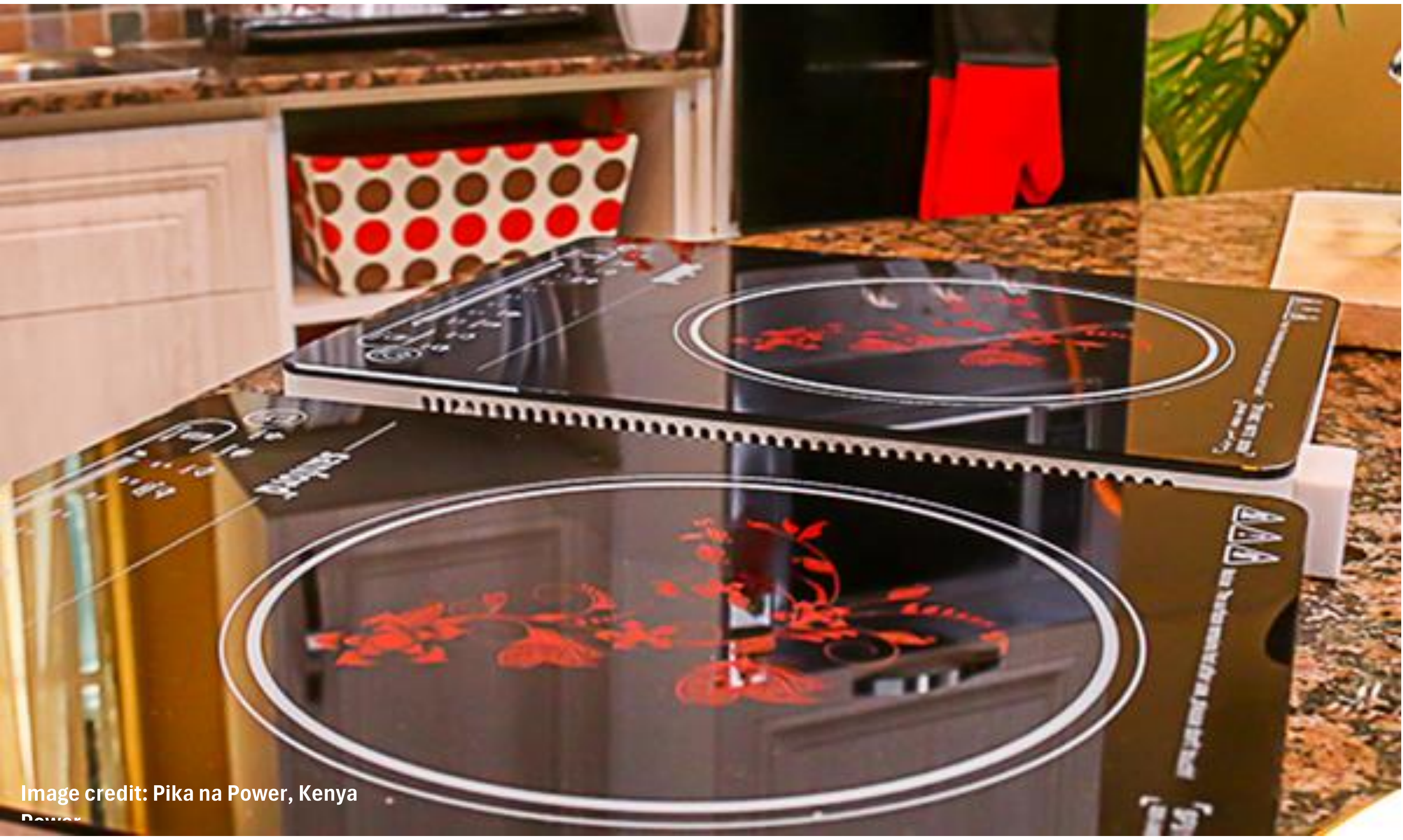
MINISTRY OF ENERGY AND PETROLEUM

REPUBLIC OF KENYA



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Kenya National electric Cooking Strategy

MODELLING REPORT

11 May 2024

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1. Overview

This document details the modelling approaches and findings used to inform the interventions within the Kenya National eCooking Strategy (KNeCS). It utilises data collected during the KNeCS Baseline and is designed to explore key research questions that have emerged during the strategy development process.

- ***Clean Cooking Scenario Modelling***: This section presents the outcomes from forecasting trends in energy demand and fuel shares between 2019 and 2050 using OSeMOSYS (Open Source energy Modelling SYStem). Findings from four scenarios are analyzed, including the Business and Usual Scenario, Net Zero, Stated Policies scenario, and the eCooking Transition Scenario.
- ***Impact of Scaling eCooking on the grid***: In this section, we focus on the projects growth in electricity demand from the adoption of eCooking in Kenyan households. Here, we model the shifting generation mix and the ability of the system to meet demand, considering the growing energy demand for electric cooking in Kenya.
- ***Modelling Stacking and eCooking Transitions***: This section assesses fuel stacking and attempts to quantify the potential impact of different eCooking interventions, taking into account various supply side and demand-side factors.
- ***Using the BAR HAP Tool: Modeling eCooking Transitions***: In this section, the BAR-HAP tool is used to assess the costs and benefits that are associated with three eCooking transition scenarios: the baseline, speculative/planned activities and experimental tariff scenario.

2. Clean Cooking Scenario Modelling

1.1 Introduction

To understand the complexities of clean cooking, OSeMOSYS (Open-Source energy MOdelling SYStem) was used to forecast trends in energy demand and fuel shares between 2019 and 2050. OSeMOSYS is an open-source modelling tool that provides a transparent and accessible platform for long-term energy system planning and optimization. Input data comprised findings from the 2023 electric cooking baseline study, enriched with insights from existing literature, industry reports, policy documents and stakeholder input. Only primary cooking solutions are modelled, and for the sake of simplicity, fuel stacking is not captured. OSeMOSYS utilizes a reference energy system (RES), linking supply-side technologies to their respective end uses across five sectors: industry, transport, services, agriculture, and residential. Within the residential sector, there is lighting, cooling, electrical appliances, heating, and cooking. For this analysis, modifications were specifically made to the cooking sector and its associated supply chains. Four scenarios were analysed: the Business-as-Usual Scenario, the Net Zero scenario, Stated Policies scenario, and eCooking Transition scenario. Below are the hypotheses made for each scenario and the resulting findings visualised in graphs.

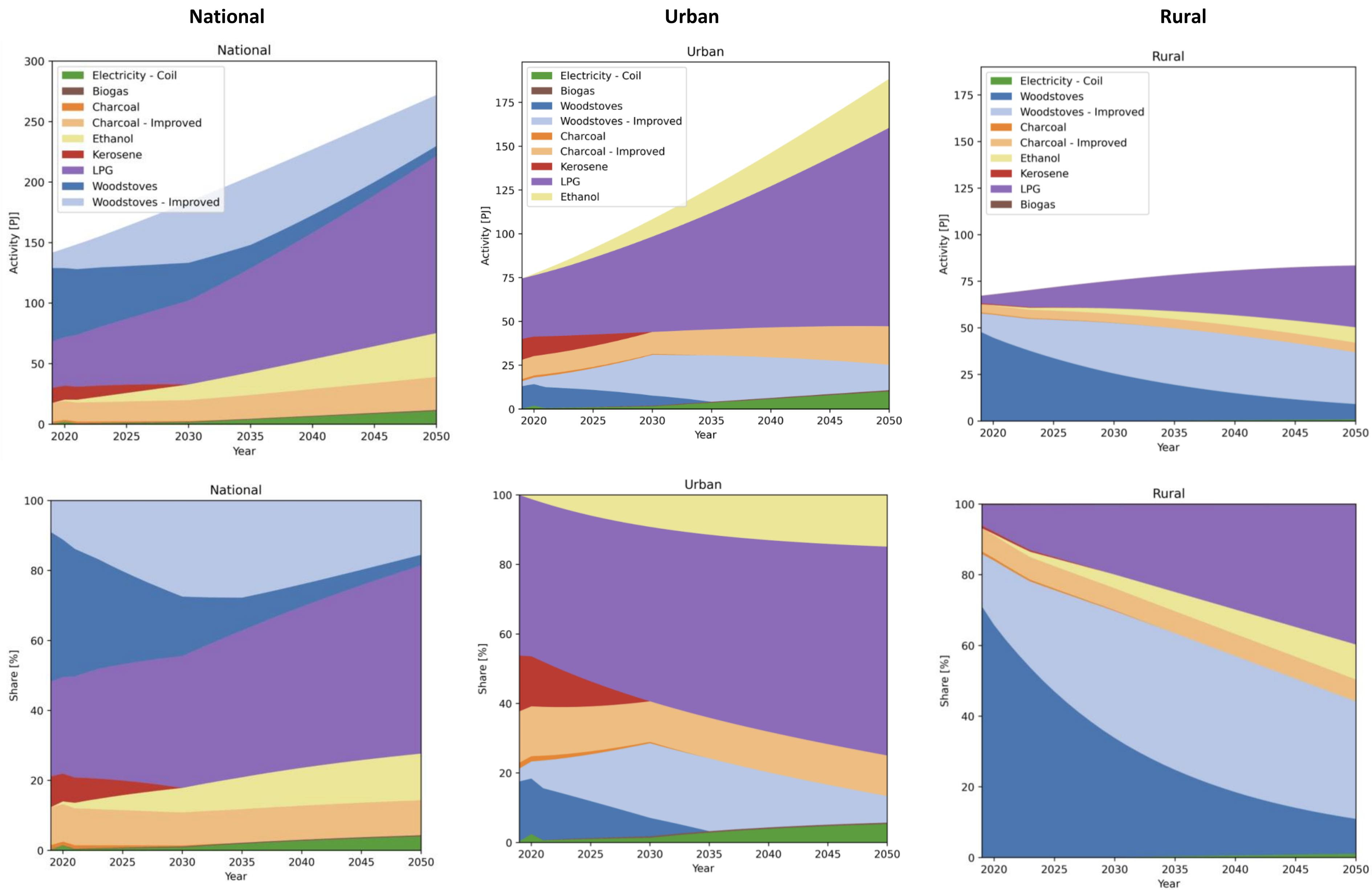
1.2 Business as Usual Scenario

The term "Business As Usual" (BAU) typically refers to a scenario where current trends and policies continue without any significant changes. In the context of clean cooking as modelled using OSeMOSYS, the BAU scenario would model the energy demand and supply patterns assuming no major new policy interventions or drastic changes in technology adoption rates. The hypotheses are summarised as follows:

- There is a slow decrease in solid biomass consumption for 2030 and 2050. Improved firewood stoves are accessible to 50% of rural firewood users by 2030.
- Improved charcoal stoves meet fuel stacking demand in urban areas.
- Kerosene is phased out by 2030, current use declines to zero (Ministry of Energy, 2019).
- Continued moderate uptake of LPG from current rates of 64.2% in urban areas and 13.7% in rural areas in 2030 (modified Bioenergy Strategy Action Plan 2023)
- 15% of urban households and 10% of rural households will choose to use bioethanol as their primary fuel in 2029 (Kenya Ethanol Cooking Fuel Masterplan, 2021).
- 0.3 percent of households will access biogas by 2030 (Bio-energy strategy, 2020).
- A moderate increase in electricity access until 2050, growing at 1% per year in urban areas and 0.5% per year in rural areas, based on projections in the SE4ALL 2016 Action Agenda (Ministry of Energy, 2016).
- Electric options are used by 3.26% of the urban population and 0.62% of the rural population, in line with current use from the eCooking baseline study. There is an increase of 0.39% (urban) and 0.055% (rural) of electric cooking per year in keeping with historical trends.

In the business-as-usual modelling outcomes, LPG emerges as the primary fuel choice for both urban and rural regions in 2030 and 2050. While biomass remains prevalent, there is a notable shift from traditional cookstoves to improved firewood and charcoal variants. The three-decade span also witnesses a marked rise in ethanol use. Conversely, the uptake of electric cooking remains minimal. See Figure 1.1 for the model plots.

Figure 2.1 Business as Usual Scenario model results



In the business-as-usual scenario, we can identify distinct trends in the adoption and usage of various fuel sources:

Growth Trends:

- **LPG**: There's a significant upward trajectory for LPG, with its usage anticipated to increase from 37% in 2028 to 56% by 2050. This surge can be attributed to robust policy support in recent years, making it more accessible and affordable despite its relatively high costs. Predominantly, urban areas seem to have a greater adoption of LPG.
- **Ethanol**: A noteworthy trend to highlight is the rising adoption of ethanol, which aligns with historical data. By 2050, it's projected to hold a prevalence rate of about 10%.

Stagnant/Minimal Growth:

- **Charcoal**: The use of charcoal is expected to remain constant throughout the period, with no significant changes in its adoption across urban and rural sectors.
- **Electric Cooking**: The scenario sees minimal adoption of electric cooking. Dominated by less efficient stoves, such as the electric coil, its usage is projected to be around 1% in 2028, growing marginally to 4% by 2050. Especially in rural areas, electric cooking remains almost non-existent.

Decreasing Trends:

- **Kerosene**: This fuel source is set to phase out, completely disappearing by 2030.
- **Firewood**: Although firewood continues to be a primary fuel, especially in rural regions, there's a notable shift from traditional firewood to its improved version over time.

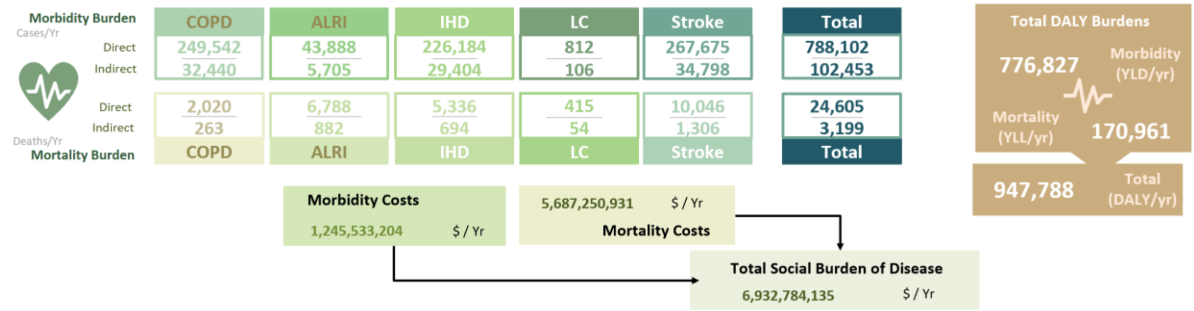
LPG's rise can be attributed to its increased accessibility and affordability, thanks to policy initiatives, although it remains cost intensive. While urban regions favour LPG, biomass retains its significance, especially in rural areas. There's an observable shift from traditional biomass sources like firewood to improved variants or alternatives such as LPG. Despite the minimal role of electric cooking in this scenario, ethanol showcases potential growth, echoing recent historical data.

Private and social burdens of the BAU scenario

Below is a summary of the current monetized costs (or burdens) associated with the baseline scenario in Kenya. For this analysis, the Benefits of Action to Reduce Household Air Pollution (BAR-HAP) Tool—a planning tool developed by the World Health Organisation for assessing the costs and benefits of different interventions that aim to reduce cooking-related household air pollution[1]—was used.

