage clean cooking value chains for nature-based solutions, contributing to inclusive and regenerative rural development while reducing pressure on critical ecosystems (CCA, 2023b).

Moreover, corporations must align their strategies with established standards on nature-based solutions and address societal challenges within local communities. Integrating clean cooking as a foundational component in nature-related carbon removal initiatives, sustainable agriculture investments, and supply chain environmental, social, and governance standards is crucial for maximizing the impact of private sector engagement in propelling access to clean cooking (ibid.).

2.5. Navigating clean cooking transitions: challenges and key considerations

Countries rely on a diverse range of fuels for cooking and should plan for an optimal blend of clean cooking options, both in the short and long term. The sustainability and risk associated with cooking fuel supply chains are influenced by various factors, affecting their long-term feasibility and scalability (Puzzolo et al., 2019). The structure and services of industries involved in supplying these fuels differ significantly, with some fuels being locally produced and marketed (e.g. typically pellets, biogas, electricity), while others depend on global supply chains (e.g. LPG). Additionally, the institutional environment plays a crucial role, directly and indirectly impacting the viability of supply chains. Each fuel comes with its own set of challenges, whether adoption (cooking practices, behaviours and preferences) or policy related.

For example, the lack of guiding policies relevant to electric cooking and national action plans has posed a significant obstacle, as many countries, particularly in SSA, have not explicitly recognised e-cooking in their frameworks, deterring financial investments (IRENA, 2023a). Additionally, low uptake of cooking with electricity has been attributed to the high up-front cost of electric stoves compared to other improved stoves, lack of awareness of efficient cooking electric appliances and the diverse electric appliance options, limited distribution points, and the cost of electricity (MECS & EED, 2023). However, innovative interventions have been rolled out in countries such as Kenya, Uganda, or Nepal, that include the cost reduction of devices, electric cooking tariffs, credit facilities, utilities-led financing, carbon finance, and RBFs which have led to the emergence of the use of multiple electric appliances at the household level (Leary, 2022; Price et al., 2022; Barnard-Tallier et al., 2022).

In the case of biofuels, challenges such as unfavourable tax regimes and the need for a robust commercial supply chain can hinder their widespread adoption. For instance, an enabling policy environment for bioethanol, such as what has been seen in Kenya, is crucial for overcoming these barriers and accelerating the transition to bioethanol for clean cooking (Osiolo, Marwah & Leach, 2023). BioLPG, as nascent clean cooking fuel, requires further piloting and de-risking for full-scale implementation (Chen et al., 2021). However, biofuels hold promise in providing access in rural areas where infrastructure and affordability of alternatives such as electricity or bio(LPG) remain significant barriers.

While it continues to be a preferred clean cooking option for numerous governments, LPG is also faced with a combination of challenges. In addition to its prices being heavily affected by international markets and frequent cost fluctuations, it also requires significant investments both on the supply and demand side. The success of LPG roll out in countries with high usage, such as India, Morocco or Indonesia, has largely been due to large-scale government programmes and significant subsidies, reaching as much as 50% of the actual price in Indonesia (IISD, 2016). However, many countries supporting LPG through various incentives have either already pulled them out or are considering doing so, either to alleviate the burden they pose for national budgets or as part of their decarbonisation strategies, or both (e.g. IISD, 2021; Birol & Kant, 2022).

Navigating transitions to clean cooking represents a critical aspect of Africa's broader energy transition pathways. Unlike one-size-fits-all approaches, Africa's context demands gradual shifts towards cleaner fuels and technologies, acknowledging the complex dynamics of local energy ecosystems. It is imperative to recognise the need for an inclusive approach that aims for universal MECS access for all over the medium- to long-term, but which also accommodates intermediate solutions such as renewable biomass (Mulugetta et al., 2022).

Moreover, integrating clean cooking access with climate mitigation goals remains underrepresented in energy systems modelling, highlighting the need for a more granular approach to mapping deep decarbonization pathways. In particular, African petro-states encounter significant hurdles and complex trade-offs when considering the utilisation of their gas reserves, primarily due to uncertainties and risks associated with transitioning to cleaner energy sources. Investments in African natural gas face challenges in aligning with the objectives of the Paris Agreement and achieving Net Zero 2050 compliance, potentially leading to substantial financial losses for governments and hindering progress towards adopting green technologies (African Climate Foundation, 2024). Projections suggest a notable decline in liquefied natural gas (LNG) imports by 2050, particularly impacting emerging gas producers and countries exploring gas reserves, such as Mozambique, Tanzania, Mauritania and Senegal, and countries currently exploring for gas (South Africa and Namibia). However, renewable energy emerges as a compelling alternative investment across Africa, offering not just energy solutions but also prospects for job creation and fostering green industrialization. By managing transitions towards low-carbon alternatives and reducing reliance on fossil fuels, African nations can advance progress on SDG7 and support the objectives outlined in the

African Union's Agenda 2063 (AU, 2013). This strategic shift towards renewable energy not only addresses environmental concerns but also aligns with broader developmental agendas, signalling a pathway towards sustainable growth and resilience in the region.

Despite these complexities, just and equitable clean cooking transitions are achievable with careful consideration of local dynamics and a commitment to inclusivity. Such transitions not only advance climate goals but also create avenues for sustainable employment, driving green industrialisation and contributing to broader global development agendas. By recognising the interconnections between clean cooking access, climate action, and socioeconomic development, African countries can navigate transitions that are both environmentally sound and socially just. We further elaborate on these complex challenges in Section 4.

3. Clean Cooking Modelling and Data Challenges

This section explores the integration of clean cooking in the energy system models used for global, regional and national energy planning, and the associated need for high quality data. Through review of energy planning tools - currently available and those in development, the section identifies best energy modelling practices as well as key challenges. The review shows that a full spectrum of clean cooking solutions should be considered by energy planners and it shows the importance of linking across all scales of analysis, such that high level decisions on national infrastructure reflect the range of options for improvements in cooking access. New hybrid models and tools are emerging, many open access, helping accelerate transfer of experience for wider scale-up. The key messages from this section are:

- **Embrace Integrated Energy Planning** - Energy planning and related modelling should include close attention to clean cooking transitions, as one of the most significant challenges in Africa and for which connections to other parts of the energy system and economy are important.

- **Understand Context -** Explicit linkage between high level energy planning and location-specific energy and cooking access planning is important. New hybrid models and tools are emerging, and many are open access, helping accelerate transfer of experience for wider scale-up.

- **Use High-Quality Data to drive this Process** - Improving access to high-quality, standardised data is crucial, including those reflecting complex cooking behaviours such as fuel and stove stacking.

3.1. Energy planning approaches

Energy planning involves crafting long-term strategies to steer the future development of energy systems at different scales (global, regional, national or local) and is pivotal for advancing both the clean energy shift and enhancing energy accessibility in what are often complex, multi-stakeholder contexts with multiple competing priorities. In the context of African economies, expanding energy access becomes an additional, and often key, priority. Such plans require finding a balance between multiple objectives, cost, reliability and socio-environmental impacts, and energy planning is typically informed by modelling of one or many sorts, helping develop alternative scenarios and explore trade-offs. In this section we look at the purposes of energy system modelling, consider the position of clean cooking within it, and overview the tools and associated data that are being developed.

Historically energy planning practices have been categorised into three segments:

i. energy system planning - examining interactions within the energy sector, emphasizing energy security, access, efficiency, and sustainability. Models often optimise energy transitions under a specified set of constraints, informing national targets and policies;
ii. sub-sector system planning - focusing on individual energy sub-sectors (e.g., oil, electricity) to identify necessary investments and technologies to meet aggregate demand. Traditionally seen as a subset of energy system planning, it evaluates generation, transmission, and distribution investments;
iii. energy access planning, which adopts a geospatial perspective, considering local factors to deliver energy services to end-users most effectively. It aims to identify suitable technologies and prioritise infrastructure investments, increasingly incorporating considerations beyond household electrification, such as productive uses, cooking energy and agricultural cooling.

An additional way to categorise models and modelling is whether this is undertaken by/for one specific country as a national planning study, or whether that country is being modelled as one within a wider international study. This distinction becomes less important as the multi-national modelling tools become increasing detailed and sophisticated, but in general, while the multi-national tools are able to make inter-country comparisons and scale up to regional, continental or even global results, they may not capture as much of the specific national and local context, which can be vital for clean cooking.

Energy access approaches in energy planning historically focused more on electricity than clean cooking, and as a result, national-level energy system planning has generally included only very simplistic treatment of cooking. Recent efforts, however, have aimed to integrate clean cooking more systematically across planning approaches. This integration is vital, starting with energy system modelling and extending to the more detailed energy access planning, ensuring consistency and comprehensive coverage of energy needs, especially in underserved areas, and effective and systematic representation of a full range of supply options – from solutions relying on solid biomass, to gaseous and liquid fuels, and electricity. However, it is worth noting that early efforts promoting such integrated approaches frequently failed to properly integrate the potential of electric cooking (e-cooking) which was typically only considered where access to electricity was already available (if at all). More recently, a full integration of electricity and clean cooking planning, inclusive of electric cooking regardless of the existing electrification rates, has been promoted. In particular, without such integration between planning for electricity access and for clean cooking in African economies, there is a risk that long term policies for, and investments in, electricity system expansion would lock electric cooking, with its range of benefits, out of the mix.

3.1.1. Clean cooking considerations in energy system planning

The 1970s marked a significant turning point in energy planning, driven by the global oil crises, which prompted the development of detailed "bottom-up" models for analysing energy systems. Notably, the Model for Long-Term Energy Demand Evaluation (MEDEE2) tool, developed in the late 1970s with joint sponsorship from the United Nations Environment Programme (UNEP) and the International Institute for Applied Systems Analysis (IIASA), exemplifies one such approach (Lapillonne, 1978). During this period, the concept of access to clean cooking was primarily framed as inter-fuel substitution, leading to various relevant analyses (Munasinghe, 1985; Fitzgerald et al., 1990; Floor et al., 1992). Since then, clean cooking has been approached from both inter-fuel substitution perspectives (e.g., shifting from wood fuel to LPG or electricity) and efficiency enhancement angles (e.g., promoting improved cookstoves to reduce overall energy intensity in cooking activities or adopting more efficient carbonisation methods). The International Energy Agency (IEA) and the International Atomic Energy Agency (IAEA) were early advocates of contextually appropriate energy system modelling, incorporating considerations of clean cooking since the 1990s (IEA, 2022; IAEA, 2009; IAEA, 2016). Tools provided by the IAEA to its member states[6], including numerous developing countries, exemplify efforts in this direction.

Energy system planning, based on modelling tools, has traditionally focused on major end-use sectors driving national energy consumption and growth, such as transportation, buildings, industry, agriculture, and healthcare. Detailed data on consumption categories and robust assumptions about the future are necessary to assess relevant fuel and technology choices for end-use services like cooking and heating. Typically, bottom-up energy demand simulation models (e.g., Model for Analysis of Energy Demand (MAED)) have been employed to evaluate energy needs for the range of end-uses, including cooking, with outputs feeding into energy supply analysis using optimisation models (see

[6] The suite of IAEA's energy modelling tools can be found here.

more on optimisation models in Section 3.3.). The IAEA's Model for Energy Supply System Alternatives and General Environmental Impacts (MESSAGE) has been instrumental in energy system planning at national and sub-national levels in developing economies since the early 2000s.

Efforts to integrate clean cooking into energy planning for developing economies have also been spearheaded by the IEA under the World Energy Outlook (WEO) reports, the first one of which was published in 1977. Early editions offered relatively basic considerations of clean cooking. However, over the decades the attention to, and the importance of, clean cooking has grown. A significant milestone was achieved in the preparation of its 2017 World Energy Outlook (WEO) (IEA, 2017) through the World Energy Model (WEM) and Energy Technology Perspectives (ETP) models, which involved extrapolating a baseline scenario of clean cooking access and household cooking practices.

A range of clean cooking solutions and their growth trajectories were considered, including LPG, electricity, biogas, natural gas, ethanol, improved biomass and solar cookstoves[7] . In general, access to modern energy services for cooking and a complete move away from inefficient biomass-based cooking was promoted, an assumption that we explore in more detail in Section 4. Whilst clearly an advance on what had existed before, considerations of interdependency between clean cooking and electrification were limited, and the underlying assumption was that e-cooking could not be adopted at scale in contexts where the power supply was unreliable or in off-grid areas due to its relatively high cost for both the end consumer and the implications on load management for mini-grid operators. As a result, e-cooking was only included as a viable modern cooking technology in countries with well-developed electricity networks, such as China and South Africa (IEA, 2017). The IEA's approach has been to include several generic electric cooking options with associated efficiencies; the assumptions on efficiency have then been changed over time to reflect the improved performance of new technologies, even if those are not included separately.

The IEA's most recent development of the Global Energy and Climate (GEC) Model (Figure 7), a hybrid approach combining the strengths of WEM and ETP models, signifies the biggest step towards a fully integrated energy planning approach. This comprehensive modelling framework is now pivotal in generating detailed long-term scenarios for various sectors, including cooking, across IEA's publications. It facilitates an in-depth assessment of implications and opportunities for achieving universal energy access at national or supra-national scales. E-cooking has been considered more systematically by the GEC than ever before. Recognition of improved appliance efficiencies, especially for induction stoves and Electric Pressure Cookers (EPCs) makes for a much more robust, and accurate, analysis reflecting the diversity of appliances available today, and the likely future trends for more efficient appliances. The IEA model fully integrates access to electricity and clean cooking and the relevant new demand by fuel is counted in the respective residential sector.

[7] Worth noting the solar cookstoves considered were not solar-electric but rather direct solar cookstoves.

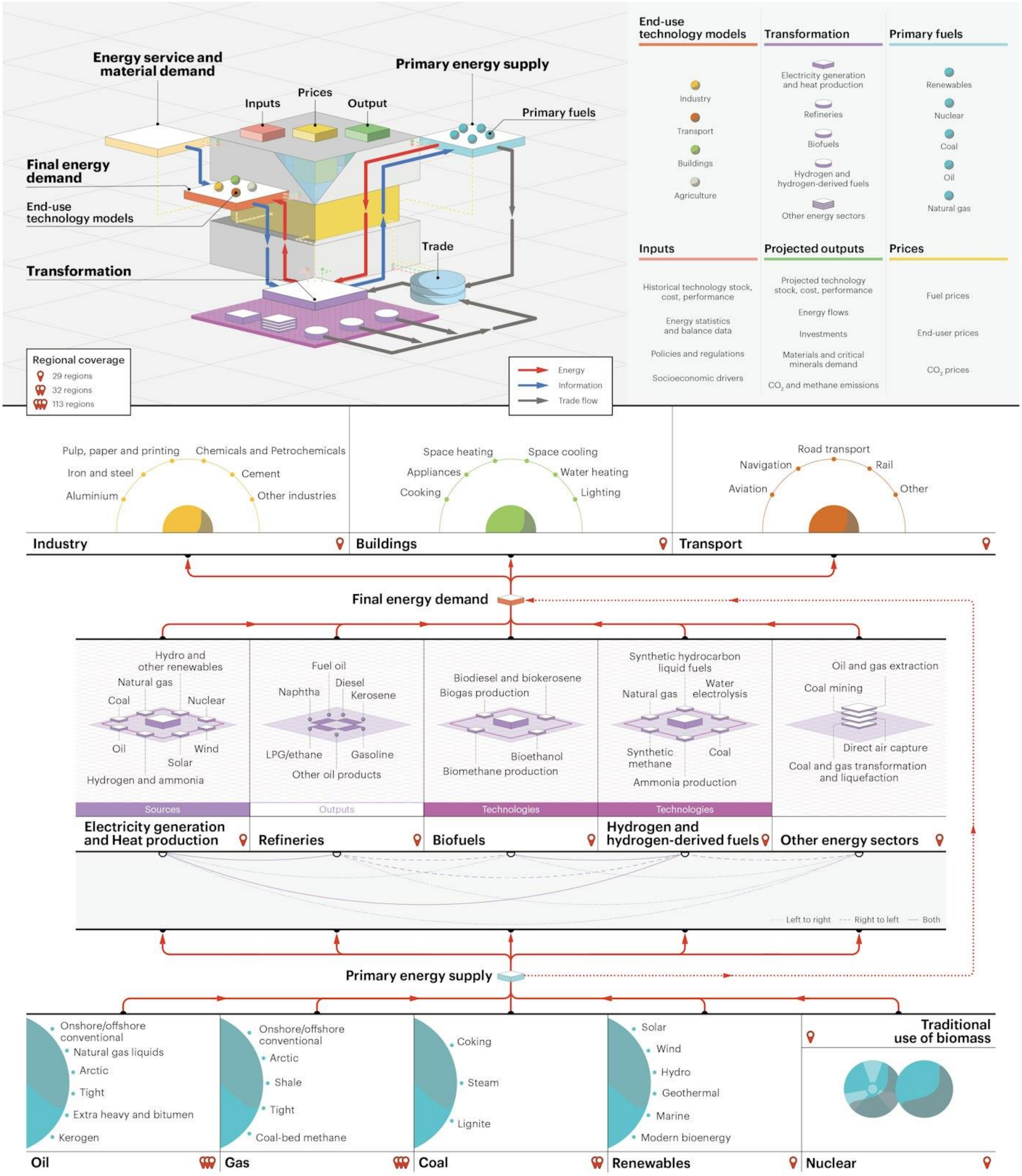


Figure 7: Detailed view of IEA's Global Energy and Climate (GEC) model (IEA, 2023).

Electricity sub-sector planning necessitates detailed demand estimations, requiring spatial and temporal granularity to assess implications for power generation and transmission and distribution investments. Modelling the impact of e-cooking demand is crucial, considering household adoption levels, residential power consumption, and usage patterns, especially during peak hours. Ideally, e-cooking demand scenarios should inform broader system optimisation, considering factors affecting household preferences for cooking technologies and fuels over time. However, clean cooking modelling remains nascent in many contexts, limiting such analyses for power sector planners. Previous attempts, as shown above, have either not considered e-cooking demand explicitly or incorporated it based on simplified assumptions without assessing its impact on the overall load profile. Where energy planning models had the capacity to factor in e-cooking, high-level political decisions favouring other cooking solutions or assumptions that e-cooking is not feasible in countries with low levels of electricity access drove choices to exclude e-cooking. The limitations of the modelling assumptions where e-cooking was explicitly considered have largely been due to the scarcity of available e-cooking data and the lack of consideration of a wider range of e-cooking appliances. Historically, e-cooking has been represented as the use of electricity with hotplate stoves which today are among the least efficient e-cooking appliances. For example, while initially reliant on the sole inclusion of hot plates as e-cooking solutions, recent national planning studies led by the Climate Compatible Growth (CCG) programme in Kenya, using OSeMOSYS, have started considering more energy-efficient e-cooking appliances, including induction stoves and EPCs, as well as a more robust power sector model (Kihara et al., 2024).

In addition to boosting energy access and ensuring energy security, carbon emissions reduction has also become a central objective for many countries (as outlined in section 2.3), necessitating mechanisms to reduce the share of unsustainably-sourced traditional biomass in final energy consumption alongside the more traditional objectives. To that end, it is again critical that a full spectrum of clean cooking solutions offering high emission reductions potential is analysed. This should include a basket of modern cooking solutions such as LPG, natural gas, biogas, ethanol, as well as e-cooking and, in particular, e-cooking powered by renewable energy (IRENA, 2023) to react to the complexity of clean cooking needs. This trend aligns with commitments under the Paris Agreement and the increasing adoption of longer-term net-zero plans.

Collaborative efforts involving development partners, international agencies, and academia have supported capacity building for national energy system planning. The formulation of Eswatini’s 2034 Energy Masterplan (2018), for example, which incorporates clean cooking components supported by initiatives from IRENA and the IAEA, exemplifies such collaboration. While clean cooking and electricity integration occurred at the system level, the exercise did not extend to geospatial analysis of results and their local implications.

3.1.2. Complexities for local energy access and clean cooking modelling

Beyond national level planning, analysis of clean cooking solutions needs to incorporate local needs and implications. Understanding how cooking needs and resources vary by location, and how variations in existing practices and population density cause hotspots of health impact, allow for targeted and tailored approaches to meet local needs effectively. For any energy access modelling exercise covering clean cooking, the variation in local contexts and resulting complexites should be considered, including:

- Affordability and accessibility: it is crucial to consider the affordability and accessibility of different clean cooking solutions, in their local contexts. While analysing various options, factors such as upfront costs, ongoing expenses, availability of fuel, and infrastructure requirements should be taken into consideration. Solutions that are cost-effective and easily accessible to the target population are more likely to be adopted and sustained.
- Cultural and cooking preferences: cultural and cooking preferences vary across regions and communities. It is important to consider these preferences when assessing clean cooking solutions. Understanding local cooking practices, traditional recipes, and the types of cookware commonly used can help tailor solutions that align with existing cooking habits and are more likely to be accepted and embraced by households.
- Health and safety considerations: clean cooking solutions should prioritize the health and safety of users. Assessing the impact of different cooking methods on indoor air quality, reducing exposure to harmful pollutants, and minimizing the risk of accidents, such as burns

or fires, should be integral to the analysis. Solutions that provide a healthier and safer cooking environment should be given priority.

- Infrastructure and energy system integration: clean cooking solutions need to be integrated into the existing energy infrastructure and systems. Evaluating the compatibility of different solutions with the energy grid in a region, considering the capacity and stability of the grid to accommodate increased demand, and assessing the potential for decentralized energy solutions can help ensure a smooth transition to cleaner cooking practices.
- Long-term sustainability: when analysing clean cooking solutions, it is important to assess their long-term sustainability. This includes evaluating the availability and sustainability of fuel sources, the environmental impact of the solution throughout its lifecycle, and the scalability of the solution to meet future energy demands, and these factors can vary strongly by location. Solutions that contribute to long-term sustainability goals, such as reducing greenhouse gas emissions and promoting resource efficiency, should be prioritized.

3.2. Towards methodologies for fully integrated modelling of electrification and clean cooking

At the core of integrated energy planning lies the definition of the energy system to be modelled, defining its sectors and technologies. An energy system encompasses the flow of energy commodities[8], linking primary energy sources with end-user services: upstream involves primary energy supply, transforming resources into secondary energy sources, while downstream focuses on energy demand, delivering services to end-users.

Many modern energy system planning tools, like MESSAGE, OSeMOSYS, and SPLAT, adopt an optimisation approach, aiming to identify the least-cost development pathway for meeting future energy demands under specified constraints. For clean cooking, optimising the mix of cooking technologies (e.g., e-cooking, improved biomass, LPG) within constraints is crucial. This optimisation informs policy insights, especially when integrated into electricity sub-sector planning, aiding in assessing factors affecting the optimal generation mix, required investments, and electricity tariffs. In optimisation approaches, end-use service demand is often defined exogenously, with tools like IAEA's MAED generating demand projections fed into supply optimisation models. Optimisation models heavily rely on accurately modelling system constraints and relationships.

Simulation approaches, on the other hand, are particularly suited for contexts with high informal activity and complex behavioural patterns, as is common in issues around clean cooking (Hollands & Daly, 2023). Simulations project scenarios from baselines, subject to constraints, to explore implications on investment, climate, and economic or health benefits. For instance, the Integrated Clean Cooking Planning Tool (ICCPT) (further explored in section 3.3.2) simulates transition pathways to universal clean cooking access, aiding in visualising potential scenarios and policy decisions' impacts.

Overall, both optimisation and simulation approaches play crucial roles in energy planning, offering insights into complex energy systems and informing policy decisions amidst evolving priorities like net zero transition pathways and universal energy access by 2030, in line with SDG7.

[8] e.g. crude oil, natural gas, coal

3.2.1. Clean cooking modelling in energy access planning

Energy access modelling primarily focuses on identifying technology options for specific end-user categories and locations, typically emphasizing the distribution segment of the supply chain. This comprehensive approach considers both supply-side factors (e.g., technical constraints, component costs) and demand-side inputs (e.g., consumer behaviour, affordability), utilising geospatial analytics to achieve detailed spatial and technological granularity. In the realm of electrification, this often translates to less precision in modelling generation and transmission aspects, usually simplified by a cost parameter for grid-based electricity supply. However, distribution infrastructure and decentralised systems receive thorough attention, with spatialised demand estimations enabling the identification of specific components, such as conductors and transformers. Various tools, including VIDA, OnSSET, and REM, adopt geospatial least-cost optimisation approaches for electrification planning, each offering different levels of technical and spatial detail.

Transitioning to an energy access planning approach for clean cooking necessitates a shift in focus towards identifying suitable cooking technology options and associated distribution infrastructure needs with high spatial granularity. This entails considering local characteristics such as population distribution, affordability, and resource availability. Given the propensity of households to use multiple cooking technologies and fuels (i.e. stacking), the approach prioritises identifying an appropriate mix of cooking technologies rather than a singular solution. The Case Study below gives an example of the Integrated Clean Cooking Planning Tool which presents a state-of-the-art approach to clean cooking access planning, integrating electrification models.

CASE STUDY – the Integrated Clean Cooking Planning Tool

The ICCPT, developed by IIT Comillas Pontifical University and MIT Energy Initiative in collaboration with SEforALL, focuses on Rwanda's clean cooking planning. The ICCPT methodology involves three main steps: incorporating base plans into geospatial modelling tools, modelling adoption while reflecting consumer behaviour and intervention impacts, and optimizing the transition to cleaner cooking considering economic, social, and environmental costs. ICCPT uses outputs from the Reference Electrification Model (REM) and the Reference Network Model (RNM) to tailor electrification infrastructure for e-cooking needs. It incorporates various cooking market segments, including electricity, LPG, biogas, pellets, as well as firewood and charcoal, with associated cookstoves or cooking appliances, considering infrastructure and adoption dynamics. ICCPT optimises clean cooking transition using multi-attribute optimization, assessing local supply costs and adoption decisions while considering social and environmental impacts. It also implements strategic financial planning paradigms for different stakeholders, including the private and public sectors and development partners.

However, the ICCPT currently excludes certain fuels (ethanol and LNG) due to data limitations. Also, its granularity is limited by data constraints on the demand side: supply areas have been aggregated into districts, to match the granularity available for demand areas with the division into rural and urban consumers, although the design of the electrical networks can be shown at the household level and the LPG supply chain at the village level. Despite these limitations, the ICCPT remains adaptable to changing policy priorities, market conditions, and the availability of clean cooking technologies.

While multiple scenarios have been developed using the ICCPT, the universal access to clean cooking scenario (the Ambitious 2030 Plan), as an example, proposes that the subsidies for LPG, biogas, pellets and Tier3+ charcoal and firewood stoves are increased to 90%. With this, a final clean cooking penetration of 87% is reached by 2030, disaggregated into 92% in urban areas and 83% in rural areas. As expected, the technologies that play the biggest role by 2030 are Tier3+ biomass stoves (30%), LPG (23%), pellets (18%) and e-cooking (13%). The social and environmental costs by 2030 are reduced and the cost of cooking for the population slightly increases for rural populations (by 1%) and decreases for urban populations (by 10%) when compared to what people pay today. The implementation of this plan requires a total investment of USD 238.5M for 2025-2030.

3.2.2. Geospatial modelling of clean cooking

To capture local variations in both drivers and barriers to diffrent clean cooking solutions, geospatial modelling has an important role. Two specialised geospatial clean cooking planning tools are the OnStove tool, developed by Sweden's KTH Royal Institute of Technology, and the ICCPT, developed by SEforALL, IIT-Comillas, and MIT-EI. While electrification planning generally adopts a least-cost approach, clean cooking planning methodologies vary. OnStove uses a net benefit approach, comparing stove and fuel transition costs with monetised externalities, while the ICCPT employs a multi-attribute least-cost approach, considering economic, social, and environmental factors. Despite differing objective functions, both tools aim to determine the most suitable local technology and fuel mixes.

OnStove, an open-source spatial tool, evaluates the relative potential of different cooking solutions based on their costs and benefits. It performs a clean cooking mix analysis optimising cost-benefit outcomes, considering geospatial variations of input parameters like fuel costs and resource endowment. OnStove calculates direct costs of clean cooking and monetises externalities like time saved, emission reduction, and improved health outcomes. However, OnStove lacks time-dynamic modelling and does not reflect changes from electrification programmes in its outputs, nor does it incorporate affordability or stove and fuel stacking considerations.

In the last few years, there has been a rise in efforts to merge various planning tools to enhance cross-sectoral and vertical integration in energy planning, especially with the increasing availability of open-source tools. Instead of re-inventing the wheel, this 'hybridisation' of energy planning tools and approaches is drawing on the advancements made to date. For instance, alongside the ICCPT's use of REM, a proprietary solution, the KTH Royal Institute of Technology and the World Resources Institute (WRI) are integrating OnStove with OnSSET for a study in Kenya (Khavari, 2024). Similarly, IRENA is working on linking SPLAT with OnSSET (e.g. IRENA, 2024), while IIASA and WRI are exploring an integration between a version of MESSAGE, OnSSET, and the Multi-sectoral Latent Electricity Demand (M-LED) model, generating geospatial and disaggregated demand estimates (Falchetta et al., 2023).

There is an opportunity to merge open-source tools into a comprehensive energy modelling workflow that can inform political and financial decisions for energy planners. The soft-linking of OSeMOSYS, OnSSET, and OnStove offers one potential pathway to achieve this and can be further strengthened by connecting with other open-source tools that provide financial, technical, and climate insights (Tan et al., 2023; CCG, 2023). This collaborative effort, as depicted in Figure 8[9], is currently supported by CCG.

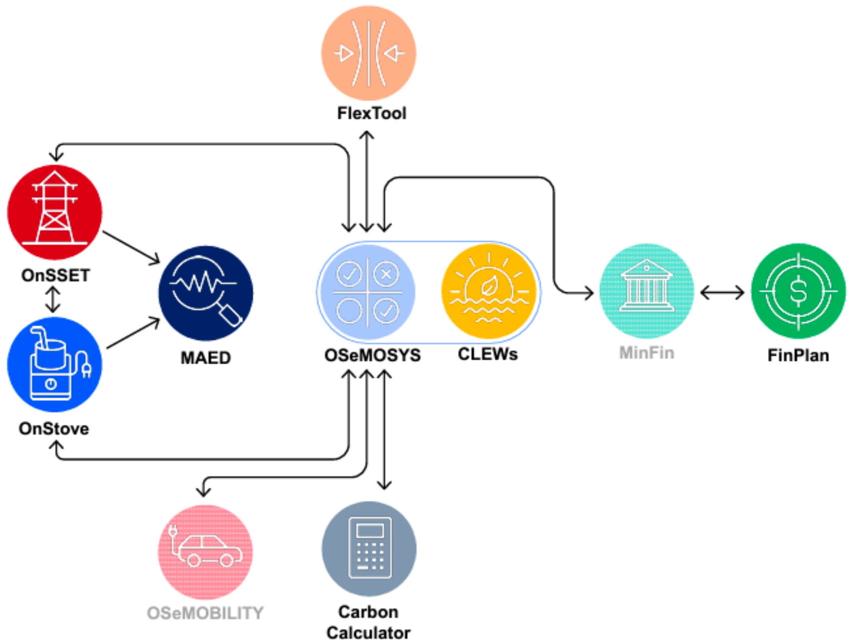


Figure 8: Developing an energy modelling analytical workflow based on open-source tools (CCG,2023).

3.3. Data for clean cooking modelling – opportunities and challenges

The backbone of any energy modelling endeavour and the resulting plans is data, yet obtaining high-quality datasets covering all necessary dimensions remains a significant challenge in integrated energy planning (AFREC, 2022, p27). Recent initiatives, such as open-access to energy datasets coupled with

[9] CLEWs stands for Climate, Land (Food), Energy and Water Systems

open-source modelling tools, offer potential solutions to accelerate progress in developing more robust energy plans and policies.

Data requirements for modelling exercises vary based on factors like methodology, tools used, energy system specifics, and the scope of the modelling effort. Despite the approach taken, reliable input data and assumptions are crucial, but challenges persist in data quality and accessibility, especially in regions with limited energy access. For instance, collecting detailed data on relevant technologies for end-use services like cooking, heating, and transport requires a combination of detailed consumption data and robust future assumptions. Other issues may relate to:

- Accurately estimating energy demand, particularly for cooking – it is complex and requires detailed baseline data on population density, lifestyle, household sizes, and affordability. E-cooking considerations add further complexity, as already alluded to in earlier sections, with challenges in estimating demand due to diverse appliance types and consumer adoption and usage behaviours. While tools like the World Bank's Multi-Tier Framework survey (see Table 1 below) aid in gathering data on the various energy access dimensions, challenges persist in data collection, especially regarding electricity demand for cooking.
- Adequately capturing stove and fuel characteristics, including lifetime, cost, efficiency, emissions, and safety - it is crucial for estimating the socio-economic and environmental benefits of modern cooking options. However, quantifying and monetising these externalities remains technically challenging.
- Gathering high-granularity infrastructure data – it provides vital contextual information, especially for geospatial approaches, but quality data at a high level of granularity is often lacking and primarily accessible through government agencies.
- Gathering data on the local availability of the variety of energy resources required for different clean cooking types, for example agricultural residues suitable for biogas production

Historically, several factors have contributed to the data deficit, including the absence of established data collection mechanisms, sustainability issues affecting historical data reliability, and insufficient cooperation among government ministries. Clean cooking planning has faced additional challenges due to reliance on informal data collection methods and the complexity of data related to traditional stove ownership, the common practice of stove and fuel stacking, and fuel distribution chains.

