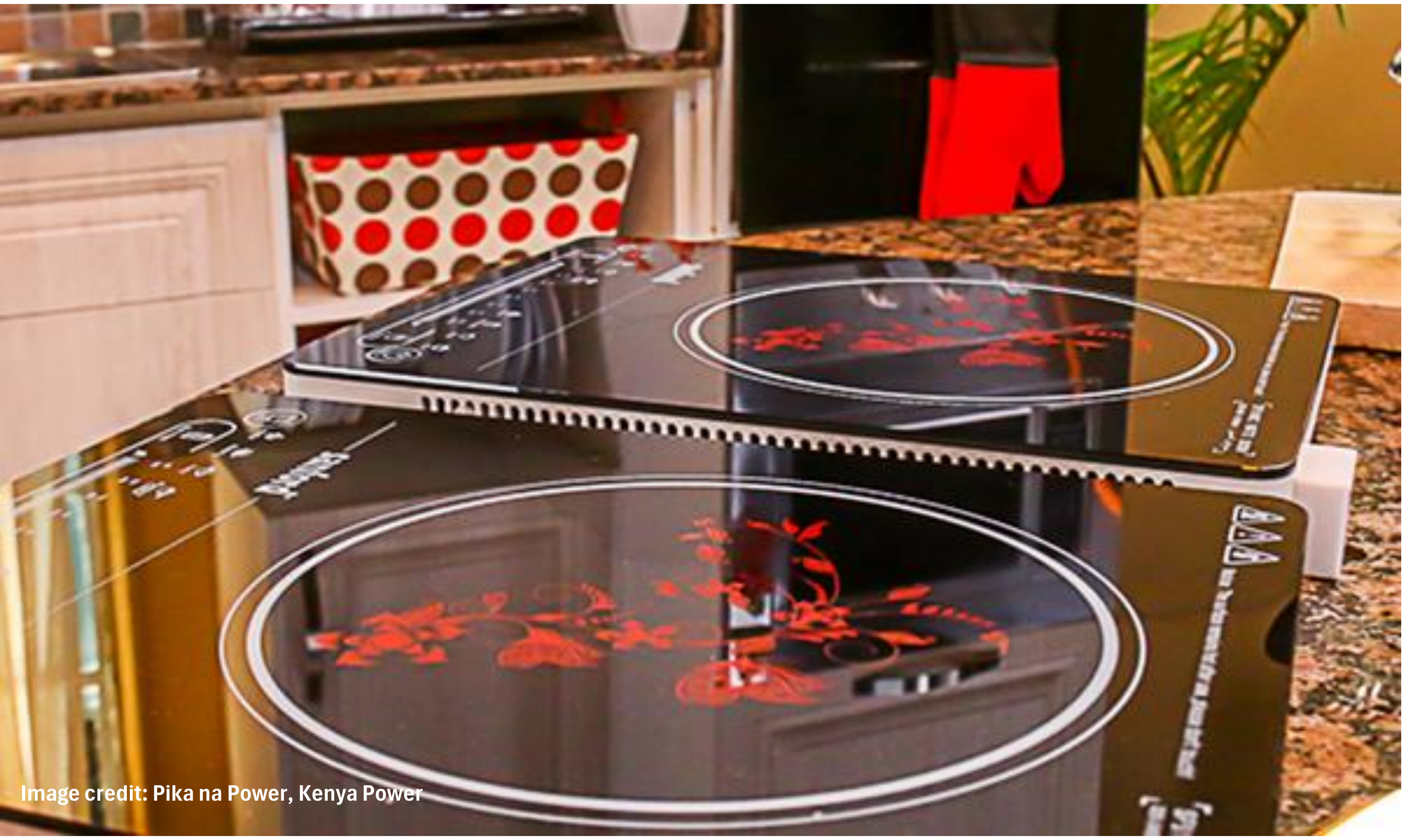
MINISTRY OF ENERGY AND PETROLEUM

REPUBLIC OF KENYA



Kenya National electric Cooking Strategy

MODELLING REPORT

15 July 2024

ACKNOWLEDGEMENTS

The Ministry of Energy and Petroleum (MoEP) is honoured to present the Modelling Report that informed the Kenya National eCooking Strategy (KNeCS). KNeCS was a collaborative effort between the MoEP through the Directorate of Renewable Energy and a consortium of development partners. The consortium comprised of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Agence Française de Développement (AfD), the UK Foreign and Commonwealth Development Office (FCDO) via the UK Partnering for Accelerated Climate Transitions (UK PACT), Climate Compatible Growth (CCG) and Modern Energy Cooking Services (MECS) programmes.

We would like to acknowledge the invaluable support accorded by the Technical Working Group (TWG), which played a pivotal role in overseeing the development of the KNeCS. The TWG was co-chaired by the Ministry of Energy and Petroleum (MoEP) and the Modern Energy Cooking Services (MECS) programme and comprised of representatives from various government ministries, non-governmental organisations, national institutions, the private sector, academia, sectoral associations and development partners.