- ***Private and social health burdens:*** Two types of health burdens from use of polluting cooking technologies are analysed: direct burdens which account for any household air pollution (HAP) that affects people due to their own cooking emissions, and indirect burdens which refer to those arising from ambient air pollution due to HAP (since HAP contributes to ambient air pollution).

[1] BAR-HAP Tool, available at https://www.who.int/tools/benefits-of-action-to-reduce-household-air-pollution-tool



The top left section shows the cases and deaths due to 5 different HAP-attributable illnesses (Chronic obstructive pulmonary disease (COPD), acute lower respiratory illness (ALRI), ischemic heart disease (IHD), lung cancer (LC), and stroke. The direct morbidity and mortality cases would be 788,102 and 24,605 respectively per year, estimated to have an economic cost of $1,245,533, and the indirect cases would be 102,453 and 3,199 per year, estimated at a cost of $5,687,250,931. These health effects hold a substantial monetary value, amounting to $6,932,784. The annual disability adjusted life year burdens arising from morbidity (years of life in disability) and mortality (years of life lost) are shown, totalling 170,961 DALY per year[2].

- ***Environmental burdens:*** These refer to impacts on climate and forest degradation. The baseline results in a CO2 equivalent emission of 47,854,663 tons per year[3], which equates to a monetary cost of $881,971,433. An estimated 10,979,026,974 kgs of non-renewable biomass would be lost due to wood harvesting[4], which is valued at $4109,790,270 per year at the cost of renewable biomass replacement (tree planting and sustainable forest management).

- ***Time burdens:*** The annual cumulative excess hours spent cooking and collecting fuels, compared to the most efficient cooking technology and fuels 351,990 person-years, which represents a monetary value of $291,007,226 per year[5].

[2] The annual economic costs of the burdens are based on cost of illness (COI) valuation for morbidity, and value of a statistical life (VSL) valuation for mortality.
[3] This pollution measure includes a basic set including only Kyoto protocol pollutants, and an extended set that also includes carbon monoxide, organic carbon, and black carbon.
[4] For reference, typical mature trees can weight anywhere from 1,000-20,000 kg, depending on the species.
[5] This time is valued as a fraction of the wage rate for unskilled labour in the country, to account for the fact that individuals spending this time are often not fully employed in the labour market.

1.3 Net Zero Scenarios

In a net-zero scenario for scaling electric cooking as the best-case scenario, the primary objective is to transition the cooking sector from traditional, polluting fuels to electric cooking technologies powered by renewable energy sources. This scenario envisions a comprehensive shift toward sustainable and clean cooking practices, contributing to the overall goal of achieving net-zero emissions in the cooking sector.

We consider two different Net Zero scenarios:

- A ***simulated* Net Zero Scenario** explores eCooking acceleration, but under current policy constraints that promote LPG, ethanol and improved woodstoves.
- An ***optimised or unconstrained* Net Zero Scenario** models clean cooking transitions with the sole target of alleviating CO2 emitted by the sector after 2025 at the least cost, assuming no policy or capacity constraints.

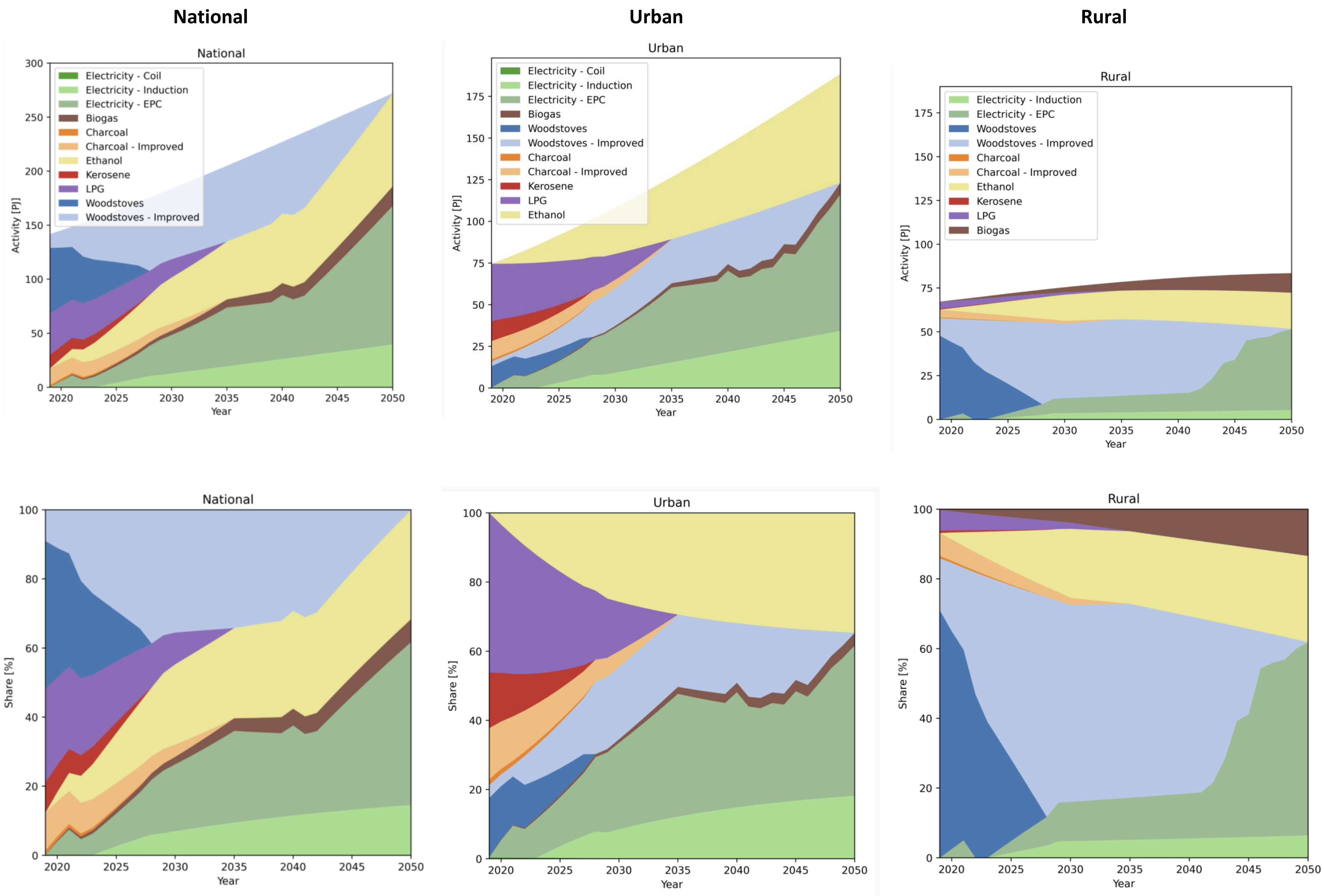
1.3.1 (Simulated) Net Zero

The simulated net-zero hypotheses are as follows:

- Emissions from BAU scenario are gradually reduced to zero.
- 100% of rural households have access to improved cookstoves by 2030.
- Solid biomass use for cooking (charcoal and firewood) is completely phased out by 2050 (Bioenergy strategy, 2020).
- Kerosene is completely phased out (Ministry of Energy, 2019).
- LPG serves as a transitioning fuel in urban areas; 64.2% in urban areas and 13.7% in rural areas by 2030
- 35% of urban households and 20% of rural households will choose to use bioethanol as their primary fuel in 2029 ('high case scenario', Kenya Ethanol Cooking Fuel Masterplan, 2021).
- At least 3% of Kenyan households transition to using biogas as their primary cooking fuel by 2028 (Bioenergy Strategy Action Plan 2023).
- The country has the potential to establish 2.3 million digesters (we assume by 2050) (Bio-energy strategy, 2020).
- 2.3 million biodigesters are deployed by 2050 (Bioenergy strategy, 2020).
- There is a strong focus on electrification in urban and rural areas:
    - 100% access to electric cookstoves by 2030 in urban areas
    - 25% access to electric cookstoves in rural areas by 2030
    - 42% access to biogas and bioethanol in rural areas by 2030

A visualisation of the findings is presented in Figure 2 below.

Figure 2.2 Simulated Net Zero Scenario model results



In the simulated net-zero scenario, several fuel adoption trends can be discerned over the forecast period:

Growth Trends:

- **Electricity**: There is a remarkable and consistent growth of EPC adoption throughout the period until 2050. Induction cooker adoption also shows growth—though delayed given that these appliances are still scarce in the market, and the efficiency of the stove is lower than the EPC.
- **Ethanol**: Though starting from a mere 2.39% in 2020, it sees steady growth to reach 30.54% in 2050. This suggests a growing preference for alcohol-based cooking due to decreased prices.
- **Biogas**: Biogas adoption grows gradually to 2050, particularly in rural areas peaking at 4.5% in 2050 with the installation of more biodigesters.

Decreasing Trends:

- **Firewood**: There's a clear decline of traditional firewood, dropping to almost zero by 2030. This indicates a move away from traditional woodstoves. There's an initial increase of improved firewood energy demand from 9.04% in 2019 to a peak of 35.81% in 2030, which is a result of the substitution between traditional and improved stoves. A subsequent decline of improved firewood follows, reaching negligible levels by 2047.
- **LPG**: LPG dominates in the early stages of the period, but decreases gradually as it is substituted by ethanol and electricity to complete phase out by 2035.
- **Kerosene**: It drops consistently, phasing out entirely by 2030.
- **Charcoal**: Traditional charcoal starts declining from the late 2020s onward, being substituted by improved charcoal, which peaks around 2029 and then begins to decrease to phase out by 2035.

General Observations:

- Traditional energy sources like woodstoves and kerosene show a clear decline, reflecting possible improvements in infrastructure, accessibility to cleaner fuels, and awareness of environmental and health concerns.
- eCooking solutions, especially EPC and induction, exhibit significant growth, which might be due to technological advancements, affordability, or policy measures promoting electrification.
- The adoption of improved woodstoves peaks in the early 2030s and then declines, suggesting a transient shift before households transition to more modern cooking solutions.
- By 2050, a competitive landscape emerges among bioethanol, biogas, and electric cooking.

1.3.2 (Optimised) Net Zero

The optimised net-zero hypothesis only considers one target: Emissions from BAU scenario are gradually reduced to zero. The scenario assumes no policy constraints, with the exception of the amount of CO2 emitted by the sector after 2025.

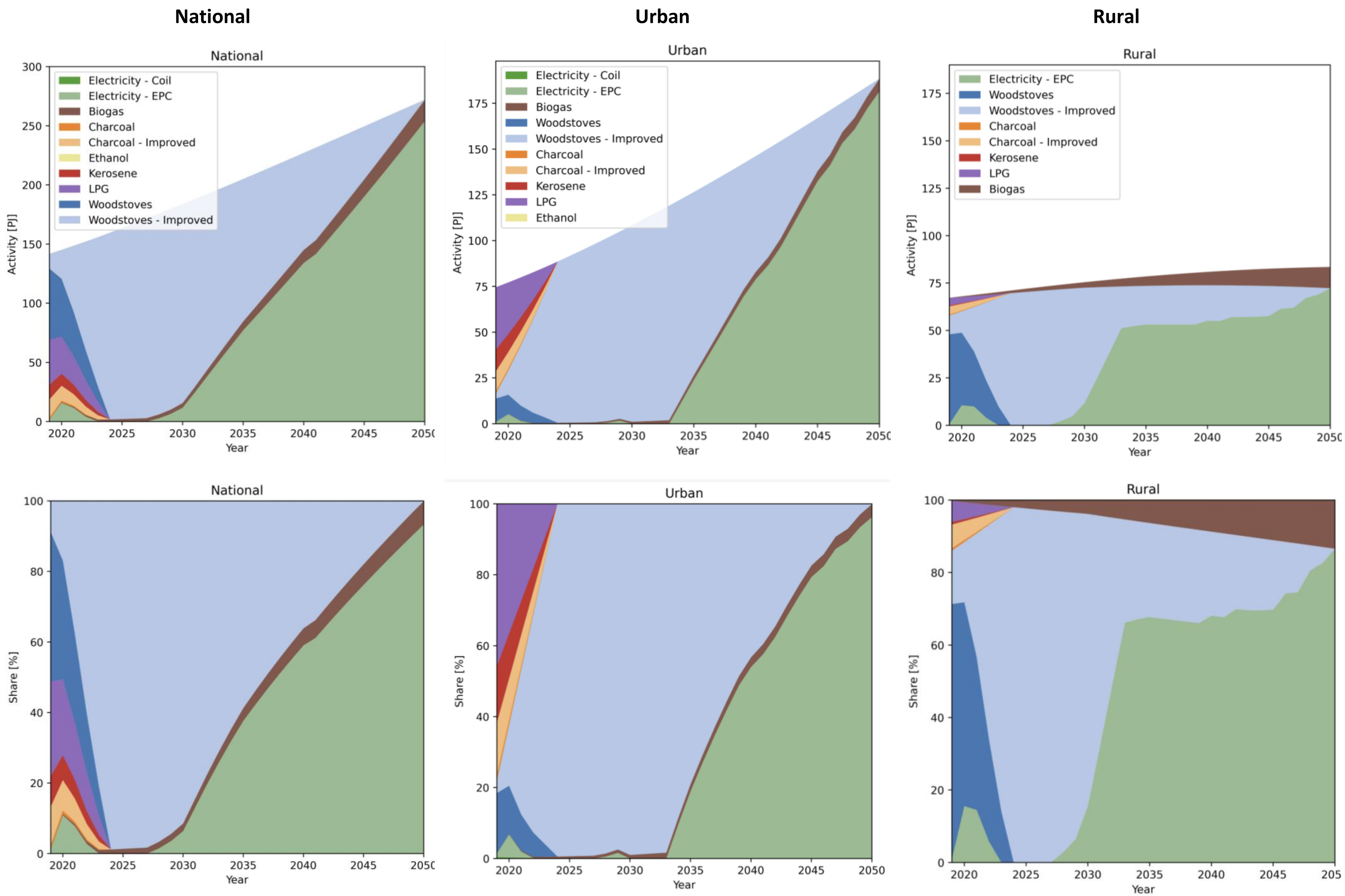
A visualisation of the findings is presented in Figure 3 below.

In the optimised net-zero scenario, several fuel adoption trends can be discerned over the forecast period:

Growth Trends:

- **Electricity**: Starting from 0.31% in 2020, EPCs are initially substituted by improved wood stoves, as the fuel is free. Then there there's a remarkable and consistent growth of EPCs as the most energy-efficient appliance from 2030, reaching 95% in 2050 to meet the net zero target.
- LPG, charcoal, kerosene and ethanol disappear rapidly from the system.
- **Biogas**: Biogas adoption grows gradually to 2050, particularly in rural areas peaking at 4.5% in 2050 with the installation of more biodigesters.
- **Improved wood** is a transitional fuel, as it is cheaper or free.