To address these challenges, promoting transparency, auditability, and data accessibility has become common practice. Organisations like CCG and SEforALL have issued guidance on data governance, and reports and approaches such as the IEA's WEO and OnStove refer to publicly available datasets. The IEA recently published the *Africa GIS Catalogue for Energy Planning* which specifically aims to avail open-access data for geospatial energy planning, and which is in line with the efforts towards more and more easily accessible resources for energy planners. Table 1 provides examples of platforms and websites offering open access energy (electrification and clean cooking) datasets. However, despite these collaborative initiatives, ensuring data quality remains a concern, with factors like consistency, completeness, accuracy, and granularity still posing challenges.

Table 1: Examples of platforms and websites promoting open access to relevant data sources.

Platforms and dedicated websites	Organisation	Description	Application examples
Electrification and clean cooking			
EnergyData.Info	World Bank	Open data platform providing access to datasets and data analytics that are relevant to the energy sector, including electrification and clean cooking	Data which can be used in energy modelling, e.g. for the application of OnSSET and OnStove or for the development of (or updates to) Integrated Energy Plans (such as those in Malawi or Nigeria).
RISE	World Bank	Set of indicators to help compare national policy and regulatory frameworks for sustainable energy, including electrification and clean cooking	RISE provides a reference point to help policymakers benchmark their sector policy and regulatory framework against those of regional and global peers, and a powerful tool to help develop policies and regulations that advance sustainable energy goals.
Tracking SDG7	IEA, IRENA, World Bank, WHO, United Nations Statistics Division	Global dashboard to register progress on the targets of SDG7, including electrification and clean cooking	The platform can be used by governments, development partners and other energy sector stakeholders to monitor progress on access to clean cooking.
Energy Access Explorer[10]	WRI	Open-source, interactive platform that uses mapping to visualize the state of energy access in unserved and underserved areas, including electrification and clean cooking	Energy planners can use the platform to explore the potential for grid extension, off-grid systems, clean cooking technologies and renewables for energy access in their countries.
SEforALL Universal Integrated Energy Planning Tools[11]	SEforALL, GEAPP, Rockefeller Foundation	Interactive data visualisation platforms displaying several layers of data, including results from extensive geospatial modelling and optimisation, including electrification and clean cooking	The tools provide geospatial analytics and modelling, and actionable intelligence for the private sector and government stakeholders to plan the expansion of least-cost access to electricity, access to clean cooking, health-facility electrification, and medical cold-chain energy assessment.

[10] The Energy Access Explorer has recently merged with the Clean Cooking Explorer (CCA, 2024).
[11] Already developed for Nigeria and Malawi; Madagascar currently under development.

Platforms and dedicated websites	Organisation	Description	Application examples
World Bank Data Catalog, including Multi-Tier Framework surveys	World Bank	Datasets from the World Bank's microdata, finances and energy data platforms, as well as datasets from the open data catalogue.	Data which can be used in energy modelling, e.g. for the application of OnSSET and OnStove or for the development of (or updates to) Integrated Energy Plans (such as those in Malawi or Nigeria).
Africa GIS Catalogue for Energy Planning	IEA (supported by Power Africa)	This platform compiles geo-referenced datasets detailing the distribution of populations, renewable energy resources, energy system infrastructure, and key demand centres as well as non-geospatial datasets of population growth rates, regulatory indicators, utility performance, and power market characteristics across the African continent. _	The repository can be used to conduct comprehensive energy modelling and energy access planning exercises for any country in Africa.
Clean cooking only			
Clean Cooking Planning tool	World Bank, MECS	Visualisation of potential transition pathways for universal access to clean cooking, including e-cooking	The tool can help energy planners, decision makers, program developers, and researchers visualize potential transition pathways to universal access to clean cooking solutions by 2030. For a selected country or region[12], users can view (i) the 2020 state of access (baseline), (ii) the 2030 business-as-usual (BAU) scenario, (iii) the cost of inaction, (iv) the current policy/regulatory environment, (v) the estimated investment cost based on the user's selected transition pathway and (vi) the estimated benefits of transition.
Electrification only			

[12] The tools covers sub-Saharan African countries only (rather than all African countries).

Platforms and dedicated websites	Organisation	Description	Application examples
Global Electrification Platform	World Bank, KTH, Development Seed, WRI, Derilinx, Google, University of Cambridge	Open access, interactive, online platform that allows for an overview of electrification investment scenarios for a selection of countries; does not include e-cooking	Electrification planners can explore 96 different scenarios to meet the access goals for 46 African countries. These different combinations and parameters are presented in the form of "layers". Users can overlay additional layers as well (e.g. wind potential, electricity networks, location of health facilities) to help illustrate useful contextual information about a selected country.
Open Energy Maps	MIT, University of Massachusetts Amherst, IEA, Power Africa, Energy for Growth Hub, Project Innerspace, e-GUIDE	An open data portal for energy systems modelling.	Open Energy Maps provide probabilistic estimates of electricity access and demand through machine learning models trained on satellite imagery and geospatial features. This innovative approach enhances planning models with uncertainty quantification, supporting decision-making for energy access initiatives in Africa.

Efforts to improve data availability, quality, and accessibility are essential for enhancing energy planning and policy development. As more data relevant to energy planning becomes available, it is important to ensure that standards and best practices for data collection, processing, storing and sharing are built and promoted across the energy sector. In particular, issues around data fragmentation and accessibility could benefit from improved multi-sectoral and multi-stakeholder collaborations and partnerships, and the challenge of comparability (where data capturing the same aspects or dimensions of energy access cannot be compared due to the differing assumptions or indicators used) could benefit from a greater standardisation in data collection mechanisms.

3.4. From Data to Multi-Fuel Clean Cooking Strategy

Access to high-quality, standardised data will continue to be crucial for conducting energy planning modelling exercises, which are also helping push the improved data agenda forward. Existing approaches often face limitations due to insufficient or incomplete data, or challenges with accessibility and data fragmentation. Poor data quality and completeness is further compounded by complex cooking behaviours, including fuel and stove stacking. The relevance and validity of energy planning exercises depend on access to quality data and the selection of appropriate energy planning tools. Achieving integrated energy plans requires collaborative efforts across sectors and stakeholders, with effective resource allocation to address socio-economic needs at local and national levels. Inter-ministerial coordination is essential for successful implementation, particularly in clean cooking planning, which involves complex cross-sectoral considerations.

To propel clean cooking transitions and maximise the opportunity to achieve the national and global net zero goals, it is crucial that a full spectrum of clean and sustainable solutions is considered, spanning both improved, efficient biomass technologies and modern cooking energy services. This should include promotion of truly integrated energy planning approaches which consider electrification and clean cooking simultaneously. It is reassuring that in recent years efforts to achieve cross-sectoral and vertical integration in energy planning have increased, especially with the availability of more open-source energy modelling tools. Integrating energy systems and access planning, while considering feedback loops between electrification and cooking, offers a comprehensive approach to conceptualise infrastructure availability, e-cooking viability, and system sizing.

Recent developments have seen an increasing trend towards hybrid approaches, which draw on the most significant advancements to date. Combining open-source tools into a holistic energy modelling workflow, such as the soft-linking of OSeMOSYS, OnSSET, and OnStove, shows promise and could lead to an open-source alternative to the recently developed Integrated Cooking and Electrification Planning Tool (ICCPT) in Rwanda, which is also represents a large step towards truly integrated energy planning. Enhancing these approaches with linkages to other open-source tools can provide critical financial, technical, and climate insights necessary for implementing energy access plans and guiding political and financial decisions. However, how do these approaches to integrated energy planning process inform the choice of infrastructure, transitions, and services to power a multi-fuel just energy transition? We address these questions in the following section.

4. Infrastructure, Transitions, and Services

In this section we consider the impact of multi-fuel clean cooking choices on the economy of Africa and the wider Just Transition. Investments in infrastructure are a deep concern of all governments and essential to a growing economy. Traditionally, the issue of clean cooking has been looked at through the dual lenses of household health and local environmental concerns (e.g. deforestation) - as in sections 1 and 2. This has enabled a cost of inaction, with the caveat that such a cost may be an underestimate of its impact on the wider economy. Accordingly, this section approaches the choice of a clean cooking strategy with specific fuel mixes through the additional and complementary lens of the wider economy. The basket of choices made to move towards clean cooking, could support, strengthen and leverage existing infrastructure or they could rely on the creation of new infrastructure which may or may not be within wider government planning. The section also touches on how governments might enable a transition from one basket of fuels to another, and finally, it considers whether clean cooking solutions should be anchored in sustainable services rather than considered a one-off intervention. The key messages are:

- **A Multi-Fuel Strategy is a key component of a Just Transition -** There is a need for a mix or basket of consumer orientated options/choices/services, to reach different socio-economic markets within any one country, and to provide a just transition.
- **Match Infrastructure Planning with Energy Services -** There is a need to integrate energy planning, including a wider view of climate commitments and infrastructure planning, so that this basket of choices matches the economic growth aspirations of the government.
- **Integrating the Economic Lens -** While health and deforestation is the traditional lens through which we look at the problem, we should consider the basket through other lenses such as economic growth, vulnerability to global price volatility and wider climate commitments.

4.1. Traditional & Modern Fuels – The Current Market Share

Within this context, the following section will provide an overview of clean cooking fuels and appliances that have significant scaling and growth potential to meet the clean cooking dimensions of SDG7 and beyond. We consider Tier 3 and 4+ Improved Cookstoves, LPG, green alternatives to LPG (biogas, bioLPG, hydrogen), electricity, and ethanol - focusing on them from an economic point of view while not neglecting the health and local environment lenses. For each, we consider the key markets, distribution mechanisms, positive attributes, negative aspects, constraints, influence of stove type, impact on foreign exchange, regulation & standards, key investors, dependencies, and potential specific national and global SDG contributions. Building on this technical overview, the discussion looks to communicate the importance of a multi-fuel strategy in the context of fuel and appliance stacking (the basket of choices), an often under recognized phenomena, and the impact of this on the economy and infrastructure of each.

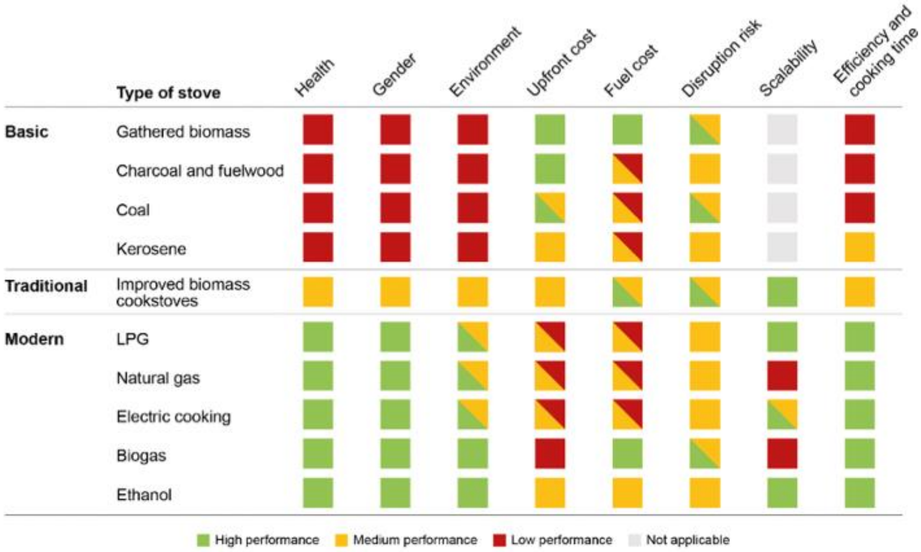


Figure 9: Cooking Stove Assessment of Performance Against Key Metrics (IEA, 2023, p. 21)

Before focusing in on the economic value characteristics, Figure 9 illustrates the specific performance characteristics of each modern fuel type which results in different barriers and enablers to initial adoption and long-term use from a **user-perspective**. As touched on in Section 1 and brought to the foreground in Section 2, these differences can act as a significant roadblock to implementing single fuel strategies as cooking needs are often complex and driven by socio-cultural context, resulting in the stacking of multiple cooking technologies to meet these needs (Jewitt et al., 2020; Ochieng et al., 2020; Robinson et al., 2021). Multi-fuel strategies then become a critical component of the transition to modern 'clean cooking for all' as blending approaches between multiples fuels and appliances can more effectively react to complex cooking needs. Section 1, 2 and 3 have provided the data and evidence for the importance of targeting the entire cooking stack or basket of choices - as per Figure 9 this would mean ensuring that basic cooking technologies transition from traditional, as a first step to improving the entire stack, and then to modern when the affordability, availability, and convenience of modern cooking fuels and appliances meet user expectations. Additionally, the balance of this multi-fuel approach, i.e. which fuels occupy which market share, must sit within a strategy that fits the country context as enabling environments differ significantly between specific countries (ESMAP, 2023, p. xxvi). Note also that we refer to the stack of available fuel/stove choices rather than a ladder which has the connotation of a step by step 'progression' through fuel choices rather than the more realistic and complex approach adopted here which prioritises fuel stacking across fuel types and allows also for the potential for 'leapfrogging' directly to 'modern' solutions.

What is the market share of these fuels now and in an 'Access for All' scenario across the African Continent? Figure 10 shows the total primary energy supply whilst Figure 11 presents the total final consumption by fuel, both presented in kilotons of oil equivalent (ktoe) across the period 2000 to 2021 for the African continent. In 2021, the primary energy supply was 808,768 ktoe with an energy dependence of 139%. Biofuels and Wastes (including fuelwood, charcoal, crop residues, processed biogas, and liquid biofuels) represent 45.3% of the total, while oil, petroleum products, coal, and natural gas shared the remainder almost equally. For energy consumption, biomass drives household consumption (51%), petroleum powers transportation (27%), and electricity accounts for 11% of total consumption, natural gas 8%, and coal 3%. (AFREC, 2023, p. 10). However, as outlined by AFREC's report Will Biomass Always Fuel Africa?, "This overall figure [for total final consumption] however masks very different realities across the continent […] the share of biofuel of the total energy consumption is above 75% for Western, Central and Eastern Africa, while it is below 25% in Southern

Africa and closer to 10% in Northern Africa" (p.13). This report argues that African governments must then diversify their energy sources and improve access to electricity while promoting renewable energies and energy efficiency for sustainable development. A critical component of this is meaningful data quality which can be significantly challenging, especially in terms of determining household level energy consumption (AFREC, 2022) – a key element in understanding the balance of fuels and appliances for a multi-fuel clean cooking strategy.

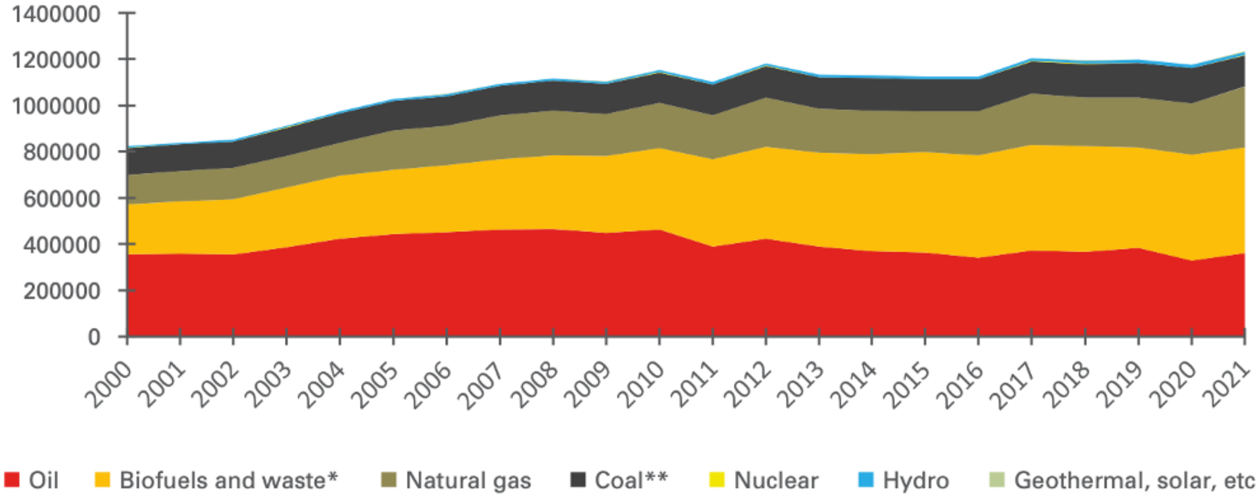


*Figure 10: Total Primary Energy Supply (TPES) from 2000 to 2021 by fuel (ktoe) (AFREC, 2023) * Includes firewood, charcoal, biogas, agro residues, waste, and others biomass ** Includes steam coal, coking coal, lignite and recovered coal.*

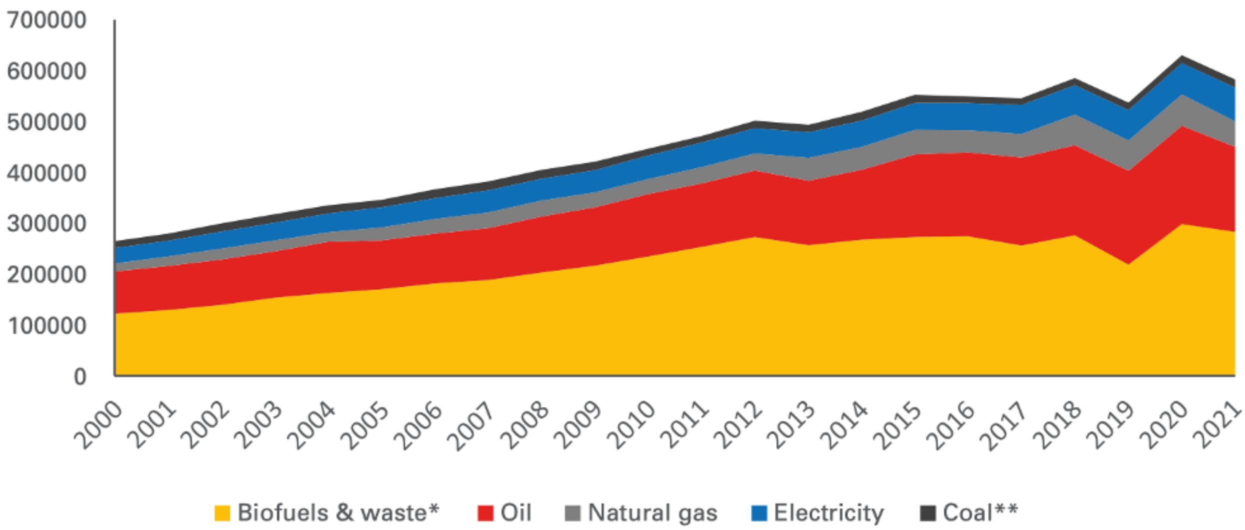


*Figure 11: Total Final Consumption (TFC) from 2000 to 2021 by fuel (ktoe) (AFREC, 2023) * Includes firewood, charcoal, biogas, agro residues, waste, and others biomass ** Includes steam coal, coking coal, lignite and recovered coal.*

In IEA's Access for All scenario, where 2.3 billion gain access to clean and modern cooking by 2030, of those gaining access "45% [will be] with LPG, 32% with improved biomass cook stoves (concentrated in rural areas), 12% with electricity and the remaining 10% with biogas or ethanol" (IEA, 2023). This scenario recognizes an uncomfortable truth, "As part of a just transition, Africa requires gas, and when global environmentalists call for an immediate end to fossil fuel utilization, developing countries in Africa will suffer economically and socially." (AFREC, 2022, p. 36). Solar, wind, and hydro energy could be a part of this just transition with natural gas playing a stabilizing role and where the cleanest source of locally available energy drives the transition In the context of clean cooking transitions "introducing gas for cooking (piped gas in urban areas and LPG in rural areas) could significantly reduce indoor air pollution, contributing to a reduction in premature deaths in Africa, and improve quality of life for the most vulnerable." (AFREC, 2022, p. 39). However, this means that clean cooking must be a central part of a multi-fuel energy strategy, not an additionality or afterthought.

Through the 'health and environment' lenses, fossil fuel-based natural gas is a higher tier solution that minimizes health and environmental impacts when compared to other unsustainably sourced biomass fuel types. The rest of this section addresses two key transitions – from biomass to improved cookstoves and from biomass to modern fuels – outlining the key infrastructure developments and associated services required to stay on track with NZE pathways. Finally, through this 'infrastructure, transition and services' lens we address the question, "what are the implications on the economy of Africa, its vulnerability to global volatility, and its needs for investment?"

4.2. Transitioning from Traditional Biomass to Improved Cookstoves

As outlined throughout this report a significant proportion of the global population rely on biomass as their primary energy source for cooking (44% according to The World Bank, 2020). Whilst it is generally accepted that relying on traditional three stone and lower tier improved cooking fuels and appliances which use biomass[13], is not a sustainable pathway to achieving SDG7 and global net zero targets by 2050, higher-tier biomass stoves may be a component of a multi fuel strategy for a just modern energy transition – as suggested in the closing of section 3. The last two decades has delivered an uptake of these stoves that has not kept pace with population growth even though they have attracted specialist financing from decisions makers (RBF, carbon finance etc.). Most policy makers now position higher tier biomass stoves as a transitional or 'stepping-stone' solution within the basket of wider solutions to enable the transition to modern fuels (such as LPG, Natural Gas, BioLPG, Ethanol, Electricity, Green Hydrogen, Biogas which are addressed in this sub-section). Whilst we share the critique that improved cookstoves have often not met the health and climate benefits often claimed for them (Havens et al., 2018; Gill-Wiehl et al., 2024 and see below), in this section we suggest that in order to strengthen the local economy, minimize vulnerability to a global volatility and to provide ongoing services to the last mile and most underserved parts of the population, they may have a place in a Net Zero world specifically in rural locations with low-density population and where their use may be matched to a renewable biomass resource.

Over the last two decades, a range of 'improved cookstoves' (ICS) have emerged onto the market. Some of these are produced locally, some in industrial settings in nearby towns and cities, and some imported. The argument for such stoves has been that they produce fewer particulates when burning biomass, which in turn should not impact the health of the user as much as traditional three stone fires, and with increased efficiencies, they would also reduce the consumption of the biomass reducing (although not eliminating) both direct carbon emissions and the destruction of forests as carbon sinks via deforestation. Throughout the 2010-decade doubt was put on the health efficacy of these ICS (Thakur et al., 2018; Thomas et al.,2015; Gemert et al., 2019) and consequently aspirations by decision makers gradually began to focus more on higher tier stoves that reduce Household Air Pollution (HAP) further, in order to fulfil World Health Organisation Guide thresholds for HAP. This focus on higher tier stoves was reinforced by systematic reviews such as Pope et al. (2021) who confirm that "*For personal exposure to PM2.5, none of the ICS (n = 11) were close to WHO-IT1 whereas 75% (n = 6 of 8) of LPG*

[13] as defined by the MTF framework

interventions were at or below WHO-IT1.". They go on to say "*stove stacking and background levels of ambient air pollution, have likely prevented most clean fuel interventions from approaching WHO-IT1*".

When analysing why the uptake of ICS has been patchy and not kept up even with population growth, Vigolo et al. (2018) (echoing findings in section 1) in their systematic review identified "*seven factors that may act as drivers or barriers to ICS adoption: economic factors; socio-demographics; fuel availability; attitude toward technology; awareness of the risks of traditional cookstoves and the benefits of ICS; location; and social and cultural influences*". This social and cultural influence often leads to the presence of stove stacking as a part of the consumers choice. Many cultural cooking practices occur with biomass cooking at the center, resulting in even greater barriers to the dis-adoption of these historically significant ways of preparing foodstuffs – simply put, in rural areas traditional stove cooking is unlikely to stop given firewood is sometimes free and forms a critical cultural component of cooking stacks (Jewitt et al., 2020). Given this background learning from the last two decades, what role do Improved Cookstoves (ICS) have in a multi fuel strategy and a just energy transition that maintains Africa's economic growth?

In a recent energy transition strategy, Kenya mapped market quadrants as illustrated in Figure 12.

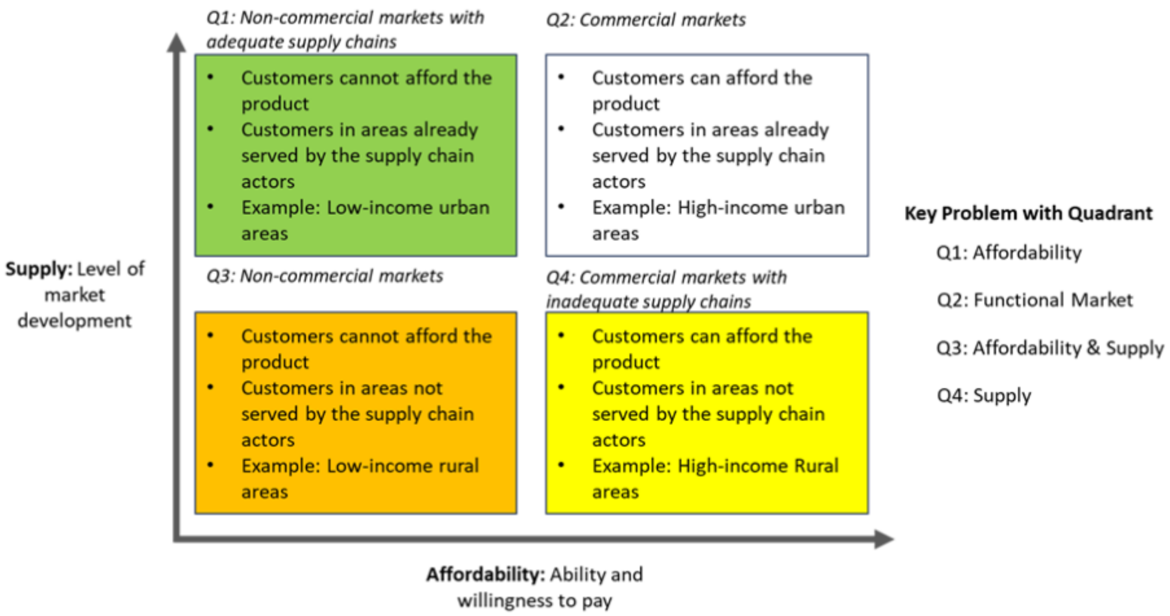


Figure 12: Quadrant Mapping of the Kenyan Energy Transition Strategy (MOEP 2024)

The learning described above on the impact of ICS of the last two decades has been across all the market quadrants. Discussion on the effectiveness and reach of ICS muddies the distinction between urban and rural and between rural high-density population agricultural contexts and rural low-density pastoral contexts. The barriers described in Vigolo et al. (2018) very much apply to traditional rural markets, and less so to urban and peri-urban areas where households are exposed to global media, are changing their socio-cultural mindsets, and have cash incomes not based on seasonal productions. For the higher tier stove supply-chain to reach remote rural areas is challenging whether that be for LPG, ethanol or electricity, and so one-off sales of an improved Tier 3 or 4 biomass stove are the most likely advance in stove transition (from traditional to ICS). While there are new developments such as Solar Home eCooking and Biogas, which are suitable for very remote locations, most other higher-tier clean cooking options require regular fuel servicing, and if all weather roads and dependable income are weak then the traction of higher-tier solutions within a multi-fuel mix will be weak in these areas.

The lack of all-weather roads could prevent the regular delivery of any modern fuel, and therefore in these cases there is likely to be a case for stand-alone cooking solutions be they ICS, solar or biogas.

There is therefore a likely role for Improved Cookstoves within a multi-fuel strategy through to 2030, and possibly all the way to 2050. If biomass consumption is reduced and is combined with policies that encourage replanting and biodiversity, then the fraction of non-renewable biomass (fNRB - the proportion of biomass that is harvested unsustainably in a given area) could be reduced and through the environmental lens, the use of biomass could become balanced. This is unlikely because of population growth, but not impossible, although it would require careful balancing within a well governed and regulated multi-fuel strategy.

However, through the health lens, there are few ICS that reduce particulates to the point where they do not affect the user's health. The issue is made more complicated by the immediate home set up. If the user is in a traditional home with few windows, then the smoke density even from a Tier 3 stove will be high. The Multi-Tier Framework identifies other factors in the exposure score such as the presence of a large window, or chimney extracting the smoke, or even if the stove is used outside, each makes a huge difference to the particulates the user is breathing in.

4.2.1. Tier 3 and Tier 4 stoves

As we shall see below, ICS use in low-density rural areas is likely to continue to be a one-off sale, for use with wood (or charcoal) rather than a service provision of a specialized fuel (such as pellets). In higher density rural areas, pellet and briquette provision may be appropriate, leading to the use of Tier 4 gasifier stoves. For both, the potential effect on the economy is important. since such stoves can be locally made, thus creating jobs, and neither the stove nor the fuel rely on imports, thus reducing dependence on foreign exchange and minimizing exposure to global price trends and energy security concerns. In a multi-fuel strategy designed to transition and grow the economy, improved cookstoves have a role.

In order to promote the cleanest possible cooking stack, policymakers should best encourage the promotion of **only** Tier 3 and 4 ICS. However, as discussed above, Tier 3 and 4 ICS often have the most significant barriers to their implementation, adoption, and sustained use due to the upfront costs to the user (compared to three stones), high customer acquisition costs for manufacturers and distributors in remote rural areas, dependence of the stove on a need for new fuel value chains, and lack of perceived alignment with cultural cooking practices (Lindgren, 2020; Perros et al., 2022; Robinson et al., 2021).

The upfront costs of the stove can be somewhat mitigated by Results Based Financing or Carbon finance. A Tier 3 stove does indeed save global emissions compared to a traditional three stone fire. Nevertheless, a recent paper by Gill-Wiehl et al. (2024) documented significant overclaiming in carbon projects and has created turbulence in the pricing of the voluntary carbon market. The same paper documented that stoves using metered methodologies (such as Gold Standard's) made more accurate verifiable claims, and while Tier 3 stoves cannot yet use the metered method, Tier 4 pellet stoves can. Since Tier 3 stoves mainly use locally collected fuel, or locally produced charcoal, then the issue of new fuel value chains applies mostly to Tier 4 stoves. In addition, there is a very limited selection of ICS products which qualify as Tier 3 and 4 based on the CCA's Clean Cooking Catalogue. Currently, the majority of tier 3 and 4 ICS are manufactured in Asia and imported to the African continent, restricting the flexibility of scalable distribution and service-based delivery models.

There is no obvious mitigation of the lack of perceived alignment with cultural practices other than to ensure the stoves are part of a multi-disciplinary strategy, which engages local and traditional authorities and other stakeholders in the discussions about the benefits of the stoves, ensures that health, community and agroforestry extension workers are aware of the benefits and are 'on-message', and there are sufficient community demonstration events led by respected known local households who have adopted the stoves.

Table 2: Tier 3 Improved Cookstoves Fuel Snapshot

Fuel name	**Tier 3 Improved Cookstoves**
Key markets	Rural
Distribution mechanisms	Local Agents, Shops, and Distributors (including self help groups) working with local and international manufacturers. Use of RBF and Carbon finance to mitigate upfront costs. Requires demonstration events until critical mass is achieved to overcome traditional reluctance to transition.
Positive attribute	Targets the most 'unclean' part of cooking stacks replacing three stone fires. Continues to use local wood reducing the time spent in collection and reducing both HAP and GHG emissions. Potentially has net zero GHG if only used with renewable biomass – but this is only possible in very limited geographic locations with low-density populations.
Negative aspect	Does not directly address the unsustainable sourcing of firewood, nor the safety and health concerns for the collector. The use of these stoves in households may not match the IWA/ISO Lab Standards and still result in health impact.
Constraints	Socio-cultural adoption constraints.
Influence of stove	Type of stove significantly affects the adoption of Tier 3+ ICS. This adoption and subsequent sustained use is based on a complex blend of socio-cultural, financial, and environmental factors.
Cookware	No special cookware is required – all pots and pans are useable on a household scale ICS. However, specialist pots are required for the institutional and commercial scale ICS.
Impact on Foreign Exchange	Rapid uptake would require significant foreign investment as many manufacturers are not yet based within the countries that require clean cooking interventions. Regional production is possible (e.g. BURN serving East Africa from Kenya).
Regulation	IWA/ISO Testing Standards for Indoor and Outdoor Emissions, Thermal Efficiency, and Safety.
Key Investors	International Development Donors, Voluntary Carbon Market, Universal Access funding
Dependencies	Either users are already purchasing fuel and wish to decrease their costs through improved efficiencies, or there is recognition that adopting better quality stoves would reduce fuel collection alleviating labour burden, and/or there is a willingness to invest in non-modern cooking technologies for other reasons (e.g.the improved cookstoves are more convenient to use than traditional three stone fires, recognition of the health and quality of life benefits)

Health impact	Tier 3+ cooking technologies which are fed with biomass often still exceed the safe levels of CO & Particle Matter as defined by WHO.
Climate impact	Black Carbon is a significant contributor to climate change and produced by the incomplete combustion of biomass, Tier 3+ cooking technologies have the potential to reduce the black carbon production due to cooking, but still emit some. Reduced fuel consumption opens the possibility that the fuelwood can be sourced sustainably leading to net zero GHG.
Local environment impact	Tier 3+ cooking technologies can increase the efficiency of burning and thus reducing the rate of deforestation associated with cooking.
Local Economic impact	Local Agents, Shops, and Distributors look to create markets for their products and this can create job opportunities and increase local cashflows. Factories for approved Tier 3 stoves could be within the country creating local jobs.
Macro-economic impact	Viable carbon credit/offset pathways.