We also would like to appreciate the Climate Compatible Growth programme for providing immense support in the modelling of the eCooking transition scenarios, and the respective impact of new eCooking demand. This work will support Kenya's energy planning process, both in the short term via the Medium-Term Plan, and longer term via the Least Cost Power Development Plan, by supporting the projection of demand growth from eCooking.

We are grateful to Nuvoni Centre for Innovation Research, who led the primary research, facilitated stakeholder input throughout the process and developed both the strategy itself and this report. MoEP, MECS and Nuvoni worked in partnership throughout the strategy development process to establish a space for co-creation amongst the key players in Kenya's emerging eCooking sector, from which the KNeCS was built. For a complete list of institutions who have contributed to the development of this strategy through the TWG and engagements with sector stakeholders, please see the KNeCS Appendix.

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1. Overview

Kenya has made significant progress in electrification, achieving a 75% coverage rate by 2022, primarily from renewable sources. Despite this, most Kenyans still rely on polluting fuels for cooking. The Kenya National eCooking Strategy aims to bridge this gap by promoting the adoption of electric cooking technologies. Developed with support from the Rapid Response Facility Consortium, this strategy complements the Kenya National Cooking Transitions Strategy (KNCTS) and sets ambitious targets to transition from traditional cooking methods to sustainable, modern eCooking solutions. This initiative is expected to improve public health, create jobs, promote gender equity, and reduce CO_2 emissions.

This document details the modelling approaches and findings used to inform the interventions within the eCooking Strategy. It utilises data collected during the KNeCS Baseline Study (2023), and is designed to explore key research questions that have emerged during the strategy development process.

The modelling effort for KNeCS utilised two major tools: Open Source energy Modelling SYStem (OSeMOSYS) and the Benefits of Action to Reduce Household Air Pollution (BAR-HAP) tool. OSeMOSYS is a comprehensive energy modelling tool used for scenario analysis. In this context, it was employed to forecast trends in energy demand and fuel shares between 2019 and 2050, producing insights from four scenarios: Business as Usual, Net Zero, Stated Policies, and the eCooking Transition. OSeMOSYS utilizes a bottom-up approach to simulate and analyse energy systems, considering various supply-side and demand-side factors to determine the most efficient energy mix. This approach is particularly relevant to the cooking sector as it helps in understanding the implications of shifting from traditional fuels to electric cooking, assessing the impact on grid capacity and energy demand.

The BAR-HAP (Benefits of Action to Reduce Household Air Pollution) tool was used to complement OSeMOSYS by modelling fuel stacking, transitions from traditional fuels to eCooking, and the associated costs and benefits. BAR-HAP provided detailed insights into the financial costs of adopting eCooking at both the household and the government's level, as well as the potential benefits in terms of time savings, improved public health, and reduced emissions.

While OSeMOSYS and BAR-HAP utilize different methodologies, they were used iteratively to identify the most feasible pathway for scaling eCooking in Kenya. OSeMOSYS focuses on the broader energy system and grid implications, whereas BAR-HAP delves into the detailed dynamics of household fuel use and its impacts. Together, these tools offered complementary insights, enabling a robust and comprehensive assessment of the potential for eCooking to contribute to Kenya's net zero targets and broader developmental goals.

Below is the outline of this report:

- ***Clean Cooking Scenario Modelling***: This section presents the outcomes from forecasting trends in energy demand and fuel shares using OSeMOSYS. Findings from four scenarios are analyzed.
- ***Impact of Scaling eCooking on the grid***: This section models the shifting generation mix and the ability of the system to meet new eCooking demand from the different scenarios.
- ***Modelling Stacking and eCooking Transitions***: This section assesses fuel stacking and attempts to quantify the potential impact of different eCooking interventions.
- ***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 the proposed eCooking transition scenario, and assesses some sensitivity scenarios.

2. Clean Cooking Scenario Modelling

2.1. Introduction

With the support of the Climate Compatible Growth (CCG) programme, 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 KNeCS Baseline Study (2023), enriched with insights from existing literature, industry reports, policy documents and stakeholder input. Specifically, the estimation considered stove type, fuel used, quantity of fuel purchased, and purchase frequency. However, many rural households reported obtaining firewood for free or producing their own charcoal. To address this, econometric modelling was used to estimate the quantities of firewood and charcoal for households that do not purchase these fuels. A regression model, incorporating variables such as age, gender, household size, education, wealth index, and urban-rural classification, was developed using data from households that do purchase firewood. This model predicted firewood and charcoal usage for all households. All fuel quantities were then converted to kilograms, with kerosene at 0.8 kg per litre and ethanol at 0.789 kg per litre. These were then converted into calorific values, expressed in joules, to standardize the energy units. The fuel consumption was adjusted for stove efficiencies to account for energy wasted during cooking and compute the useful energy estimates. The estimation yielded an aggregate annual national energy demand of 103.63 Petajoules, divided into 42.78 Petajoules for urban areas and 60.85 Petajoules for rural areas. This energy demand was then input into OSeMOSYS for further analysis. The estimated energy demand covered primary, secondary and tertiary cooking solutions.