Figure 2.3 Optimised Net Zero Scenario model results



1.4 Stated Policies scenario

These scenarios explore the effects of existing policies in the sector should they be implemented as planned. Below is the current policy framework for electrification and clean coking in Kenya:

- 100% Access to Clean Cooking by 2028, including improved firewood and improved charcoal stoves (2016 Kenya Action Agenda and SE4All Initiative; Bioenergy Strategy, 2020)
- Reduce biomass consumption by 50% in 2040 by promoting the adoption of LPG and other cleaner cooking fuels and technologies (Kenya draft energy white paper: Kenya energy sector roadmap 2040, Ministry of Energy, 2022)
- 3 percent of households will access biogas by 2030 (Bioenergy strategy action plan, 2023). Establish 23 million digesters (by 2050) (Bio-energy strategy, 2020)
- 25% of urban households and 15% of rural households will choose to use bioethanol as their primary fuel in 2029 ('base case scenario', Kenya Ethanol Cooking Fuel Masterplan, 2021).
- LPG will be used as a primary cooking fuel by 44% of households (Bioenergy strategy action plan 2023)
- 100% electricity access (Kenya National Electrification Strategy, 2018), with an ambitious case assuming:
    - 100% of urban households access to Tier 3+ electricity by 2030
    - 50% of rural households access to Tier 3+ electricity by 2030
- By 2030, aim for a 32% reduction in emissions compared to business-as-usual, with the cooking sector contributing an abatement potential of 7.3 $MtCO_2e$ (Kenya's Updated Nationally Determined Contribution (NDC) to the Paris Agreement)

A visualisation of the findings is presented in Figure 3 below.

Based on the Stated Policies Scenario model results, here are the observed trends for each fuel source:

Growth Trends:

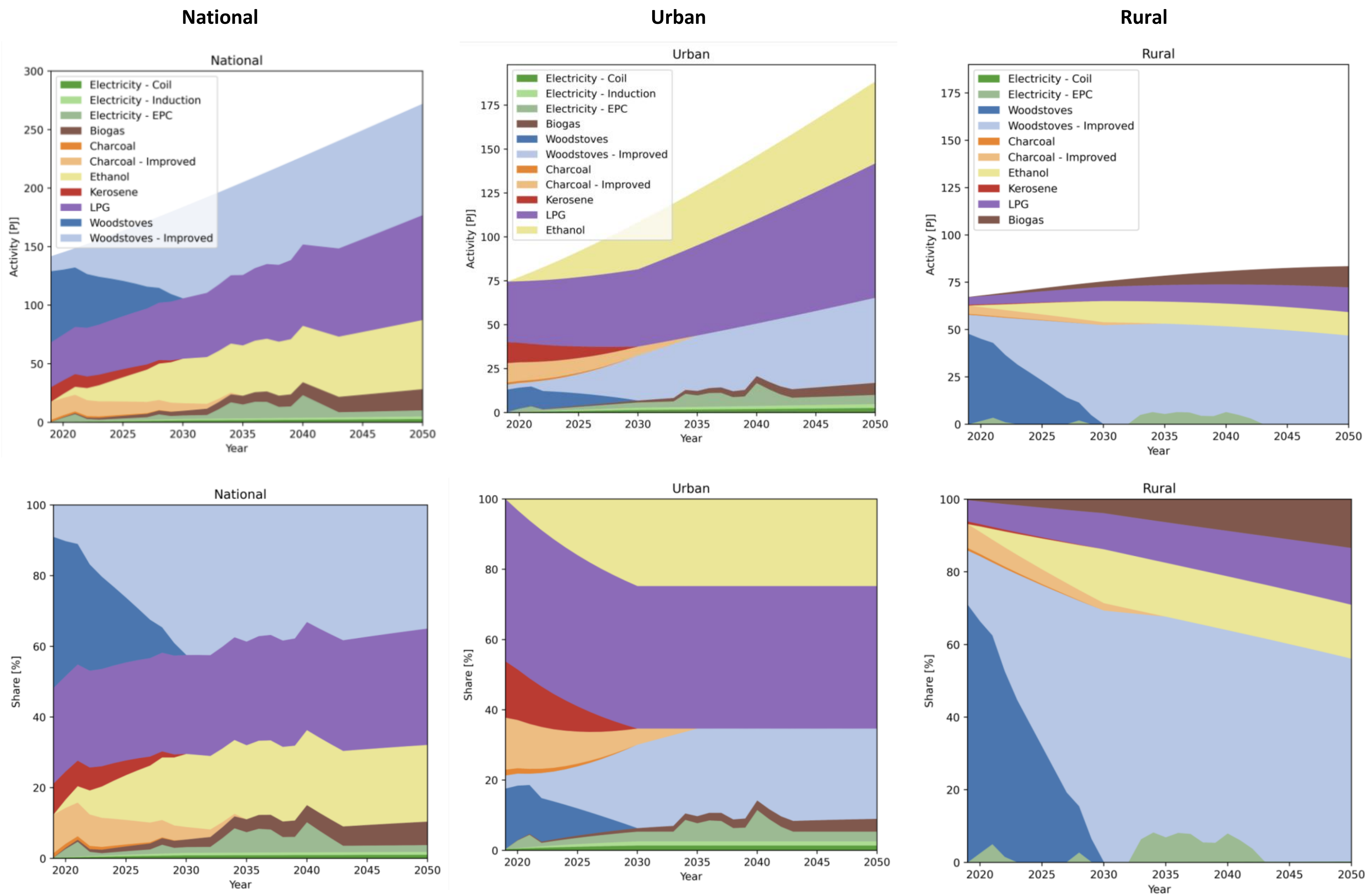
- **Firewood**: There's an upward trend of improved firewood reaching 38.73 in 2028 as it replaces traditional firewood which is phased at by 2030. However, it slightly decreases to about 40% by 2050. Improved cookstoves continue to receive policy support.
- **LPG**: Increases slowly but consistently from 27.09 in 2019 to 30.26 in 2028, and further to 36.51 by 2050. LPG continues to receive policy support, making it more accessible and affordable despite its relatively high costs. Predominantly, urban areas seem to have a greater adoption of LPG.
- **Ethanol**: Also experiences a substantial increase reaching 14% by 2028 and growing to 19% by 2050 as the price of ethanol declines. There is a higher preference of ethanol in urban areas compared to rural areas.
- **Biogas**: It exhibits a consistent growth from almost zero in 2019 to 1.5% in 2028, and further to 4.5% by 2050 as more biodigesters are installed in rural areas.
- **Electricity**: There's a steady but negligible upward trend of eCooking, moving to 0.84% in 2028 and reaching 1.14% by 2050. As there is not yet any clear policy support for electric cooking, it has a minimal impact on energy demand due to existing tangible and perceived barriers such as high electricity costs, appliance costs, and persistent beliefs and attitudes towards electric cooking.

Decreasing Trends:

- **Charcoal**: Traditional and improved charcoal decline over time, with improved charcoal gradually replacing traditional charcoal. Traditional charcoal disappears by 2028, while improved charcoal disappears from the system in 2035.
- **Kerosene**: Kerosene disappears from the system in 2029.

General Observations: There's a clear shift from traditional fuel sources to more sustainable and cleaner sources. By 2028, fuels like charcoal and kerosene are nearing their phase-out in this scenario. Post-2028, charcoal, kerosene, and traditional firewood stoves are completely phased out. Ethanol, biogas, electricity, LPG, and improved firewood continue to be in use, with ethanol and biogas experiencing significant growth rates. The consistent growth of LPG, albeit slower, shows its importance as a transitional fuel

Figure 2.4 Stated Policies Scenario model findings



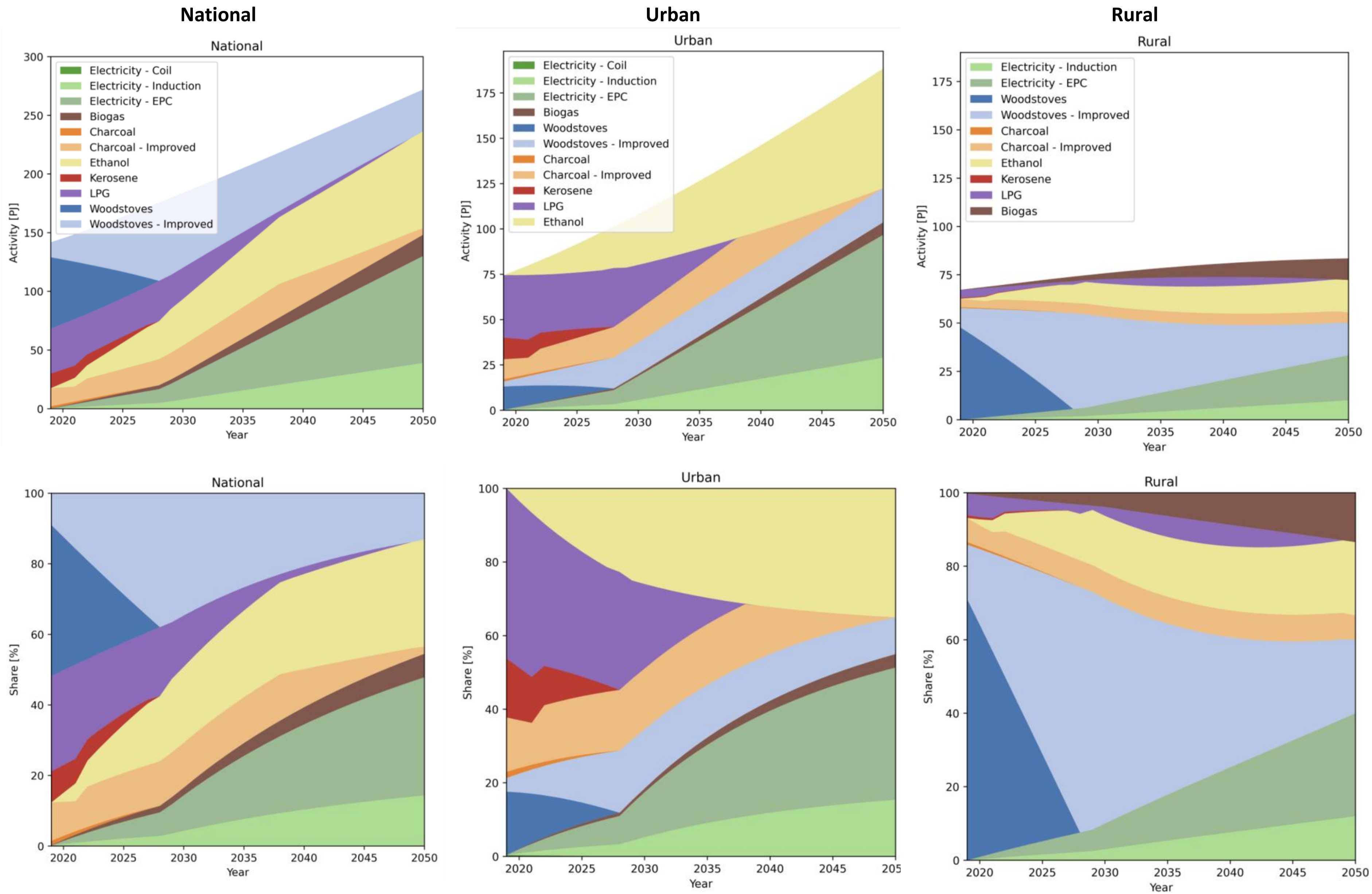
1.5 eCooking Transition scenario

The eCooking transition scenario builds upon the stated policies scenario acknowledging the government's pre-existing commitments as outlined in strategic documents such as the Bioenergy Strategy and Kenya's Updated Nationally Determined Contribution (NDC) targets. Additionally, the scenario builds on the Net Zero Scenario, which emphasizes a robust electrification drive and seeks to comprehensively eradicate emissions from the cooking sector by 2050. By harmonizing these two paradigms, the eCooking transition scenario presents a pragmatic roadmap for Kenya's cooking sector transformation. Below are the hypotheses made in this regard:

- States Policies hypotheses:
    - 100% Access to Clean Cooking by 2028, including improved firewood and improved charcoal stoves (2016 Kenya Action Agenda and SE4All Initiative; Bioenergy Strategy, 2020)
    - Solid biomass use for cooking (charcoal and firewood) is completely phased out by 2050 (Bioenergy strategy, 2020).
    - Improved biomass decreases to about 50% in 2050 (Energy Transitions and Investment Plan, 2023).
    - Kerosene is completely phased out (Ministry of Energy, 2019).
    - At least 3% of Kenyan households transition to using biogas as their primary cooking fuel by 2028 (Bioenergy Strategy Action Plan 2023). 2.3 million biodigesters are deployed by 2050 (Bioenergy strategy, 2020).
    - By 2030, aim for a 32% reduction in emissions compared to business-as-usual, with the cooking sector contributing an abatement potential of 7.3 $MtCO_2e$ (Kenya's Updated Nationally Determined Contribution (NDC) targets)
    - LPG will be used as a primary cooking fuel by 44% of households by 2030 (Bioenergy strategy action plan 2023). Based on the eCooking baseline study, we argue that LPG will be used by at least 64.2% in urban areas and 13.7% in rural areas by 2030. LPG is phased out in 2050 (Energy Transitions and Investment Plan, 2023).
- Conservative Net zero hypotheses:
    - For bioethanol:
        - 25% of urban households and 15% of rural households will choose to use bioethanol as their primary fuel in 2029 ('base case scenario'). (stated policies) **and this grows to** 35% of urban households and 20% of rural households in 2050 ('high case scenario'), (Kenya Ethanol Cooking Fuel Masterplan, 2021).
    - There is a strong focus on electrification in urban and rural areas (building on the Kenya National Electrification Strategy, 2018):
        - 100% of urban households access to Tier 3+ electricity by 2030
        - 75% of rural households access to Tier 3+ electricity by 2030
        - 100% Tier 3+ electricity nationally by 2050
    - Electricity reaches about 50% of the cooking energy mix by 2050 (Energy Transitions and Investment Plan, 2023)

A visualisation of the findings is presented in Figure 4.

Figure 2.5 eCooking Transition Scenario model results



Based on the eCooking Transition Scenario findings in Figure 4, here are the observed trends for each fuel source:

Growth Trends:

- **Electricity**: eCooking grows steadily as biomass and LPG decline over the duration to 2050. The electric coil is phased out by 2028. More energy efficient appliances diffuse in the system, with EPC prevalence 4.6% in 2028 and 32% by 2050. Induction cookers reach 2.5% in 2028, and climb to 16% by 2050. Cumulatively, ***eCooking will account for about 9.5% as a primary cooking solution in households, and 48% in 2050.*** These findings relate to increased Tier 3+ electrification and decreasing costs of appliances and tariffs gradually over the period.
- **Ethanol**: Grows to 14% in 2028, and 26% by 2050, also due to declining prices of stoves and alcohol. There is a higher propensity to ethanol in urban areas.
- **Biogas**: As in the stated policies scenario, biogas exhibits a consistent growth from almost zero in 2019 to 1.5% in 2028, and further to 4.5% by 2050 as more biodigesters are installed in rural areas.

Decreasing Trends:

- **LPG**: LPG drops to 30% by 2028 as more households replace it with electricity and ethanol, and eventually reduces significantly to 2.5% by 2050. Thus, LPG is a transitional fuel, particularly in urban areas.
- **Firewood**: Traditional firewood diminishes continuously, getting phased out by 2028. It is replaced by improved firewood to some extent, which increases to 40% in 2028, and stabilizes around the range of 25% to 30% between 2028 and 2050.
- **Charcoal**: Traditional charcoal reduces to negligible usage by 2027, and disappears from the system post-2028. Improved charcoal also decreases to 5% in 2028 and is not present post-2035.
- **Kerosene**: Kerosene disappears from the system in 2028.