To reach Tier 4 biomass combustion, the stove requires either passive or active airflow to ensure gasification, and/or regular-shaped fuel. This additional technical complexity has resulted in higher-tier improved cookstove manufacturers needing to have more control over their value chains, beyond manufacture and distribution, to include fuel supply - referred to as vertically integrated companies. These vertically integrated companies have looked to develop delivery models which rely more heavily on providing services rather than technological solutions, examples include Mimi-moto and African Clean Energy and previously Inyenyeri. By focusing on providing longer term services, for example providing tier 4 stoves at a subsidized cost and a subscription service to biomass pellets, these vertically integrated companies are stepping past many of the barriers associated with initial adoption by incentivizing long-term use. Nevertheless, regular provision of a fuel such as pellets is subject to infrastructural constraints similar to the regular provision of say LPG or Ethanol[14]. Across the African continent, this transition is made simpler by the rise of African based Tier 4 manufacturers who not only have more control over their pricing and market but also create wider macro and micro socio-economic benefits. Despite the emergence of these companies, as is the case with Tier 3 stoves, currently, the majority of Tier 4 ICS are manufactured in Asia and imported to the African continent, restricting the flexibility of scalable distribution and service-based delivery models. Some organisations define Tier 4 stoves with fuel provision as a modern energy cooking solution (mecs).

[14] The experience of Inyenyeri (Rwanda) was that some households were not able to attain timely delivery of their next batch of fuel. ESMAP 2021

Table 3: Tier 4 Improved Cookstoves Fuel Snapshot

Fuel name	**Tier 4 Improved Cookstoves**
Key markets	Rural and Peri-Urban
Distribution mechanisms	Local Agents, Shops, and Distributors working with international manufacturers – typically Tier 4 Improved Cookstoves are internationally imported. Small wins have been made through the integration of remote monitoring sensors which allow effective fault detection of devices, integrated payment, and carbon mechanisms
Positive attribute	Targets the most 'unclean' part of cooking stacks by, in an ideal setting, replacing three stone fires. Can use local biomass although there is generally a need for uniformity of fuel. Local production of pellets or briquettes gives job creation. If fuel is created from waste or sustainable sources, then GHG emissions are 'balanced' to Net Zero over long term. When used properly, kitchen generated HAP is near equivalent to LPG.
Negative aspect	The stoves rely on a supply of fuel, which in turn depends on an infrastructure to deliver it. They also monetize the fuel even though it is biomass, which means their use in rural areas where collection of (free) firewood is the norm faces socio cultural and economic challenges. Upfront costs can be higher than even electrical appliances and therefore requires mitigation by PAYG, RBF or Carbon finance mechanisms.
Constraints	There are significant financial and sociocultural barriers to adoption, and pellet stoves require a new value chain for the sustainable distribution of cooking pellets.
Influence of stove	The adoption and subsequent sustained use are based on a complex blend of socio-cultural, financial, and environmental factors.
Cookware	No special cookware is required – all pots and pans are useable on a household scale ICS4. However, specialist pots are required for the institutional scale ICS.
Impact on Foreign Exchange	Rapid uptake would require a significant foreign investment as many manufacturers are not based within the countries that require clean cooking interventions. However, pellet and briquette production could be localised industry.
Regulation	IWA/ISO Testing Standards for Indoor and Outdoor Emissions, Thermal Efficiency, and Safety.
Key Investors	International Development Donors, Voluntary Carbon Market.
Dependencies	Users are already purchasing fuel and wish to decrease their costs through improved efficiencies, or there is recognition that it would reduce fuel collection alleviating labour burden, and/or there is a willingness to invest in non-modern cooking technologies, that the improved cookstoves are more convenient to use than traditional three stone fires.

Health impact	Tier 4 cooking technologies which are fed with biomass can offer safe levels of CO & Particle Matter as defined by WHO.
Climate impact	Black Carbon is a significant contributor to climate change and produced by the incomplete combustion of biomass, Tier 4 cooking technologies have the potential to reduce the black carbon production due to cooking. Reduced fuel consumption opens the possibility that the fuelwood can be sourced sustainably leading to net zero GHG.
Local environment impact	Tier 4 cooking technologies can increase the efficiency of burning and thus reduce the rate of deforestation associated with cooking and/or use processed waste materials formed into pellets and briquettes.
Local Economic impact	Local Agents, Shops, and Distributors look to create markets for their products and this can create job opportunities and increase local cashflows. Factories for approved Tier 4 stoves could be within the country creating local jobs. New pellet and briquette production could create jobs in production and distribution.
Macro-economic impact	Viable carbon credit/offset pathways.

Pathways to 2030 and beyond. Given the overall intent to provide a cleaner cooking stack through a multi-fuel strategy, only Tier 3 and above ICS should be implemented within National Clean Cooking strategies in order not to take away valuable resources from other modern cooking fuels and appliances. ICS 3+ is best offered as part of a basket of choices to rural areas which have limited transport infrastructure that can enable regular fuel deliveries[15]. If consumers are collecting firewood and not monetizing their cooking with regular payments for fuel, then ICS3+ can be helpful to reduce fuelwood consumption. There remain strong cultural barriers, nevertheless, which can only be overcome by community engagement. Tier 4 ICS with pellet and briquette fuel supply chains also have significant barriers to adoption and sustained use, most importantly the technical cost is broadly equivalent to e-cooking and LPG appliances. Carbon finance is possible with metered verification.

4.3. Transitioning from Biomass to Modern Fuels

In this section we address our second key transition - from biomass to modern fuels - through the lens of health, environment, and economy, paying special attention to the relevant infrastructure developments and associated services. As discussed throughout this report, the transition to modern fuels through a multi-fuel strategy is key to effectively reacting to the complexity of clean cooking needs (ESMAP, 2021). Whilst the balance and specific market shares of this multi-strategy will be country specific, LPG, Natural Gas, BioLPG, Green Hydrogen, Ethanol, Electricity, and Biogas, all provide viable longer-term solutions to the clean cooking challenge.

4.3.1. LPG

While developed economies are beginning to question the impact of kitchen emissions from gas cooking on health, particularly but by no means exclusively on children (Blair et al, 2023), it is

[15]See below for example for the needs of LPG to have a road network for delivery, eCooking to have electricity supplies, ethanol to have a network of deliveries – and see above for ICS4 to have pellet and briquette supply.

understood that LPG is a higher tier fuel, that is designated by the World Health Organisation as safe for the cook and strongly beneficial in terms of reducing carbon emissions and deforestation. As such it is a desirable part of the multifuel mix to achieve clean cooking access and in many recent interventions within the clean cooking arena, LPG has been presented as being ripe for relatively easy deployment (e.g. as mentioned previously, nearly half (45%) of the 2.3 billion people to be brought clean cooking solutions (in order to meet the 2030 target) will be served by LPG according to the IEA, 2023). Lessons from India, Indonesia, Morocco and Brazil, who have taken LPG to scale, suggest that with the enabling policy environment and a basic transport network, LPG can be accessed at scale.

Nevertheless, despite some impressive results in terms of the spread in access to LPG and stove distribution (100 million households in eight years in India), the affordability of LPG remains a challenge. Most LPG programmes have incorporated significant levels of subsidization, the costs of which have had to be borne by the state. There are some mechanisms being explored for other financing sources for LPG, including somewhat controversially the use of carbon finance.

Even with these levels of subsidization, longer-term affordability and sustainability have been questioned in several contexts with, for example, India reporting low refills among many poorer households even with significant subsidies (e.g. Indian government figures suggest that "LPG consumption trends of last few years show consumption has not increased despite a rise in number of LPG connections" (Business Today, 2020)). This has been offset to some degree by moving from subsidizing the distributor to introducing direct cash transfers to individual households (which have gradually become more targeted) but these have depended upon the development of digital delivery systems and pre-payment infrastructure.

Once subsidies are introduced, they are difficult to readjust, with Ecuador, for example, experiencing public disorder when subsidies were removed within an effort to counter major public losses (LPG subsidies cost the Ecuadoran government USD 700 million per year, with the figure as high as USD 2.1 billion for Morocco and USD 3.9 billion for Indonesia in 2018 (Anggono et al., 2022)). LPG imports and subsidies can, therefore, represent huge costs to countries that have adopted large-scale LPG programmes, both in terms of foreign exchange losses and government budgets for subsidies. Of course, the former is not such an issue for countries that are able to make use of their own supplies rather than having to import LPG from abroad, whilst smaller land-locked countries are less able to strike lower priced contracts with their suppliers. This suggests again, the importance of national context to the nature of dynamics of individual multi-fuel clean cooking strategies and the potential importance of cross-border infrastructure.

In terms of household affordability and supply systems, pay as you go processes can mitigate upfront costs, and improved cylinder tracking can enable timely refilling and safe cylinder reticulation. LPG is frequently popular with consumers, having been part of the suite of cooking fuels for many years (even where take-up has been relatively low) and associated with aspirational transitions in status and income. The cook experiences a flexible and clean kitchen environment, with LPG able to cook most foods to taste satisfaction.

Table 4: LPG Fuel Snapshot

Fuel name	**LPG**
Key markets	Urban and Peri Urban (+ densely populated rural).
Distribution mechanisms	Local agents, sellers or shops – specialised infrastructure is required to ensure cylinder reticulation by seller and safety checks with refills.
Positive attribute	Potentially a flexible clean cooking experience. Minimal kitchen-based emissions (Tier 5). Fits the mindset of 'going to the market to get food and other things'.
Negative aspect	Often an import with associated drain on foreign exchange. Price subject to global commodities trading. Sometimes it requires subsidies to price compete with alternatives like charcoal. Refilling even with subsidies has chequered history. Some safety concerns by consumers.
Constraints	Requires investment in processing plants, storage and distribution networks, with regular secure flows.
Influence of stove	Stoves are of international design and burners are well established.
Cookware	No special cookware required – all pots and pans useable.
Impact on Foreign Exchange	Often an import with associated drain on foreign exchange.
Regulation	Tight regulation required to ensure cylinder safety and consumer protection
Key Investors	Oil industry and International Development Banks
Dependencies	Very dependent on the global supply and exploitation of African resources.
Health impact	A cleaner alternative for the Cook than cooking with biomass (wood, charcoal, agricultural residues).
Climate impact	The extraction and use of non-renewable resources have a significant climate impact and drive the increased CO2 concentrations. However, these are less than biomass on a traditional stove with Black Carbon and currently high fractions of Non Renewable Biomass (fNRB).
Local environment impact	Reduces dependency on biomass, which has the potential to reduce local deforestation and thus stabilize local forests.
Local Economic impact	Investment required in import terminals, processing, handling, distribution and cylinder refilling – all of which can create semi skilled jobs. Dependency on global prices.
Macro economic impact	Import/export of LPG is dependent on global trends in oil industry. Emerging pressure of Net Zero could make markets turbulent.

The role of LPG in a multifuel strategy has been captured in much of the modelling work. In their global Access for All scenario, IEA report 29% as a proportion gaining access though LPG, but this is a scenario that includes Asia and 23% gain access through Natural Gas. Given the infrastructure for Natural Gas is not common in Africa, the proportion of transition to LPG in SSA is likely to be higher given the same modelling assumptions which is reflected in the figures cited above. Indeed, in a similar exercise by ESMAP in State of Access to Modern Cooking (2020), in the 2030 scenario with everyone reaching tier five stoves, LPG formed 70% of the fuels.

Pathways to 2030 and beyond. LPG uptake at the levels suggested in some of the cited analyses will require significant investment across Africa – refilling networks for cylinders, distribution infrastructure, road networks for cost-effective transport, import terminals and or refining capacity for LPG offtake and storage. FGE 2024 (to be published in coming week) in its "Long-Term Price and Dynamics for LPG Markets' attempts to look at the longer-term price volatility. In the US, MB LPG flat prices are often referenced as a percentage of crude oil. Historically, this ranged between 40% to 60% of WTI. In lengthy markets, US MB LPG will be priced under 40% of WTI, and in tight markets it will be priced above 60% of WTI. FGE forecasts the price sensitivity analysis based on the ranges of Brent crude outlook, positive and negative variances to the MB/WTI ratio including how lengthy or tight the market could be given key factors. Figure 13 details the price forecast of the MB price marker.

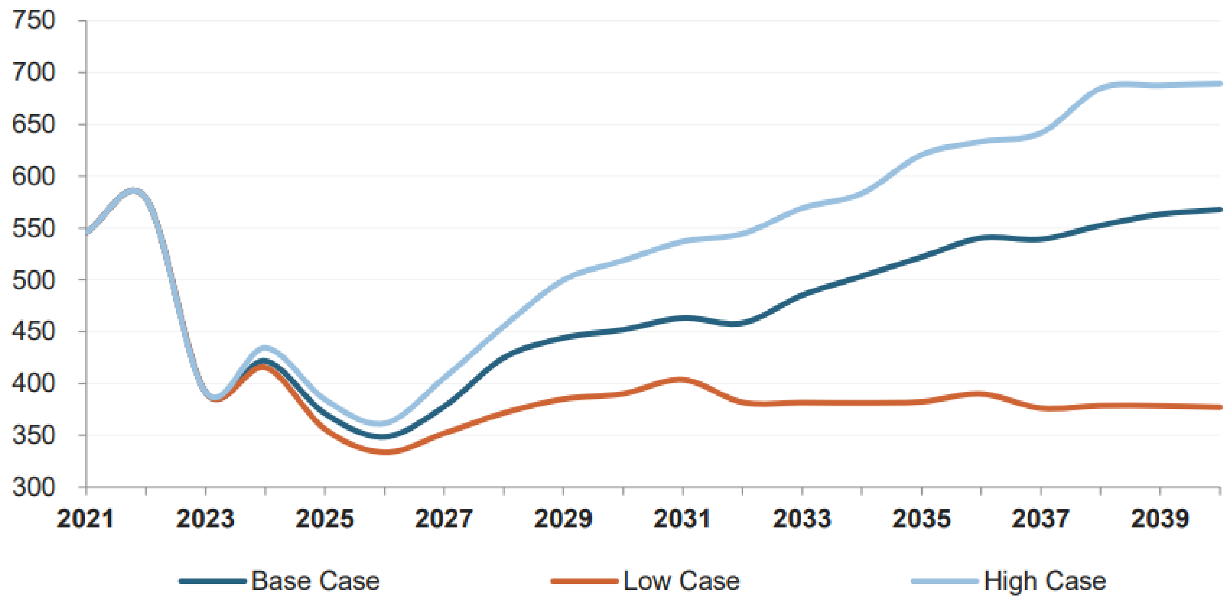


Figure 13: US LPG (MB) Price Forecast Sensitivity Analysis (Nominal), US$/t (FGE, 2024)

As one can see, with the low case, the price remains much as it is today, however, the base case suggests it will return to the highs seen in 2021 as a result of COVID and the Ukraine war, and in the high case, the price may exceed those levels. While LPG provides a potential Tier 5 experience for consumers, its deployment at scale may expose African economies to an unwelcome global price volatility.

4.3.2. Natural Gas

With a number of major natural gas discoveries across the African continent over the last 10 years resulting in significant existing and emerging producers – Figure 14 – an uncomfortable reality is that both oil and gas will play a significant role in Africa's just energy transition (AFREC, 2022). However, investments in natural gas extraction, especially for domestic consumption, as well as the emergence of modern, sustainable, and reliable energy systems and services at a lower energy unit cost create significant 'external' climate transition risks for African producers (Anwar et al., 2022). New renewable projects are already competitive with gas projects on today's markets (IRENA, 2022; Breyer et al., 2023; CAP-A, 2023).

Within the context of clean cooking, natural gas is often seen as a cleaner alternative to biomass, charcoal, and other processed crude oil fuels, such as kerosene, for residential cooking and heating. It is also generally cheaper than LPG (particularly where utilized close to production facilities).Typically, this requires compressed gas infrastructures to directly feed residential homes through a network of gas pipes or the natural gas is refined to produce LPG further increasing the complex role of natural gas in just energy transitions (Coroneo-Seaman, 2023). North Africa is the only region within the continent where Natural gas plays a major role in meeting clean cooking targets. According to the IEA (2020) 45% of the region's population use natural gas as their primary cooking fuel (with 51% being supplied by LPG). These figures are dominated by the 60% of Algerian and Egyptian populations who cook with natural gas given their country's natural gas resource-base (as opposed to the dominance of LPG in Tunisia and Morocco). Egypt has invested significantly in the infrastructure needed to transition its citizens away from expensive LPG imports to utilizing its own sources of LNG directly. The Household Natural Gas Connection Project was launched in 2015 to increase and facilitate household access to a reliable, low cost, grid-connected supply of natural gas. By 2015 12 million residential and commercial buildings has been connected to gas supplies and current plans will see this reach 19 million by 2025.

With a number of African countries having recently started to develop significant natural gas reserves, there may be some important lessons to draw on from Egypt's experiences in connecting its urban populations, although it is also true to say that few countries with significant LNG reserves have invested heavily in domestic piped gas infrastructure (India being one exception to this in its urban areas where 15 million urban households are served) and it is difficult to see many African nations following in the footsteps of those who have, given the costs of infrastructural development for PNG.

Figure 14: Map of Existing & Emerging Natural Gas Producers (Anwar et al., 2022)

Table 5: Natural Gas Fuel Snapshot

Fuel name	**Natural Gas**
Key markets	Primary market in urban households. The market is households for cooking and heating as well as commercial power generation and feedstock for fertilizer and LPG production.
Distribution mechanisms	International distribution through Liquid Natural Gas, national distribution through pipe network with Compressed Natural Gas.
Positive attribute	Minimal kitchen emissions and provides similar cooking experience to LPG.
Negative aspect	Often an import with an associated drain on foreign exchange, however, domestic natural gas production is increasing across the African continent. Imported prices are based upon international trade and often require subsidizing to be affordable for hard-to-reach customers. In most cases, requires significant infrastructure development to get gas safely and efficiently to customers.
Constraints	Significant infrastructure costs and costs associated with the establishment of domestic and international markets – including extraction, processing, storage, distribution, and consumption networks.
Influence of stove	Use similar stove to LPG, however, the gas jets would need to be modified between using the two gasses due to the difference in gas density.
Cookware	No special cookware required – all pots and pans useable.
Impact on Foreign Exchange	When imported can have a significant drain on foreign exchange, when exported can have a net positive on foreign exchange.
Regulation	Given the emergence of natural gas production on the African continent, significant effort would be required to develop content specific regulations and standards
Key Investors	Oil Industry and International Development Banks.
Dependencies	Dependent on global industry, a slow transition to renewable energy production, and the social acceptance of promoting fossil fuel as a clean cooking fuel.
Health impact	A cleaner alternative for the Cook than cooking with biomass (wood, charcoal, agricultural residues).
Climate impact	The extraction and use of non-renewable resources have a significant climate impact and drive the increased CO2 concentrations. However, they are less than biomass on a traditional stove with Black Carbon and with the currently high fractions of Non Renewable Biomass (fNRB).

Local environment impact	Reduced dependency on biomass, which has the potential to reduce local deforestation and thus stabilize local forests.
Local Economic impact	Limited local economic impact as gas for cooking and heating is directly piped to households, at extraction sites there is potential for industrial jobs.
Macro-economic impact	Potential for the export of natural gas to African/global markets has the potential for large macro-economic impacts.

Pathways to 2030 and beyond. Both LNG and LPG are key components when modelling a NZE case by 2050 (UN Energy, 2023) and identified as a key element of the just transition by the African Union (AFREC, 2022). However, the increase in affordability of other renewable energy generation mechanisms is slowing the growth of natural gas markets and resulting in the rise of alternative approaches to the challenge of cleaner cooking systems and services powered by natural gas. Natural gas may be a viable interim solution to the longer-term solutions outlined below.

4.3.3. BioLPG (and Circular LPG)

An emerging technology that holds considerable promise is bioLPG. This is one of many processes that can deliver Liquefied Petroleum, that can be inserted into existing LPG supply chains. With a multitude of global companies focusing on decarbonising there are increasing investments into the renewable space often called 'circular LPG'. BioLPG, which is only one example of circular LPG, is the production of bio-derived Liquefied Petroleum Gas from waste in anaerobic processes the same as biogas (see below), but with the added refinement that the propane is isolated. This means that the resulting gas can be used in the existing network of LPG cylinders. Municipal waste is a prime candidate for such production, and there are emerging plans for refineries in Kenya, Cameroon and Rwanda. Adding this to the fuel basket potentially gives all the benefits of LPG without the dependencies on the global price of oil although the technology remains in its infancy.

Table 6: BioLPG Fuel Snapshot

Fuel name	**BioLPG**
Key markets	Urban and Peri Urban
Distribution mechanisms	Local agents, sellers or shop – has to have specialised infrastructure, to ensure cylinder reticulation by seller and safety checks with refills.
Positive attribute	Potentially a flexible clean cooking experience. Minimal kitchen based emissions (Tier 5). Fits the mindset for the user of 'going to the market to get food and other things'. Creation of the fuel contributes positively to the problem of municipal waste. Similar byproduct of organic residue fit for agricultural use.
Negative aspect	Creation of the fuel requires investment in the waste system. Separation of organic material is essential. Refining to Propane only requires extra process, and the raw (mixed fractions) gas could be used in other processes including running generators that feed into the grid.
Constraints	Requires investment in waste systems.

Influence of stove	Stoves are of international design and burners are well established.
Cookware	No special cookware required – all pots and pans useable.
Impact on Foreign Exchange	Locally produced fuel, so potentially minimal impact on FX.
Regulation	Tight regulation required to ensure cylinder safety and consumer protection
Key Investors	Municipalities working in partnership with LPG distributors
Dependencies	Very dependent separation of municipal organic waste.
Health impact	A cleaner alternative for the Cook than cooking with biomass (wood, charcoal, agricultural residues).
Climate impact	The use of a renewable resource (municipal waste) which otherwise would potentially create methane is a win win.
Local environment impact	Reduced dependency on biomass, which can reduce local deforestation and stabilize local forests.
Local Economic impact	Investment required in waste management is likely as cities grow. Local jobs created.
Macro economic impact	Cost effectiveness of the strategy and the resulting cost per kg of bioLPG will depend on sunk costs in waste management.

It can be noted that the processes above start with commercial waste disposal (from agricultural residues as well as municipal waste) to biogas through anaerobic digestion. Gas from waste can of course also be used as a fuel for power plants, for instance, the 20.4 GWh of electricity annually generated from landfill gas in Mauritius or the 2.8 MW installed capacity of an anaerobic digestion power plant in Kenya. The additional processing for bioLPG is proposed in order to produce a distributable fuel that is suitable for cooking and can substitute the source of LPG production from a fossil fuel to local sustainable waste management. We will pick up on domestic biogas below.

Pathways to 2030 and beyond. Waste to energy is an important part of urbanization and its necessary infrastructure (IEA, 2020). Waste disposal, can potentially have its costs mitigated by turning the waste into energy. Without waste processing, landfill with organic matter can release methane to the atmosphere, and is a powerful contributor to climate change. Industrial sized biogas is considered an important element of the global and African green transition and Net Zero 2050 development (IEA, 2022). The latent energy of wastes and residues can be managed by reduction, reuse, recycling, and recovering. It can mitigate the need for energy imports, decarbonise the energy supply and justify modern waste handling investments. Waste to energy, then, is both an essential mitigation of rotting organic matter, and a potential benefit to the clean cooking space. Of the various processes available, processes such as COOL LPG and IH2, are additional refinements that produce propane that can be inserted directly into existing LPG infrastructure. UNEP projects 224 mmtpa of MSW produced by Africa by 2025 before doubling by 2050 (UNEP, 2018). Bio-LPG would appear to be important in the context of long-term planning for clean cooking but unlikely to form a significant part of more medium-term solutions.

4.3.4. Green Hydrogen

Green Hydrogen – produced from the hydrolysis of water from renewable electricity – has the potential to compete on cost and reduce dependence on other cooking fuels such as LPG or electricity beyond 2030 (Galan, 2023). IEA (2020) argue that, depending on the extent of declining solar and electrolyser costs, green hydrogen has the potential to be costed at 1.4-2.0 USD/Kg by 2030. In addition, given the nascent market of green hydrogen production and the expected growth of the Hydrogen sector from 87 million metric tons (MT) in 2020 to 500-680 MTs by 2050 (IEA, 2020), there are significant opportunities for both satisfying domestic markets and driving industrialisation exports across the African continent. For some,. Nevertheless, when looking more closely, whilst the role of green hydrogen in larger-scale applications is clear, it is far from clear under what circumstances hydrogen could provide a cost-effective addition to the clean fuel stack for cooking. There appear to be three potential answers to that question currently under development as described below which all appear to have their limitations.

Table 7: Green Hydrogen Fuel Snapshot

Fuel name	**Green Hydrogen**
Key markets	Short Term – Urban, Long Term – Rural: Highly dependent on distribution mechanism.
Distribution mechanisms	There are three potential distribution methods to hydrogen clean cooking pathways, first, replicating activities in the UK and EU by blending hydrogen with natural gas in existing gas grids with concentrations between 0.1-14 Vol.% - above 15 Vol.% would require significant infrastructure upgrades due to the highly corrosive nature of hydrogen (Galan, 2023). Second, by mirroring the LPG transition and leveraging exiting LPG distribution networks by storing hydrogen in pressurized cylinders with accompanying hydrogen stoves that are sold directly to the end-users. Whilst this pathway has significant benefits there would also have to be additional end user training around safety (due to the colourless flame) (Galan, 2023). Third, through the development of hydrogen fuel cells which are suitable for clean cooking. In this case, fuel cells "generate electricity through the oxidation of hydrogen electrochemically" (Mukelabai et al., 2022, p. 9) with a solid state storage of hydrogen, however, whilst this reduces the need for pressurized cylinders there are significant losses from the electricity-hydrogen-electricity conversion process (Schöne et al., 2022).
Positive attribute	Green Carbon is a low-carbon fuel that can meet the long-term global net zero goals.
Negative aspect	Colorless nature of flame (when not cooking with a catalytic combustion stove) would require retraining users that transition from other fuel types. Green Hydrogen for clean cooking is largely left out of national energy planning.
Constraints	When combined with natural gas concentrations of more than 15 Vol.% would require significant infrastructure upgrades due to the highly corrosive nature of hydrogen (Galan, 2023). There must be significant investment in technological advancement before hydrogen can be seen as a scalable method of clean cooking, especially around hydrogen stoves, hydrogen compressed cylinders, and fuel cells.
Influence of stove	In terms of appliances for hydrogen cooking, there are three areas of interest – stoves adapted from LPG designs, catalytic combustion stoves, and hybrid stoves (Mukelabai et al.,

	2022) – which all required significant development to be ready for large scale deployment, with most being at early ideation or small-scale testing phases.
Cookware	No special cookware required – all pots and pans useable.
Impact on Foreign Exchange	For all distribution mechanisms there would need to be significant market creation, infrastructure development, and technological advancement. Import of hydrogen would drain foreign exchange.
Regulation	Clean cooking with hydrogen would, in most cases, required the creation of new regulations and standards particularly given the safety implications.
Key Investors	Oil Industry, European Governments. Potential competitive advantages for African initiatives.
Dependencies	May be dependent on international markets if importing hydrogen, however the national production of green hydrogen has little dependencies.
Health impact	Unlike LPG, cooking with hydrogen does not contribute to indoor air pollution and lead to the increase of respiratory conditions (i.e. Asthma).
Climate impact	Green Hydrogen provides the lowest carbon route to large scale clean cooking pathways, yet, much of the hydrogen produced today is produced with fossil fuels.
Local environment impact	Shares similar local environmental impact as LPG.
Local Economic impact	Shares similar local and economic impact as LPG.
Macro-economic impact	Opportunities for African states without fossil fuel reserves to establish themselves as green energy producers through developing national green hydrogen production facilities.

Pathways to 2030 and beyond. Given the infrastructure investment required to transition existing natural gas and LPG infrastructure it is unlikely that hydrogen will provide a scalable pathway for clean cooking before 2030 – however, whilst there may be opportunities to blend natural gas in existing infrastructure to test the viability of a full transition to hydrogen cooking, there also contention around the effectiveness of this method for climate emissions reductions (National Observer, 2024). The most significant opportunity is in the long term once the distribution mechanisms of green hydrogen, supported by programs such as ESMAP's Green Hydrogen Support Program, for clean cooking have reached sufficient technical maturity. Ultimately, Green Hydrogen sits on the horizon with the potential to be an effective 'end-game' technology for 2050 net-zero goals and beyond.

4.3.5. Ethanol

Bioethanol, an alcohol-based fuel, is produced by fermenting sugars and starch derived from crop wastes/residues or energy crops. Bioethanol has diverse applications, serving as transportation and cooking fuel, industrial solvent, chemical feedstock, power generation fuel, small engine fuel, and disinfectant. As bioethanol is derived from agricultural crops it is renewable in nature, this reduces dependence on finite fossil fuels and helps mitigate greenhouse gas emissions. However, the large-scale production of bioethanol may displace agricultural crops and repurpose land from food use to bioethanol production. Bioethanol as bioenergy plays a dynamic role in enabling clean cooking (UNIDO, 2022), facilitating energy access, and promoting healthier indoor air quality while reducing health risks in regions reliant on traditional biomass fuels supporting progress on 13 out of the 17 SDGS (Osiolo, Marwa and Leach, 2023). Bioethanol usage across Africa has transitioned from industrial to transportation and clean cooking applications, aiming to mitigate greenhouse gas emissions and enhance energy security. Kenya has been the major success story for bioethanol cooking, the growth of Koko Networks has seen more than 1 million Kenyans become customers. Initiatives in other countries, e.g. Mozambique, Nigeria have been less successful, although a number of other interventions are emerging with, for example, UNIDO heading an initiative in Tanzania designed to reach 160,00 households over the next five years.

Table 8: BioEthanol Fuel Snapshot

Fuel name	**BioEthanol**
Key markets	Urban and Peri Urban
Distribution mechanisms	Local agents, sellers or shops – does not need specialised infrastructure due to automated dispenser innovations.
Positive attribute	Potentially a renewable energy source – locally grown or imported. Can be produced from wastes/food crops and processed on a micro and/or large scale. Clean flame from burners and very safe (non-explosive) for cooks. Commoditized - fits the mindset of 'going to the market to get food and other things'.
Negative aspect	Ethanol can be sourced from food crops plants and increased demand could lead to change in land use and impact agricultural water ecosystems, promoting unbalanced (of corn crop) farming monocultures. Limited availability and seasonality of feedstock impacts the sustainability of the supply chain. Can impact on food prices. Increased demand for water impacting ecosystems.
Constraints	Requires financing and investment in stoves, processing plants and distribution networks, with regular secure financing flows.
Influence of stove	Early stoves gave a weak flame with slow cooking. Improvements over the last 5 years have been significant and are likely to be ongoing. Currently sector-leading companies are deploying with a two-burner stove that reduces meal preparation time.
Cookware	No special cookware required – all pots and pans useable.
Impact on Foreign Exchange	If there is a local source of bioethanol, then the sustained requirement for foreign exchange is minimal. However, experience from Kenya has shown that rapid uptake (1m users in 3 years), led to the need to import the ethanol.
Regulation	Beverage industry competition influences unfavorable tax policies for bioethanol. Enabling environment i.e. bioethanol policy, strategy, master plans and safety standards are key.
Key Investors	Synergies with oil industry for storing and distributing bioethanol. Bioethanol fuel and stove producers.