The scenario modelling thus took into account the total energy consumption of households, including primary, secondary, and tertiary cooking solutions. 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.

2.2. Business as Usual Scenario

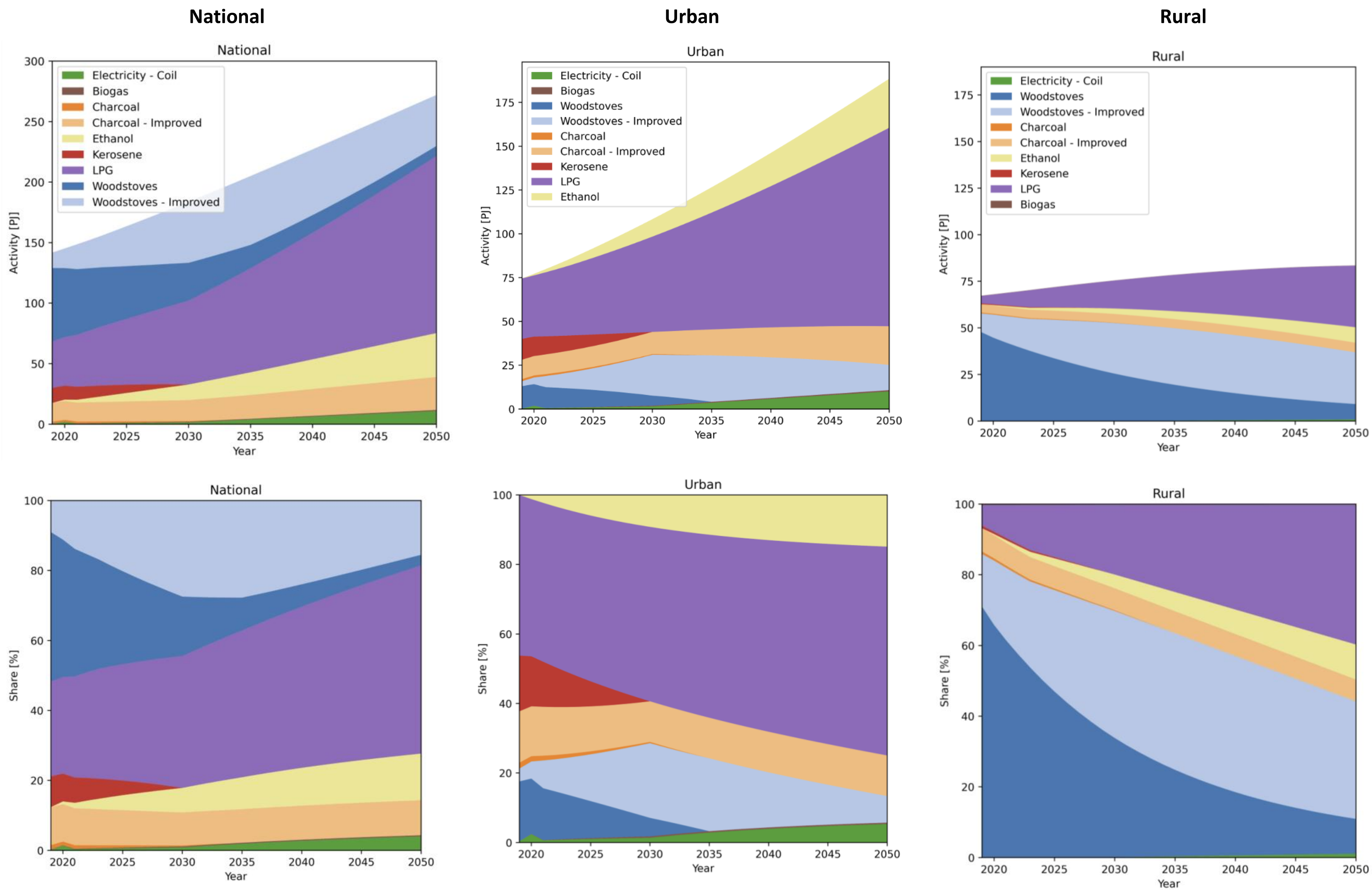
The term "Business as Usual" (BAU) typically refers to a scenario where current trends and policies continue without any significant changes. In the context of clean cooking as modelled using OSeMOSYS, the BAU scenario would model the energy demand and supply patterns assuming no major new policy interventions 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 KNeCS Baseline Study (2023) 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 2.1 for the model plots.