General Observations:

- The eCooking Transition Scenario highlights a shift towards electric cooking solutions, as evidenced by the consistent growth in electricity (both EPC and Induction).
- The phasing out of traditional firewood stoves, charcoal, and kerosene is reflective of efforts to adopt cleaner cooking methods.
- LPG and improved firewood are transitional technologies serving as interim solutions until total adoption of relatively cleaner solutions such as electricity, bioethanol and biogas.
- As in the net-zero scenario, there is a competition between eCooking and ethanol in 2050. However, in this case, improved cookstoves continue to play a role in system.

1.6 Conclusion

The scenarios presented are layered in a progressive manner, representing varying degrees of ambition and policy impetus towards the adoption of eCooking in Kenya:

A. **Business as Usual Scenario:** This represents the baseline or worst-case scenario, where no significant changes in current trends or practices are assumed. It operates on the premise that the status quo remains unchanged, with traditional and non-renewable fuel sources continuing to dominate, leading to higher emissions and continued reliance on environmentally detrimental cooking methods.
B. **Stated Policies Scenario:** While slightly more ambitious than the business-as-usual scenario, it still signifies minimal progression towards eCooking. Here, policies are in place, but they are not adequately robust to drive a major shift towards sustainable cooking solutions. There's a noticeable, albeit limited, transition from traditional fuels, but the landscape still lacks the necessary momentum for a full-scale eCooking revolution.
C. **eCooking Transition Scenario:** This marks a significant pivot from the previous two scenarios. It indicates a proactive and substantial uptake of eCooking solutions. The decline of traditional cooking fuels like woodstoves and charcoal is evident, replaced by a clear trend towards electric cooking solutions. This scenario represents a blend of policy-driven directives, societal awareness, and technological advancements that together champion the cause of eCooking.
D. **Net Zero Scenarios:** The best case scenario is the optimised version, while the simulated version has a dampened growth of eCooking due to existing policy constraints. For the simulated version, the focus is not just on eCooking but on a holistic approach to achieving net-zero emissions. Every cooking method adopted is geared towards minimizing carbon footprints, maximizing efficiency, and fostering an environmentally sustainable society.

In essence, these scenarios depict a continuum: from a passive, non-interventionist approach in the business-as-usual scenario to a fully engaged, environmentally sustainable strategy in the simulated and optimised net zero scenarios. The transition from each scenario to the next showcases the increasing importance of and reliance on eCooking, underlining its potential role as a cornerstone in Kenya's journey towards sustainable development and environmental stewardship.

The eCooking Transition Scenario, identified as the most feasible intervention, will serve as the foundational blueprint for the Kenya National Electric Cooking Strategy. The strategy will delve into a multifaceted approach to facilitate a transition to electric cooking. It will consider direct interventions, including behaviour change campaigns that aim to shift societal mindsets towards eco-friendly cooking. To make eCooking appliances more accessible, appliance subsidies will be introduced, supported by innovative credit financing mechanisms. Additionally, the strategy will push for a waiver on the value-added tax, further reducing the financial burden on the end consumer.

Recognizing the importance of practical, on-ground testing, the strategy will also lay the groundwork for eCooking pilot programs. These programs will serve as experimental grounds for innovative solutions such as specialized eCooking tariffs, the harnessing of carbon markets for financing, and utility-enabled financing especially in mini-grids.

To address barriers in the enabling environment, the eCooking strategy will also focus on indirect interventions: enhancing the supply chain infrastructure, promoting local manufacturing to reduce costs and dependencies, expanding after-sales services to ensure long-term appliance usability, and setting rigorous appliance quality standards, and enhancing the policy framework to support eCooking scale-up. The strategy will also mainstream gender to ensure that the benefits of eCooking are equally accessible to all members of society, addressing historical disparities and promoting inclusivity in the energy transition.

In conclusion, the Kenya National Electric Cooking Strategy, inspired by the eCooking Transition Scenario, will serve as a comprehensive roadmap, guiding Kenya's journey towards a sustainable, equitable, and climate-friendly cooking future.

2. Impact of Scaling eCooking on the electricity grid

2.1 Introduction

Kenya is experiencing a significant increase in electricity demand, primarily fuelled by economic growth and the electrification across different sectors. To accommodate the dramatic rise in electrification over recent years—currently standing at 77%—Kenya as actively invested its renewable resource generation capacity, particularly geothermal and wind energy. The country anticipates continued growth in electricity demand up to 2030, especially with sectors like manufacturing showing promise.

One key area of focus is the projected growth in electricity demand comes from the adoption of electric cooking in Kenyan households. This aligns with the nation's goal of achieving universal access to clean cooking by 2028. However, rapid growth in demand brings its own set of complications. The current infrastructure grapples with challenges like transmission constraints that lead to load shedding, a system characterized by low inertia, and issues arising from low off-peak demand, among others. The government, recognizing these hurdles, is proactively looking into solutions through planning initiatives like the Mid-Term Plan and the Least Cost Power Development Plan.

2.2 Approach

We model the variability of renewable energy sources, taking into account the anticipated energy demand for electric cooking in Kenya. In our analysis, we employ OSeMOSYS, a Capacity Expansion Model, that identifies the energy mix that minimises total system costs while meeting the exogenously defined energy demands (in this case, for eCooking adoption), subject to predefined constraints[6] (Howells et al, 2016).

This modelling endeavour aims to understand whether and how Kenya has, or has planned, for the capacity to meet the new electricity demand for eCooking as illustrated in the proposed eCooking Transition scenario model, while continuing to prioritize a renewable energy mix. The scenario analysis builds upon both the Medium-Term Plan and the most recent version of the LCPDP (2022-2041), specifically the LCPDP's reference scenario (whereby additional renewable sources potential starts to be available after 2025, and nuclear energy is available from 2036). For details on the analytical approach, including the demand forecasts, future capacity mix considerations, and economic assumptions, refer to LCPDP (2022-2041) and Kihara et al. (2023).

In order to see the impact of electric cooking on the power sector model, we have estimated the energy demand from the whole energy system model for the Business as Usual (BAU) scenario and for the eCooking Transition scenario previously modelled. The difference between the two is the new demand generated from new eCooking households, as illustrated in Figure 1 below.

[6] OSeMOSYS does have its constraints. It tends to oversimplify the issue, potentially underestimating power system variability. Though this limitation can be mitigated by soft-linking it with a production cost model like Flextool, our present focus remains solely on OSeMOSYS.

2.3 Findings

The results show that by 2028, electricity demand from eCooking will reach 3.75TWh. In the long-term, there is a dramatic increase in electricity demand in the residential sector based on new eCooking demand of 28.85TWh.

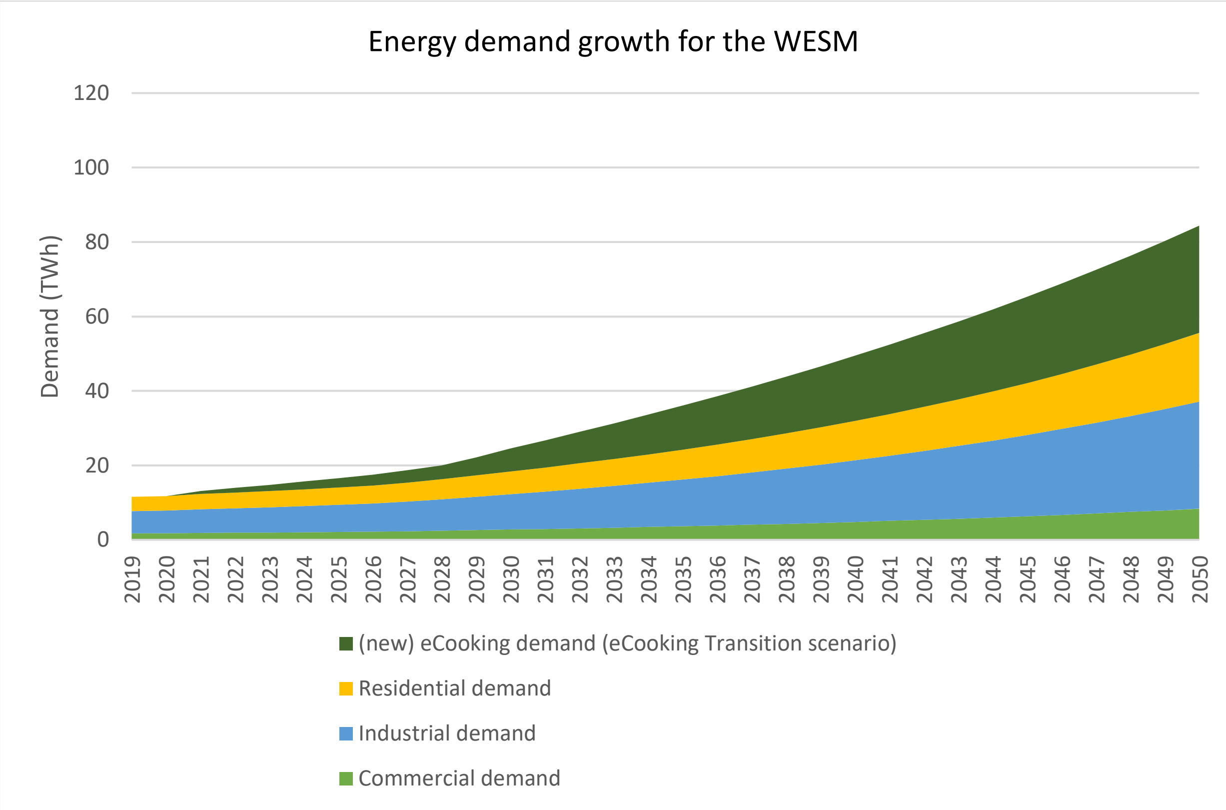


Figure 2.1. Electricity demand growth for the Whole Energy System Model, with new eCooking demand

Given the considerable impact of eCooking on electricity demand, we then investigate how existing and planned capacity and electricity production can meet this demand. We assess the capacity that needs to be built up to 2028, and also up to 2050, and examine how the least cost technology mix needed to cover the new demand evolves. We calculate the difference between the outcomes of the baseline and eCooking scenarios. Figure 2 below graphically presents the evolution in the energy mix in the power sector both in terms of capacity installed and actual energy production.

According to this power sector model, additional eCooking demand in 2030 under the eCooking Transition Scenario will reach 13.5 PJ, requiring about 1.3 GW of new capacity from various energy sources, and rising to 9 GW in 2050. Thus, in the short term, the existing and planned renewable energy capacity falls short, necessitating reliance on diesel generators or imports. Starting from 2025, according to the LCPDP projections, more geothermal power plants will be commissioned, complemented by incremental hydro and wind capacities. Additionally, more electricity imports can be utilised to add capacity

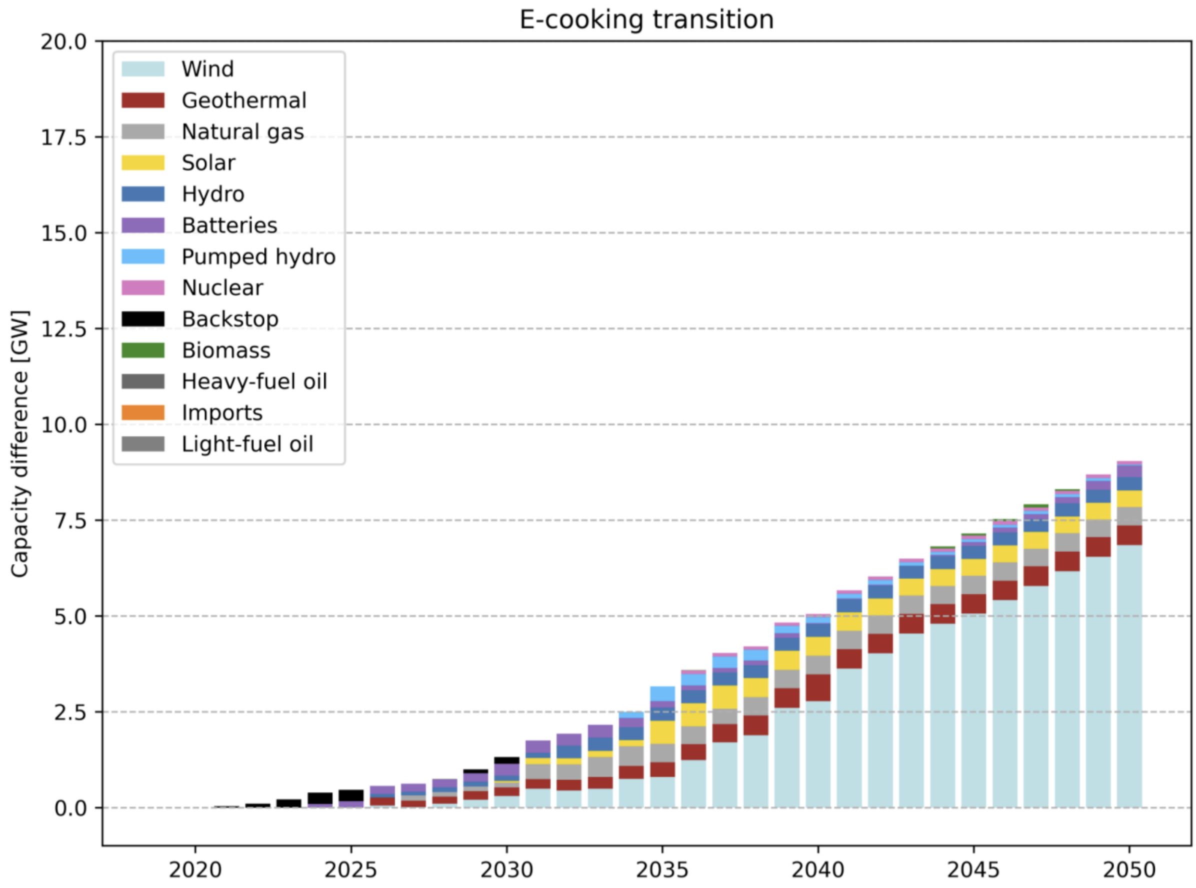


Figure 2.2 The evolution in the energy mix in the power sector in terms of capacity installed.

Thus, looking at these projections, such an eCooking scenario is feasible if the government continues to invest in planned capacity over the years, even though those investments are substantial.

Building on the increased electricity demand anticipated from the eCooking Transition Scenario, the model forecasts additional revenue through 2050, using the average tariffs of the past year[7], for the domestic 30-100 kWh band[8]. The outcomes are illustrated in Figure 3.5 presented below.

[7] This analysis has not factored inflationary effects, thus further studies could better establish projected tariff rates.

[8] It is assumed that households cooking primarily with electricity will be categorized in the “Domestic Customer Category 2’ tariff band introduced in April 2023 by the Energy and Petroleum Regulatory Authority to promote the uptake of eCooking.