Dependencies	Very dependent on the supply of bioethanol supplies/biomass feedstocks
Health impact	Reduces respiratory related illness especially among women and children, burns, eye disorders, complicated pregnancy and death. Improved air quality and reduced indoor pollutants. Reduced health risks associated with wood collection.
Climate impact	Reduces greenhouse gas emissions as bioethanol combustion is considered carbon neutral.
Local environment impact	Reduces dependence on fossil fuels, mitigating environmental damage. Reduced deforestation and enhances tree cover regeneration.
Local Economic impact	If waste is utilized in production, bioethanol contributes to food security. Increased time and fuel savings. Formal bioethanol markets boost government revenue.
Macro economic impact	Bioethanol production creates new jobs and incomes. Increases agricultural sector's demand for fuel from agricultural by products. Presents fresh investment prospects in agriculture sector. Yields increased financial resources and boosts GDP in fossil fuels dependent economies.

Pathways to 2030 and Beyond. According to the IEA (2022), bioethanol is projected to contribute to 6% of the population gaining access to clean cooking technology in Africa between 2022 and 2030. The future growth of bioethanol, as outlined by UNIDO (2022), relies on specific interventions. These include implementing targeted policies with diverse delivery models and incentives, establishing a stable investment framework to support local feedstock production, and designing a fiscal regime to bolster bioethanol solutions for stability. Additionally, efforts to enhance opportunities for accessing carbon finance, invest in gender-sensitive awareness, strengthen standards and certification, and balance supply and demand-side incentives while addressing subsidies on fuels are crucial for fostering bioethanol's expansion as a long-term pathway to clean cooking for all.

4.3.6. Electricity

Using electricity for e-cooking is best conceived of as three different fuels generated in very different market contexts - national grid electricity, mini-grid electricity, and stand-alone systems.

The development of the national grids across Africa varies considerably although it is certainly true that, even in low electricity access countries, rural households are much more likely to have access to electricity than to LPG or PNG. Progress has been patchy although ongoing progress of National Grids is a high priority for governments across Africa. Improved electricity infrastructure will be essential for economic growth. For the past 4 years $24 billion has been invested in generation, distribution, maintenance and improving the electrical networks of Sub-Saharan Africa, and the likelihood is that this level of finance will continue (IEA 2023). Leveraging national infrastructure to deliver a clean cooking experience via electric cooking is a cost effective strategy (for example Nigeria IEP pg11), particularly given the advances in grid extension realized in some countries over recent years. Increasing demand for electricity in urban centres due to enhanced uptake of electric cooking could be a virtuous cycle, giving utilities higher Average Revenue Per User, and improving the financial balance sheet, leading to improved investment terms. This view depends on the utility utilizing a full cost recovery tariff, which is not always the case. While the electricity supply in many countries is thought of as unreliable (with issues of supply reliability in front of the meter and questionable wiring behind the meter), the Saifi and Saidi indexes (REF) of most countries are improving. When eCooking is used as a part of fuel stacking, the user can overcome times when the supply is not available. In fact, evidence shows that most households already use some forms of electric cooking (via kettles for water boiling for example) even in informal settlements facing both supply and wiring challenges.

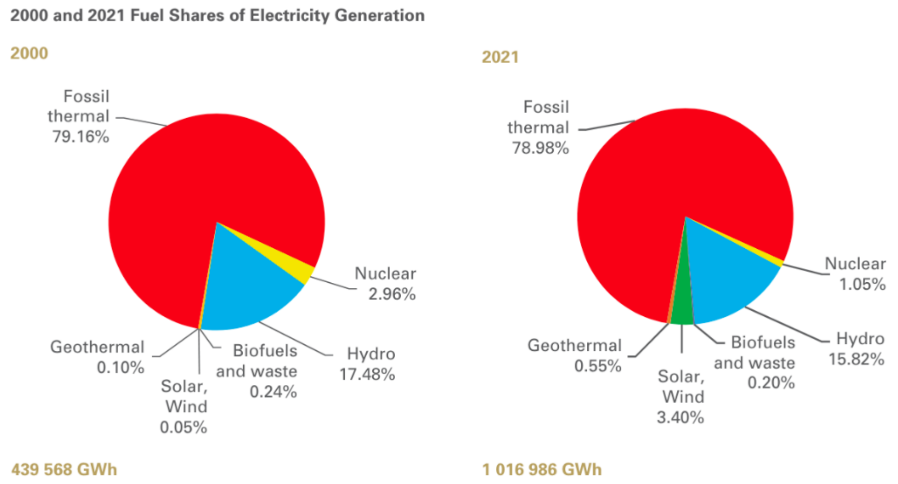


Figure 15: 2000 and 2021 Fuel Shared of Electricity Generation Across the African Continent(AFREC, 2023, p.26)

While it is often thought that National grids in Africa tend to have a high proportion of renewable energy generation making the use of their capacity to substitute for biomass cooking desirable, Figure 15 from AFREC suggests that progress in that direction remains weak (although a number of major new renewable investments are due to come online imminently with others well underway in the pipeline). Whilst there remain multiple and complex problems with many of the grids, there are strong political commitments to improving the grid for the good of the economy and a strong future focus on renewables offers strong prospects for climate finance. Africa is rapidly urbanising, and it is the urban areas that have access rates above 40% and in some cases reach 90% making them prime sites for eCooking adoption, especially where tariffs are lower. Ten years ago such transitions would have been unthinkable but eCooking transitions are now being rapidly embraced by stakeholders across the region (national strategies are currently being finalized in Uganda and Kenya, for example).

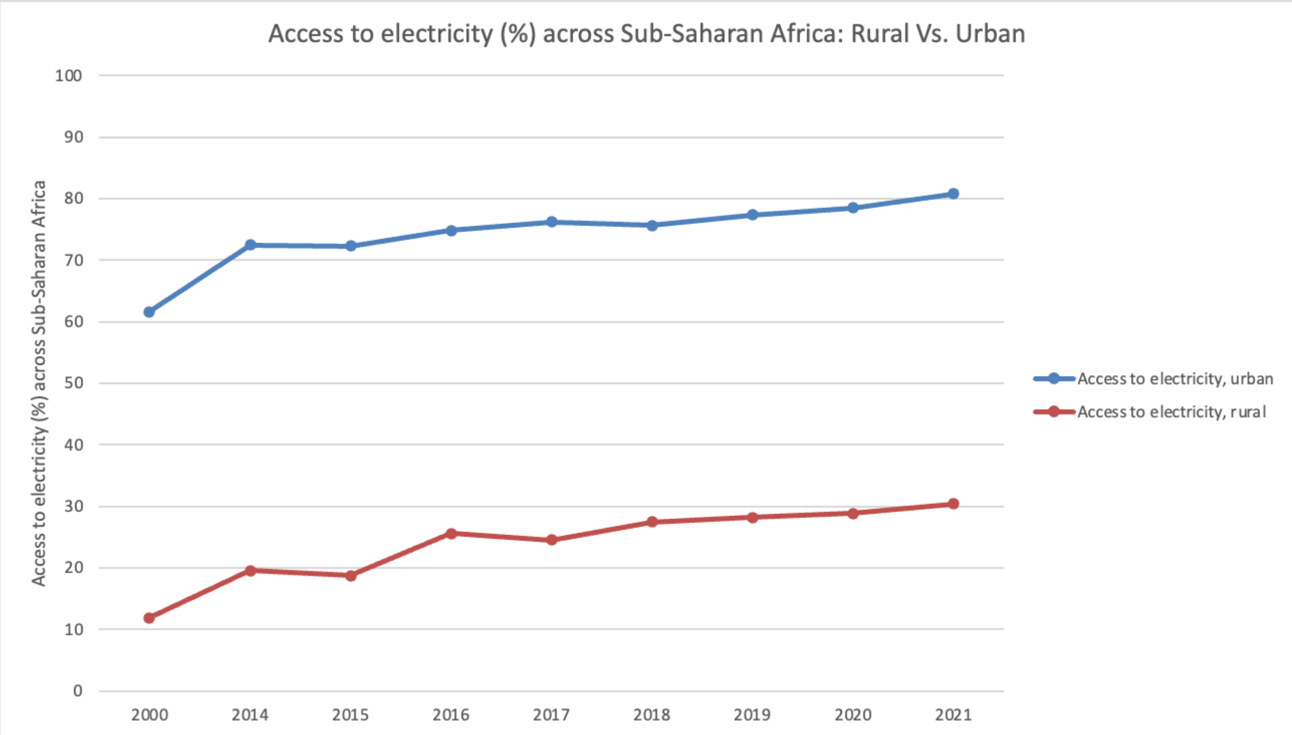


Figure 16: Access to Electricity (%) across Sub-Saharan Africa ([World Bank, 2024](#))

Grid electricity can be utilized for cooking as is the norm in developed economies, and a new crop of energy-efficient appliances means that in most urban contexts, e-cooking is equal to or more cost effective than charcoal or LPG. Even more importantly, however, when considering clean cooking from a medium to long-term economic perspective, it is clear that electric cooking is going to be the fuel of choice as governments intensify their commitments to full electric coverage for their populations. As that process happens, electric cooking provides an opportunity to build demand (in the process giving return to electricity infrastructure investments already made and those being contemplated) and avoid being locked into an expensive dependence on imported fossil fuels subject to rapid price movements.

As with other fuels, e-cooking on the grid has a range of characteristics:-

Table 9: On Grid Electricity Fuel Snapshot

Fuel name	**On Grid Electricity**
Key markets	Urban and Peri urban
Distribution mechanisms	Local Agents, Shops, and Distributors working with international manufactures. Challenges with importation and quality standards. Wins have been made through the integration of remote monitoring sensors which allow effective fault detection of devices and integrated payment and carbon mechanism
Positive attribute	Gives a modern cooking experience with no household emissions. Can be very cost effective in Urban settings, with lifetime cost much lower than some alternatives. Also offers time saving. Metered methods can access premium carbon finance. Payment for the fuel is part of daily access to whole household electricity (ie no special trips to the market), leverages the connection

	fee paid previously, and can be in small units (via pre-paid or post-paid). Increase demand on grid, which increases ARPU.
Negative aspect	The upfront cost is high, with a majority requiring some form of credit. Some HH connections not wired in to standard. Local distribution infrastructure may be weak. With significant uptake peak demand may stress the grid. Black outs and burn outs could occur during cooking – user has limited control over supply timeliness.
Constraints	Imported stoves can be of varying price and quality, lack of awareness, and currently lack of repair networks. Depends on utility generation having enough for expected demand, and either getting full cost recovery through tariff, or determining that subsidies are worthwhile as a social good.
Influence of stove	The historical exploration by some pioneer users of simple (low quality) hotplates with badly fitting pots, has reinforced the idea that e-cooking is expensive. New generation electric pressure cookers are very energy efficient, using 0.4kWh for a substantial meal such as Githeri in Kenya (which has a relatively high tariff). Induction stoves are also efficient and more flexible in the range of dishes. Air fryers, Kettles and other devices are more task specific but offer a very energy efficient experience.
Cookware	Appliances such as an EPC come with a pot, although many users request a second pot. Induction stove require specialized pots which can be more expensive than the appliance itself – most sellers now bundling cookware and appliance as a package.
Impact on Foreign Exchange	Rapid uptake would require a significant foreign investment as many manufactures are not based within the countries that require clean cooking interventions.
Regulation	All appliances give a Tier 5 experience with almost zero indoor pollutants. IWA/ISO Testing Standards for Indoor and Outdoor Emissions, Thermal Efficiency, and Safety.
Key Investors	International Development Donors, Middle class, Voluntary Carbon Market
Dependencies	Very dependent on supply of electricity and being connected to it.
Health impact	eCooking use on the grid is a Tier 5 experience with almost zero kitchen emissions. Minimal risk or electric shock and burns from hot surfaces.
Climate impact	The climate impact of eCooking use depends on how the electricity is generated. Some countries may rely on older fossil fuel generation, while some, like Uganda, are almost entirely renewable energy. Grid based renewable energy generation is becoming cheaper, and recent renewables in Morocco came in at around 3 cents a unit.
Local environment impact	Grid based eCooking based on a renewable energy supply would not impact the local environment.

Local Economic impact	The utility working with Local Agents, Shops, and Distributors look to create markets for appliances and this can create job opportunities and increase local cashflows. With good demand from ecooking, pivoting existing cooking fuel expenditure into the grid improves the Average Revenue Per Unit (ARPU), and enhances the grid infrastructure.
Macro-economic impact	Viable carbon credit/offset pathways.

For electricity we need to distinguish between national infrastructure grid networks, and off-grid solutions. Off-grid solutions are commonly subdivided into min-grids and stand-alone systems. The advent of mesh technologies can sometimes blur the divide between mini grid and stand-alone systems, creating micro grids, but for this report we will ignore this development. The landscape is further complicated by the use of decentralized generation such as rooftop solar that feeds into the grid. The advent of cost-effective energy storage at the household level can mitigate the effects of a weak grid and blur evidence on the uptake of eCooking. This is being explored in India, where a solar PV rooftop programme is now encouraging eCooking. Again for simplicity we will set these aspects aside.

Table 10: Mini-Grid Generated Electricity Fuel Snapshot

Fuel name	**Mini-Grid Generated Electricity**
Key markets	Small towns and dense rural clusters (although also now in some urban contexts such as the metro-grids in DRC)
Distribution mechanisms	The mini-grid developer encourages and sets up networks as increased demand increases revenue and makes the grid more viable. Developer, Local Agents, Shops, and Distributors working with international manufacturers for appliance supply. Challenges with importation and quality standards. Wins can be made through the integration of both mini-grid smart meters and remote monitoring sensors which allow effective fault detection of devices and integrated payment and carbon mechanism
Positive attribute	Gives a modern cooking experience with no household emissions. High mini-grid tariffs reduce the cost-effectiveness compared to grid-based ecooking, but often mini-grids are in areas of high deforestation and alternative fuels are expensive. Offers time saving. Metered methods can access premium carbon finance. Payment for the fuel is part of daily access to whole household electricity (ie no special trips to the market), leverages the connection fee paid previously, and can be in small units (via pre-paid or post-paid). Increase demand on mini-grid, which increases ARPU. A marginal increase to the mini-grid CAPEX can accommodate appliance provision.
Negative aspect	The upfront cost of an appliance is high, with a majority requiring some form of credit. Mini-grid developers can build in credit provisions for appliances into their investment costs on the whole mini-grid. With significant uptake peak demand may stress the mini-grid, but is more under the control of the developer/operator than national grid.
Constraints	Imported stoves can be of varying price and quality, lack of awareness, and currently lack of repair networks. Depends on mini-grid operators having enough expected demand to enable localized repair and maintenance of appliances. Tariff on mini-grid are generally higher than national grid, and so comparative cost-effectiveness is reduced, however, operator has

	opportunities for time of use tariff reductions (to encourage shifting peak demands) and could determine that subsidies are worthwhile as a social good.
Influence of stove	The historical exploration by some pioneer users of simple (low quality) hotplates with badly fitting pots, has reinforced the idea that e-cooking is expensive. New generation electric pressure cookers are very energy efficient, using 0.4kWh for a substantial meal such as Githeri in Kenya (which has a relatively high tariff). Induction stoves are also efficient and more flexible in the range of dishes. Air fryers, Kettles and other devices are more task specific but offer a very energy efficient experience. All of these devices can be used on mini-grids as well as National Grids.
Cookware	Appliances such as an EPC come with a pot, although many users request a second pot. Induction stove require specialized pots which can be more expensive than the appliance itself – most sellers now bundling cookware and appliance as a package.
Impact on Foreign Exchange	Rapid uptake would require significant foreign investment as many appliance manufacturers are not based within the countries that require clean cooking interventions. However as a proportion of a mini-grid development, the appliances are a small cost, and the ongoing electricity generation would be renewable energy based and therefore not requiring FX.
Regulation	All appliances give a Tier 5 experience with almost zero indoor pollutants. IWA/ISO Testing Standards for Indoor and Outdoor Emissions, Thermal Efficiency, and Safety.
Key Investors	International Development Donors, Mini-grid developers under licence, Independent Power Producers, Voluntary and Article 6 Carbon Market
Dependencies	Household very dependent on mini-grid operators provision of electricity.
Health impact	Mini-grid eCooking use is a Tier 5 experience with almost zero emissions. Minimal risk or electric shock and burns from hot surfaces.
Climate impact	Mini-grid eCooking use based on a renewable energy supply such as Solar Photovoltaic would have minimal climate impact, except during the manufacturing of the system.
Local environment impact	Mini-grid eCooking use based on a renewable energy supply would not impact the local environment. Indeed, the calculation of benefits could include the savings in the fraction of non-renewable biomass (fNRB) and the effective ongoing carbon sequestration from that biomass.
Local Economic impact	The mini-grid operator working with Local Agents, Shops, and Distributors look to create markets for appliances and this can create job opportunities and increase local cashflows.
Macro-economic impact	Viable carbon credit/offset pathways.

Table 11: Stand-alone Generated Electricity

Fuel name	**Stand-alone Generated Electricity**
Key markets	Weak grid, informal settlements, displaced contexts, dispersed rural areas
Distribution mechanisms	Customer acquisition is big challenge for stand alone systems. Customer acquisition and retention can often cost far more than the technology itself. When stand alone systems were only delivering lights, the customer acquisition was a large part of the overall cost. With eCooking the potential ratio of marketing/technology/PAYG is more balanced. Local Agents, Shops, women's collectives and Distributors working with international manufacturers. Challenges with importation and quality standards. Wins can be made through the integration of remote monitoring sensors which allow effective fault detection of devices and integrated payment and carbon mechanism
Positive attribute	Gives a modern cooking experience with no household emissions. Can be cost effective in some contexts, with lifetime cost much lower than some alternatives. Offers time saving. Metered methods can access premium carbon finance. Repayment of credit for the system can be matched to seasonal incomes. Stand alone systems that support agriculture such as solar pumping, can leverage investments to include ecooking upgrade.
Negative aspect	The upfront cost is high, with a majority requiring some form of credit. Lifetime costs are now comparable to national grid tariff, but monetization of cooking costs is a mindset barrier. Some households would rather use (women's) labour to collect wood than sign up for regular payments on a PAYG system.
Constraints	Imported stoves can be of varying price and quality, lack of awareness, and currently lack of repair networks. Depends on utility generation having enough for expected demand, and either getting full cost recovery through tariff, or determining that subsidies are worthwhile as a social good.
Influence of stove	The historical exploration by some pioneer users of simple (low quality) hotplates with badly fitting pots, has reinforced the idea that e-cooking is expensive. New generation electric pressure cookers are very energy efficient, using 0.4kWh for a substantial meal such as Githeri in Kenya (which has a relatively high tariff). Induction stoves are also efficient and more flexible in the range of dishes. Air fryers, Kettles and other devices are more task specific but offer a very energy efficient experience.
Cookware	Appliances such as an EPC come with a pot, although many users request a second pot. Induction stove require specialized pots which can be more expensive than the appliance itself – most sellers now bundling cookware and appliance as a package.
Impact on Foreign Exchange	Rapid uptake would require a significant foreign investment as many manufactures are not based within the countries that require clean cooking interventions.
Regulation	All appliances give a Tier 5 experience with almost zero indoor pollutants. IWA/ISO Testing Standards for Indoor and Outdoor Emissions, Thermal Efficiency, and Safety.
Key Investors	International Development Donors, Middle class, Voluntary Carbon Market
Dependencies	Very dependent on supply of electricity and being connected to it.

Health impact	Tier 5 almost zero emissions. Minimal risk of electric shock and burns from hot surfaces.
Climate impact	Stand-alone systems eCooking use based on a renewable energy supply such as Solar Photovoltaic would have minimal climate impact, except during the manufacturing of the system.
Local environment impact	Stand-alone systems eCooking use based on a renewable energy supply would not impact the local environment. Indeed, the calculation of benefits could include the savings in the fraction of non-renewable biomass (fNRB) and the effective ongoing carbon sequestration from that biomass.
Local Economic impact	Local Agents, Shops, and Distributors look to create markets for their products and this can create job opportunities and increase local cashflows.
Macro-economic impact	Viable carbon credit/offset pathways.

Pathways to 2030 and beyond. As stated in the introduction to this 'fuel', national grids are improving and there is strong political commitment to improving both the generation supply, and the reach of the grid networks (universal access). In some countries, off-grid solutions such as mini-grids and stand-alone systems will be required where the main grid cannot cost-effectively reach. With all forms of electricity supply there are cost-effective clean cooking options, with energy-efficient devices. The IEA suggest that electricity will become 12% of the clean cooking fuel mix by 2030. As electricity relies more on renewable energy sources, its use for clean cooking contributes to the just transition, and clean cooking naturally becomes more of a service than a one off provision of equipment. Documenting which households rely on electricity for cooking will be challenging because national data sets the focus purely on the primary fuel.

4.3.7. Biogas

As discussed above, one green alternative to LPG is biogas produced through the Anaerobic Digestion (AD) of organic waste (usually animal, human, and food waste) which is typically seen as a low-cost just transition pathway to mitigating climate change (Robinson et al., 2023; Somanathan and Bluffstone, 2015). The process of AD occurs through decomposition of organic matter in an oxygen limited environment resulting in the production of a flammable gas and a nitrogen-rich liquid digestate or bio-slurry (Achinas et al., 2017). The gas, composed of methane, carbon dioxide, and hydrogen sulphide, can be used directly for cooking and powering appliances (fridges, lights, generators, agricultural equipment) or further refined and bottled into bio-methane (Black et al., 2021; Twinomunuji et al., 2020). The digestate can be used directly on crops as a liquid fertiliser, as a component of an enriched compost, fermented into an additional foliar fertiliser, or further refined into a solid organic fertiliser (Nalunga et al., 2019; Orskov et al., 2014). Anaerobic digesters range in size from micro (1m^3) to industrial scale (150m^3) and are implemented through a wide variety of delivery models, financing structures, and policy mechanisms across the globe. Within the African context, programs such as the Africa Biogas Partnership Program and the Africa Biogas Component, focus primarily on East Africa and have encouraged the uptake and sustained use of over 100,000 household scale digestors[16] (between 4-12 m^3) – however, at this household scale there have been significant challenges with failure and abandonment (Hewitt et al., 2022). As a reaction to these challenges (often around operation, maintenance, and knowledge erosion) with user-owned decentralised approaches to biogas programming there are significant opportunities in the remote monitoring of biogas units, resulting in faster fault detection, integrated pay-go metering, carbon market integration, and user-centered optimisation strategies (Robinson et al., 2023). This sparks a transition to biogas systems based around the energy-as-a-service model blending the centralised and decentralised approaches through larger scale systems (20m^3) for enterprise and institutions.

Table 12: Biogas Fuel Snapshot

Fuel name	**Biogas**
Key markets	Typically, Rural and Peri-Rural - including Individual Households, Institutions, Enterprises.
Distribution mechanisms	Smaller scale systems are end-user owned and operated whereas larger commercial systems produce biogas for further refining to biomethane.
Positive attribute	Anerobic digesters provide a clean and modern fuel for cooking and powering agricultural appliances as well as an effective waste management process that coverts potentially toxic human and animal waste to a highly effective liquid organic fertilizer. Additionally, the technology is easily scaled to accommodate larger use cases and delivery models (e.g. energy-as-a-service and productive uses of energy)
Negative aspect	Failure and abandonment of biogas units has typically been high due to a lack of access to post-sales support on operation and maintenance. This technology also requires people to mix and process food, human, and animal waste which can clash with socio-cultural practices.
Constraints	Typical barriers to adoption, sustainable use, and scale include: • Initial financing for cost of high cost of digestors. • Availability and consistency of feedstock. • Knowledge erosion – the people who own the plants are not necessarily the ones who operate them thus gaps appear in operation and maintenance, there must be regular training on use. • Quality of installation (for masonry fixed done type) • Lack of specific policy and regulatory environment to establish marketplace for anerobic digestion technologies.
Influence of stove	Specific biogas stove required – hydrogen sulfide filter needed in kitchen to avoid the corrosion of the stove. A modified LPG stove can be used but will not last due to corrosive nature of biogas.
Cookware	No special cookware required – all pots and pans usable.

[16] A significant proportion of these household scale digestors are either bag, floating dome or fixed masonry dome digesters, all of which have individual challenges and opportunities around large scale implementation.

Impact on Foreign Exchange	There are two distinct anerobic digestor markets – locally built masonry dome digestors and internationally produced and imported plastic bag digestors. The large uptake of plastic bag digestors could influence foreign exchange for the initial purchase, but thereafter the feedstock does not require FX.
Regulation	There is very little regulation for biogas systems and services, they often fall in regulatory gaps due to their multi-use functionality i.e. for gas and fertiliser.
Key Investors	Trusts and Foundations, Carbon Markets, Government Programs, middle class farmers
Dependencies	Effective operation and management practices of units – they require attention at least twice weekly – independent of scale.
Health impact	Reduction of IAP (compared to fuelwood, kerosine etc.) Reduction of synthetic fertilizers on crops (healthier for human consumption)
Climate impact	When effectively managed, reduced methane emissions of untreated waste.
Local environment impact	Reduces deforestation. Effective waste treatment, avoiding waste polluting waterways with waste and chemical fertilizer.
Local Economic impact	Job Creation – ability to create local value chains with locally made products when technicians are trained on building and maintenance of units. And a network of trainers with internationally imported products. Can disrupt local charcoal, firewood, and fertilizer value chains. Savings - Biogas & digestate are effectively free (if not accounting for time feeding unit) for user-owned units – savings on both other fuels (firewood or LPG) and chemical fertilizers. Can increase profitability of animal husbandry and crop production due to utilization of products that would otherwise be wasted. Income Generation – selling excess gas (in biogas backpacks) and digestate (in containers)
Macro-economic impact	Viable carbon credit/offset pathways however monitoring costs are high due to often dispersed nature of biogas units.

Pathways to 2030 and Beyond. The anaerobic digestion of waste products to produce a clean cooking fuel and digestate that can be used as an organic fertiliser has a significant role to play in the road to SDG7 in 2030 and global net zero in 2050. Whilst the central technology (the digester itself) is a centuries old technology, there are significant advancements in low-cost, IoT monitoring technologies that can help mitigate many of the issues around fault detection, knowledge erosion, end-user financing, and after sales support – these monitoring technologies can be applied to the household, institutional, and commercial scales of biogas production. For example, Inclusive Energy's Smart Biogas Meter provides all the functionality of a commercial smart meter at a fraction of the cost, with the addition of unlocking carbon revenues. These other scales of operations include, industrial scale biogas production which has the potential to power mini grids, anchor industrial heat, provide a core component of bioLPG and smaller scale standalone systems which are suitable for remote rural low-density populations often out of the reach of LPG distributors. Perhaps these technological advancements can provide a significant clean cooking fuel to the 60% of the population of sub-Saharan Africa who are small holder farmers (McKinsey, 2019).

4.4. Multi-Fuel Transitions through the Health, Environment, and Economic Lens

Figure 4.9 Representing the three lenses of 'clean cooking' and the complexity of criteria when assessing the fuel mix.

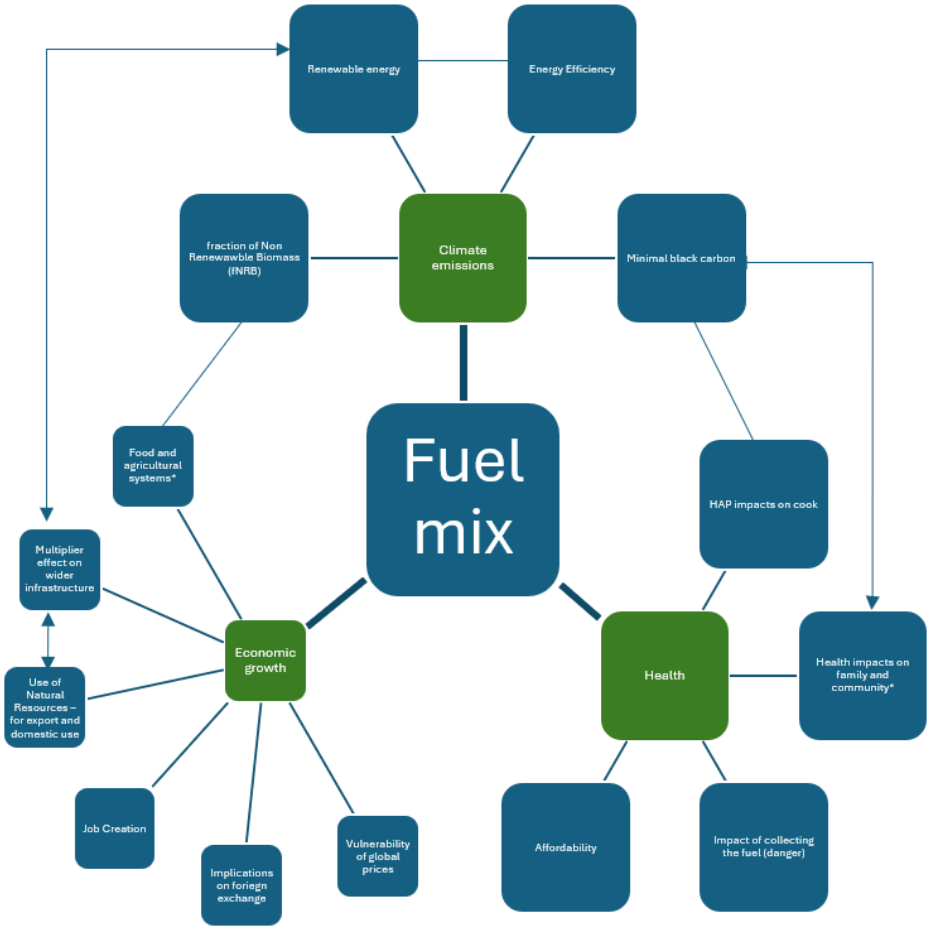


Figure 17: The Fuel Mix - Health, Environment, Economy

Each of the fuels presented above have advantages and disadvantages depending on the assessment criteria applied. While acknowledging that Section 2 notes that clean cooking has been generally a neglected issue, it is also worth repeating that to date much of the work on clean cooking has been applied with a health (and safety) lens and to some degree a localised environment lens (deforestation). Indeed, the very term 'clean cooking' is based on emissions analysed from a household point of view. With this view, the higher tier fuels are desirable emitting minimal particulates within the household, reducing consumption of non-renewable biomass and barely affecting health. We note that while Tier 3 stoves (and above) are used in global statistics as fulfilling SDG7, there is research that they continue to affect the health of the user.

In the interim years since the formation of SDG7, the issue of climate change has come more to the foreground, and the COP processes have moved some of the global priorities more towards a NET

Zero target of 2050. If we apply a 'Net Zero' Climate change lens to fuel choice, the relative merits of each fuel adjust. Within the category of 'higher tier' stoves, encouraging the ongoing use of oil and gas contrasts to the use of renewable energy. Oil use to produce LPG and electricity is less favourable than renewable energy for the climate, although oil-based gas and electricity is still less damaging to the climate than emissions from non-renewable biomass. In some contexts though, the use of renewable biomass in higher tier stoves that minimise particulates (and black carbon) can be more climate friendly than, say, the use of coal to generate electricity without any carbon recapture.

However, a third lens needs to be applied, and that could be called the economic impact – on households (which fuels are affordable) and the wider economy. Some of the fuels require importation, and that makes the country vulnerable to global prices and the implication of that on its foreign exchange balance. The reliance on the global price of crude oil for either gas or electricity production may limit the growth of African economies. It may also strengthen the growth of those countries that have oil and gas resources and can fund investment to exploit them. From an economic point of view, and as outlined by SEforAll (2024), local production of renewable biomass becomes even more important, and ethanol or local briquette production can deliver a higher-tier experience for the cook while creating a local economy and jobs. While Tier 3 stoves deliver a limited health improvement, they can often be made locally, and thus create manufacturing and distribution job creation. SDG7, as well as calling for clean cooking, also calls for improved electricity access, increased use of renewable energy, improvements of energy efficiency and increased investment in this journey to clean energy. These improvements and trends can be taken into account when calculating the strategic fuel mix. What approach will leverage the anticipated gains in each of the other aspects of the full SDG7 energy aspiration and support self determining economic growth?

These three lenses, represented in Figure 17, change the criteria and priorities across the fuel mix, and therefore no one basket of fuels will work with all situations. Governments seeking to create enabling environments need to line up the mechanisms with a view to improving health, the environment, and the economy. The private sector and development finance institutions responding to that enabling environment can also view the fuels through the three lenses – what may give the best long term returns – both in social benefits, their contribution to climate mitigation and addressing the need for a strong growing economy in Africa that takes into account food and agricultural systems, industrialisation, security and self-determination.

Figure 18: - Basic, Transitional, and Modern Fuels through the Infrastructure, Transition, and Service Lens

5. A Country-Level Analysis: Indicators to track progress on the Clean Cooking Challenge

Previous sections established the scale of the clean cooking challenge, outlined high level strategies for addressing those challenges, dived into the modelling of best-case clean cooking strategies, and identified the key fuels which can provide access to a basket of cleaner and modern clean cooking systems and services – these previous sections provide the foundational knowledge to explore the meaningful deployment of scalable country-specific implementation pathways. Aligned with this vision, this section explores 'the how' of clean cooking pathways. It explores widely applicable decision criteria and accompanying indicators, within the context of specific country level case studies. One critical, and often under-recognised, component of clean cooking pathways is inclusion of marginalized groups. Given the importance of effective and meaningful inclusion, this section also highlights these dimensions throughout the decision criteria and case studies. The key messages of this section are:

- Access to different cleaner and modern cooking challenges need different modes of governance – as the wide variety of approaches in the case studies illustrate, there is no one-size-fits-all solution to this complex and contextually driven challenge.
- Clean cooking is not only about creating and supporting access to a basket of modern fuels and appliances which make economic sense, but also ensuring that this access makes a positive contribution to a just, fair, and equitable transition. Direct action is needed to address gender, health, and income inequalities as part of the solution.
- Scales beyond the household must receive direct attention – cooking for institutions, enterprises, and the forcibly displaced in humanitarian settings are critically under-resourced sub-sectors.

5.1. Establishing criteria which drive Clean Cooking Transitions

Unfortunately, there is no "one-size-fits-all" approach to securing clean cooking pathways to 2030 and achieving net zero cooking by 2050 due to the complexity of national cooking cultures, existing resource endowments, levels of energy infrastructure development (including available fuel types), governance capacity and accompanying (or lack of) policy and regulatory environments. Kueppers et al. (2021) raise these same questions within the context of wider decarbonisation pathways: "How can as many countries as possible be modelled in a comparable and transferable way if their current energy systems are different? Can similarities between countries help to anticipate future developments, e.g. regarding their status on a decarbonization pathway or with respect to favoured future technologies?". Using this approach as a general framework, this section identifies critical criteria that can be used to better understand the mechanisms and infrastructure requirements that result in a successful transition to modern clean cooking fuels and appliances, as well as the wider systems and support services which are required for sustainable and long-term clean cooking ecosystems. We pay specific attention to the economic lens of section 4, as this is an under-leveraged dimension of clean cooking transitions. Not only are there health, environmental, and climate benefits to a sustainable transition to modern cooking fuels and appliances but there is also a clear economic case.

5.1.1. Strategic Decision Matrix for Clean Cooking Policy

To determine a set of criteria which can capture the complexity of clean cooking transitions, we build on the key considerations outlined in sections 1,2, and 3 – especially around the economic lens – and connect them with the infrastructure, transitions, and services approaches as detailed in section 4. This strategic decision matrix for clean cooking policy then enables the exploration of contextual variations in approaches at a country level and indicates how single decisions throughout the clean cooking ecosystem have wide reaching impacts on the completion of clean cooking for all. We recognise that this group of indicators may not capture every dimension of clean cooking decision-making processes (here we focus most strongly on the previously under-played economic and strategic components) but hope that it can act as an elementary framing to initiate further research further strengthening, for example, how these systemic elements relate to the health, gender and environment lenses.

<table>
<tr><th></th><th colspan="4">Infrastructure</th><th colspan="4">Transitions</th><th colspan="4">Services</th></tr>
<tr><td>Economic Landscape 2024</td><td>UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking</td><td>Manufacturing value added as a proportion of GDP (%) - 2023</td><td>Proportion of small-scale industries in total industry value added (%) - 2021</td><td>Proportion of the rural population who live within 2km of an all-season road in 2023</td><td colspan="2">Central Government Debt (% of GDP) - 2022</td><td>Trade (% of GDP) 2022</td><td>Rural population (% of total population) in 2022</td><td>Access to Bank Account (%,15+) - 2021/2022</td><td>Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022</td><td>Ease of doing business index</td><td>Profitability of National Electricity Utilities (yes/no)</td></tr>
<tr><td>Enabling Environment for Clean Cooking</td><td>Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021</td><td>Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022</td><td colspan="2">LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021</td><td>Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010</td><td>Access to electricity (all areas)</td><td>Access to electricity (urban)</td><td>Access to electricity (rural)</td><td colspan="4">Grid reliability (SAIDI * SAIFI)</td></tr>
<tr><td>Economic Aspirations</td><td colspan="2">Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023</td><td colspan="2">Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)</td><td>Regulatory Indicators for Sustainable Energy (RISE)</td><td>Unrealised potential for electric cooking</td><td colspan="2">Affordability of electricity (grid only)</td><td colspan="4">Urban population growth (% Annual)</td></tr>
</table>

Throughout the following case studies this matrix is presented as a national snapshot either, in the case of countries such as Brazil which have 100% access to clean cooking, as a potential scenario to learn from, or, in the case of countries such as DRC (who have a long way to go), a method of understanding where resources can be allocated to drive access to modern and clean cooking fuels and appliances. Given the complexity and contextually driven nature of these transitions, we have actively chosen not to provide overall weighted ratings based on these criteria and indicators[17]. As outlined throughout the report, there is no "one-size-fits-all" approach to clean cooking transitions, however, national governments can build on the small wins and integrate these learnings into their own integrated energy planning scenarios – such as the scenarios outlined in the Kenyan case study below.

[17] Criteria such as the "Regulatory Indicators for Sustainable Energy" (ESMAP, 2023) do have their own national ranking system, however they do not consider the other dimensions such income and gender inequality.

5.2. Country Case Studies

In the following sub-section, we explore how key decisions at the national level, which are linked to the indicator matrix, have enabled (or not enabled) scalable clean cooking pathways for all. As outlined in these case studies across Africa, Asia, and Latin America, we show how the prioritisation of different criteria has affected the basket of available fuels and technologies (and their accompanying infrastructure, energy transitions, and services).

5.2.1. African Case Studies

5.2.1.1. Kenya – A Multi-Fuel Approach

SDG Overview. Kenya is a global leader in advancing the clean cooking cause, with a stable economy and a diverse market for clean cooking solutions. The recent CCA industry snapshot (CCA, 2022) states that a significant portion of global Clean Cooking finance has been attracted to Kenya over the last decade (72% of total global investment in 2020), due in part to its high policy readiness (RISE) scores and its growing economy. Figure 19 shows the progress that has been made over recent years, reflecting strong leadership on the issue from successive governments and innovation in the rapidly evolving private sector. This has resulted in an array of different clean cooking solutions offering much greater choice to the everyday cook than in other markets.

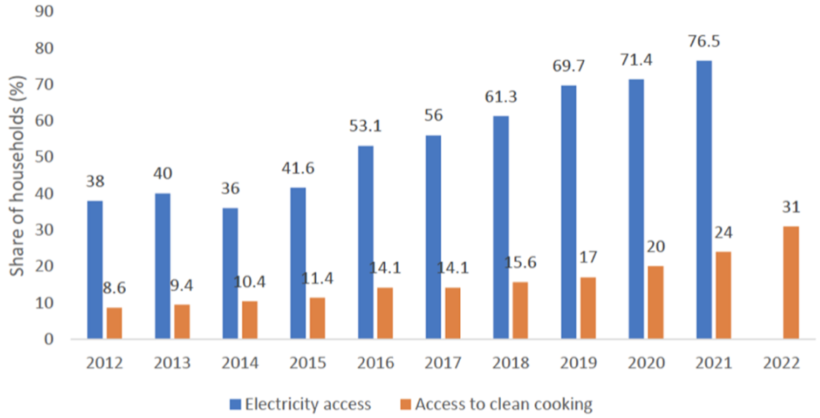


Figure 19: Kenya Clean Cooking and Electricity Access Rates (MOEP 2024)

Approaches for Clean and Modern Cooking Transitions. It is interesting to note the contrast between the progress on scaling clean cooking with the far more rapid progress Kenya has made on expanding electricity access over the same time period (Figure 20). With around three quarters of the population now connected to the main grid (KPLC, 2023), it is likely that of all the clean cooking fuels, electricity now has the most complete supply chain. Although the use of electricity as a primary cooking fuel remains low (<1%), innovations in appliance efficiency, consumer financing and smart-metering are driving rapid growth in Kenya's emerging eCooking sector. The baseline study for the forthcoming Kenya National eCooking Strategy (MoEP, 2023) indicated that 24% of the population own an electric appliance that can be used for cooking, however the majority are task-specific appliances that are stacked alongside other fuels. Meanwhile, Kenya is the first country on the continent to see bioethanol reach scale as a cooking fuel (Osiolo et al, 2023). This transition has been primarily driven by the private sector, with Koko Network's streamlined IoT-enabled supply chain now reaching over 1 million customers and companies such as Giraffe Bioenergy developing local production techniques to ensure domestic fuel supply.

However, of the 31.49% of households currently using clean cooking fuels and technologies as their primary cooking solution, 31% utilise LPG. LPG has received strong support from the national government in recent years, with a raft of fiscal incentives, showing the important role it plays as a transition fuel, enabling households to move away from biomass. Private-sector innovations such as PayGo metering (enabling gas to be sold in small quantities to low income households by fitting an IoT metering device to cylinders) and public sector initiatives such as the Mwananchi Gas project (distribution of cylinders to low income households) aim to facilitate a just LPG transition by enabling access amongst low-income households.

Policy on clean cooking in Kenya reflects both government commitments to energy access and its decarbonisation commitments, as exemplified in the Energy Transition and Investment Plan (ETIP) (MoEP, 2024) and the Kenya National Cooking Transition Strategy (KNCTS) (MOEP 2024). Aspirations to contribute to the Paris Agreement can be fulfilled by adjusting transition policies towards a net zero target while maintaining economic growth and meeting access targets, in particular the goal of achieving universal access to clean cooking by 2028 (Figure 20).

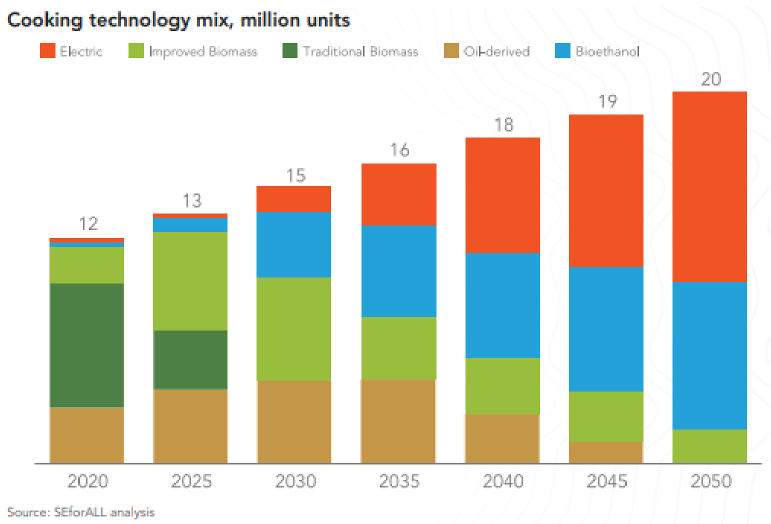


Figure 20: The transition pathway mapped out by the Energy Transition & Investment Plan connects the short-term universal access to clean cooking and long-term net-zero aspirations with successive transitions driven by fossil fuels and renewables respectively (MoEP, 2024)

Kenya has recently completed its National Cooking Transition Strategy (KNCTS) (REF). With a vibrant clean cooking sector, with many different sub-sectors offering consumers a diverse array of solutions, the KNCTS was commissioned to harmonise across this broad set of actors and provide coherence to Kenya's clean cooking sector. The strategy joins the dots between the existing fuel-specific strategies, such as the Bioenergy Strategy, the Bioethanol Masterplan, the LPG Growth Strategy, and the Electric Cooking Strategy, to create a cohesive enabling environment under which all solutions, both transitional and truly clean, can thrive. However, the strategy focuses in on enabling access to truly clean cooking solutions (aligned with the WHO's guidelines on household air pollution) that have a critical role to play in transitioning large segments of the population away from unsustainably harvested and inefficiently burned biomass. This includes LPG, as well as renewable fuels such as bioethanol, low emission/clean burning sustainable biomass (e.g., briquettes and pellets), biogas, and electricity (Figure 21). In Kenya, electric cooking offers a long-term sustainable pathway that leverages the nation Figure 21, as electricity generation is already around 90% renewable from a diversified mix of geothermal, hydro, wind and solar.

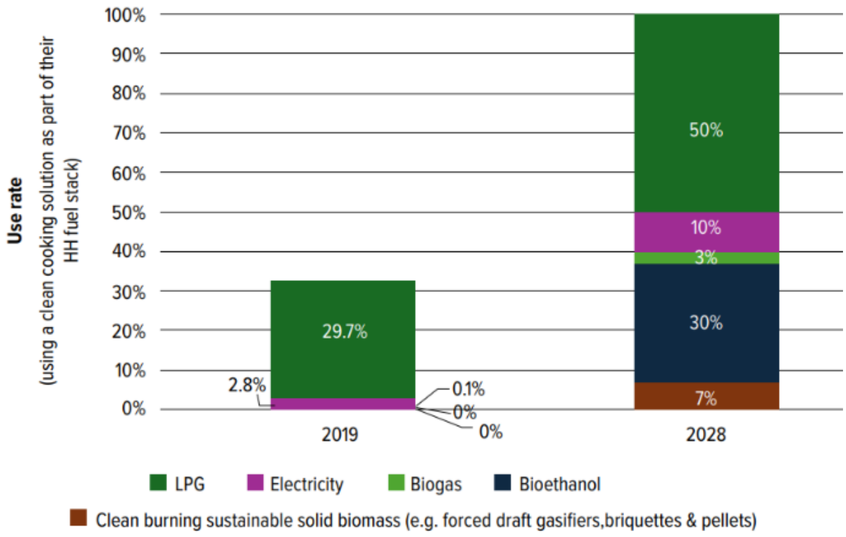
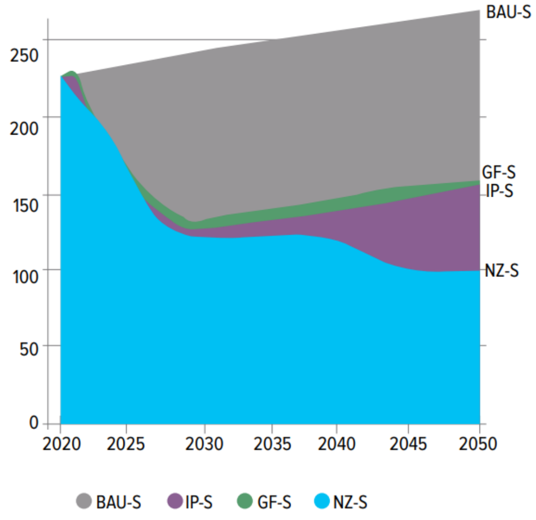


Figure 21: Percentage of Households Gaining Accessing to a Clean Cooking Solution by 2028 in the Composite Scenario (CP-S) of Kenya's Cooking Transition Strategy (MOEP 2024)

Through a participatory approach that brought together key stakeholders from Kenya's rapidly growing clean cooking sector and deepened the evidence-base on critical sub-sectors (funded by a novel collaboration between UK, German and French funders under the Energy Transitions Council), the KNCTS has been able to harmonise across the many different approaches to tackling the clean cooking challenge. It charts a pathway towards universal access that leverages Kenya's unique position as a regional innovation hub, with an array of clean cooking technologies already deployed at scale in the market. By building upon the firm foundation laid by the existing fuel-specific government strategies and the actions of the private sector, this strategy aims to create the enabling environment in which all clean cooking solutions can thrive.

Key Challenges for Clean and Modern Cooking Transitions.

Conscious of the need for a just transition for clean cooking, a broad fuel mix for clean cooking for improved health and environment was considered in the KNCTS, which models 5 scenarios (MOEP 2024): Business as Usual (BAU-S); Implemented Policies (IP-S); Gas-Focussed (GF-S); Net Zero (NZ-S); and Composite Policy (CP-S). The GF-S is derived from IEA 2020 and Hystra 2023 and enables universal access to clean cooking by 2030, but without an explicit focus on climate emissions and the economy. Focusing on LPG as a transition fuel, 50% of users will rely on LPG by 2030, with the balance utilising improved biomass cookstoves. NZ-S which also builds on the IEA 2020 data, and considers Lambe 2020, places more emphasis on eCooking, biogas and bioethanol as renewable fuels.



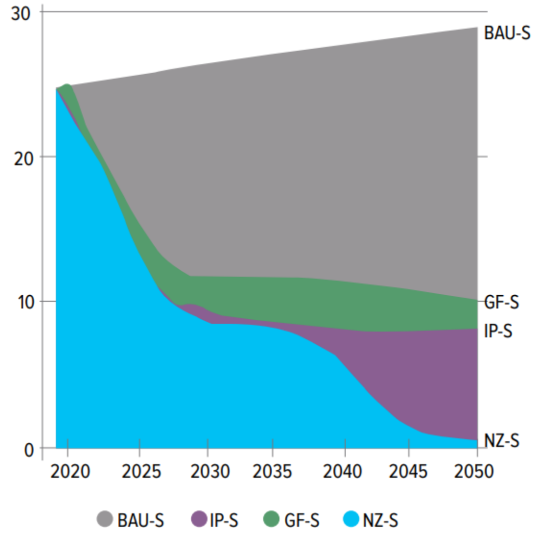
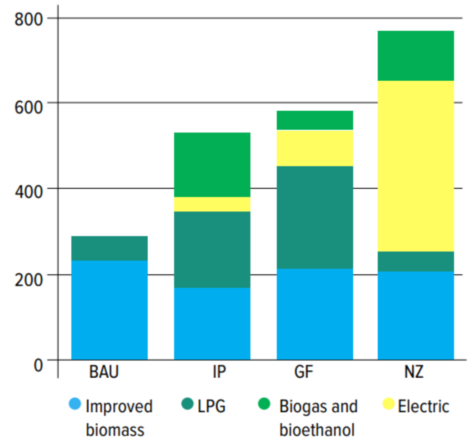


Figure 22: Energy Demand Across All Scenarios (in PJ) (MOEP 2024)

Figure 23: GHG Emissions Across All Scenarios (in $MtCO_2e$) (MOEP 2024)

All modelled scenarios halve energy consumption by 2030, and thereafter level out. In the NZ-S the ongoing push towards net zero and a growing use of renewables achieves this net zero aspiration by 2050. The estimated capex required to acquire the new cooking devices within these scenarios is shown in Figure 25. Due to the higher capital cost of electric and biogas cookstoves, the total capital cost of the NZ-S is highest. However, when also accounting for the costs related to the number of premature deaths caused by air pollution (Figure 24), they by far outweigh the capex costs, making the NZ-S the most cost competitive based on this perspective.



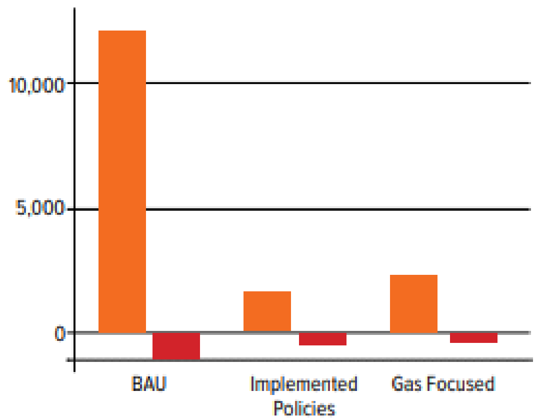


Figure 24: Capital Expenditures by Technology and Scenario between 2019 and 2030 (mil US$) (MOEP 2024)

Figure 25: Additional costs related to premature deaths compared to the capex in the NZ scenario (mil US$) (MOEP 2024)

The insights derived from this modelling analysis contributed to the formulation of the 2028 fuel mix target in the CP-S presented in Figure 21. The emphasis in the CP-S is placed on promoting renewable fuels such as electricity, biogas, and bioethanol, with LPG recognised as a crucial transitional fuel despite being a fossil fuel.

Implication of this Policy Approach. The multi-fuel approach of the CP-S (shown in Figure 21) attempts to balance between the relative advantages and disadvantages of each fuel, offering consumers greater choice and therefore greater resilience against supply chain disruption, global price trends and other fuel-specific challenges. It takes into account that LPG emits less GHG than biomass, and seeks to use the gains in electricity access for eCooking for a just transition process, however it does still introduce economic challenges, leaving Kenya vulnerable to global price instabilities and the need for subsidies. Kenya's public debt-to-GDP ratio hit 69% by May 2022. Consequently, a significant portion of government revenue is allocated to servicing debt, leaving little capacity for subsidising social programmes like clean cooking. For instance, the utility tariffs were reviewed upwards in April 2023 to reduce government allocations to the electricity sector by lowering the limit for qualifying for the monthly lifeline tariff allowance, equivalent to a 24.1% cross-subsidy, from 100kWh to 30kWh. As a result, the KNCTS proposed a pathway that minimises direct subsidies from the government, instead leveraging their convening power to unlock private-sector monetization of the co-benefits of clean cooking transitions (e.g. carbon credits, averted DALYs, time savings). Modelling within the KNCTS (Figure 25 and Figure 27) suggests that implementing the strategy and achieving 100% sustained use of the acquired clean cooking technologies will result in total net social and private benefits of US$240m from time savings for cooks and reductions in unsustainable woodfuel harvest, GHG emissions reductions and burden of disease. In fact, the benefits are higher than this as the tool does not incorporate calculations on job created and revenues to the government such as taxes. For comparison, with an annual expenditure of around US$5.8m programming and $16.5m administrative costs the total annual government spend for the CP-S is projected to be $22.3m. However, the government will need to play a key role in enabling the private sector to monetize the co-benefits generated from the sustained use of clean fuels and technologies in order to raise the $178m and $10.3m needed for fuel and stove subsidies respectively. The remaining annual costs of $71m are the costs paid by the end consumer, which the private sector will need to raise to deliver the fuels and cooking devices to households. However, some of these costs will of course be offset by savings on existing expenditures on polluting fuels.

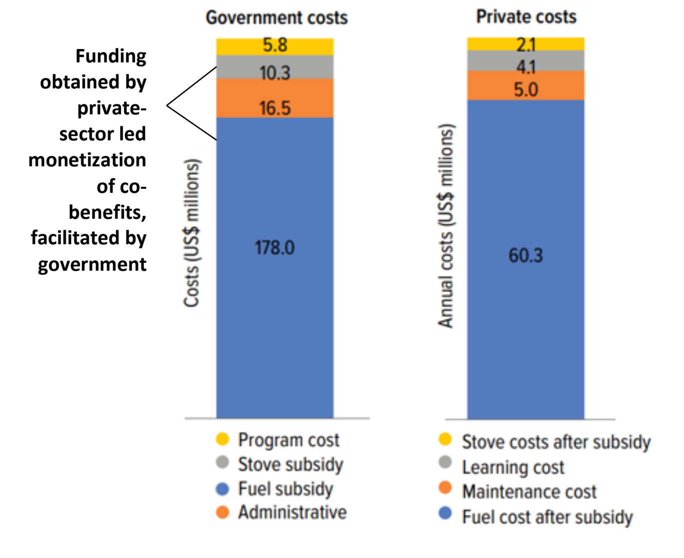


Figure 26: Breakdown of Costs of implementing the KNCTS (MOEP 2024)

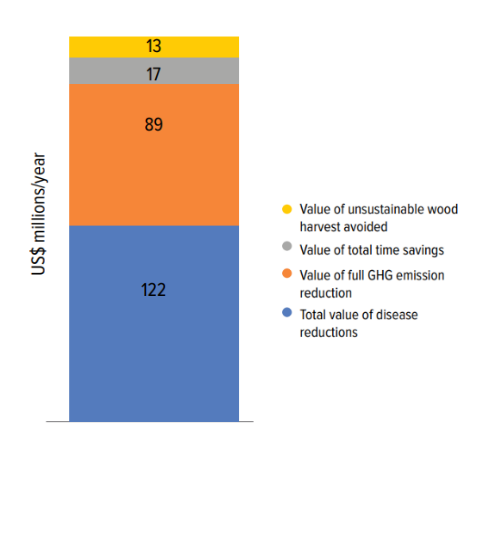


Figure 27: Annual Private and Social Benefits of implementing the KNCTS (MOEP 2024)

Conclusion This case study demonstrates the benefits of collaboration between private sector and government to accelerate the clean cooking transition. The KNCTS articulates the next steps that households across Kenya can take in the journey towards universal access to clean cooking. It outlines five key actions that the government will take to facilitate this journey by addressing key challenges in the sector: bridging the supply gap for clean cooking solutions; bridging the affordability gap for the demand side; promoting local manufacturing and fuel production for local use and export; reframing and raising awareness on the role of clean cooking; and instituting accountability, planning, and continuous tracking of progress. By enabling multiple clean cooking transition pathways simultaneously, the KNCTS offers an accelerated pathway towards achieving universal access, leveraging the unique strengths and weaknesses of each fuel/technology.

Table 13: Kenya Clean Cooking Matrix Indicators

Dimension	Pillar	Value	Indicator
Economic Landscape 2024	Infrastructure	108	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking
Economic Landscape 2024	Infrastructure	8.7	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023
Economic Landscape 2024	Infrastructure	n/a	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021
Economic Landscape 2024	Infrastructure	82.9	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023
Economic Landscape 2024	Transitions	67.9	Central Government Debt (% of GDP) - 2022
Economic Landscape 2024	Transitions	34	Trade (% of GDP) 2022
Economic Landscape 2024	Transitions	71	Rural population (% of total population) in 2022
Economic Landscape 2024	Services	79.2	Access to Bank Account (%,15+) - 2021/2022
Economic Landscape 2024	Services	39.69	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022
Economic Landscape 2024	Services	73.2	Ease of doing business index
Economic Landscape 2024	Services	No	Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	Infrastructure	2.3	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021
Enabling Environment for Clean Cooking	Infrastructure	3.3	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022
Enabling Environment for Clean Cooking	Infrastructure	3.16	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021
Enabling Environment for Clean Cooking	Transitions	0.0033	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010
Enabling Environment for Clean Cooking	Transitions	76.5	Access to electricity (all areas)
Enabling Environment for Clean Cooking	Transitions	97.5	Access to electricity (urban)
Enabling Environment for Clean Cooking	Transitions	68.2	Access to electricity (rural)
Enabling Environment for Clean Cooking	Services	82.8	Grid reliability (SAIDI * SAIFI)
Economic Aspirations	Infrastructure	No	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023
Economic Aspirations	Infrastructure	Yes	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)
Economic Aspirations	Transitions	73	Regulatory Indicators for Sustainable Energy (RISE)
Economic Aspirations	Transitions	74.2	Unrealised potential for electric cooking
Economic Aspirations	Transitions	203.7	Affordability of electricity (grid only)
Economic Aspirations	Services	3.7	Urban population growth (% Annual)

5.2.1.2. Zambia – A Demand/Supply Challenge

Zambia is an example of how imbalanced energy planning can threaten existing gains and challenge the economy. While electricity access has grown (Figure 28), high levels of deforestation driven through increased use of charcoal undermines progress, hence the fragmentation between electricity access and clean cooking approaches has led to slow overall progress on clean cooking. Strategic use of integrated energy planning and efficiency measures which promote technologies such as eCooking can more effectively utilise existing resources and build on the electricity access gains of the last two decades. However, disparity between demand and supply means that , Zambia's government owned electricity utility has chosen to prioritise the mining sector over the domestic sector further complicating clean cooking transitions.

SDG Overview. Zambia continues to make progress in increasing access to electricity, although rural electrification remains low at 4%, compared to 75% of urban households. The Integrated Resource Plan (IRP), the Ministry of Energy's blueprint for the development of the power sector, is based on achieving full electrification by 2030. This will be achieved through a mix of grid (44%), solar home systems (36%) and mini-grids (20%) (Ministry of Energy, 2024). The IRP models an increase in electricity generating capacity from 3.7 GW (2023) to 23 GW by 2050. A diversified generating mix would decrease reliance on hydro from 85% to 36% mostly by introducing wind (24%) and solar PV (21%) (Ministry of Energy, 2024).

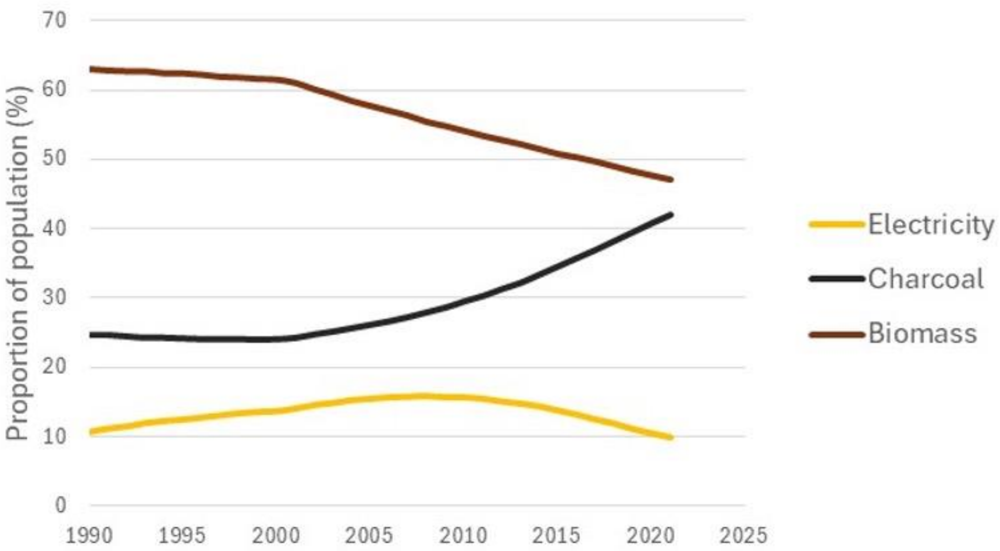


Figure 28: Primary cooking fuel mix trends (Zambia) (WHO Cooking Fuel and Technology Database) * Biomass refers to unprocessed biomass which includes wood, crop residues and dung.*

Electric cooking has historically been at relatively high levels in Zambia due to low tariffs. However, ZESCO (the government owned utility) has been keen to reduce domestic cooking loads as a means of improving network performance and freeing up capacity to serve the mining sector, which is an economic priority for the country. More recently, despite increasing electrical generating capacity, demand continues to outstrip supply, leading to persistent load shedding. These factors have combined to result in the continuous unprofitability of ZESCO which has reached such a level that ZESCO applied to more than double domestic tariffs (an increase of 120%) over a five-year period from 2022 to 2027; this was approved in 2023.

Zambia is one of a small handful of countries that have gone backwards in terms of access to clean cooking. This is due to households previously cooking with electricity (levels of which are relatively high in Zambia compared to regional averages) resorting to charcoal in response to load shedding. Use of fuelwood has also declined in recent years, being displaced by charcoal (Figure 28). In rural areas, 84% of households burn biomass on open fires (Luzi et al., 2019).

Key Challenges for Clean and Modern Cooking Transitions. Policy makers are concerned with the high rate of deforestation in Zambia and this serves as motivation behind several energy related policies and initiatives. Charcoal production is estimated to account for 25% of deforestation and forest degradation which lies between 180,000 and 250,000 hectares each year (USAID, 2021). The total forest land cover is 46 million Ha, of which 11 million Ha is primary forest (FAO and The Ministry of Energy Zambia, 2020). The charcoal industry supports livelihoods for several hundred thousand producers, a few transporters and wholesalers, and tens of thousands of traders. Charcoal provides a safety net for millions of marginalised people. The low barrier to entry for charcoal production means that people can resort to informal production when, for example, agricultural activities fail (Tetra Tech and USAID, 2021). Whilst alternatives, such as bio-ethanol[18] and LPG, have significant potential this is yet to be realised. LPG was seen as a better alternative to charcoal for cooking, but the Indeni refinery was then shut down in 2021 (PMRC, 2023); it since recommenced operations in June 2023.

Technological Approaches to Energy & Clean Cooking. The IRP, and the similar Cost of Service Study (EMRC, 2021), are examples of donor funded support for the power sector; Beyond the Grid Fund for Africa (BGFA) provides financing to incentivise private sector companies to provide electricity access in rural areas, with the hope that this drives the adoption and/or return to eCooking. Other initiatives that specifically address clean cooking include the Modern Cooking Facility for Africa (MCFA), which provides financial incentives to private sector companies. This is encouraging international companies to expand into Zambia (e.g. BURN, ATEC). The USAID funded Alternatives to Charcoal programme has a mandate to reduce charcoal consumption in urban areas. The Ministry of Energy has convened the Energy Sector Advisory Group (EAG), which includes a Clean Cooking sub-committee. These efforts are supporting the development of some interesting technologies and business models aiming to make modern fuels such as LPG more affordable and easier to procure; e.g. smaller cylinders, PAYGO solutions, and barcodes for tracking cylinders and remote refilling. The current government introduced free education and, as a signatory of the EFP school meals Coalition, aims to double the number of school meals provided (Schools Meals Coalition, 2023). The government is also engaged with the GIZ SPAR6C project, supporting the government to put in place the structures needed to access Article 6 carbon finance (see section 3 for more detail on carbon financing). Whilst this is driven by an interest in agriculture and forestry projects, it provides an additional financing vehicle for clean cooking.