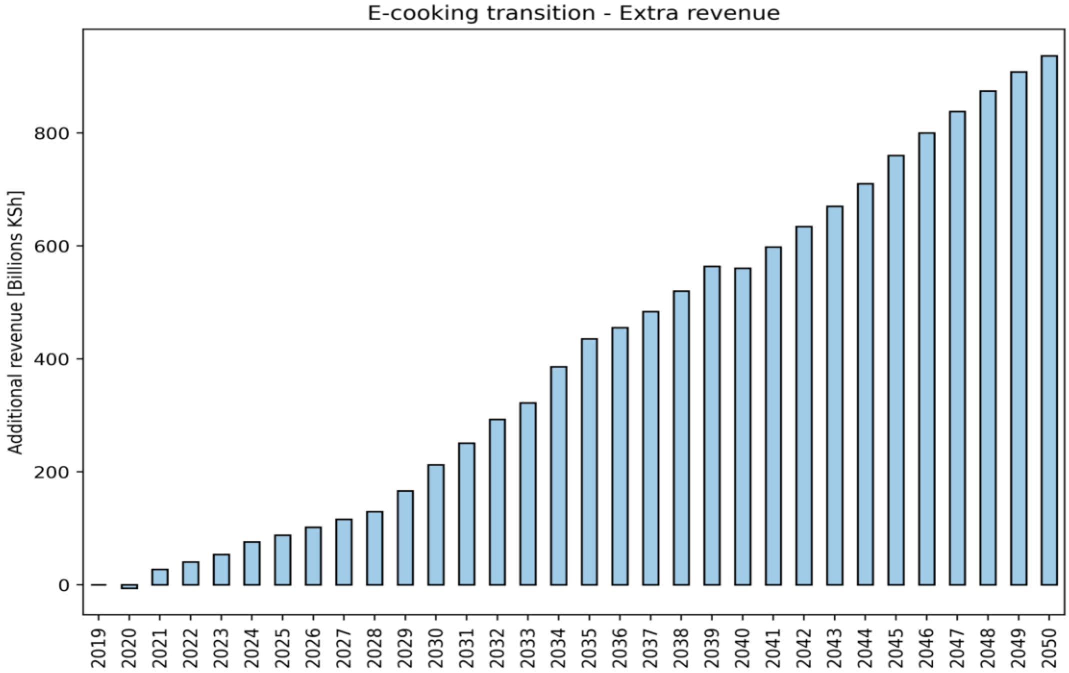


Figure 2.3 Projected additional revenue from the power sector on implementing the eCooking transition scenario

The model indicates that the eCooking Transition Scenario, with its progressively increasing demand for electricity, is projected to yield an estimated 175 billion shillings in additional revenue for Kenya Power by 2028, and approach one trillion shillings by 2050 based on the current tariff rates. Consequently, eCooking serves as a potent demand stimulation tool, potentially yielding considerable revenue that could further strengthen the grid infrastructure.

3. Modelling Stacking and eCooking Transitions

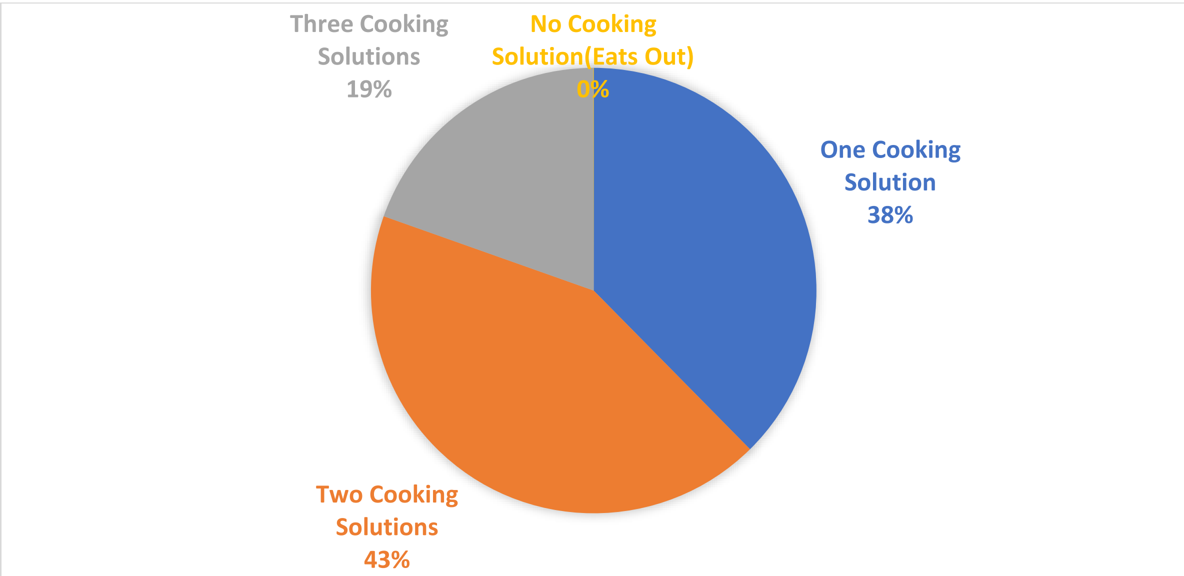
The methodological approach in this note is predominantly built on the Kenya National eCooking Baseline Study (Onsongo, Nayema, Kinuthia, Kausya & Okoko, 2023), hereafter the 'eCooking Baseline Study'. The eCooking Baseline Study was commissioned by the Ministry of Energy and Petroleum, and is part of the broader efforts aimed at developing the Kenya National Cooking Transitions Strategy. The eCooking Baseline Study is the first eCooking focused survey of household cooking energy use in Kenya. In addition, data collection was guided by the Multi-Tier Framework and as such provides estimates of the baseline eCooking potential in Kenya.

3.1 Modelling Stacking

3.1.1. Definition and prevalence of stacking

Stacking in eCooking Baseline Study was considered as the use of multiple cooking solutions to meet households' energy needs. A cooking solution is defined as the combination of cookstove(s) and fuel(s) used to meet households cooking energy demand. Stacking is a prominent feature of households' cooking solutions in Kenya. The study estimated that about 62.4 percent of households use at least two cooking solutions to meet their cooking energy demand. Only 37.6 percent of households use one cooking solution to meet their cooking energy demand as shown in figure 2.1. The implication is that nearly 2 in every three households in Kenya have at least two cooking solutions.

Figure 3.1: Household Stacking in Kenya Based on 2023 Kenya National eCooking Study



Household stacking estimates in Figure 3.1 above are based on the household cooking solutions presented in Table 3.1.

Table 3.1 Household Cooking Solutions Considered in 2023 Kenya National eCooking Study

Charcoal-Based Cooking Solutions	**Kerosene Based Cooking Solutions**	**Electric Cooking Solutions**
	• Kerosene stove	• Water Heater Coil • Electric Kettle • Microwave

• Improved Charcoal Stove (Ceramic lined stoves) • Metallic charcoal stove • Nyama Choma Grill	**Biogas Based Cooking Solutions** • Biogas Stove	• Electric Induction Stove • Hot Plate • Rice Cooker • Electric-Oven • Mixed LPG-Electricity stove • Air Fryer • Electric Frying Pan • Electric Pressure Cooker • Electric coil stove • Slow Cooker • Infra-red Stove
Firewood Based Cooking Solutions • Three stone open fire • Improved firewood stoves (e.g., Kuni mbili stove, gasifier stoves)	**LPG Based Cooking Solutions** • LPG stove • Mixed LPG-Electricity stove	
Biofuel Based Cooking Solutions • Biofuel Stove	**Solar Based Cooking Solutions** • Solar Cooker	

The eCooking Baseline Study categorizes the household cooking solutions presented above into primary, secondary, and tertiary cooking solutions in line with the requirement of the terms of reference (ToR) of the study. The study further reclassifies primary, secondary, and tertiary cooking solutions into the following nine distinct categories guided by the households' responses in the Kenya National eCooking Baseline Survey:

1. Ethanol Based Solutions (Ethanol Stove + Ethanol Fuel)
2. Kerosene Based Solutions (Kerosene Stove + Kerosene)
3. Improved Charcoal Stoves Solutions (Improved Charcoal Stove +Charcoal)
4. Traditional Charcoal Stoves Solutions (Metallic Charcoal Stove + Charcoal)
5. Traditional Firewood Stoves Solutions (Three Stone Open Fire + Firewood)
6. Improved Firewood Stoves Solutions (Improved Firewood Stove + Firewood)
7. Liquified Petroleum Gas (LPG) Solutions (LPG Stove +LPG)
8. eCooking Solutions (eCooking Appliances + Electricity)
9. Others

The "others" category comprises cooking solutions with notably low prevalence rates in the study sample. This encompasses options such as coal, briquettes/pellets, agricultural residue, woodchips, sawdust, and biogas, based solutions.

3.1.2. Methodology: Classification and Estimation

In modeling household stacking, we take into account the primary, secondary, and tertiary categories. To ensure that households are assigned to distinct groups based on their cooking solutions, we use permutations to determine the prevalence and actual form of various cooking solution combinations. For example, if two households both use an electric pressure cooker (EPC) and LPG (liquefied petroleum gas), but one household uses the EPC as the primary solution and LPG as the secondary solution, while the other household uses LPG as the primary solution and EPC as the secondary solution, they are classified into separate groups. Following this rationale, the total number of different household stacking choices is calculated as follows:

1) **Households with Two Cooking Solutions (Primary and Secondary)**

$$nPk = \frac{n!}{(n-k)!} = \frac{9!}{(9-2)!} = 72$$

Where: n is the number of cooking solutions considered (9 in the Study); k is the size of the household stack (2 in the Study - primary cooking solution and secondary cooking solution).

This implies that there are 72 potential ways that households could stack the 9 cooking solutions.

2) Households with Three Cooking Solutions (Primary, Secondary, and Tertiary)

$$nPk = \frac{n!}{(n-k)!} = \frac{9!}{(9-3)!} = 504$$

Where: n is the number of cooking solutions considered (9 in the Study); k is the size of the household stack (3 in the Study—primary, secondary, and tertiary cooking solution).

There are 504 potential ways that households could stack the 9 cooking solutions.

Considering the Study's sample size of 2,432 households, it is impractical to model a stack of 3 cooking solutions (primary, secondary, and tertiary cooking solutions), as this would result, on average, in statistically insignificant subgroups for analysis. Therefore, we restrict the modelling of stacking to stacks of two cooking solutions (primary and secondary). Further, in order to account for the entire universe of households' cooking solutions, households with only one cooking solution are included. Table 3.2 presents the universe of households' cooking solutions, contingent on the assumption of households' stack of two cooking solutions.

Table 3.2: Household Stacking Options for One Cooking Solution and Stack of Two (Primary and Secondary Cooking)

One Cooking Solution

1) Ethanol Only
2) Kerosene Only
3) Improved Charcoal Stove Only
4) Traditional Charcoal Stove Only
5) Traditional Firewood Stove Only
6) Improved Firewood Stove Only
7) Liquified Petroleum Gas (LPG) Only
8) eCooking Only
9) Other Only

Stack of Two Cooking Solutions

10) Ethanol – Kerosene
11) Ethanol - Improved Charcoal Stove
12) Ethanol - Traditional Charcoal Stove
13) Ethanol - Traditional Firewood Stove
14) Ethanol - Improved Firewood Stove
15) Ethanol - Liquified Petroleum Gas (LPG)
16) Ethanol – eCooking
17) Ethanol – Other
18) Kerosene – Ethanol
19) Kerosene - Improved Charcoal Stove
20) Kerosene - Traditional Charcoal Stove
21) Kerosene - Traditional Firewood Stove
22) Kerosene - Improved Firewood Stove
23) Kerosene - Liquified Petroleum Gas (LPG)
24) Kerosene – eCooking
25) Kerosene – Other
26) Improved Charcoal Stove – Ethanol
27) Improved Charcoal Stove – Kerosene
28) Improved Charcoal Stove - Traditional Charcoal Stove
29) Improved Charcoal Stove - Traditional Firewood Stove
30) Improved Charcoal Stove - Improved Firewood Stove

46) Traditional Firewood Stove - Improved Firewood Stove
47) Traditional Firewood Stove - Liquified Petroleum Gas (LPG)
48) Traditional Firewood Stove – eCooking
49) Traditional Firewood Stove – Other
50) Improved Firewood Stove – Ethanol
51) Improved Firewood Stove – Kerosene
52) Improved Firewood Stove - Improved Charcoal Stove
53) Improved Firewood Stove - Traditional Charcoal Stove
54) Improved Firewood Stove - Traditional Firewood Stove
55) Improved Firewood Stove - Liquified Petroleum Gas (LPG)
56) Improved Firewood Stove – eCooking
57) Improved Firewood Stove – Other
58) Liquified Petroleum Gas (LPG) – Ethanol
59) Liquified Petroleum Gas (LPG) – Kerosene
60) Liquified Petroleum Gas (LPG) - Improved Charcoal Stove

31) Improved Charcoal Stove - Liquified Petroleum Gas (LPG)
32) Improved Charcoal Stove – eCooking
33) Improved Charcoal Stove – Other
34) Traditional Charcoal Stove – Ethanol
35) Traditional Charcoal Stove – Kerosene
36) Traditional Charcoal Stove - Improved Charcoal Stove
37) Traditional Charcoal Stove - Traditional Firewood Stove
38) Traditional Charcoal Stove - Improved Firewood Stove
39) Traditional Charcoal Stove - Liquified Petroleum Gas (LPG)
40) Traditional Charcoal Stove – eCooking
41) Traditional Charcoal Stove – Other
42) Traditional Firewood Stove – Ethanol
43) Traditional Firewood Stove – Kerosene
44) Traditional Firewood Stove - Improved Charcoal Stove
45) Traditional Firewood Stove - Traditional Charcoal Stove
61) Liquified Petroleum Gas (LPG) - Traditional Charcoal Stove
62) Liquified Petroleum Gas (LPG) - Traditional Firewood Stove
63) Liquified Petroleum Gas (LPG) - Improved Firewood Stove
64) Liquified Petroleum Gas (LPG) – eCooking
65) Liquified Petroleum Gas (LPG) – Other
66) eCooking – Ethanol
67) eCooking – Kerosene
68) eCooking - Improved Charcoal Stove
69) eCooking - Traditional Charcoal Stove
70) eCooking - Traditional Firewood Stove
71) eCooking - Improved Firewood Stove
72) eCooking - Liquified Petroleum Gas (LPG)
73) eCooking – Other
74) Other – Ethanol
75) Other – Kerosene
76) Other - Improved Charcoal Stove
77) Other - Traditional Charcoal Stove
78) Other - Traditional Firewood Stove
79) Other - Improved Firewood Stove
80) Other - Liquified Petroleum Gas (LPG)
81) Other – eCooking

Building on the universe of household cooking solutions in Table 3.2 and the household responses in the eCooking Baseline Study, Table 3.3 presents the prevalence of of household stacking.

Table 3.3: Prevalence of Household Stacking Based on KNeCS Baseline Survey.