Policy Approach. Despite a fairly comprehensive policy approach to the transition to clean, modern, and sustainable fuels (8th National Development Plan; Nationally Determined Contributions; Energy Efficiency Strategy and Action Plan; Renewable Energy Strategy and Action Plan; Gender Equality Strategy and Action Plan, to name a few), Zambia still suffers from supply side constraints in both the LPG and electricity sectors. As outlined above, the LPG industry has experienced disruption due the closing of the Indeni refinery and global volatility of the petroleum industry. A transition away from cooking with biomass is supported by the Vision 2030, which has the aim of reducing woodfuel use from 70% to 40% of the population in addition to increasing electricity access. However, there remains a need to unify the currently fragmented approach to achieving universal access to clean cooking. In a direct move to address this the Ministry of Energy have recently convened a multi-stakeholder process to develop a national Clean Cooking Strategy and Action Plan.

[18] The production capacity from feedstock available in Zambia is estimated at 240 million litres/year.

Table 14: Zambia Clean Cooking Matrix Indicators

Infrastructure

Economic Landscape 2024	**n/a** UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking	**9.5** 9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023	**n/a** 9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021	**66.1** SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023
Enabling Environment for Clean Cooking	**3.1** Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021	**7** Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022	**1.21** LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021	
Economic Aspirations	**Yes** Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023		**No** Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)	

Transitions

Economic Landscape 2024	**52.4** Central Government Debt (% of GDP) - 2022	**51** Trade (% of GDP) 2022	**50** Rural population (% of total population) in 2022	
Enabling Environment for Clean Cooking	**0.0038** Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010	**42.0** Access to electricity (all areas)	**67.0** Access to electricity (urban)	**18.0** Access to electricity (rural)
Economic Aspirations	**37** Regulatory Indicators for Sustainable Energy (RISE)	**40.8** Unrealised potential for electric cooking	**163.8** Affordability of electricity (grid only)	

Services

Economic Landscape 2024	**48.61** Access to Bank Account (%,15+) - 2021/2022	**11.14** Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022	**52.4** Ease of doing business index	**No** Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	**4673.2** Grid reliability (SAIDI * SAIFI)			
Economic Aspirations	**3.8** Urban population growth (% Annual)			

5.2.1.3. Benin –beyond LPG and ICS to potentially integrated eCooking

Benin is an example of another country which to date also has a disconnect between energy planning for electrification and clean cooking. With high aspirations for electrification, the clean cooking focus is on decreasing biomass use through improved cookstoves. Benin is aware that LPG offers potential as a transition fuel, however due to significant central government debt there needs to be an alternative to fossil fuel imports.

SDG Overview. Benin's progress on electrification has been steady over the last two decades, bringing the electrification rate to 42% in 2021, up from 22% in 2001, however, stark differences remain between urban (67% access) and rural areas (18% access). Progress on clean cooking access has in contrast stagnated over the last 10 years and stands at only 5% as of 2021 (ESMAP, 2023). A majority (>90%) of Beninese rely on biomass for cooking which leads to high levels of wood fuel consumption - 3,085 kton per year. This, in turn, leads to high rates of deforestation: between 2005 and 2015 Benin's forest cover dropped by over 20% (from 7.6 to 6 million hectares). Deforestation rates continue to be very high at 2.2% annually (World Bank, 2020), with associated emissions of around 12 Mio tCO2e/yr.

Figure 29: Cooking Fuel Balance (MECS et al., 2022).

Close to 80% of Benin's electricity generation comes from natural gas, 20% from oil and 1.5% from solar PV (IEA, 2023). The country is heavily dependent on external energy importation with the cost of importing electricity, mostly from Nigeria, Ivory Coast and Ghana, exceeding $130 million annually (Mensah et al., 2021). However, Benin is one of the countries with the most affordable electricity for consumers, scoring 78 out of 100 in the affordability category of the electricity access pillar in 2021 (ESMAP, 2022). With a total surface area of 114 763 km2, the country is endowed with a high potential for energy resources, particularly solar and hydro energy (3532MW and 761MW technical potential, respectively), yet to be fully tapped into (Akpahou et al., 2023).

Opportunities for Clean and Modern Cooking Transitions. Together with other Economic Community of West African States (ECOWAS) nations, the Government of Benin (GoB) implemented a coordinated strategy to carry out the SEforALL Country Action. By 2025, the ambition is to achieve electricity access of 95% and 65% in urban and rural areas, respectively; to have 24.6% of the total energy mix coming from renewable sources; and 30% of renewable energies in the electricity mix by 2035 through the introduction of at least 25% of the total solar PV capacity (SEforALL, 2022). The GoB has initiated the transformation of the country's energy mix, particularly by formulating the Benin National Renewable Energy Development Policy (PONADER) (Republic of Benin, 2020). The Off-Grid Electrification Master Plan (PDEHR) is another tool for implementing the Off-Grid Electrification Policy (EHR) over the period of 10 years, focusing on decentralised mini-grids and standalone solar home systems (Benin Energie, 2020).

Significant funding of $375 million through the compact with the U.S. Millennium Challenge Corporation, combined with an additional $700 million in other donor financing, has been committed to the GoB to build generation assets, pursue IPP transactions, expand transmission capacity, and modernise its distribution network, while expanding access through grid and off-grid connections (MECS, 2022). Recently, the Universal Energy Facility (UEF) – a multi-donor results-based financing facility managed by SEforALL, signed a $886,816 funding agreement with a private sector developer to support the construction of three solar mini-grids in the communities of Sinlita, Gbowele and Don Akadjamey (SEforALL, 2024). With the significant commitment towards speeding up electrification efforts and boosting renewable energy generation in the country, both for grid and off-grid electrification, combined with the urgent need to cut down deforestation, there is an opportunity for Benin to include electric cooking in its ongoing electrification efforts, particularly by integrating clean cooking and electrification access planning. The country already includes the promotion of renewable energy in their Nationally Determined Contributions (NDCs) to preserve forest, as renewable energy can replace the use of traditional biomass for heating and cooking purposes and hence safeguard forest resources (IRENA, 2021). However, challenges remain in the affordability and availability of modern energy cooking appliances, including e-cooking ones, due to underdeveloped supply chains (MECS, 2022).

Technological Approaches to Energy & Clean Cooking. Historically, improved cookstoves (ICS) have been promoted in Benin through non-governmental initiatives, including capacity building for ICS production, improved efficiency in charcoal carbonisation for ICS combustion, and the development of standards for ICS. For example, EnDev Benin has been working since 2009 to support 60 cooperatives and enterprises that produce and distribute ICS. Activities have ranged from strengthening production capacity to improving commercial, managerial and organisational skills as well as enlarging distribution networks (EnDev, 2022). Recently, with further support from the European Union, EnDev Benin have started financing innovation activities on improved and efficient stoves and modern cooking technologies, including electric cooking solutions. This could help demonstrate the economic, environmental and health benefits of e-cooking solutions, whether off-grid standalone or mini-grid powered ones.

Current Policy Approach. The National Renewable Energy Development Policy document (PONADER) 2019 and the National Energy Management Policy document (PONAME), 2020 focus on the expansion of renewable energy and energy efficiency. Clean cooking is considered through the energy saving factor and the promotion of more sustainable use of biomass resources and higher uptake of modern cooking techniques. The planned activities are geared towards strengthening conditions favouring the use of improved stoves and increased energy efficiency, for example by replacing charcoal with LPG. The goal is to achieve 100% rate of access to improved cookstoves by 2030, with a national rate of ownership of LPG cooking equipment of 41% in consistency with the National Action Plan for Renewable Energies (PANER) of July 2015. However, there is currently no national policy that integrates clean cooking into the energy access targets. The National Clean Cooking Action Plan (PANCP) commissioned by EnDev is under development, presenting an opportunity to consider a wider basket of clean and modern cooking options. In particular, to gain economic benefits from reducing the reliance on fossil fuel imports, including LPG, and to support the achievement of the NDCs, the GoB could look towards renewables-based e-cooking (IRENA, 2023) as it develops its clean cooking strategy.

Table 15: Benin Clean Cooking Matrix Indicators:

Infrastructure

Economic Landscape 2024	**126**	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking	**8.4**	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023	**n/a**	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021	**45.8**	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023
Enabling Environment for Clean Cooking	**3**	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021	**1.8**	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022	**0.07**	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021		
Economic Aspirations	**Yes**	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023	**No**	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)				

Transitions

Economic Landscape 2024	**115.2**	Central Government Debt (% of GDP) - 2022	**69**	Trade (% of GDP) 2022	**54**	Rural population (% of total population) in 2022		
Enabling Environment for Clean Cooking	**0.0081**	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010	**46.7**	Access to electricity (all areas)	**85.7**	Access to electricity (urban)	**14.5**	Access to electricity (rural)
Economic Aspirations	**46**	Regulatory Indicators for Sustainable Energy (RISE)	**46.7**	Unrealised potential for electric cooking	**778.3**	Affordability of electricity (grid only)		

Services

Economic Landscape 2024	**48.52**	Access to Bank Account (%,15+) - 2021/2022	**14.78**	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022	**66.9**	Ease of doing business index	**No**	Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	**250.9**	Grid reliability (SAIDI * SAIFI)						
Economic Aspirations	**4.0**	Urban population growth (% Annual)						

5.2.1.4. Morocco – A Second Transition?

Morocco is an example of an economy that has already transitioned from traditional biomass use to LPG. Household subsidy levels for LPG are more than 50%, with the national bill at around $2.1 billion in 2023. Aspiring to reduce the economy wide GHG, there have been discussions about transitioning to electric cooking, but the prevailing ideas which maintain economic growth revolve around a transition to Natural Gas.

SDG Overview. Morocco is the fifth largest economy in Africa, and growth in final energy use has matched average annual economic growth of 4% over the past decade, and despite national efforts for energy efficiency, projections suggest similar levels of future growth. Morocco heavily relies on imported hydrocarbons for its energy sector, with approximately 90 percent of its energy needs met through imports. Moroccan households are approximately 75% urban and 25% rural. Electricity access is close to 100% and access to clean cooking stands at around 98%. There is currently no pipe infrastructure for natural gas distribution, and as of 2018, 99.2% of urban households reported butane (LPG) as their primary cooking fuel, compared to 90% of rural households. Both groups use wood as the main secondary choice, with some use of electric cooking appliances by wealthier households. (Ministry of Health, 2018). LPG thus dominates the energy demand in the residential sector, representing more than 60% of the total, mainly for cooking purposes, with a smaller portion used for domestic hot water heating. Significantly, the residential sector accounts for roughly 12% of Morocco's greenhouse gas (GHG) emissions. Butane gas was the predominant energy source in this sector, comprising 63.3% of the total primary energy consumption.

Morocco's electricity production comprises around 62% fossil fuels (37% coal, 18% natural gas, 7% fueloil), and 38% renewables (17% hydroelectricity, 13% wind, 8% solar). There has been significant investment in new generation and transmission and distribution, which has much improved security of electricity supply (IEA, 2019). A new Development Model (NDM) announced in 2021 aims to boost private sector competitiveness, human capital and economic inclusion, as well as advance sustainable regional development. This private sector focus is attracting international investment support, eg from the EBRD. A key target is to expand the use of renewable energy sources for electricity generation, largely through regulatory reforms and stimulating private sector investment.

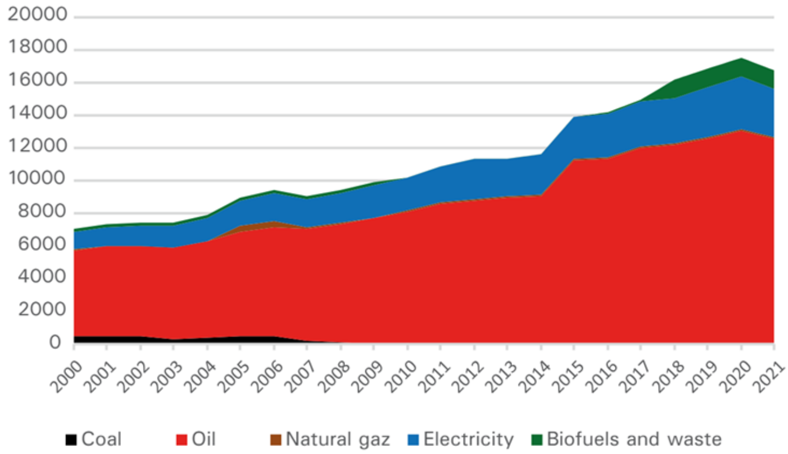


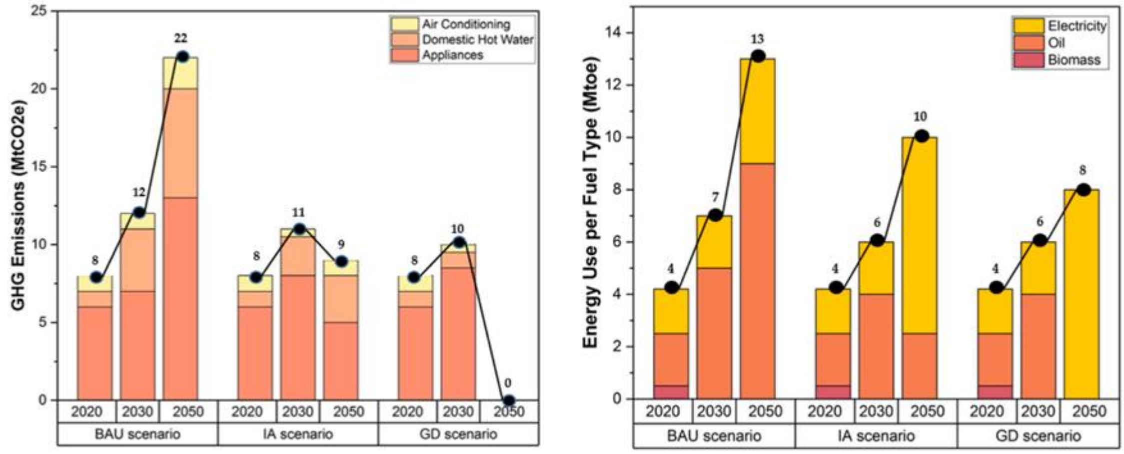
Figure 30: Morocco Total Final Consumption (ktoe)[19](AFREC, 2022)

[19] Note: "Oil" includes LPG for household and agriculture use, as well as oil products for transport

Key Challenges for Clean and Modern Cooking Transitions. IEA (2019) note that the Government started significant reform of subsidies in 2013 and by 2015 gasoline and diesel were subsidy-free, creating fiscal space for investments in renewable energy, of all the refined oil products, only butane used in households and agriculture (largely for irrigation pumping) retained subsidies. Household subsidy levels for LPG are more than 50%, with the national bill at around $2.1 billion in 2023 (IMF, 2023). Government subsidies and infrastructure development for butane distribution have reduced reliance on polluting solid fuels, benefiting health, society, and the economy but bear a high economic cost. The government has continued subsidising butane to prevent an excessive burden on impoverished and rural communities, which heavily rely on it for cooking, lighting, and agricultural irrigation. This approach aimed to mitigate the risk of rising butane prices also causing an increase in food prices. There have also been concerns that there were no viable alternatives for poor and rural households. Renewable alternatives such as solar stoves and solar irrigation pumps were still under study at that time. Initiatives like the "Faran Eco" efficiency label and technical assistance program target improvements in the efficiency and safety of gas appliances, thus decreasing butane consumption (GERES, 2019), but butane remains an expensive imported fossil fuel, straining households, government finances, energy security, and contributing to greenhouse gas emissions.

Technological Approaches to Energy & Clean Cooking. The IEA (2021) led a project to explore the potential role of electric cooking in both improving clean cooking access and reducing the national butane subsidy burden. Cooking trials focused on the most efficient device, Electric Pressure Cookers, and showed that they were suitable for around half of typical Moroccan cuisine, and could reduce cooking costs by 82%. For rural households that rely on a combination of butane and firewood, EPCs could provide an overall financial saving of 30% in monthly cooking costs and eliminate their use of firewood for indoor cooking, improving air quality and health. Electric cooking is already aspirational for wealthier households, and the eventual phase out of LPG subsidies will increase interest in alternatives (such as ICS, biogas, and solar cookers). The Ministry of Industry has noted significant growth potential in the local market for electric kitchen appliances, valued at MAD 100-150 million, driven by increased access to consumer credit and new housing developments (Ministry of Industry, 2020). Whilst there is potential for domestic manufacture of appliances, there are demand side barriers to electric cooking, such as bread baking at home and stacking multiple fuels for cooking, hot water and heating. Electricity tariff structures may also be a barrier: they are currently progressive up to 150 kWh/month, but thereafter all consumption is charged at a higher rate. Electric cooking could push households from lower to higher tiers, and this needs careful study for different segments, with tariff reforms.

Unfortunately, there is an absence of publicly available government analysis on clean cooking options, perhaps reflecting the low priority given to this area in the NDC and related strategies. There have however been several modelling studies undertaken by independent researchers, exploring the choices and best strategies for Morocco to deliver on its 2030 and 2050 objectives. For example, The Policy Center for the New South and Enel Green Power Morocco explored current emission reduction plans via "Increased Ambition" (reflecting current governmental ambitions) and "Green Development" scenarios (reflecting all possib le decarbonization levers) (Berahab et al, 2021). Relevant to cooking transition options, under these scenarios 40% -70% of the energy consumption for domestic hot water comes from solar thermal systems, 2.5 GW of low voltage rooftop PV is installed by 2030 and 4.6 GW by 2050, and additional electrification includes large scale uptake of heat pumps for space heating and of induction cookers. Heat pumps, solar heaters, and induction cookers are the drivers for decarbonization in the residential sector. The increased efficiency of the new technologies also reduces the growth rate of energy consumption, reducing the need for continuous energy infrastructure investment. Figure 31 shows the significance for both emissions reduction and energy use of the electrification of cooking in the above scenario analysis.



(a) GHG Emissions in the Residential Sector (b) Energy Use Scenarios per Fuel Type

Figure 31: GHG emissions and energy use scenarios in the building sector (El Hafdaoui et al., 2024)

Policy Approach. Morocco issued a revised Nationally Determined Contribution (NDC) in 2021 (Climatewatch, 2021) which presents a target of 45.5% GHG emission reduction by 2030, and suggests 77% by 2050. The key sectors for short term action are industry and power generation, followed by agriculture; despite their relatively high levels, emissions associated with household fuel use are not prioritised. An important contribution is from the planned increase in renewable energy's share in the electricity mix to 52 percent by 2030. The National Office of Electricity and Water (ONEE) aims to achieve an installed electrical capacity of 10 GW from renewable sources by 2030 (4.5 GW from solar, 4.1 GW from wind, and 1.3 GW from hydropower) (ITA, 2024).

In terms of modern clean cooking transitions, the Government has spoken of intentions to remove the LPG subsidy from all but low-income households for more than five years, but this is socially and politically challenging. The new plan is from April 2024 to increase the current $4 price of an LPG cylinder refill by $1 per year until it reaches the market level (currently around $10) (Argus, 2024). According to the Energy Federation in Morocco, this is not intended to reduce LPG use significantly, which is regarded as a clean cooking fuel, and is not a key focus of Morocco's GreenHouse Gas mitigation plans. Despite this apparent lack of high-level policy attention to clean cooking transitions, Morocco presents many characteristics that could support a second transition in cooking, following on from the first transition from solid biomass to LPG. There is a reliance on fuel imports and determination to remove LPG subsidies; the planned gradual reduction of subsidies for LPG will improve the cost competitiveness of other cooking types; the country has near-universal electricity to access, with relatively high reliability, plus a very good solar resource, suited for local generation, as well as a growing national renewables industry.

However, despite the potential in renewable energy generation and manufacturing, there are plans to diversity the national energy supply mix, with an emphasis on natural gas imported as LNG, with a matching strategy for expanding natural gas use by industry initially followed by the residential sector. Thus, one transition that may be in mind for urban areas is LPG to piped natural gas. While to meet the medium-term climate goals reduction in household use of fossil fuels may not be a priority, as several modelling studies have shown, longer term goals will require shifts to lower carbon cooking options which may also have significant medium-term economic advantages.

Table 16: Morocco Clean Cooking Matrix Indicators

Dimension	Category	Value	Indicator
Economic Landscape 2024	Infrastructure	66	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking
Economic Landscape 2024	Infrastructure	15.1	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023
Economic Landscape 2024	Infrastructure	n/a	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021
Economic Landscape 2024	Infrastructure	91.9	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023
Economic Landscape 2024	Transitions	68.8	Central Government Debt (% of GDP) - 2022
Economic Landscape 2024	Transitions	101	Trade (% of GDP) 2022
Economic Landscape 2024	Transitions	35	Rural population (% of total population) in 2022
Economic Landscape 2024	Services	44.37	Access to Bank Account (%,15+) - 2021/2022
Economic Landscape 2024	Services	5.05	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022
Economic Landscape 2024	Services	73.4	Ease of doing business index
Economic Landscape 2024	Services	Yes	Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	Infrastructure	9.7	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021
Enabling Environment for Clean Cooking	Infrastructure	9.9	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022
Enabling Environment for Clean Cooking	Infrastructure	65.05	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021
Enabling Environment for Clean Cooking	Transitions	0.0141	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010
Enabling Environment for Clean Cooking	Transitions	100	Access to electricity (all areas)
Enabling Environment for Clean Cooking	Transitions	100	Access to electricity (urban)
Enabling Environment for Clean Cooking	Transitions	100	Access to electricity (rural)
Enabling Environment for Clean Cooking	Services	1.1	Grid reliability (SAIDI * SAIFI)
Economic Aspirations	Infrastructure	Yes	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023
Economic Aspirations	Infrastructure	No	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)
Economic Aspirations	Transitions	74	Regulatory Indicators for Sustainable Energy (RISE)
Economic Aspirations	Transitions	68.8	Unrealised potential for electric cooking
Economic Aspirations	Transitions	619.4	Affordability of electricity (grid only)
Economic Aspirations	Services	1.8	Urban population growth (% Annual)

5.2.1.5. The Democratic Republic of the Congo – High Population, Limited Stability, Free Firewood.

The DRC is an example of a particularly challenging economic context. Infrastructure investment has been patchy, and there has been limited transition from traditional cooking methods. With significant forestry resources, there many be significant promise in generating carbon financing to fund DRC's transition to both clean and modern fuels and appliances.

SDG Overview. The Democratic Republic of the Congo (DRC) is the largest country by landmass in SSA, a large part of which lies in the densely forested Congo Basin. The regional and global importance of Congolese forests have stimulated large internationally supported forest protection initiatives that seek to reform the charcoal sector, a major driver of deforestation, and mainstream alternative cooking materials and fuels. The DRC has a widely dispersed population of near 100 million, (54% in rural and 46% in urban areas) who have a huge dependence on biomass for cooking (97%), predominantly firewood (rural) and charcoal (urban), the former collected at little to no cost. The country has made slow progress on extending access to electricity, with an estimated 21% having access in 2021. Over 95% of DRC's electricity is currently renewably generated (largely hydropower) and suffers from a legacy of underinvestment. The state-owned utility company (SNEL) operates at a loss and is burdened with debt, however, there are enormous diverse untapped clean energy resources, including hydropower, solar, wind and geothermal. The mini-grid and off-grid sectors have developed rapidly in recent years, due to a more welcoming enabling environment, developer interest and the DRC government's electrification strategy, although overall there remains an absence of supporting policy contexts such as a national energy policy (approved on a technical level but waiting formal adoption by Ministerial Council) or clean cooking strategy, and many challenges remain, including complicated, costly, and irregular import systems and regulatory frameworks.

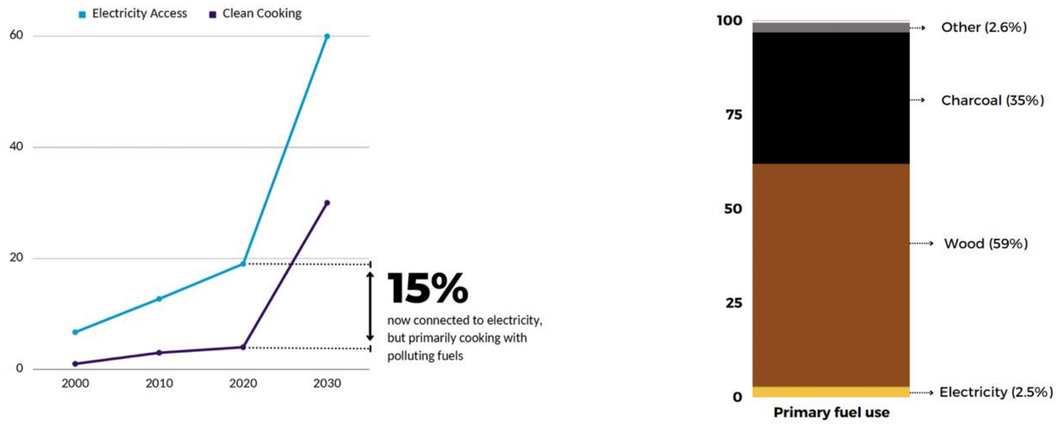


Figure 32: Electricity & Clean Cooking Access and Use (Todd et al., 2022)

Key Challenges for Clean and Modern Cooking Transitions. Residential electricity tariffs for those connected to the national grid are relatively low and electricity is used for cooking by 2.5% of the population as part of a fuel stack in some grid-connected urban areas (such as Kinshasa). LPG has historically had negligible uptake, but in recent years the sector has received some government backing, including an emphasis in prospective policy documents, and has attracted the interest of some private operators, such as Bboxx. However, the size of the DRC presents challenges for in-country transport, storage and logistics, as well as a challenging business environment. The country has suffered from a history of political instability and there are cycles of violent conflict, particularly in the eastern provinces. The economy is growing with steady annual economic growth but around 75% of the population still live in extreme poverty (under $2.15 pp per day), and GDP growth is largely driven by the mining sector. The mining sector is both a major consumer (using over half of the electricity produced) and a catalyst for increased energy generation.

Technological Approaches to Energy & Clean Cooking. In the DRC electricity access space, Bboxx, a data-driven platform that provides innovative technologies and financing for energy access and cooking, has promoted solar home systems and financing mechanisms such as PayGo in rural and peri-urban areas. It is also the market leader for LPG in the Eastern DRC, where it has been supported by USAID. It focuses on last-mile distribution and financing pioneering mechanisms such as its smart cooking valves (LPG PayGo smart meter). Some Microfinance institutions have paired with clean cooking distributors to trial LPG. Virunga Energies, a hydroelectric energy provider based in Goma, has been trialling electric cooking using EPCs with its clients since 2021, with the support of a host of partner research and funding organisations. It aims to expand its pilot to 1500 households and explore micro and on-bill financing options. Other solar and hydro mini-grid providers, such as Nuru SASA, Electriclac S.A.S and Orange, are expanding and have secured financing, agreements or have begun to develop mini-grids in the DRC.

To support clean cooking transitions, a small number of Results Based Financing (RBF) programmes are active in the DRC. These include the Modern Cooking Facility for Africa, which offers non-reimbursable catalytic grants and RBF, for private clean cooking providers of modern and affordable clean cooking solutions (Tier 3+ to 5). It encourages Paygo and stove use monitoring initiatives. The Beyond the Grid Fund for Africa aims to create access to affordable renewable energy solutions for people living in rural and peri-urban areas in the country, and the fund manager, Nefco, has signed a letter of intent with ANSER (the national authority in charge of planning, overseeing and financing off-grid electrification in the DRC).

The voluntary carbon market has grown in recent years and several carbon projects focussing on forest protection and providing local communities with energy-efficient stoves are registered or under development (e.g. with VERRA) in the DRC (and the in the wider Congo Basin region). However, despite the potential for generating important financial return, the projects have not been immune from criticisms levelled at carbon markets and are at early stages. In 2021, the DRC Minister of the Environment and Sustainable Development presented 10 urgent measures including the creation of a carbon market regulatory authority.

Policy Approach. There are manifest challenges for clean cooking in a large low-income country with a widely dispersed population and challenging business environment, but there are enormous largely untapped clean energy resources, and important carbon stores in its forests, which are globally significant. The government has called for more climate finance investment in the DRC. Private sector led off- and mini-grid initiatives are growing as a response to national grid electrification expansion challenges, and to meet electricity access targets (30% by 2025). A letter of intent between the Central Africa Forest Initiative and the DRC government, outlined some key objectives such as reducing the share of unsustainable wood for cooking by 50% by 2031, as well as political milestones such as validating the National Energy Policy and developing the legal, regulatory and fiscal framework for the LPG sector, and creating an intersectoral coordination mechanism for sustainable energy, including clean cooking. The purported deadline for political action was by the end of 2023, however, national elections took place in December, which were contested, yet the incumbent, President Felix Tshisekedi, who endorsed the CAFI letter of intent, was elected for another five-year term (until 2028).

Table 17: Democratic Republic of Congo Clean Cooking Matrix Indicators

Economic Landscape 2024	Infrastructure	n/a	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking
Economic Landscape 2024	Infrastructure	14	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023
Economic Landscape 2024	Infrastructure	n/a	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021
Economic Landscape 2024	Infrastructure	55.2	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023
Economic Landscape 2024	Transitions	14.58	Central Government Debt (% of GDP) - 2022
Economic Landscape 2024	Transitions	95	Trade (% of GDP) 2022
Economic Landscape 2024	Transitions	53	Rural population (% of total population) in 2022
Economic Landscape 2024	Services	27.44	Access to Bank Account (%,15+) - 2021/2022
Economic Landscape 2024	Services	5.32	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022
Economic Landscape 2024	Services	36.2	Ease of doing business index
Economic Landscape 2024	Services	No	Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	Infrastructure	0.9	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021
Enabling Environment for Clean Cooking	Infrastructure	0.8	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022
Enabling Environment for Clean Cooking	Infrastructure	0.00	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021
Enabling Environment for Clean Cooking	Transitions	0.0063	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010
Enabling Environment for Clean Cooking	Transitions	20.8	Access to electricity (all areas)
Enabling Environment for Clean Cooking	Transitions	43.8	Access to electricity (urban)
Enabling Environment for Clean Cooking	Transitions	1.0	Access to electricity (rural)
Enabling Environment for Clean Cooking	Services	4673.2	Grid reliability (SAIDI * SAIFI)
Economic Aspirations	Infrastructure	Yes	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023
Economic Aspirations	Infrastructure	Yes	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)
Economic Aspirations	Transitions	31	Regulatory Indicators for Sustainable Energy (RISE)
Economic Aspirations	Transitions	9.0	Unrealised potential for electric cooking
Economic Aspirations	Transitions	111.0	Affordability of electricity (grid only)
Economic Aspirations	Services	4.5	Urban population growth (% Annual)

5.2.1.6. Egypt – A Fossil Fuel Transition.

Egypt's energy sector is powered by Natural Gas. This case study illustrates the need to diversify away from one fuel type, due to significant global price fluctuations and national demand growth, in order to create a basket of clean cooking solutions with distributed access amongst rural and urban populations.

SDG Overview. Egypt is the third most populated country in Africa, and the most populous country in the Arab world (SEforALL, 2024). Egypt's population reached 106 million in 2024 (CAPMAS, 2024), the average annual growth rate is approximately 2% (between 2010 and 2022) (The World Bank, 2024), with 57% living in rural areas and 43% living in urban areas (The World Bank, 2024; The World Bank, 2024). Despite that, Egypt has universal access to electricity and clean cooking. Approximately 94% of its energy supply is from fossil fuels (natural gas, oil, and coal) (IEA, 2024; SEforALL, 2024). The largest source of electricity is natural gas (81% of the total generation), and the share of renewable energy is only 11% (6% hydropower, 3% wind and 2% solar power) (Figure 34 and Figure 35) (IEA, 2024). Egypt is considered one of Africa's highest produces of fossil fuels (oil and natural gas) (The World Bank, 2021). In 2014, Egypt became an energy importer after being an energy exporter for decades due to the increasing domestic demand and population growth (The World Bank, 2021) – leading to an increased reliance on imported fuels. Additionally, Egypt is expected to face multiple climate hazards and a significant increase in temperature, causing an increase in electricity demand for cooling coupled with urbanization and population growth, which taken together will add more stress on the power and electricity generation landscape (IEA, 2023).

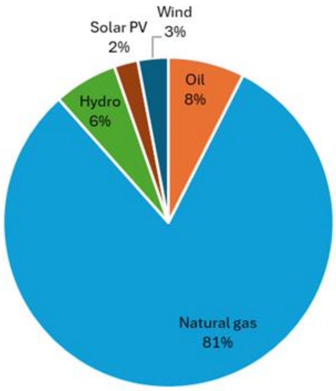


Figure 33: Electricity generation sources in Egypt, 2021 (IEA, 2024).

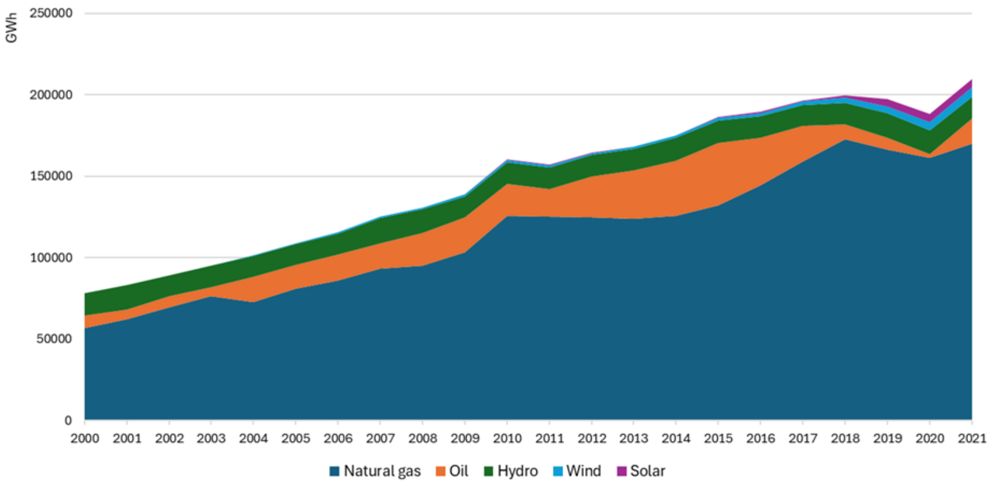
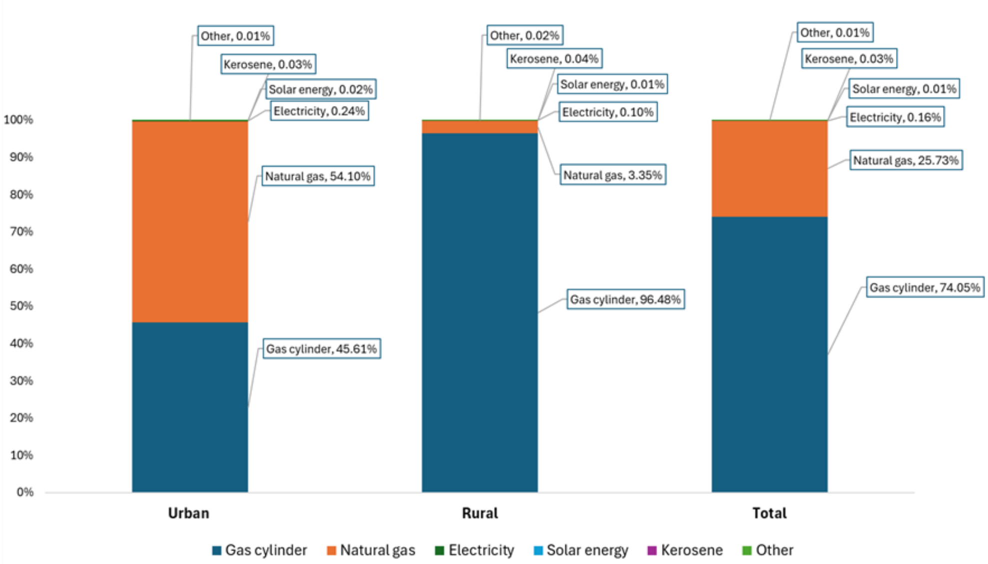


Figure 34: Evolution of electricity generation source in Egypt since 2000 (IEA, 2024)

Key Challenges for Clean and Modern Cooking Transitions. According to Egyptian national statistics from 2017 (CAPMAS, 2017), more than 74% of households rely on imported LPG (gas cylinders) as their primary cooking fuel which is heavily subsidised by the government, whilst approximately 26% use natural gas (CAPMAS, 2017; Khalifa, 2021). Urban and rural households have unequal access to the natural gas-grid, only 3% of rural households are connected to the grid compared to 54% of urban households (CAPMAS, 2017; Khalifa, 2021). Recurring issues with handling and transport have hampered the distribution of cylinders, which has disproportionately affected women, the elderly and people with disabilities (World Bank, 2021). The cylinder market was also controlled by vendors, frequently causing price hikes and a black market (The World Bank, 2021). Therefore to address these challenges, the Household Natural Gas Connection Project was launched in 2015 to connect 1.5 million households to the natural gas-grid, a more reliable and cheaper fuel compared to LPG (The World Bank, 2021). The project was funded by the World bank and the French development Agency with a grant from the European Union to subsidise the connection fee by providing financial support for



poorer families (World Bank, 2021).

Figure 35: Percentage of households by main type of fuel used for cooking in Egypt in 2017 (CAPMAS, 2017; Khalifa, 2021)

The most recent data shows that the total number of residential consumers connected to the natural gas-grid reached 11.15 million in 2020, approximately 10.7% of the total population (The Egyptian Natural Gas Holding Company (EGAS), 2019). According to the Egyptian Natural Gas Holding Company, the government is planning to increase natural gas connections for all sectors (electricity, industrial, commercial, residential, etc.) (EGAS, 2019). To ensure a just transition, 86 villages (rural areas) were connected to the natural gas-grid and the government will extend the connections to 180 villages serving 476,000 residents (Egypt's Second Updated NDCs, 2023).

Technological Approaches to Energy & Clean Cooking. Given that natural gas is the largest source of CO_2 emissions in Egypt (IEA, 2024), increasing the use of natural gas as a cooking fuel will lead to futher emissions. Despite natural gas emissions being lower than other fossil fuels, it is still necessary to reduce natural gas emissions to meet the international climate goals (IEA, 2024). Furthermore, the increase of the domestic consumption of natural gas will have a significant impact on Egypt's exports and the flow of foreign currency which is needed to import other essential products (Figure 36) (Khalifa, 2021). As a short-term benefit, increasing the use of natural gas as a cooking fuel has the potential to reduce the consumption of LPG (gas cylinders) which is imported and heavily subsidised. However, the removal of energy subsidies will increase the prices of natural gas which is especially problematic as the inflation rate in Egypt is 32.5% in 2024 and an increase of energy prices will add more financial stress on low-income households (Figure 37) (IMF DataMapper, 2024).

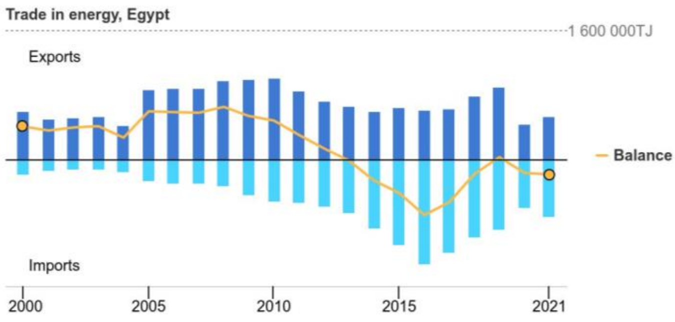


Figure 36: Trade in energy, Egypt (IEA, 2024).

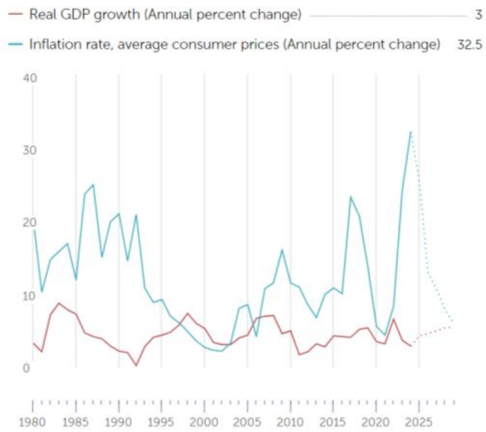


Figure 37: Real GDP growth, inflation rate, average consumer prices in Egypt (IMF DataMapper, 2024).

Policy Approach. The government aims to increase the share of renewables in the electricity generation mix to 42% by 2030 by investing in solar and wind power and implementing energy efficiency programs (Egypt's Second Updated NDCs, 2023). Given that Egypt has universal access to electricity, electric cooking could be considered as a viable alternative option as part of a longer-term transition to a decarbonised future. However this could not be achieved without the support of the international funding agencies, such as the EU[20] and World Bank[21] to aid the development of renewable energy projects in rural and urban areas. In addition, the recent update to Egypts NDC's includes improving the solid waste management infrastructure and expanding the municipal and industrial wastewater coverage and treatment including the development of waste to energy and sludge to energy projects (Egypt's Second Updated NDCs, 2023).

Shifting to a cooking strategy with a larger electric cooking component in Egypt would also involve careful consideration of current subsidization policies across the energy sector (- spending on fuel subsidies comprised 22% of Egypt's budget expenditures and approximately 6% of Egypt's GDP (Egypt's Second Updated NDCs, 2023)). Over recent years, Egypt has initiated a number of energy sector reforms that include energy subsidy phase-out, gradually reducing electricity subsidies and introducing feed-in tariffs to promote renewable energy production (Egypt's Second Updated NDCs, 2023; IEA, 2024) There is a huge potential for renewable energy resources in Egypt (such as solar, wind, waste to energy, sludge to energy, etc.), but the long-term subsidization of energy and electricity has delayed the development of such projects (Khalifa et al., 2021). Effective strategies for the development of electric cooking as part of such decarbonisation ambitions will require careful consideration of the overall structure of energy subsidies and the potential for attracting international climate finance.

[20] Joint Declaration on the Strategic and Comprehensive Partnership between The Arab Republic Of Egypt and the European Union - European Commission (europa.eu)

[21] World Bank Group Statement of Support to Egypt's Development and Reform Efforts

Table 18: Egypt Clean Cooking Matrix Indicators

Economic Landscape 2024	Infrastructure	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking	68
Economic Landscape 2024	Infrastructure	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023	14.1
Economic Landscape 2024	Infrastructure	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021	n/a
Economic Landscape 2024	Infrastructure	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023	97.6
Economic Landscape 2024	Transitions	Central Government Debt (% of GDP) - 2022	88.53
Economic Landscape 2024	Transitions	Trade (% of GDP) 2022	37
Economic Landscape 2024	Transitions	Rural population (% of total population) in 2022	57
Economic Landscape 2024	Services	Access to Bank Account (%,15+) - 2021/2022	27.44
Economic Landscape 2024	Services	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022	7.5
Economic Landscape 2024	Services	Ease of doing business index	60.1
Economic Landscape 2024	Services	Profitability of National Electricity Utilities (yes/no)	Yes
Enabling Environment for Clean Cooking	Infrastructure	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021	17.1
Enabling Environment for Clean Cooking	Infrastructure	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022	23.8
Enabling Environment for Clean Cooking	Infrastructure	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021	31.71
Enabling Environment for Clean Cooking	Transitions	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010	0.0001
Enabling Environment for Clean Cooking	Transitions	Access to electricity (all areas)	100
Enabling Environment for Clean Cooking	Transitions	Access to electricity (urban)	100
Enabling Environment for Clean Cooking	Transitions	Access to electricity (rural)	100
Enabling Environment for Clean Cooking	Services	Grid reliability (SAIDI * SAIFI)	6.0
Economic Aspirations	Infrastructure	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023	Yes
Economic Aspirations	Infrastructure	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)	No
Economic Aspirations	Transitions	Regulatory Indicators for Sustainable Energy (RISE)	76
Economic Aspirations	Transitions	Unrealised potential for electric cooking	98.9
Economic Aspirations	Transitions	Affordability of electricity (grid only)	1217.5
Economic Aspirations	Services	Urban population growth (% Annual)	1.8

5.2.2. Rest of the World Case Studies

5.2.2.1. Brazil – A Case of Energy Justice

The example of Brazil shows how transitions can take decades and how policies have to change and evolve to keep pace with the economic realities of domestic and global change otherwise countries maybe faced with policies that consolidate an un-just energy transition.

SDG Overview. Brazil is within 1% of achieving universal access to electricity, uses 45% renewable sources to meet national energy demand, and 97% of the population have access to clean fuels and technologies for cooking (World Bank, 2021) - this means that Brazil's energy sector is one of the least carbon-intensive in the world (IEA, 2024). However, whilst 63% of electricity generation for national consumption is from Hydro (and 83% from renewable sources overall), 51.3% of the total energy supply is still powered by oil, coal, and natural gas with Brazil being the major crude oil producer and processer in Central & South America (with expected growth in this output over the coming years). This results in Brazil being the largest CO2 emissions producer in Central & South America both in real and per capita terms, with a percentage increase in emissions of 40% between 2000-2022 (IEA, 2024). This dichotomy between environmental protection and energy security (seen across the Amazon and the oil and gas sectors (Columbia Energy Exchange, 2024)), places Brazil – the host of COP30 - at a strategic crossroads. The core components of a just energy transition (Santos et al., 2023; Mowrer and Dubytz, 2023) sit on one side, whist potential economic prosperity sits on the other – but are these mutually exclusive? What does a just transition look like in Brazil as one energy leader in Latin America (Schilmann et al., 2021)?

Technological Approaches to Energy & Clean Cooking. This dichotomy has resulted in a multi-fuel approach to for clean cooking, which has used both renewable and non-renewable resources, to achieve almost universal access to clean fuels and technologies for cooking. Given the statistical completion of this key SDG challenge, it is challenging to identify publications which both address the up-to-date status of household energy consumption for cooking and the data which may support these insights. Gioda (2019) provide a household cooking snap shot from the national household survey, "LPG was the most used (98.4%), followed by electricity (32%) and firewood + charcoal (16.1%); other fuels (e.g., kerosene, biogas, natural gas, etc.) had insignificant indices (0.1–0.2%)" - this equates to between 10-11 million people using firewood for cooking (Coelho et al., 2018; Gioda, 2019).

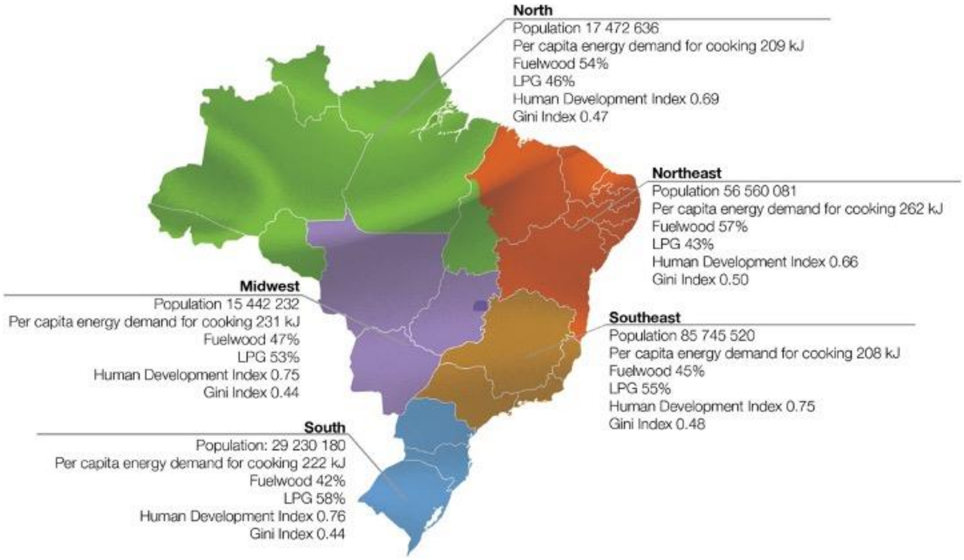


Figure 38: Brazilian geographic regions and their key figures in 2015 (Coelho et al., 2018)

However, there are significant variation in the regional consumption of fuel types due to the socio-cultural, financial, and environmental complexity of Brazilian society (Coelho et al., 2018, Mazzone et al., 2021). For example regional variations see levels of firewood use vary from 17-87% whilst between 60 and 90% stack LPG with firewood (Specht et al., 2015; Ramos et al., 2008; Araújo et al., 2013) – specific regional differences are shown in Figure 38.

The History of Clean and Modern Cooking Transitions. This uptake in LPG has been driven by rapid urbanisation, price regulation, and strong governmental policies which connected development and social outcomes. Coelho et al. (2018) provide a detailed analysis of the key transition pathway from firewood to national LPG use, through six phases:

- *Period 1*, from 1920 to 1955, in which there were no direct interventions;
- *Period 2*, from 1955 to 1973, in which governmental incentives for fossil fuel consumption, including LPG, were introduced;
- *Period 3*, from 1973 to 2001, in which the government provided LPG subsidies to all citizens;
- *Period 4*, from 2001 to 2002, in which the government removed subsidies and LPG prices became deregulated;
- *Period 5*, from 2002 to 2004, in which the government implemented a social policy to assist low-income families in purchasing LPG through a voucher.
- *Period 6*, from 2004 onwards, in which the government establishes a direct income transfer program that benefits families living in poverty and extreme poverty in the country, the Family Allowance Program.

However, a critical challenge in this LPG dominated market is the dependence of households across Brazil on consistent LPG prices, following the end of global subsidization when prices rise a significant number of household "backslide" and resort to using unclean and unhealthy fuels (Lima, 2021) – which is a central part of low income energy security strategies (Coelho et al., 2018). Given the significant variation in access to energy across Brazil, there are also additional challenges around food insecurity and social inequalities (Ribeiro et al., 2023) which can significantly affect economic choices around fuel use under the family allowance program. Given Brazil's decarbonisation objectives, a transition towards eCooking could certainly be part of clean cooking strategy going forward. Even with a switch to e-cooking, there are significant challenges with, for example, expanding national hydropower production, especially around "territorial matters of hydropower plant locations in areas with high biodiversity, the uncertainty about future water availability, and the impact of climate change on water resources" Werner and Lazaro, 2023).

Current Policy Approach. Brazil has a history of long-standing renewable energy policies (Werner and Lazaro, 2023) as evidenced from the very high share in national electricity production. The current policy approach looks to connect social, climate, and economic agendas with energy planning through key three dimensions - financing the energy transition (both nationally and internationally), addressing social dimension of transition and advancing markets for sustainable fuels (Columbia Energy Exchange, 2024). As part of this Brazil will accelerate the expansion of non-hydro renewables (for example in green hydrogen), digitalise their transmission and distribution networks, and invest in smart and efficient cities (World Economic Forum, 2021). All of which raise the potential for a greater engagement with electric cooking as part of the new policy mix (although such considerations do not appear to have taken root amongst Brazilian policymakers as yet).

Whilst Brazil has tackled the challenge of clean cooking for all through a complex mix of renewable and non-renewable fuels (LPG, electricity, woodfuel, and charcoal), there are still tensions between environmental protection and energy security within the context of a just transition. This case study illustrates that even after the completion of the two core transitions outlined in section 4 (from traditional to improved and from improved to modern) an additional transition emerges – fair, equitable, and just energy systems and services for all which, it seems, is still not particularly effectively addressed by Brazil's policy landscape (Climate Transparency, 2019; Louback, 2023).

Table 19: Brazil Clean Cooking Matrix Indicators

Economic Landscape 2024	Infrastructure	42	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking
Economic Landscape 2024	Infrastructure	9.6	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023
Economic Landscape 2024	Infrastructure	0.5	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021
Economic Landscape 2024	Infrastructure	86.7	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023
Economic Landscape 2024	Transitions	81.5	Central Government Debt (% of GDP) - 2022
Economic Landscape 2024	Transitions	39	Trade (% of GDP) 2022
Economic Landscape 2024	Transitions	12	Rural population (% of total population) in 2022
Economic Landscape 2024	Services	84.04	Access to Bank Account (%,15+) - 2021/2022
Economic Landscape 2024	Services	41.28	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022
Economic Landscape 2024	Services	59.1	Ease of doing business index
Economic Landscape 2024	Services	No	Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	Infrastructure	3.4	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021
Enabling Environment for Clean Cooking	Infrastructure	3.2	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022
Enabling Environment for Clean Cooking	Infrastructure	n/a	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021
Enabling Environment for Clean Cooking	Transitions	0.0064	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010
Enabling Environment for Clean Cooking	Transitions	99.5	Access to electricity (all areas)
Enabling Environment for Clean Cooking	Transitions	99.8	Access to electricity (urban)
Enabling Environment for Clean Cooking	Transitions	97.3	Access to electricity (rural)
Enabling Environment for Clean Cooking	Services	24.4	Grid reliability (SAIDI * SAIFI)
Economic Aspirations	Infrastructure	No	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023
Economic Aspirations	Infrastructure	No	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)
Economic Aspirations	Transitions	82	Regulatory Indicators for Sustainable Energy (RISE)
Economic Aspirations	Transitions	98.8	Unrealised potential for electric cooking
Economic Aspirations	Transitions	848.6	Affordability of electricity (grid only)
Economic Aspirations	Services	0.7	Urban population growth (% Annual)

5.2.2.2. India – The Sociocultural Cost of LPG

The example of India is included as it reinforces the challenges faced by different consumers in differing markets. Despite offering strong subsidies to shift to LPG use, the outcome has shown that refill rates among low-income households are low. The example draws attention to the affordability of the solutions and the need for leveraging all aspects of the economy to deliver an integrated energy system.

SDG Overview. India has made significant progress on SDG7 indicators. The most recent reporting shows 99.6% of the country's 1,408m population had access to electricity in 2021, drawing India out of the top 20 countries with most people lacking access (as it had been for 2020) (ESMAP, 2023). 71.1% have access to clean cooking, with the rate of access increasing by an average 3.9 percentage points per year between 2017 and 2021 – the third highest globally. Challenges remain as the country still has the largest population without access to clean cooking (404.9m). Clean cooking access is predominantly via LPG, which is the primary cooking fuel for the majority (62%) of the population. However, there are large inequalities in use between urban/rural locations, different states and across caste and income level (MoSPI, 2023). Renewable energy comprised 35.8% of total final energy consumption in 2020: approximately level with the share recorded in 2010 but up 2.4 percentage points from 2019.

Statement 13: Percentage distribution of households by primary source of energy used for cooking

all-India

Primary sources of energy	Percentage of households		
	Rural	Urban	All
Firewood, chips and crop residue	46.7	6.5	33.8
LPG	49.4	89.0	62.0
Other sources*	3.7	2.8	3.5
No cooking arrangement	0.2	1.7	0.7
All	**100**	**100**	**100**

*Other sources include: other natural gas, dung cake, kerosene, coke, coal, gobar gas, other biogas, charcoal, electricity (incl. generated by solar/ wind power generators), solar cooker, others

Figure 39: Multiple Indicator Survey, 2020-21 (NSS 78th Round) (MoSPI, 2023).

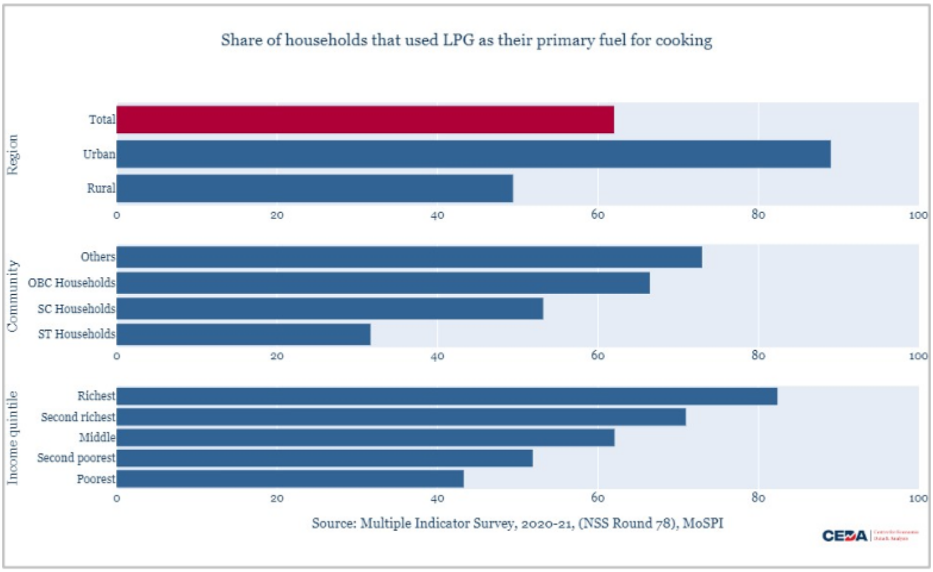


Figure 40: MoSPI (2023) data visualised by the Centre for Economic Data & Analysis (CEDA, 2023)

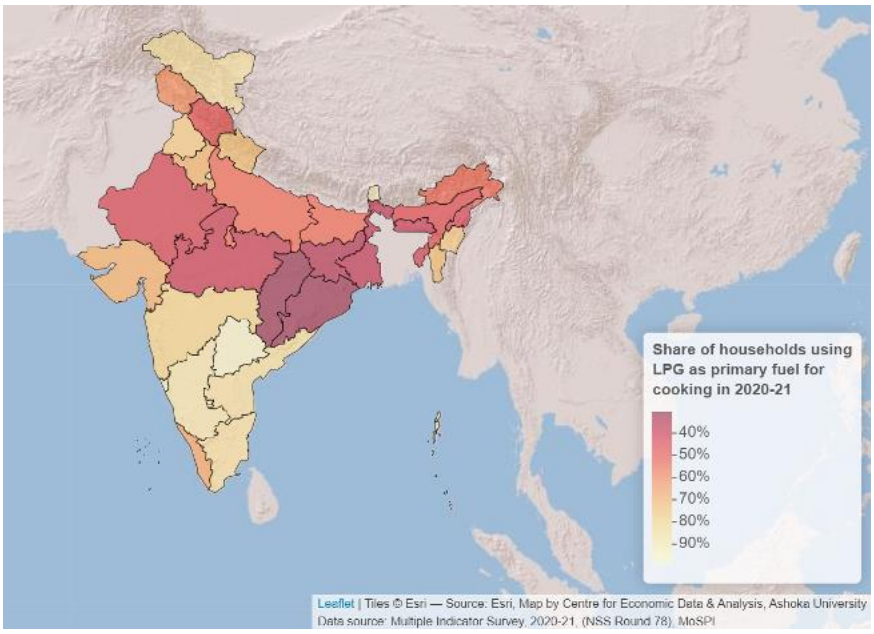


Figure 41: MoSPI ([2023]) data geospatially visualised by the Centre for Economic Data & Analysis ([CEDA, 2023])

Key Challenges for Clean and Modern Cooking Transitions. There is significant opportunity for electric cooking to be a much larger part of India's clean cooking basket of choices. The country was ranked first overall among Global South countries with the greatest opportunities for scale up of electric cooking by the MECS Global Market Assessment (GMA) (MECS, 2023) due primarily to near universal electricity access, surplus electricity generation capacity, a strong policy narrative, and the need to reduce high LPG import and subsidy costs. India has an installed capacity of 428GW (Ministry of Power, 2024) and a reliable national grid (SAIDI 8.88hrs/yr) although supply quality varies by region and is generally poorer in rural localities (MECS, 2023). The government plans to have 500GW of installed renewable capacity by 2030, increasing the proportion of renewables in the grid from the current 40% (Ministry of Power, 2024).

India is also endowed with vast solar energy potential and was ranked second in both mini-grid and off-grid scenarios for electric cooking scale up opportunities in Global South countries by the MECS GMA. Further supporting this potential, a large proportion of the vast international public financial flows India receives are directed to the solar sector. 15m people are connected to off-grid solar products (second highest globally) and to support net-zero ambitions, technologies such as the Indian Oil Corporation's solar stoves (Surya Nutan) and Concentrated Solar Thermal Power (CSP) Cookers need to be adopted on a commercial stage (MECS, 2023).

Technological Approaches to Energy & Clean Cooking. Subsidised LPG has been the predominant approach to increasing clean cooking access in India. Launched in 2016, the government Pradhan Mantri Ujjwala Yojana (PMUY) scheme has heavily subsidised LPG connections and fuel for 102.7m beneficiaries (Business Standard, 2024). Despite rapidly increasing the number of LPG connections, reviews of PMUY found it did not lead to widespread adoption of LPG as a primary cooking fuel by beneficiaries, with refill rates low beyond the initial free replacement cylinder provided under the scheme (ORF) (2021). Furthermore, 50% of LPG connected households still use some proportion of traditional solid fuels, due primarily to the relatively higher cost of LPG refills. LPG as a clean cooking fuel also has fiscal and energy security risks due to stagnating domestic LPG production and increasing imports (64% LPG import dependence for 2022-23).

The 2 decade journey to establish the use of LPG has not been smooth. Between 2005 to 2013, total annual subsidies on LPG rose from USD 2.7 billion to USD 7.6 billion. By introducing targeted subsidies aimed at the lower income households, the general subsidies were reigned in to USD 2 billion by 2016 and the PMUY rose to a USD 2 billion peak and then reduced. However, the picture remains complex - the increased demand meant imported LPG supplies doubled, while COVID support mechanisms gave three months of free gas to PMUY particiants. In the same period the basic price of LPG doubled. Rising prices of imported gas saw the government extend its support under PMUY in 2023 by Rs 100 to Rs 300 per cylinder, a subsidy set to cost the exchequer Rs 12,000 crore/US$ 1.44 billion for the financial year 2024-25 (Business Standard, 2024). Price sensitivity of consumers leads to shifting back to solid fuels when subsidies are withdrawn, which impacts health and productivity.

These issues have led to increasing recognition of the need to shift from an overly LPG centric approach. Focusing on the low carbon transition of India's oil and Gas Sector, the Ministry of Petroleum & Natural Gas (MoP&NG) (2023) 'Green Shift' report sees LPG remain the primary cooking fuel to ensure the shift from solid (the most commonly used fuel previously) to clean fuels, but calls for transitions to a more varied basket of cooking fuels recommending the following:

- Blending LPG with biogas and potentially DiMethyl Ether and Hydrogen
- 50m (mainly urban) PNG connections in the next 5 years
- Popularising use of Methanol and Ethanol
- Heavy emphasis on promoting electric cooking to transition at a rapid pace, calling for a target of 25% of households using electricity for cooking by 2030 and "Wherever possible at least 50% of the cooking should be done through electricity".

Policy Approach. A less LPG centric clean cooking policy which would help mitigate fiscal and energy security risks and move India towards its 2070 Net Zero commitments is challenged by several political economy factors. The PMUY scheme has been critiqued as a heavily politicised initiative targeting voters ahead of elections; there has been significant job creation through associated industries and service sectors (e.g. distribution, sales, packaging); while once introduced, subsidies are politically difficult to modify - a broader basket of fuels could be encouraged by a better targeted subsidy that reduces the number of subsidised refills from the current 12 (average annual consumption is 7-8 cylinders) and lowers the eligibility income threshold to exclude wealthier households (Green Shift Report).

The Indian Government has sought to promote electric cooking via the nationwide GoElectric Campaign (launched 2021) while the state-run Energy Efficiency Services Ltd (EESL) has a large-scale programme leveraging bulk procurement to increase affordability of electric cookstoves. However, there is a government acknowledged need for a national strategy to "popularise or deploy electricity-based cooking options" (MoPNG, 2023). Decentralised approaches will also be required as electricity supply quality varies by and within state, electricity tariffs are a state-led mandate, and utilities are state based with some already actively promoting electric cooking. Purchasing polluting fuels such as charcoal and kerosene is also uncommon, indicating that the ability and willingness to pay for a transition from traditional towards modern cooking fuels may also be a challenge (MECS, 2021).

Table 20: India Clean Cooking Matrix Indicators

	Infrastructure				Transitions				Services			
Economic Landscape 2024	**41**	**15.3**	**2.2**	**88.7**	**55.5**	**49**	**64**		**77.53**	**12.81**	**71**	**No**
	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023	Central Government Debt (% of GDP) - 2022	Trade (% of GDP) 2022	Rural population (% of total population) in 2022		Access to Bank Account (%,15+) - 2021/2022	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022	Ease of doing business index	Profitability of National Electricity Utilities (yes/no)
Enabling Environment for Clean Cooking	**8.7**	**10.6**	**n/a**		**0.0038**	**99.6**	**100.0**	**99.3**	**8.9**			
	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021		Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010	Access to electricity (all areas)	Access to electricity (urban)	Access to electricity (rural)	Grid reliability (SAIDI * SAIFI)			
Economic Aspirations	**Yes**		**No**		**78**	**97.6**	**382.4**		**2.0**			
	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023		Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)		Regulatory Indicators for Sustainable Energy (RISE)	Unrealised potential for electric cooking	Affordability of electricity (grid only)		Urban population growth (% Annual)			

5.3. Discussion & Analysis of Key Criteria & Case Studies

The variety and diversity of case studies clearly illustrate that there is no single path to clean cooking or its higher tier manifestation ‘modern energy cooking’ across the African continent or the rest of the world.

Within a health, gender, and environmental (or wider climate) lens, the transition to higher tier stoves is of potentially broadly equal benefit. Acknowledging for the moment that Tier 3 and 4 biomass stoves have some questions hanging over them from the health effects, nevertheless, use of any of the cleaner fuels and appliances, utilising LPG, Ethanol, Biogas, Electricity, etc. reduces the use of non-renewable biomass, reduce levels of household air pollution, reduces the rate of forest loss, and contributes to more gender equity by releasing time, improving safety and leading to greater well-being. However, the case studies illustrate how not all solutions are broadly equal and in different contexts they can have a very different effect on the economy and often rely heavily on the broader infrastructural development.