	Household Stack	No of Households	Weighted Proportions
1	Traditional Firewood Stove Only	475	20.166%
2	LPG Only	220	11.001%
3	Traditional Firewood Stove-Traditional Charcoal Stove	215	8.466%
4	Traditional Firewood Stove-LPG	150	7.551%
5	Traditional Firewood Stove-Improved Charcoal Stove	190	6.501%
6	LPG-Improved Charcoal Stove	143	5.278%
7	LPG-Traditional Charcoal Stove	133	5.207%
8	LPG-Kerosene	93	4.968%
9	Improved Charcoal Stove Only	105	2.841%
10	Improved Firewood Stove-LPG	49	2.578%
11	Improved Charcoal Stove-Traditional Firewood Stove	103	2.537%
12	LPG-Traditional Firewood Stove	42	2.295%
13	Improved Charcoal Stove-LPG	92	1.887%
14	Traditional Charcoal Stove Only	47	1.669%

	Household Stack	No of Households	Weighted Proportions
31	eCooking-LPG	9	0.359%
32	Improved Charcoal Stove-Other	4	0.313%
33	Ethanol Only	7	0.280%
34	Kerosene-Improved Charcoal Stove	5	0.252%
35	eCooking Only	5	0.204%
36	Kerosene-Traditional-Charcoal Stove	5	0.191%
37	Traditional Firewood Stove-Ethanol	4	0.165%
38	Ethanol-Improved Charcoal Stoves	4	0.153%
39	Improved Firewood Stove-Other	2	0.141%
40	Improved Charcoal Stove-Improved Firewood Stove	3	0.115%
41	Kerosene-Traditional Firewood Stove	2	0.113%
42	Traditional Charcoal Stove-Improved Firewood Stove	2	0.110%
43	Kerosene-Ethanol	3	0.098%
44	eCooking-Kerosene	1	0.089%

15	Improved Firewood Stove Only	25	1.364%
16	Traditional Charcoal Stove-LPG	32	1.283%
17	LPG-eCooking	23	1.241%
18	Kerosene Only	26	1.180%
19	Traditional Charcoal Stove-Traditional Firewood Stove	49	1.175%
20	LPG-Ethanol	21	1.134%
21	Improved Firewood Stove-Improved Charcoal Stove	21	1.119%
22	Other Only	14	0.785%
23	LPG-Improved Firewood Stove	14	0.762%
24	Traditional Firewood Stove-Other	12	0.727%
25	Improved Charcoal Stove-Kerosene	14	0.569%
26	Improved Firewood Stove-Traditional Charcoal Stove	12	0.503%
27	LPG-Other	8	0.487%
28	Traditional Firewood Stove-Kerosene	8	0.453%
29	Traditional Charcoal Stove-Kerosene	10	0.441%
30	Traditional Firewood Stove-Improved Firewood Stove	9	0.438%
45	Other-LPG	1	0.084%
46	Traditional Charcoal Stove-Ethanol	1	0.076%
47	Improved Firewood Stove-Kerosene	1	0.074%
48	Ethanol-Kerosene	2	0.064%
49	Traditional Firewood Stove-eCooking	1	0.055%
50	Improved Firewood Stove-Traditional Firewood Stove	1	0.053%
51	Ethanol-Traditional Firewood Stove	1	0.044%
52	Other-Traditional Firewood Stove	1	0.044%
53	Other-Improved Firewood Stove	1	0.044%
54	Ethanol-Traditional Charcoal Stoves	1	0.043%
55	Kerosene-Others	1	0.043%
56	Improved Charcoal Stove-Ethanol	1	0.043%
57	Improved Charcoal Stove-eCooking	4	0.043%
58	Kerosene-LPG	1	0.039%
59	No Cooking Solution (Eats Out)	1	0.032%
60	Ethanol-LPG	1	0.031%
61	Improved Charcoal Stove-Traditional Charcoal Stove	1	0.001%

3.2 Modelling eCooking Transitions

Modelling households' transitions to eCooking is built on the eCooking Baseline Study, which considers the following solutions as earlier discussed:

1. Ethanol Based Solutions (Ethanol Stove + Ethanol Fuel)
2. Kerosene Based Solutions (Kerosene Stove + Kerosene)
3. Improved Charcoal Stoves Solutions (Improved Charcoal Stove +Charcoal)
4. Traditional Charcoal Stoves Solutions (Metallic Charcoal Stove + Charcoal)
5. Traditional Firewood Stoves Solutions (Three Stone Open Fire + Firewood)
6. Improved Firewood Stoves Solutions (Improved Firewood Stove + Firewood)
7. Liquified Petroleum Gas (LPG) Solutions (LPG Stove +LPG)
8. eCooking Solutions (eCooking Appliances + Electricity)
9. Others

The eCooking transitions are modelled based on the medium-term period of 5 years (2024-2028) in line with the government of Kenya's target of achieving universal access to clean cooking by 2028.

3.2.1 Assessing the eCooking Capacity

The assessment of households' eCooking potential is based on the supply side of household electricity systems. The objective of the assessment is to assess the ability of the current household electricity system in supporting eCooking. However, eCooking potential is adjusted for the influence of demand side factors to derive effective eCooking potential that is used in modelling eCooking transitions.

eCooking potential in the Kenya National eCooking Strategy is based on the Multi-Tier Framework (MTF) approach as developed in Bhatia and Angelou (2015) and the MTF operationalization guideline outlined in World Bank and World Health Organization (2021). The MTF approach measures households' access to electricity based on the 7 attributes of capacity, availability, reliability, quality, affordability, formality, and health and safety[9]. The MTF assigns a tier classification for each of the seven attributes independently. Tier 0 is the lowest applicable tier, representing no access, and Tier 5 is the highest classification, representing full service. Each household is then assigned an overall tier classification that corresponds to the lowest tier of all seven, which can then be averaged over the population or subpopulations of interest.

Guided by the MTF overall tier assignment criteria, the eCooking Baseline Study set the threshhold for eCooking potential as MTF Tier 3 and above (henceforth, MTF Tier 3+) to ensure that all households classified as potential eCooking households have access to household electricity that has the capacity to power all cooking appliances. Specifically, the MTF attribute of capacity measures the ability of the household electricity system to provide sufficient electricity to operate different appliances, ranging from a few watts for light-emitting diode (LED) lights and mobile phone chargers to several thousand watts for space heaters or air conditioners. Tier 3 is the lowest capacity tier that can power eCooking appliances such as electric pressure cooker, rice cooker, microwave, toasters among others (see World Bank and World Health Organization, 2021). It is worth noting that households with access to grid and mini-grid electricity systems are all assigned capacity tier 5, implying that they can power all eCooking appliances. Households with other electricity systems such as solar home systems, generators, and rechargeable batteries are assigned capacity tiers depending on the ability of the electricity system to power electric appliances (see Onsongo et al, 2023).

However, the assessment of eCooking potential in the Study is based on the overall tier. The implication is that a household may have access to grid and mini-grid electricity systems, which have tier 5 capacity and can power all electric appliance, but have availability tier 2, resulting in classification of such households under tier 2 access, and as such assessed as lacking access to electricity that can support eCooking. In summary, MTF tier 3+ threshold for eCooking potential implies that potential eCooking households have access to electrcity with the following attribututes:

1. **Capacity:** households have access to electricity that can at least power the efficent eCooking appliances such as electric pressure cooker, rice cooker, microwave, toasters among others. All grid and mini-grid households meet this attribute.
2. **Availability:** households electricity is available for at least 8 hours in a day (24 hours period) and at least 3 hours in the evening period between 6 pm and 10 pm, considered as the peak hours for cooking.
3. **Reliability:** the frequency of unscheduled outages (blackouts) experienced by households is less than 9 per week and preferably the duration of the unscheduled outages (blackouts) is less than 2 hours per week.
4. **Quality:** households have not experienced fluctuations in electricity voltage that has damaged electric appliances in the past one year.
5. **Affordability:** households spend less than 5 percent of their monthly expendture on electricity bills.

[9] See Bhatia and Angelou (2015) and World Bank and World Health Organization (2021) for a comprehensive discusion of MTF, definitions, and measurement of MTF attributes; and the Kenya National eCooking Baseline Study (2023) for the definitions and measurements of MTF attributes in the context of Kenya.

6. **Formality:** households using grid and mini-grid electricity pay for electricity to the utility company. The implication is that households with informal connection are not included in the estimated eCooking potential.
7. **Safety and health:** household have not reported incidences of death and bodily injury directly caused by their electricity system. Further, household have no perception of high risk of incidences of death and bodily injury in future.

Based on these attributes, the eCooking Baseline Study estimated that 68.7 percent of households have access to electricity systems that can support transition to eCooking based on overall MTF 3+ criterion. Therefore, the supply side assessment of eCooking potential is estimated as 68.7 percent of the households as shown in Figure 3.2.

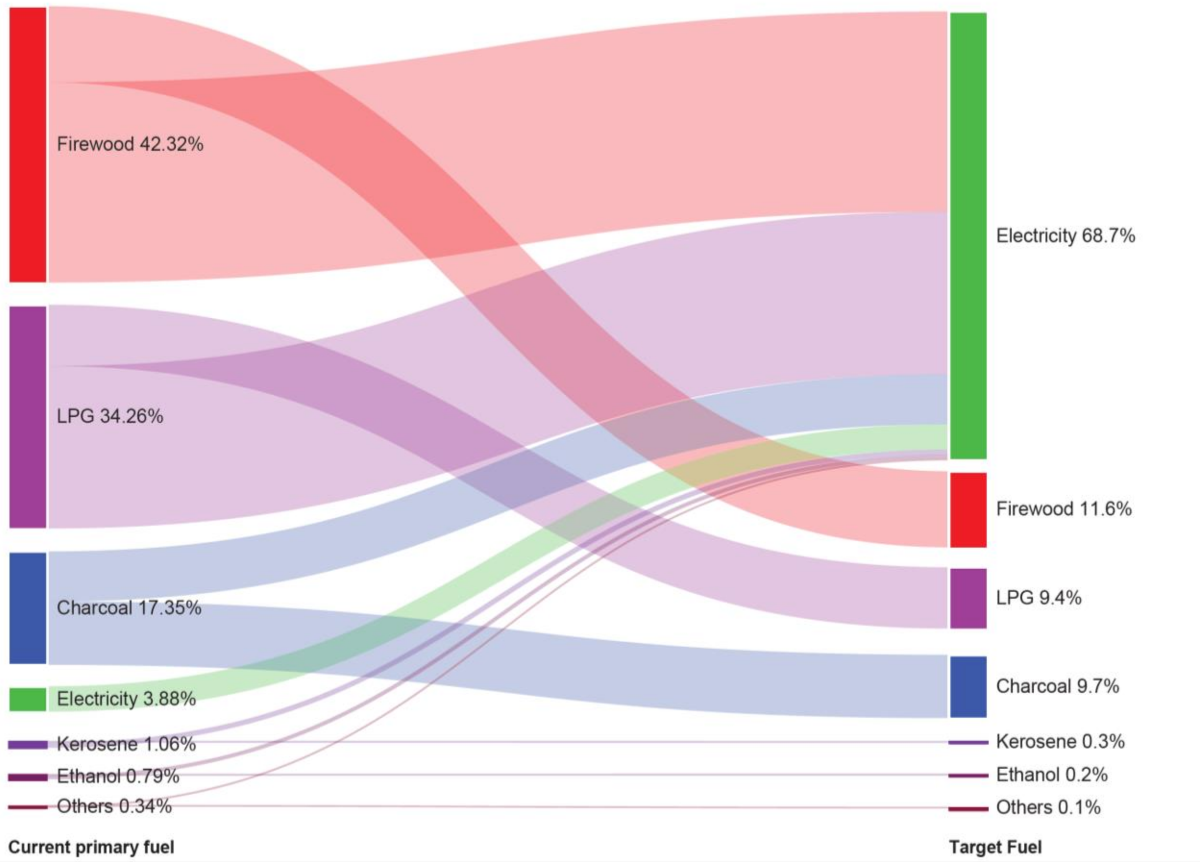


Figure 3.2: MTF Tier 3+ Supply Side Assessment of eCooking Potential

Table 3.3: Household connectivity statistics

Estimated Number of Households (KNeCS)	**13,814,794**
Household Connectivity Statistics:	
Grid Connection	76.5%
Mini-grid	2.6%
Solar Home Systems	13.3%
Rechargeable Battery	0.3%
Unconnected	7.3%
Household with MTF Tier 3+ Connection	**68.7%**

4. Using the BAR HAP Tool: Modelling eCooking Transitions

The household transition to eCooking is modelled using the Benefit of Action to Reduce Household Air Pollution (BAR-HAP) tool[10]. The BAR-HAP tool is an excel based tool developed by the World Health Organization (WHO) to assist stakeholders in the cooking energy sector calculate the costs and benefits of transitioning to various cleaner cooking options. The tool allows users examine the baseline fuel use situation, analyze one or multiple transition(s) to cleaner cooking fuels or technologies, as well as policy interventions to apply to the transition scenario(s). The tool incorporates evidence on the effectiveness of different interventions and on the demand for improved cooking solutions, for prediction of impacts from different interventions. The tool uses cost-benefit analysis following WHO advice on health economic analysis and evaluation[11].

4.1 The BAR HAP Tool – A Primer

Fuel and Technology Transitions in BAR-HAP Tool

The tool analyzes transitions from more polluting cooking solutions to cooking solutions that are either cleaner relative to polluting cooking solution or clean for health and environmental. However, the tool also models transition from LPG to electric cooking both of which are considered clean for health. In the context of BAR-HAP, transition to clean cooking solutions involved the transition to Biogas, LPG, Ethanol, and Electric (BLEE) cooking solutions. Clean cooking solutions are defined as cooking solutions that achieve substantial reductions in air pollution levels as defined by WHO guidelines on Indoor Household Air Pollution. It should be noted that while the guideline defines Biogas, LPG, Ethanol, Electricity, Natural Gas, Solar (BLEENS) as clean, the tool only considers BLEE. Additionally, the tool defines cleaner cooking solutions as solutions that provide some health and environment benefits relative to polluting cooking solutions but do not reach WHO Guidelines levels for clean cooking solutions. The cleaner solutions included in the tool are improved biomass stove with chimney, improved natural draft biomass stove, improved forced draft biomass stove, and improved forced draft biomass stove with pellets[12]. Figure 4.1 summarizes the 16 transitions considered in BAR-HAP tool.

[10] For comprehensive introduction to BAR-HAP tool see BAR-HAP user manual, journal article, and the references therein.

[11] Lauer, J.A., Morton, A., Culyer, A.J. and Chalkidou, K., 2020. What Counts in Economic Evaluations in Health? Benefit-cost Analysis Compared to Other Forms of Economic Evaluations

[12] For comprehensive description of the improved cooking solution see the BAR-HAP user manual, journal article, and the references therein.

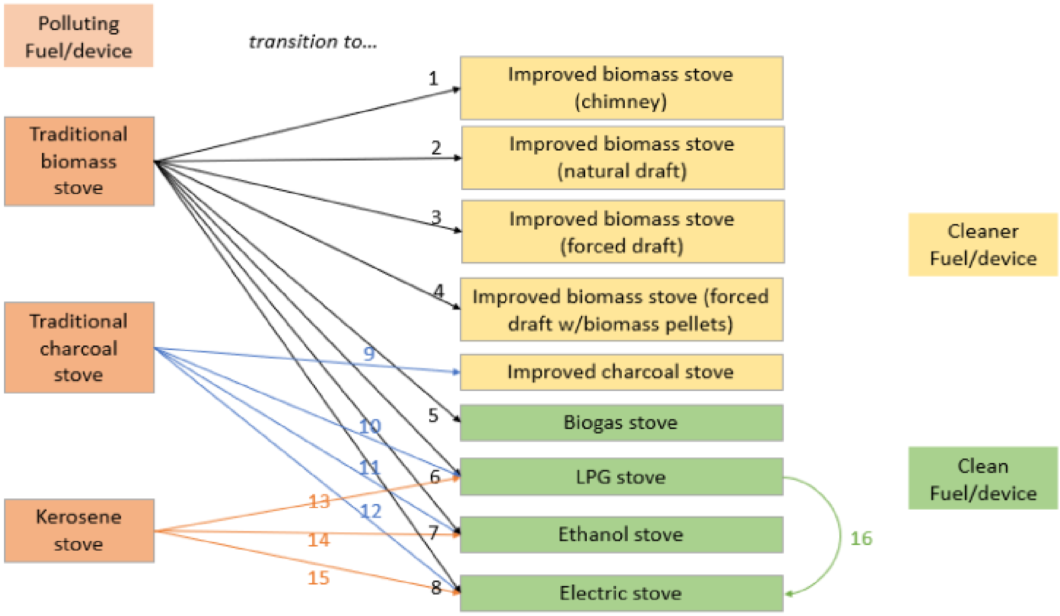


Figure 4.1 16 transitions considered in BAR-HAP tool Source: BAR-HAP user manual.

Policy Interventions in BAR-HAP to Accelerate Transitions

The tool provides for five policy interventions that include: Subsidy for stoves only; Subsidy for fuel (where fuel subsidy is only possible for biomass pellets, LPG, electricity and ethanol); Stove financing that would allow adopting households to spread payments for new technology over time; Behaviour Change Communication (BCC); and Technology ban. The tool allows for combination of Fuel Subsidy, Financing, and Intensive Behavior Change communication with stove subsidy. Figure 4.2 summarizes the possible policy interventions in BAR-HAP.

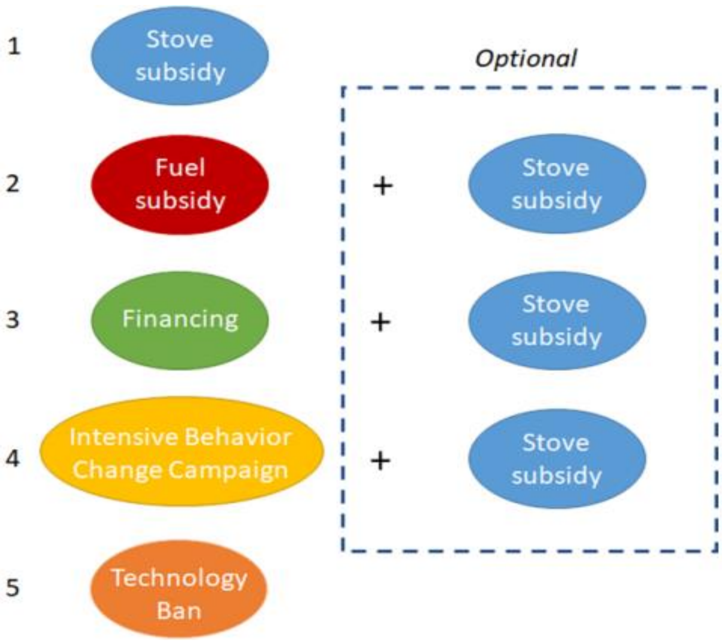


Figure 4.2 Possible policy interventions in BAR-HAP Source: BAR-HAP user manual

Cost Benefits Analysis in BAR-HAP Tool

The tool analyzes the Costs and Benefits of various clean cooking transitions based on the intervention implemented to influence transitions. Table 4.1 below defines the costs and benefits considered in BAR-HAP tool.

Table 4.1 Costs and benefits considered in BAR-HAP tool. Source: BAR-HAP user manual.

Costs	
1. Government subsidy costs (i) Stove subsidy cost (ii) Fuel subsidy (iii) Program costs	2. Private costs (i) Stove cost (ii) Fuel cost, pecuniary and non-pecuniary, e.g., collection time cost (iii) Maintenance cost (iv) Learning costs
Benefits	
1. Private health benefits (i) Morbidity reductions of chronic obstructive pulmonary disease (COPD) (ii) Mortality reductions of COPD (iii) Morbidity reductions of acute lower respiratory infections (ALRI) (iv) Mortality reductions of ALRI (v) Morbidity reductions of ischemic heart disease (IHD) (vi) Mortality reductions of IHD (vii) Morbidity reductions of lung cancer (LC) (viii) Mortality reductions of LC (ix) Morbidity reductions of stroke (x) Mortality reductions of stroke	2. Social health benefits (incorporating HAP contribution to ambient air pollution (AAP)) (i) Morbidity reductions of COPD, ALRI, IHD, LC and stroke – using social discount rate and accounting for health spillovers (ii) Mortality reductions of COPD, ALRI, IHD, LC and stroke – using social discount rate and accounting for health spillovers
3. Time savings	4. Basic (Kyoto-protocol gases) and full (with additional pollutants) climate benefits
5. Other environmental benefits (sustainability of biomass harvesting)	

Some considerations based on the eCooking Study

- **Analysis of eCooking Transitions:** Although the BAR-HAP tool analyzes multiple cooking from polluting cooking solutions to both cleaner and clean cooking solution, this analysis focuses on transitions to eCooking solutions. The analysis is built on the 2023 Kenya National eCooking Baseline Study (KNeCS) which provides the baseline for household cooking sector indicators.

- **Cooking Solutions:** The transition to eCooking is analyzed on the basis of three mutually exclusive households cooking solution(s) use patterns. These patterns are (1) households have only one cooking solution (2) Primary cooking solution in households that have a stack of two cooking solutions, (3) secondary cooking solution in households that have a stack of two cooking solutions.

- **Calculating cooking energy demand:** To account for stacking, household cooking energy demand is considered by analyzing the household's monthly fuel consumption and factoring in the efficiency of the cookstove. Stacking is proxied by share of energy use contributed by both primary and secondary solutions. The energy shares are computed as follows:

$$Use\ of\ Primary\ Solution = \frac{Useful\ Energy\ (Primary\ solution)}{Total\ Household\ Useful\ Energy\ (Priamry\ Solution+Secondary\ Solution)}$$

$$Use\ of\ Secondary\ Solution = \frac{Useful\ Energy\ (Secondary\ solution)}{Total\ Household\ Useful\ Energy\ (Priamry\ Solution + Secondary\ Solution)}$$

Where:

$$useful\ Energy = Fuel\ Energy\ Content\ \times Stove\ Efficiency$$

The fuel energy content and stoves efficiency data are based on BAR-HAP tool and the references thein.

4.2 BAR-HAP Transition Analysis Results

The BAR-HAP tool is used to assess the costs and benefits associated with three indicative eCooking transition scenarios. These are the Baseline scenario that is based on targeted interventions, a speculative scenario based on potential cooking sector programs, and an experimental eCooking tariff scenario.

4.2.1 Baseline eCooking Transition Scenario

Interventions for the Baseline eCooking Scenario

The baseline scenario models households' transition from baseline cooking solutions to eCooking as driven by policy interventions. Using the BAR-HAP tool, transition pathways are mapped out, guided by the evidence on effectiveness of interventions and the demand for eCooking. The tool predicts potential transitions to eCooking from policy interventions, and also the corresponding cost and benefits. The policy interventions considered are: behaviour change communication (BCC), stove subsidy, financing, tax waivers, and subsidy on tariff.

In the baseline scenario, eCooking transitions are influenced by household profiles such as access to tier 3+ electricity, the willingness to transition to eCooking, and wealth quintiles. As a result, policy interventions are precisely tailored to these specific criteria.

- **Behaviour Change Communication (BCC):** this intervention targets households that have the potential to transition to eCooking (i.e. they have MTF tier 3+ access to electricity) but are currently not willing to transition. These households are targeted by the BCC program that is assumed to run for a period of 2 years. In line with the BAR-HAP tool, it is assumed that BCC has an effective rate of 10 percent (see Das, et al., 2021).
- **Stove Subsidy:** this intervention is designed to target the households classified under the poor wealth quintile and willing to transition to eCooking. The intervention is based on the assumption of a subsidy of 80 percent of the cost of eCooking stove. The stove subsidy program is further assumed to run for a period of 3 years.
- **Financing:** this intervention targets households classified under the lower middle wealth quintile and the middle wealth quintile and are willing to transition. The intervention is based on the assumption that these households may have the capacity to buy eCooking stoves through installment payments. The financing program is assumed to run for the entire period of the strategy (5 years). Financing is assumed to increase the demand by 60 percent.
- **Tax Waiver:** this intervention is assumed to target households classified under the upper middle wealth quintile and wealthy quintile that are willing to transition. This intervention assumes a waiver on the Value Added Tax (VAT) and the import duty. The tax waiver program is assumed to run for a period of 2 years.

The estimated households eCooking transitions and estimated costs and benefits are based on the BAR-HAP tool are presented table below. The indicative government costs for implementing the interventions and the potential costs to the households occasioned by a shift to eCooking. Additionally, it highlights several benefits associated with this transition, encompassing potential fuel expenditure savings, health benefits, environmental benefits, and time savings.

Households fall into two categories: those with a single cooking solution and those stacking two cooking solutions. The transition assumes that households with a single cooking solution will exclusively use electricity for cooking post-transition. Among the stacking households, eCooking will account for 61 percent of household cooking energy demand post transition for household using eCooking as primary solution and 39 percent of households' energy demand for households using eCooking as a secondary solution in stack of two[13]. In addition, the estimations rely on BAR-HAP default assumptions[14] but also incorporate specific estimates from the eCooking Baseline Study regarding baseline fuel distribution, stove, and fuel costs. For example, the cost estimation for eCooking stoves is set at USD 83.95, derived from the average cost of a pressure cooker and induction stove outlined in the Study. The electricity cost is approximated at USD 0.183 per kilowatt-hour, based on the domestic lifeline 100 tariff band prevailing at the time of analysis. Further, the expenses incurred during the transition are shared between the government and households, depending on the nature of the intervention.

The BAR-HAP estimation shows that implementing targeted interventions is likely to result in 10.8 percent of the households transitioning to eCooking, as presented in Table 4.2.

Table 4.2 Estimated eCooking prevalence in 2028 based on the Baseline Scenario

Interventions	Targeted Households	Proportion of Targeted Households	One Solution	Primary Solution	Secondary Solution	Prevalence
Behaviour Change Communication (BCC)	2,897,862	21.0%	0.70%	0.80%	0.10%	1.60%
Stove Subsidy	1,049,833	7.6%	0.50%	0.30%	0.00%	0.80%
Financing program	2,471,754	17.9%	0.60%	2.90%	0.00%	3.50%
Tax Waiver	3,087,451	22.3%	1.20%	2.30%	0.10%	3.60%
Baseline Prevalence			0.13%	0.11%	1.02%	1.26%
Total Prevalence	**9,506,900**	**68.8%**	**3.13%**	**6.41%**	**1.22%**	**10.76%**

Cost-Benefit Analysis of the Baseline eCooking Scenario

Table 4.3 presents the overall costs and benefits of the eCooking Transition scenario, while Table 4.4 disaggregates these costs based on interventions. This transition is associated with households' savings in fuel expenditure over the 5-year analysis period. The health benefits would include more than 1213 lives saved. Other additional benefits outlined in the table include unsustainable wood harvest, and time savings by households. Equally, the transition would make a significant reduction in greenhouse gas emissions. The table summaries the various physical and financial impacts of the transition in monetary terms. The social benefits from avoided time spent cooking are significant, reflecting mainly time savings using an EPC and induction stove, and the opportunity cost for peoples' time, as used in BAR-HAP. Health benefits are also

[13] This estimate is based on energy shares computed from the 2023 eCooking Baseline Study data.

[14] For a comprehensive review of the more than 300 BAR-HAP assumption inputs see World Health Organization (2021) and Das, et al.,(2021).

considerable, mainly associated with the lives saved. The scenario has very significant net social benefit overall, based on the WHO's physical impact and impact monetisation methodologies.

Table 4.3 Overall costs and benefits of the eCooking Transition scenario

			Baseline eCooking Scenario	
Category	**Item**	**Unit of Measure**	**One Cooking Solution (BCC, Financing, Subsidy, Tax waiver)**	**Two Cooking Solutions (BCC, Financing, Subsidy, Tax waiver)**
Government Costs	Government costs	USD	-70,771,316.52	-70,771,316.52
	Program implementation costs	USD	-6,284,821.35	-9,521,538.86
	Stove subsidy costs	USD	-12,379,594.75	-15,954,378.11
	Fuel subsidy costs	USD		
Private Costs	Fuel Cost	USD		
	Stove costs	USD	5,673,825.39	9,913,650.88
	Maintenance & learning	USD	1,300,831.36	1,957,637.12
Cost of Fuel Benefit	Saving on Cost of Fuel/Change in Fuel Cost	USD	-19,834,927.32	-1,676,769.19
Health Benefits	Health Impact Total: DALYS Avoided	DALYS	17,677.80	22,418.90
	Mortality Reduction	YLL	6,478.60	17,397.20
	Mortality Reduction	Lives	388.00	1,050.00
	Morbidity Reduction	YLD	2,757.00	7,410.90
	Morbidity Reduction	Cases	14,523.00	38,926.00
Impact on Drudgery	Average time savings (adopting household)	HOURS	1,918.50	1,688.60
Environmental Benefit	CO2-equivalent reduction (CO2, N2O, CH4, CO, OC, BC) in Tonnes	TONNES	5,043,776.00	7,062,279.00
	Unsustainable wood harvest avoided	KGS	398,675,421.00	1,167,402,580.00
	Net Present Value of Social Benefits (Full Program)	**USD**	82,091,069.68	159,607,378.51

Table 4.4 Costs disaggregated by intervention

Item		Baseline Scenario		
		Unit of Measure	**One Cooking Solution**	**Two Cooking Solutions**
Behaviour Change Communication (BCC)				
Government Costs	Government/Admin Costs	USD	-11,310,314.24	-11,310,314.24
	Program Implementation Cost	USD	-1,612,113.66	-2,313,005.29
	Stove Subsidy Cost	USD	-1,303,244.63	-1,869,850.61
	Total Government Cost	**USD**	-1,612,113.66	-2,313,005.29

Private Costs	Fuel Cost (After Subsidy)	USD	0	0
	Stove Cost (After Subsidy)	USD	-3,688,497.40	-5,284,037.74
	Maintenance Cost	USD	-804,252.06	-987,864.3171
	Total Private Costs	**USD**		
Financing Program				
Government Costs	Government/Admin Costs	USD	-29,217,786.94	-29,217,786.94
	Program Implementation Cost	USD	-2,910,063.61	-4,322,997.91
	Stove Subsidy Cost	USD	-4,670,438.11	-6,938,093.78
	Total Government Costs	**USD**	-7,580,501.72	-11,261,091.69
Private Costs	Fuel Cost (After Subsidy)	USD	0	0
	Stove Cost (After Subsidy)	USD	-11,618,549.71	-17,216,209.26
	Maintenance Cost	USD	-1,902,165.12	-2,555,147.176
	Total Private Cost	**USD**		
Subsidy Program				
Government Costs	Government/Admin Costs	USD	-19,259,854.04	-19,259,854.04
	Program Implementation Cost	USD	-1,133,674.67	-941,789.46
	Stove Subsidy Cost	USD	-5,598,352.28	-4,650,777.93
	Total Government Cost	**USD**	-6,732,026.95	-5,592,567.39
Private Costs	Fuel Cost (After Subsidy)	USD	0	-19,259,854.04
	Stove Cost (After Subsidy)	USD	-1,084,858.237	-941,789.4558
	Maintenance Cost	USD	-752,962.924	-4,650,777.93
	Total Private Cost	**USD**		
Tax Waiver				
Government Costs	Government/Admin Costs	USD	-10,983,361.31	-10,983,361.31
	Program Implementation Cost	USD	-628,969.41	-1,943,746.20
	Stove Subsidy Cost	USD	-807,559.73	-2,495,655.79
	Total Government Cost	**USD**	-1,436,529.14	-4,439,401.99
Private Costs	Fuel Cost (After Subsidy)	USD	0	0
	Stove Cost (After Subsidy)	USD	-2,288,494.674	-7,062,668.989
	Maintenance Cost	USD	-534,569.3428	-1,555,355.023
	Total Private Cost	**USD**		

4.2.2 Speculative scenario - Planned interventions

The speculative scenario is constructed based on the anticipated developments within the cooking sector. This encompasses various elements such as Kenya Power announcements, Burn Manufacturing plans, and the emergence of carbon markets. These expected developments are modelled in the following manner:

- **Kenya Power Press Release:** In this part of the speculative scenario, we're building upon Kenya Power's initiative to transition 500,000 households to primary eCooking within three years. Our assumption here is that this plan will take a financing structure akin to the ongoing Kenya Power pilot program with PowerPay.