5.3.1. Exploring Contextual Variations on Clean Cooking Progress

Gas Infrastructure, Transitions, and Services. Morocco and Egypt are examples where a transition from polluting fuels to the clean cooking experiences of LPG have indeed improved the lives of households. This was achieved by applying subsidies (as seen in the total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021/2022), and now costs Morocco a significant $2.1 billion per annum from the public purse. These subsidy levels for LPG are more than 50%, so if LPG is set to double in price, maintaining affordability for the consumer could increase that National Bill, which would be especially challenging given the central government debt is currently 68.8% of GDP. Aspiring to reduce the economy wide GHG, there have been discussions about transitioning to electric cooking given the 100% urban and rural access to electricity and almost unique positive cost recovery of national energy utilities, but the prevailing ideas which maintain economic growth revolve around a transition to Natural Gas – reflected in no inclusion of E-Cooking in NDCs or Long Term Targets. We note that Morocco has led the way in exploring solar concentrated electricity generation (CSP), although this has stalled through project dynamics (Reuters, 2024). Nevertheless, the long-term possibility of renewable energy technologies generating significant electricity remain strong.

The vulnerability of the economy to the winds of oil price changes is what leads us to include the case studies of India and Brazil. LPG is cited as a potentially quick transitional fuel. However, the example of Brazil shows how it took decades to embed it into daily life and meant that it had to explore and adapt multiple different social policies to adequately respond to the clean cooking need without bankrupting the treasury. This was due to long standing renewable energy policies, funded by the large crude oil reserves, resulting in an accommodating regulatory environment for alternative renewable energy technologies (as reflected in a score of 82 for the Regulatory Indicators for Sustainable Energy (RISE)). Similarly, India is aware of its own vulnerability to LPG subsidies and is presented as a case where, looking to the future means pivoting to electric cooking especially given its high affordability of electricity. India, Indonesia, Ecuador, Brazil are often cited by African leaders as transitioning to clean cooking, and as transitions that should be copied, however as illustrated through this report there are no one-size -fits-all solutions.

One-Size-Does-Not-Fit-All. Context is the key driver of clean and modern cooking energy transitions, what worked for the economy of those countries, India and Brazil in this case, may not work for African countries. The case study of Kenya illustrates this; in their integrated energy plan they seek a multi-fuel mix which does not leave them vulnerable to any one fuel, appliance, or technology - the role of integrated energy modelling has been critical in being able to assess the potential basket of fuels for a successful clean cooking strategy. The national government identify and acknowledge the very different markets – the sophistication of central cities, from the informal settlement within those towns and cities to the relatively densely populated farming areas, to the low-density areas with pastoralists. Regular supply of LPG to some areas of Kenya has limitations due to the lack of all-weather roads (almost 20% of the rural population do not live within 2km of an all season road), while increased connectivity and electricity access to smaller towns is a priority for the government.

Fragmented approaches to energy planning result in disconnected progress. Whereas Kenya provides an example of an integrated energy strategy which looks to provide access to multiple fuels and appliances, the case of Benin is an example of a country which to date has a disconnect within its energy planning – a fragmented approach. With high aspirations for electrification, the clean cooking focus is on decreasing biomass use (and increasing combustion efficiencies) through improved cookstoves to combat high forest loss. Aware that LPG offers potential as a transition fuel, it is also aware that it needs to reduce reliance on fossil fuel imports, which is especially challenging give the low UNIDO Competitive Industrial Performance Index score at 126, high central government debt at 115.2% GDP, and virtually non-existent LPG use (0.07% of total household fuel consumption). How can a country such as Benin balance the aspirations for a modern economy with the realities of its infrastructure and economy? As a final example of a fragmented approach the lack of integrated planning in Zambia also threatens existing gains and challenges the economy. While electricity access has grown at both a rural and urban level, deforestation through increased use of charcoal undermines progress. Strategic use of and a focus on energy efficiency, through integrated energy planning which promotes technologies such as eCooking can more effectively utilise existing resources and build on the electricity access gains of the last two decades. However, as outlined in the case study, due to a lack of network performance, Zambia's government owned electricity utility has chosen to prioritise the mining sector over the domestic sector further complicating clean cooking transitions.

A complete lack of infrastructure and services. Finally, the DRC with its less than stable political economy, is an example a challenging economic context – with some of the worst scores within the clean cooking decision matrix, for example, infrastructure investment has been patchy, there has been limited transition from traditional cooking methods, and the population is widely dispursed across a vast land mass. However, there is intent to address these challenges through the inclusion of clean cooking and electric cooking within its NDC's. In additional, with significant forestry resources, DRC is an example of where carbon financing may hold promise for the near future.

5.3.2. Clean Cooking For All - Looking beyond the Household Scale at Data, Implementation, and Policy Gaps

The case studies outlined in this section provide a comprehensive overview of country level clean cooking landscapes and how these landscapes have evolved, however, there are several dimensions which receive little attention in the transition to modern fuels and technologies. As outlined across the rest of the report, a lack of access to modern energy fuels and appliances disproportionately affects women and children due to the gendered roles of cooking, cooling, lighting, and heating activities. Access to clean cooking can provide avenues for economic empowerment and challenging existing social norms to create a more inclusive society (IEA, 2024), yet, despite women playing a critical role in the clean cooking system (Clean Cooking Alliance, 2021) and being a central component of successful modern energy cooking projects (Khalifa, 2023) they are often not specifically addressed in the policy landscape (AFREC, 2021, p.10). Unfortunately, additional policy 'blindspots' exist beyond gender and the household scale.

The majority of clean cooking technologies, delivery models, and pathways to SDG7, both outlined in these case studies and around the world, are focussed on the household consumption and national energy production or transformation scales. Bisaga et al. (2022) outline three additional, and often intersecting, scales of clean cooking - institutional, enterprise, and displacement settings - given the critically important nature of these scales of clean cooking in the completion of SDG7, we directly address the importance of different approaches towards support for these scales and advocating for more inclusive policies.

The Institutional Scale. Whilst these three scales share many technological similarities with household cooking and also have a gendered dimension, the socio-cultural, environmental, and financing drivers which make up the critical contextual implementation ecosystems of technological adoption and sustainable use are significantly different. This means that these scales of cooking require individual attention in both scoping challenges and implementing solutions. The **Institutional scale**, which includes schools, health facilities, religious centers, workplaces, prisons, public institutions, "has been under- researched and under-acknowledged and has lacked a structured approach, including within in-country policies around energy access to institutions and the provision of meals" (Bisaga et al., 2022). The World Food Programme lead the way, bringing a more structured approach to school meal preparation with various institutional pilots including in Nepal, Lesotho and Chad (GPA, 2024; WFP, 2023a, 2023b). When considering e-cooking for institutions, there is a significant opportunity to connect into renewable energy policies, for example "in Lesotho, around 54 per cent of 1,452 schools had access to electricity in 2019 with 204 additional schools planned to be electrified under the Lesotho Renewable Energy and Energy Access Project 2020-2027 through minigrids" (WFP 2023b).

At the **enterprise scale**, which includes restaurants (food preparation and sales), hotels, and agricultural food processing, there are significant job, empowerment, and inclusion opportunities. Whilst the enterprise scale can be seen as a sub-set of institutional cooking, it often sits within a different policy framework managed by a different government agency or ministry. This is a result of this clean cooking sub-sector being primarily driven by small businesses, rather than state services - as with schools, health facilities, religious centers, workplaces, prisons, and public institutions. The rise of the importance of this enterprise scale of cooking has resulted in accompanying global standards to regulate the quality of products for this market, this includes the development of new ISO standards for larger scale stoves (US EPA, 2024). As outlined by AFREC (2021) the energy use for business largely reflects the household reality – the majority of energy use for commercial businesses across the African continent is driven by biomass.

Whilst **displacement settings** is not technically a scale of cooking, as there are households, institutions, and enterprises in displacement settings, this humanitarian energy clean cooking sub-sector receives disproportionately little attention compared to the significant clean cooking needs in this context. Humanitarian Energy is defined as "Institutions, policies, programmes, global initiatives, actions and activities which use a range of sustainable and fossil fuel energy sources in contexts of displacement, to meet the energy needs of people in camps and urban settings, self-settled refugees, host communities, and internally displaced people" (Al-Kaddo and Rosenberg-Jansen, 2021). Within these settings, over 80% of people living within camps only based basic fuels for cooking (Grafham, 2022) and yet, clean cooking within displacement settings sees negligible policy support. This is often due to limited political will and silo'ing of traditional 'development' and 'humanitarian sectors' leading to disjointed and fragmented long-term clean cooking strategies. The Global Platform for Action on Sustainable Energy in Displacement Settings are working towards creating a more coordinated sector where humanitarian energy projects, including clean cooking, connect onset crisis response, protracted displacement, and longer-term development goals (Ndahimana et al., 2023). For example, the Roadmaps for Energy Access in Displacement Settings Reports outline practical opportunities for increasing energy access in these settings.

Within the context of the case studies outlined in this section there are significant opportunities to engage with clean cooking in disablement settings. The global statistics which highlight a significant lack of access to clean cooking fuels and appliances are often reflected at the country level, where significant effort is needed to unlock these solutions in this hyper-contextually specific setting – one method which has gained significant attention in recent years is through the productive use of energy (U-Learn Uganda, 2023). In addition, given the complexity and high-risk nature of displacement settings, dimensions such as gender and income equality are often heightened with energy access acting as one pathway to improving livelihood opportunities and quality of life (Dave et al., 2023).

Table 21: Data on Clean Cooking in Displacement Settings (MECS, 2021, Global Market Assessment for Clean Cooking)

	Number of displaced persons (DPs) per 1000 population	DPs using clean cooking fuels (grid)	DPs using clean cooking fuels (off/mini grid)	DPs with unrealised potential for eCooking
Benin	0.14	0.14	0.05	0.36
Brazil	1.72	0.95	0.64	0.05
Congo, Democratic Republic	60.40	0.14	0.05	0.35
Egypt	3.23	0.95	0.95	0.05
India	0.15	0.77	0.04	0.16
Kenya	9.67	0.61	0.00	0.06
Morocco	0.27	0.95	0.87	0.05
Zambia	4.81	0.39	0.05	0.06

5.3.3. No "One-Size-Fits-all" – but key learnings to build on.

Economic Development. Looking at the challenge of clean cooking through the lens of economic development refreshes the policy approaches and brings in dimensions more than gender equity, health and the environment. Solving for 'clean cooking' and it effects on the household, can lead to vulnerabilities in an economic dependence on imported fuels, on government subsidies and an absence of a local job-creating economy.

Market differentiation. Market differentiation suggest that even within one country there is rarely one solution that fits all markets. What may be appropriate in an urban setting may not be appropriate for even small towns let alone rural areas. Modernisation, changing eating habits, affordability, even intrahousehold decision-making all affect the household choice of cooking fuel and general energy consumption. Offering consumers a basket of choices does not mean they will go for the least cost option. New business models can facilitate a choice based on a longer-term view, where the households themselves are also considering the longer-term economic vulnerabilities e.g. their credit risks exposure.

Energy Access for all through Inclusive Energy Planning Processes. As highlighted by the lack of focus on additional scales of the clean cooking sector throughout the case studies – institutional, enterprise, and displacement – a key element of market differentiation practices is ensuring that these clean cooking sub-sectors are effectively integrated into energy planning process and not left behind. For example, as see in Table 21 there is both a significant challenge and potential for clean cooking policies and programs in displacement settings.

Future projections. Africa is incredibly vulnerable to climate change effects, and the coming three decades may see changes in climate that affect the natural resources of Africa, that create demand for some of those resources, and expose the vulnerable to changing weather patterns. 'Clean cooking' may seem a long way from climate change, but current practice contributes significantly and while Africa was barely responsible for emissions over the last 100 years, it will be important for Africa to position itself with an economy that is resilient against climate changes.

6. Moving Forward: Planning for Scalable Sustainability

Throughout this report there has been a focus on multiple dimensions of sustainable scaling pathways for universal access to modern cooking fuels and appliances which have the power to meet the clean cooking challenge across the 55 countries of the African continent.

Recap:- The report opened by outlining the scale of this challenge by distilling the insights from sector leading publications and presenting work around the significant cost of inaction on health, gender, and climate. In section 2 we highlighted the key strategies and progress on this challenge, paying particular focus to how carbon financing flows can be leveraged to improve clean cooking outcomes. Section 3 then dove into the modelling and integrated energy planning detail through a state-of-the-art summary of the different data sources, the energy system models and the focused clean cooking models currently available (and in development) – focussing on their ability to provide guidance for the development of effective long-term sustainable clean cooking strategy development. Aligning with AFRECs focus on national-level fuel strategies for supply, transformation, and consumption, section 4 guided the reader through the key factors affecting the supply, infrastructural development, likely price movements, financing needs and affordability of key modern energy cooking fuels and technologies when applied to the deeply socio-culturally and contextually driven African context. Finally, section 5 applied a widely applicable clean cooking decision matrix, and accompanying indicators, to scalable country-level case studies and implementation pathways. This section highlighted that there are no “one-size-fits-all” solutions but significant specific learnings to be leveraged for faster clean cooking transitions.

Ultimately our aim is for this report to enable the more effective planning, coordination, and implementation of clean and modern strategies, policies, and programs which drive the transition to modern fuels and appliances. Whilst there are significant health, gender, environmental (and wider climate) benefits, **this transition must also make national economic sense and be aligned with contextual clean cooking needs** – whilst this report provides foundational knowledge, further work must be done at a national level to generate clean cooking strategies, policies, and plans which are integrated into the national energy strategies.

In this final section, we provide a series of key recommendations for effective national clean cooking strategy development for all options of fuels, as well as how effective delivery can best be orchestrated.

6.1. Recommendations for Effective National Clean Cooking Strategy Development across the African Continent

Recommendation 1 - Action on clean cooking must be seen as both an economic imperative and significant financial opportunity for Africa and it must be part of longer-term strategic energy planning not simply a short-term delivery issue

The challenges of cooking with biomass are well documented and this report builds on a body of literature that defines the negative effects from an health, environmental and time use point of view. The health impact of this total sum is estimated at US$ 526.3 billion per year, calculated by quantifying the deaths and disability-adjusted life years (DALYs) linked to household air pollution produced by stoves and fuels. Africa has rich agro-forestry resources with broad biodiversity, and yet biomass-based cooking is depleting these resources faster than they can be replaced leading to deforestation and this is costing African economies more than US$39.3 billion per year. The direct time spent collecting and using biomass as cooking fuel for everyday domestic meals has been calculated as costing the US$225.8 billion annually, reflecting the time women spend daily on cooking-related tasks, including fuel collection, cooking, and stove cleaning.

All of these costs may be underestimates. When trees are lost, the ongoing capacity to sequester carbon is also lost; when people are laid up through illness it's not just the cost of their health care but it's the lost productivity. In addition, the above calculations do not yet include institutional meal cooking which affects school children, and shortfalls in productive use and commercial businesses which could add economic value to the food nutritional system. The implementation of policies that can address these costs do of course have their own costs (and some of these can be extremely high and ongoing as we have discussed extensively).

The potential economic gains are also generally underestimated. As is made clear through this report, long-term transitions to modern fuels and appliances, especially when integrated effectively into modern energy planning, can increase the financial viability of these wider energy generational and transmission systems – and thus recover this cost. Expenditure on cooking fuels already exists in the economy – a transition to an alternative affordable fuel is not a drain on the economy as such and may leverage and strengthen existing investments in infrastructure. Coupled with the falling prices of renewable energy generation this provides a significant financial opportunity.

Recommendation 2 – Balance the basket of fuels to ensure clean cooking transitions support economic growth.

Taking decisive action to tackle clean cooking deficits rapidly could translate into substantial economic benefits or it could create longer term economic vulnerability. In the points below we focus on some of the key issues that need to be considered when implementing a multi-fuel strategy that will support Africa's economic growth. Recently there have been significant finds of Natural Gas in Africa. This creates new opportunities for economic growth. Given that the predicted real price of oil and gas is set to grow above inflation levels, it is difficult to say whether this will enable Africa to utilize its new finds for economic inflows, or whether it will impoverish those countries that do not have the resources. In a multi-fuel mix addressing the issue of clean cooking, LPG and Natural gas are said to have a transitional role, but it will be challenging to governments, particularly if they offer the consumers a subsidy, that they keep a tight view on rising global prices so they do not allow the burden on public finances to become excessive.

In support of a complementary strategy, Africa is also rich in renewable energy resources. As the cost of renewable energy technology continues to comes down, and with advancements in both centralised and decentralised technologies and energy storage, there are increasing opportunities to develop modern energy domestic infrastructure. Many policy makers are suggesting that oil and gas reserves can be used for exports, while renewable energy can service domestic markets. There is therefore potential, through targeted policies, for Africa to transition from biomass to electric cooking, ethanol, bioLPG and biogas, leapfrogging the intermediatory transitions.

In thinking through this challenge, substantial lessons can be derived from the longer-term experiences of India, Brazil, and Morocco. It may feel very specific to mention these countries, but they provide an important insight into the use of fossil fuels for clean cooking. They have been successful in pivoting significant proportions of their populations to access cleaner fuels. They have done this by subsidising the fuel costs to the consumer, and this costs the government very significant finance each year. While this provision has enabled a transition and resulted in economic gains in improved health and environmental issues, it comes at a cost that places pressure on public finances. These countries are now seeking to pivot to decarbonized unsubsidized alternatives.

Recommendation 3 - Turn the increased International interest into Domestic political will.

On the national platform clean cooking is often not seen by policy makers as a linchpin of economic growth. Domestic cooking is a gendered issue, and the primacy of its effects on women and children has tended to marginalize it as an issue in planners minds. It is nevertheless an integral part of energy planning and needs to be treated as such. Additionally, the will to deliver real progress on clean cooking requires governments to actively prioritise clean cooking development within their own financial decision-making.

For example, several international financial institutions have recently made commitments to expand their funding for clean cooking within their funding and lending practices. As those leading the implementation of such initiatives have confided to us, that will only happen if national governments make requests for financing within those policy areas. It also of course involves directing domestic budgets towards those spending priorities and to focus geopolitical effort towards effective cross-border coordination between African nations in driving down gas and electricity prices to increase access to modern fuels and appliances.

Recommendation 4 – Clean cooking policy must be part of integrated energy and economic planning

Throughout this report we have tried to show how clean cooking is best conceived of and planned for within the wider modern energy and economic planning processes. Clean cooking needs to be a strategic part of comprehensive energy planning not as a siloed stand-alone delivery. While this is most obvious when eCooking is considered as it directly impacts the demand on the national and decentralised grids, it equally applies in getting returns on other infrastructure such as all weather roads and digital services. An absence of a distribution network can limit the use of certain clean cooking fuels in some markets. Persistence of biomass use will lead to ongoing deforestation, which removes a valuable resource from resilience strategies.

This integrated approach is increasingly possible with emerging planning software as described in Section 3. However, modelling and scenario creation is only as good as the data being entered. Integrated approaches will need better global tracking (e.g. better resourcing for data collection and analysis). **Significant funding is required both to close these data gaps and establish a meaningful data baseline that can be used for effective integrated energy and economic planning.** They will also need capacity building for effective multi-sectoral strategy development (eg the Kenyan National strategy development included bringing multiple stakeholders together with varying skillsets and views). Such multi-sectoral convening will only occur if suitable funding is made available, and only by bringing all these aspects together will effective cost analysis modelling of different scenarios occur.

And once transitions are underway establishing robust monitoring and evaluation mechanisms is crucial to assess the impact of cleaner cooking interventions. Monitoring energy consumption, emissions reduction, health outcomes, and economic benefits will provide valuable insights for further improvements and informed decision-making.

Recommendation 5 - Embrace technological innovation to drive contextually aligned solutions

Gains have been made on infrastructure, not just electrical networks but also all-weather roads, digital and financial services all of which can support a transition to modern energy cooking. Leveraging the infrastructure allows for a win win – with utilities and service providers experiencing increased demand and getting a return on investments. For example **leverage the gains in electricity infrastructure;** while many urban households are connected, most continue to polluting fuels for their cooking. LPG and Ethanol need bespoke distribution networks, while electricity is supplied as a service for a wide range of use. Pivoting urban and peri urban connected households to include eCooking as part of a clean cooking stack, can when appropriate increase the Average Revenue Per User (ARPU) for the utility, and thereby improve their bottom line. Steady increased revenue can give a better return on investment, and lead to a virtuous cycle of upgrading of infrastructure and networks. Encouraging the use of on-grid e-cooking in conjunction with renewable energy generation can significantly reduce carbon emissions and enhance the environmental sustainability of the cooking process. Policymakers could prioritize the expansion of renewable energy infrastructure to meet the increasing demand for on-grid electricity.

However, this is only true if there is full cost recovery in the electricity tariff. It may be affordable to the population, set by the regulator, but if it is not covering the costs of generation, transmission and distribution, then more demand can mean more losses. If the government is effectively subsidizing electricity access, then its increased use could leave the treasury exposed in the same way an LPG subsidy might. This is particularly true if the electricity generation is heavily dependent on fossil fuels and old inefficient plant - it leaves the country exposed to global price volatility. This cost focus strengthens the argument for renewable energy technologies – cost-effective, leveraging Africa's natural resources, and once in give a buffer between the national supplies and global pricing. An example of this has been shown in decentralised mini-grids, where increased ARPU can give better returns for the developer, and can lead to lower but unsubsidised tariffs for the users.

Similarly the ubiquitousness of digital services now enables new approaches to clean cooking. New metered methodologies can more accurately track the use of higher tier stoves, and that can both enable microfinance, ensure results based financing and contribute to the global carbon finance economy. This can again lead to **leveraging the gains in digital infrastructure,** improving ARPU and improving the returns on investment particularly in rural areas. This ties in closely with improved financial services, where over the last 10 years new models of facilitating credit to the poor have emerged. All these wider economic gains support new approaches to clean cooking, and new approaches to clean cooking support these wider changes in the economy.

Recommendation 6 – Leverage decarbonisation financing flows to future proof economic growth

Future proofed economic growth. As the world moves to decarbonisation, including the use of carbon finance flows, Africa will seek to ensure its own economies are future proofed. Renewable energy technologies costs continue to decrease due to the learning curve with Africa leading the way in Morocco As stated above their installation can be more nimble than traditional centralized infrastructure. There are also new smart technologies, new business models that can create affordable mechanisms for access for all and new synergies emerging from a wider economic global perspective. By considering the issue of clean cooking as integral to a healthy economy, Africa will be able to position itself to maximise the use of climate finance for adaptation, mitigation and resilience.

Decarbonisation as an opportunity for financial flows. Africa as a part of the global economy has barely contributed to the problem of climate change, and will by all estimates be one of the worst affected continents by the effects of climate change. This is disturbing, but also presents an opportunity. To date the voluntary carbon market has been able to address some issues with clean energy and forestation. In recent negotiations, the carbon market is formalizing through Article 6, and this presents significant future opportunities for carbon flows. However, European and US-based corporate sponsors are becoming wary of carbon financing which is linked to biomass to fossil fuel transitions, and would prefer a clear shift from biomass to a renewable energy (ethanol, electricity, bioLPG, biogas).

There are therefore two points to consider – the general economy can decarbonise through say the wider use of renewable energy, and utilise its fossil fuel resources for export. This will to some extent decouple Africa's reliance on international global energy pricing as the world navigates the difficult pathway to Net Zero. However, it also opens a transitional opportunity to offset carbon emissions from that global economy, and the progress on Article 6 should formalize those flows.

Recommendation 7 Use economic planning to leverage multiple financing opportunities for modern cooking transitions.

When clean cooking is considered an isolated challenge, it leads to policy makers thinking it needs particular fund raising, and lamenting the international inflows to tackle it (70% of which go to Kenya alone). Considering clean coking as an underlying need of a healthy economy could enable repositioning of budgetary decision-making. For instance **health budgets** are effectively dominated by Household Air Pollution, so while the first response is to address the health impact on the people, a wider economic view could see health budgets used to mitigate the source of the HAP. Similarly youth **employment budgets**, could target the increase in jobs associated with a transition strategy.

There are considerable budgets associated with modern energy infrastructure. Africa spends approximately $24 billion each year generating, transmitting distributing and extending the use of electricity. As discussed above, pivoting even a portion of user to utilise ecooking as part of a clean stack can be a minute cost compared to such sums.

Returning for the moment to the global view – we have acknowledged that Africa will be strongly affected by Climate Change. Since transitioning from biomass to modern energy mitigates GHG emissions, **Green Climate funds** are a source of finance that can be used. Nepal is currently using Green Climate Fund to pivot 500,000 households to eCooking. In the same way that carbon emissions have both formal and informal markets, there are other emerging approaches where other outcomes are monetised. The co-benefit savings on health, time and environment (biodiversity) may all lead to new forms of financing. Explicit presentation of the co-benefits with related SDGs wherever they arise (e.g., SDG3/health, SDG13/climate, SDG15/forests, SDG8/job, SDG9/industries, SDG2/food system and hunger) may illustrate how access to modern energy cooking services would underpin the overall progress towards sustainable development.

And ending this point back on a national view, one of the strongest sources of modern energy cooking will be the purchasing power of the consumer. While in some rural areas, woodfuel is collected, and the cost is captured in daily labour, in urban, peri urban and dense rural areas, there is often a monetary cost. Particularly where there is a charcoal industry, consumers are seeing rising prices over the last 10 years, so if the alternatives are affordable and there is a sufficient uplift in awareness of their existence, the funding is less of an issue as housheolds pivot their existing expenditure to a cleaner modern alternative.

Recommendation 8 – Ensuring Inclusivity

Inclusivity to ensure clean cooking for all. As outlined in section 5, clean cooking transitions are not always fair, just, and equitable. Special attention is needed to understand the importance of inequality within countries and the need for interventions to be targeted. This targeting will likely be through increasing social safety nets, social expenditure, and targeted subsidies. Often the unincluded sub-sectors, such as people living in displacement settings, require different approaches and delivery models to ensure that they are not left behind in the race to 2030.

Recommendation 9 Embrace the transitions of Africa's socioeconomic culture.

Clean cooking is commonly positioned as an issue that traditional societies do not want to embrace. The increasing urbanization of Africa is connected to an evolving socio-economic culture. Habits such as purchasing energy (as opposed to collecting fuelwood), purchasing processed food (pre-cooked beans, street food, etc), joint decision-making between man and wife, smaller household sizes will all create market differentiation – solutions and narratives of how to solve the problem of clean cooking need to take into account not just how the African economy was for the last 40 years, but how it will look in the coming 40 years.

Recommendation 10 – Restructure Clean Cooking Value Chains

African Appliance Manufacturing and Repair Networks. By moving manufacturing value chains to Africa, and linking to the African free trade area, the local production of modern cooking appliances, such as electric pressure cookers, LPG stoves, and biogas digester, has a positive impact on job creation and local economic development. Promoting partnerships between international manufacturers and local agents or distributors can facilitate the availability and affordability of high-quality appliances. A key component of providing effective after sales support is establishing repair networks. These networks both create additional economic opportunities and appliance longevity. This requires collaboration between manufacturers, distributors, and local service providers to offer reliable repair services and spare parts.

For all fuels educational campaigns can inform consumers about the efficiency, safety, and environmental advantages of using cleaner cooking, dispelling misconceptions, and encouraging widespread acceptance. Regulation and standards: Implementing and enforcing testing standards for indoor and outdoor emissions, thermal efficiency, and safety is necessary to ensure the quality and performance of e-cooking appliances. Regulatory bodies should collaborate with international standards organizations to establish guidelines and certification processes.

Secondary Job creation and localized food production, Part of any successful economy is translating human creativity into added value. While job creation within the context of clean cooking has been discussed as being about local stove creation, the wider economic issue is the absence of added value to food production. Small semi-industrial clean cooking processes that add value to the farm gate produce can create a local economic growth and ensure exports utilize that value to gain better inflows. This will create jobs and build the economy.

Recommendation 11 – African clean cooking transitions must be driven by African Organisations

African leadership and coordination. In the national context, a central component of designing and delivering an integrated energy plan (which includes a transition to modern fuels and appliances) is the intra-governmental coordination required to align the many ministries, agencies, and utilities within the national energy system – this can only be effectively done by governmental teams which have oversight of all these cross-cutting areas and are located within the institution that actively has the responsibility for delivering on its strategies

In the international context, the global clean cooking sector has historically been driven by interests outside of the African continent – in order to unlock the next generation of clean cooking strategies, policies, and projects the clean cooking sector must be driven by and for African. African leadership is critical to 2030 and 2050 targets. The African Union an play a major role in coordination of this effort.

Supporting this last recommendation, this report has been developed to support the design of the African Union's ***African Clean Cooking programme*** called for by the African Ministers responsible for Transport and Energy during the 4th Ordinary Session of the Specialised Technical Committee on Transport, Transcontinental and Inter-regional Infrastructure, and Energy held on 12-15 September 2023 in Zanzibar, Tanzania. The intent is to help establish a baseline and track progress on clean cooking in the continent; disseminate information on the current status of clean cooking across Africa and support the development of a properly informed and targeted continental clean cooking strategy.

It is hoped that this will lead to the establishment of an AU-led *Africa Clean Cooking Facility* to provide technical and financial support to AU Member States in their nationally determined transition efforts.

Annex 1 – Data Sources for Section 5 Clean Cooking Indicators

	Indicator	Source
Economic Landscape 2024	UNIDO Competitive Industrial Performance Index (CIP) - 2021 - World Ranking (higher better)	UNIDO (2022) Competitive Industrial Performance. https://stat.unido.org/cip/ (accessed 03.05.24)
	9.2.1. Manufacturing value added as a proportion of GDP (%) - 2023	UNIDO (2022) Competitive Industrial Performance. https://stat.unido.org/cip/ (accessed 03.05.24)
	9.3.1. Proportion of small-scale industries in total industry value added (%) - 2021	UNIDO (2022) Competitive Industrial Performance. https://stat.unido.org/cip/ (accessed 03.05.24)
	SDG INDICATOR 9.1.1 Proportion of the rural population who live within 2km of an all-season road in 2023	Center for International Earth Science Information Network (Columbia University) (2023) SDG Indicator 9.1.1: Rural Access Index (RAI). Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/fcre-m572.
	Central Government Debt (% of GDP) - 2022	IMF (2022) Government Central Debt Indicator. https://www.imf.org/external/datamapper/CG_DEBT_GDP@GDD/CHN/FRA/DEU/ITA/JPN/GBR/USA (accessed 24.04.24)
	Trade (% of GDP) 2022	World Bank (2022) Trade (% of GDP) Indicator. https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS (accessed 13.05.24)
	Rural population (% of total population) in 2022	World Bank (2022) Rural Population Indicator. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS (accessed 13.05.24)
	Access to Bank Account (%,15+) - 2021/2022	World Bank (2021) The Global Findex Database 2021. https://www.worldbank.org/en/publication/globalfindex/Data#sec3 (accessed 03.05.24)
	Borrowed any money from a formal institution or using a mobile money account (%,15+) - 2021/2022	World Bank (2021) The Global Findex Database 2021. https://www.worldbank.org/en/publication/globalfindex/Data#sec3 (accessed 03.05.24)
	Ease of doing business index	Modern Energy Cooking Services (2021) Global Market Assessment for electric cooking Visualisation. https://gma.mecs.org.uk (accessed 29.04.24)
	Profitability of National Electricity Utilities (yes/no)	Full Economic Cost Recovery of National Utilities contained in Annex
Resources/Environment/Climate - Enabling Environment	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2021	IMF (2023) IMF Fossil Fuel Subsidies Data: 2023 Update
	Total fossil fuel subsidy (oil + gas + electricity + Coal) share of GDP (%) in 2022	IMF (2023) IMF Fossil Fuel Subsidies Data: 2023 Update
	LPG as % of total household fuel consumption (African Countries form AFREC Energy Balance) - 2021	AFREC (2023) Energy Balance 2023
	Tree cover loss	Modern Energy Cooking Services (2021) Global Market Assessment for electric cooking Visualisation. https://gma.mecs.org.uk (accessed 29.04.24)
	Access to electricity (all areas (G))	
	Access to electricity (urban)	
	Access to electricity (rural (MG))	

	Grid reliability (SAIDI * SAIFI)	
Economic Aspirations	Whole or Partial Inclusion of Clean Cooking in NDCs (yes/no) - December 2023	Clean Cooking Alliance (2023) Nationally Determined Contributions and Clean Cooking.
	Inclusion of E-Cooking in NDCs or Long Term Targets (yes/no)	IRENA (2023) Renewables-based electric cooking: Climate commitments and finance.
	Regulatory Indicators for Sustainable Energy (RISE)	Modern Energy Cooking Services (2021) Global Market Assessment for electric cooking Visualisation. https://gma.mecs.org.uk (accessed 29.04.24)
	Unrealised potential for electric cooking	
	Urban population growth	

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