- **Burn Manufacturing Plans:** We're incorporating Burn Manufacturing's strategy to distribute 3 million appliances across East Africa by 2026 into our model. This plan involves selling appliances through a "pay as you cook" financing model, where households gain ownership of the appliance after a year of payments. This approach utilizes Internet of Things (IoT) technology, aiming to leverage the carbon credit market. This will influence eCooking transition through reduction in cost of appliances and financing.
- **Carbon Financing Project:** The potential carbon credit market development for 1 million appliances is expected to impact eCooking transitions by potentially subsidizing the cost of these appliances (and potentially tariffs too).
- **Result-Based Financing (RBF) program:** Likewise, result-based financing influences the demand for cookstoves by lowering their prices.

To delve into the potential impact of these upcoming sector programs, we're operating under certain assumptions. These programs are expected to affect eCooking transitions by providing financing and subsidizing the cost of eCooking appliances. Our assumption is that these initiatives will cut the appliance cost by 50 percent. Expanding upon the anticipated interventions, here is the quantified contribution we foresee from the sector programs:

Potential Additions	No. of households
KPLC	500,000
Burn Manufacturing (assume 1/3 will be in Kenya)	1,000,000
Carbon Markets	1,000,000
Increase in Potential Market	**2,500,000**
Current Potential Market	**9,506,900**
Potential contribution of sector programs	**26.3%**

Interventions for the 'Planned Interventions Scenario'

Assuming the implementation of these planned interventions, we anticipate that the percentage of households using eCooking in 2028 will be 16.5%.

Table 4.5 Estimated eCooking prevalence in 2028 based on the Planned Interventions Scenario

Speculative Scenario - Planned interventions				
Interventions	**One Solution**	**Primary Solution**	**Secondary Solution**	**Prevalence**
Behaviour Change Communication, Tax Waiver, Cooking Sector Programs.	1.90%	2.10%	0.20%	4.20%
Financing, Tax Waiver, and Cooking Sector programs	3.60%	7.00%	0.40%	11.00%
Baseline Prevalence	0.13%	0.11%	1.02%	1.26%
Total Prevalence				**16.46%**

Cost-Benefit Analysis of the Planned Interventions Scenario

Table 4.6 Overall costs and benefits of the Speculative scenario - Planned Interventions

	Planned Interventions Scenario

Category	Item	Unit of Measure	One Cooking Solution	Two Cooking Solutions
Government Costs	Government costs	USD	-79,701,650.36	-79,936,603.22
	Program implementation costs	USD	-11,689,690.70	-19,349,347.28
	Stove subsidy costs	USD	-38,858,753.45	-66,341,332.88
	Fuel subsidy costs	USD	-	-
Private Costs	Fuel Cost	USD	-	-
	Stove costs	USD	-12,207,470.73	-20,608,911.71
	Maintenance & learning	USD	-7,367,871.30	-11,675,295.88
Cost of Fuel Benefit	Saving on Cost of Fuel/Change in Fuel Cost	USD	-61,911,311.64	-282,726,927.03
Health Benefits	Health Impact Total: DALYS Avoided	DALYS	36,550.60	49,253.90
	Mortality Reduction	YLL	23,340.10	36,088.10
	Mortality Reduction	Lives	1,403.00	2,175.00
	Morbidity Reduction	YLD	9,953.50	15,370.80
	Morbidity Reduction	Cases	22,346.00	80,790.00
	Average time savings (adopting household)	HOURS	1,923.10	1,702.30
Environmental Benefit	CO2-equivalent reduction (CO2, N2O, CH4, CO, OC, BC) in Tonnes	TONNES	9,271,274.00	14,585,769.00
	Unsustainable wood harvest avoided	KGS	1,935,159,201.00	2,960,638,784.00
	Net Present Value of Social Benefits (Full Program)	**USD**	**178,419,468.78**	**118,865,422.70**

Table 4.7 Cost and benefits disaggregated by intervention for the Speculative scenario - Planned Interventions

Planned Interventions Scenario				
Item		**Unit of Measure**	**One Cooking Solution**	**Two Cooking Solutions**
Behaviour Change Communication (BCC)				
Government Costs	Government/Admin Costs	USD	-13,837,772	-13,876,479
	Program Implementation Cost	USD	-3,808,107	-5,558,036
	Stove Subsidy Cost	USD	-8,998,699	-13,133,845
	Total Government Cost (Implementation Costs)	**USD**	-3,808,107	-5,558,036
Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-2,787,724	-4,055,881
	Maintenance Cost	USD	-1,873,705	-2,393,629
	Total Private Costs	**USD**		
Financing Program				
Government Costs	Government/Admin Costs	USD	-33,054,498	-33,054,498
	Program Implementation Cost	USD	-4,903,884	-7,437,749
	Stove Subsidy Cost	USD	-18,404,564	-27,914,308
	Total Government Cost (Implementation Costs)	**USD**	-23,308,448	-35,352,057

Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-6,248,268	-9,418,318
	Maintenance Cost	USD	-3,197,603	-4,419,489
	Total Private Cost	**USD**		
Subsidy Program				
Government Costs	Government/Admin Costs	USD	-19,259,854	-19,456,100
	Program Implementation Cost	USD	-1,417,555	-1,221,662
	Stove Subsidy Cost	USD	-5,600,176	-6,032,855
	Total Government Cost (Implementation Costs)	**USD**	-7,017,731	-7,254,518
Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-1,347,688	-1,155,410
	Maintenance Cost	USD	-973,444	-678,083
	Total Private Cost	**USD**		
Tax Waiver				
Government Costs	Government/Admin Costs	USD	-13,549,526	-13,549,526
	Program Implementation Cost	USD	-1,560,145	-5,131,901
	Stove Subsidy Cost	USD	-5,855,315	-19,260,325
	Total Government Cost (Implementation Costs)	**USD**	-1,560,145	-5,131,901
Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-1,823,792	-5,979,302
	Maintenance Cost	USD	-1,323,120	-4,184,095
	Total Private Cost	**USD**		

4.2.3 Experimental eCooking Tariff speculative scenario

We investigate the possibility of experimenting with a dedicated eCooking tariff. Specifically, we have contemplated a 50% reduction in household electricity tariff on the Domestic Ordinary Band 30-100kWh, where majority of eCooking households would fall. However, it is important to note that this scenario is distinct and separate from the other potential eCooking sector programs being considered.

Interventions for the 'eCooking Tariff Scenario'

We estimate that the percentage of households using eCooking in 2028 will be 17.06% with a halved tariff.

Table 4.8 Estimated eCooking prevalence in 2028 based on the Experimental Tariff Scenario

Experimental Tariff Scenario

Intervention	One Solution	Primary Solution	Secondary Solution	Prevalence
Experimental Tariff, Tax Waiver, and Cooking Sector Programs	5.80%	9.40%	0.60%	15.80%
Baseline Prevalence	0.13%	0.11%	1.02%	1.26%
Total Prevalence				**17.06%**

Cost-Benefit Analysis of the Experimental Tariff scenario

Table 4.9 Cost and benefits disaggregated by intervention for the Experimental Tariff Scenario

Experimental Tariff scenario				
Category	**Item**	**Unit of Measure**	**One Cooking Solution**	**Two Cooking Solutions**
Government Costs	Government costs	USD	-79,876,484.82	-79,740,357.17
	Program implementation costs	USD	-11,733,966.45	-19,516,758.16
	Stove subsidy costs	USD	-40,363,422.61	-67,204,181.24
	Fuel subsidy costs	USD	-196,973,881.19	-291,120,311.99
Private Costs	Fuel Cost	USD	-	-
	Stove costs	USD	-12,264,889.65	-20,772,285.31
	Maintenance & learning	USD	-7,381,367.80	-11,916,180.35
Cost of Fuel Benefit	Saving on Cost of Fuel/Change in Fuel Cost	USD	-196,973,881.19	-291,120,311.99
Health Benefits	Health Impact Total: DALYS Avoided	DALYS	36,720.40	49,683.80
	Mortality Reduction	YLL	23,374.70	36,876.20
	Mortality Reduction	Lives	1,403.00	2,222.00
	Morbidity Reduction	YLD	9,967.30	15,706.50
	Morbidity Reduction	Cases	51,647.00	82,564.00
	Average time savings (adopting household)	HOURS	1,920.90	1,770.10
Environmental Benefit	CO2-equivalent reduction (CO2, N2O, CH4, CO, OC, BC) in Tonnes	TONNES	9,288,180.00	14,882,535.00
	Unsustainable wood harvest avoided	KGS	1,938,660,145.00	3,028,781,583.00
	Net Present Value of Social Benefits (Full Program)	**USD**	**42,165,206.05**	**121,736,099.29**

Table 4.10 Cost and benefits disaggregated by intervention for the Experimental Tariff Scenario

Experimental Tariff scenario				
Category	**Item**	**Unit of Measure**	**One Cooking Solution**	**Two Cooking Solutions**
Behaviour Change Communication (BCC)				
Government Costs	Government/Admin Costs	USD	-14,012,607	-13,876,479
	Program Implementation Cost	USD	-3,852,383	-5,552,066
	Stove Subsidy Cost	USD	-9,103,324	-13,119,737
	Tariff Subsidy Cost	USD	-52,017,478	-62,832,233
	Total Government Cost (Implementation Costs)	**USD**	-3,852,383	-5,552,066

Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-2,824,482	-4,051,434
	Maintenance Cost	USD	-1,887,201	-2,389,301
	Total Private Costs	**USD**		
Financing Program				
Government Costs	Government/Admin Costs	USD	-33,054,498	-33,054,498
	Program Implementation Cost	USD	-4,903,884	-7,405,326
	Stove Subsidy Cost	USD	-18,404,564	-27,792,625
	Tariff Subsidy Cost	USD	-83,815,087	-92,481,766
	Total Government Cost (Implementation Costs)	**USD**	-23,308,448	-35,197,952
Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-6,260,747	-9,378,930
	Maintenance Cost	USD	-3,197,603	-4,410,221
	Total Private Cost	**USD**		
Subsidy Program				
Government Costs	Government/Admin Costs	USD	-19,259,854	-19,259,854
	Program Implementation Cost	USD	-1,417,555	-1,412,559
	Stove Subsidy Cost	USD	-7,000,220	-6,975,550
	Tariff Subsidy Cost	USD	-22,457,779	-19,908,273
	Total Government Cost (Implementation Costs)	**USD**	-8,417,774	-8,388,109
Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-1,354,409	-1,344,777
	Maintenance Cost	USD	-973,444	-927,684
	Total Private Cost	**USD**		
Tax Waiver				
Government Costs	Government/Admin Costs	USD	-13,549,526	-13,549,526
	Program Implementation Cost	USD	-1,560,145	-5,146,807
	Stove Subsidy Cost	USD	-5,855,315	-19,316,269
	Tariff Subsidy Cost	USD	-38,683,537	-115,898,040
	Total Government Cost (Implementation Costs)	**USD**	-1,560,145	-5,146,807
Private Costs	Fuel Cost (After Subsidy)	USD	-	-
	Stove Cost (After Subsidy)	USD	-1,825,252	-5,997,144
	Maintenance Cost	USD	-1,323,120	-4,188,976
	Total Private Cost	**USD**		

4.3 Comparing the scenarios

The table below compiles the benefits of the three scenarios, combining the benefits accruing from households cooking primarily with electricity, and those who will be stacking eCooking and another solution. Table 4.11 below summarises the findings.

Table 4.11 Comparing the benefits of the baseline eCooking transition scenario against the two speculative scenarios

Benefit	Measure	Unit of Measure	Baseline Scenario (10.76% eCooking)	Speculative/ Planned Activities Scenario (16.46% eCooking)	Experimental Tariff (17.06% eCooking)
Health Benefits	Health Impact	DALYS avoided	40,096	85,804	86,404
	Mortality Reduction	YLL	23,875	59,428	60,250
	Mortality Reduction	Lives	1,438	3,578	3,625
	Morbidity Reduction	YLD	10,167	25,324	25,673
	Morbidity Reduction	Cases	53,449	103,136	134,211
Impact on Drudgery	Total Time savings	HOURS	126,152,393	282,276,403	285,934,508
	Average time savings (adopting household)	HOURS	3,607	3,625	3,691
Environmental Benefit	CO2-equivalent reduction (CO2, N2O, CH4, CO, OC, BC)	TONNES	12,106,055	23,857,043	24,170,715
	Unsustainable wood harvest avoided	KGS	1,566,078,001	4,895,797,985	4,967,441,728
	Net Present Value of Social Benefits (Full Program)	**USD**	**241,698,448**	**297,284,891**	**163,901,305**

The above comparative analysis shows that the experimental tariff scenario offers the highest benefits across various metrics, except for net present value (NPV). The lower NPV of the experimental tariff scenario is due to the substantial cost of subsidizing electricity as captured by the experimental tariff, estimated at USD 488,094,193.18 for the strategy period. However, when considering other metrics, the experimental tariff scenario still delivers the greatest benefit. For instance, in terms of Disability-Adjusted Life Years (DALY) avoided, it prevents more than twice the number of years that would be lost due to disease, disability, or premature death (86,404.4 compared to 40,096.70 for the baseline scenario). Similar trends are observed for other indicators such as years of life lost (YLL), years lived with disability or diseases (YLD), time savings, emissions reduction, and unsustainable wood harvest.

Despite the experimental tariff scenario offering the most benefits across various metrics, the speculative/planned activities scenario, based on the planned cooking sector activities like KPLC pronouncements, implementation of carbon credit projects, and ambitions of eCooking appliance manufacturers, could yield the highest NPV. However, other benefits are marginally lower than those of the experimental tariff scenario. On the other hand, the baseline scenario provides a more conservative prediction of the anticipated transition to eCooking, with lower costs and relatively lower impact on health, time savings, and the environment. It serves as a reference point for more ambitious initiatives within the cooking sector.

Summary of the Implications:

- If maximizing health benefits while achieving a balance with time savings and environmental benefits is the primary goal, both planned interventions and the experimental tariff scenario are comparable. However, implementing planned interventions might be more feasible due to the complexity of the experimental tariff implementation.

- If cost-effectiveness and a gradual approach are prioritised, the planned interventions scenario offers a good option, closely aligned with the experimental tariff scenario.
- The baseline eCooking scenario is a conservative option with lower costs and relatively lower impact on health, time savings, and the environment.

Ultimately, budget availability and potential grid impact (assuming no solar eCooking or battery-supported eCooking) would influence the choice of a transition option.

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