Figure 2.1 Business as Usual Scenario model results



In the business-as-usual scenario, there are identifiable 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.

2.3. 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[1]:

- 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 2.3 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 2.2 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% in 2019 to 30% in 2028, and further to 37% 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.

[1] Since the conclusion of this scenario modelling exercise, the Government of Kenya has shown increased commitment to eCooking through several new strategies and plans. These include the Kenya National Cooking Transitions Strategy, the Energy Transitions and Investment Plan, and the updated National Climate Change Action Plan. Notably, the development process of the Kenya National eCooking Strategy has directly influenced these documents.

- **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.

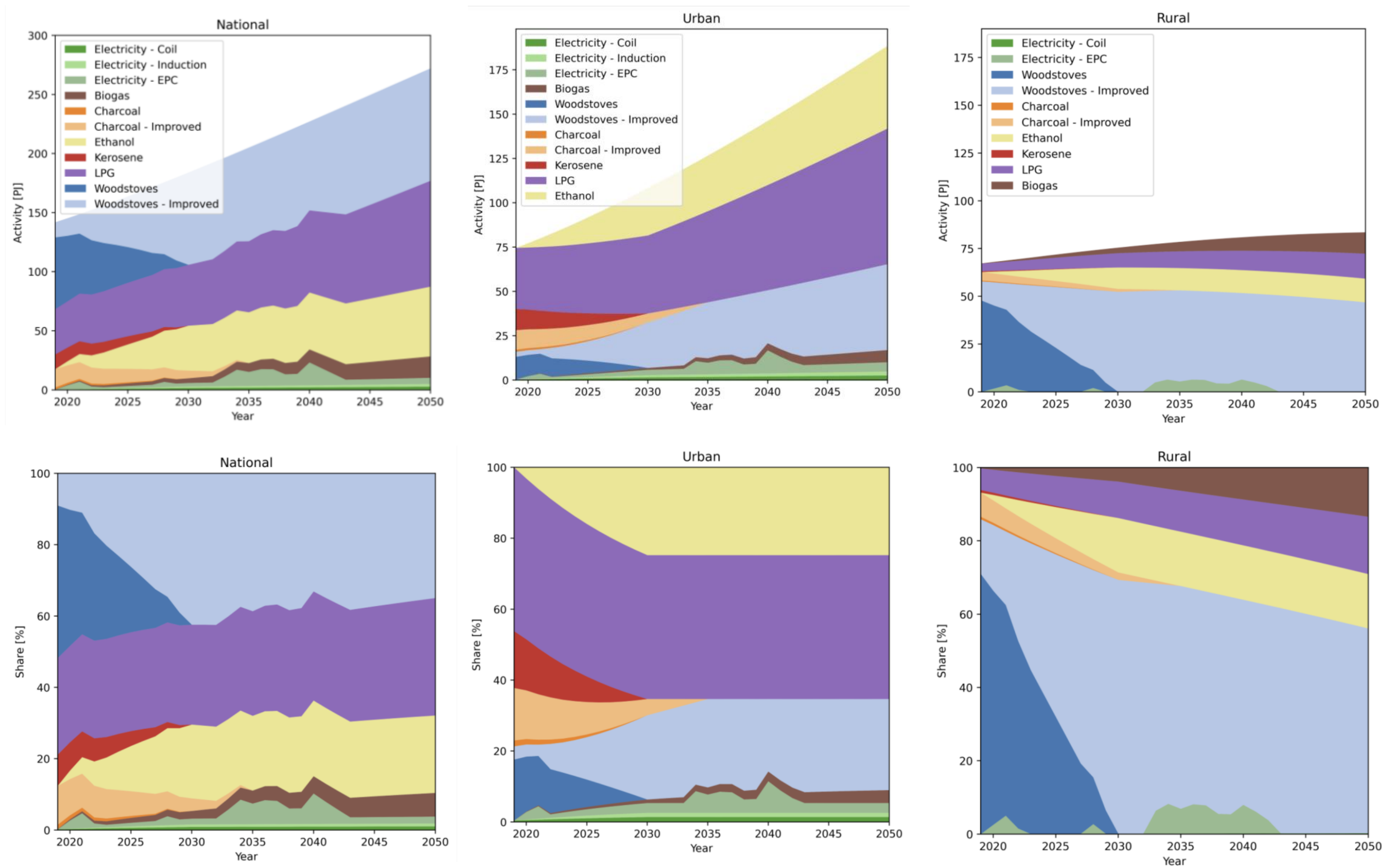
Decreasing Trends:

- **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 2.2 Stated Policies Scenario model findings

National **Urban** **Rural**



2.4. 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.

Two different Net Zero scenarios are considered:

- 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.

2.4.1. (Simulated) Net Zero

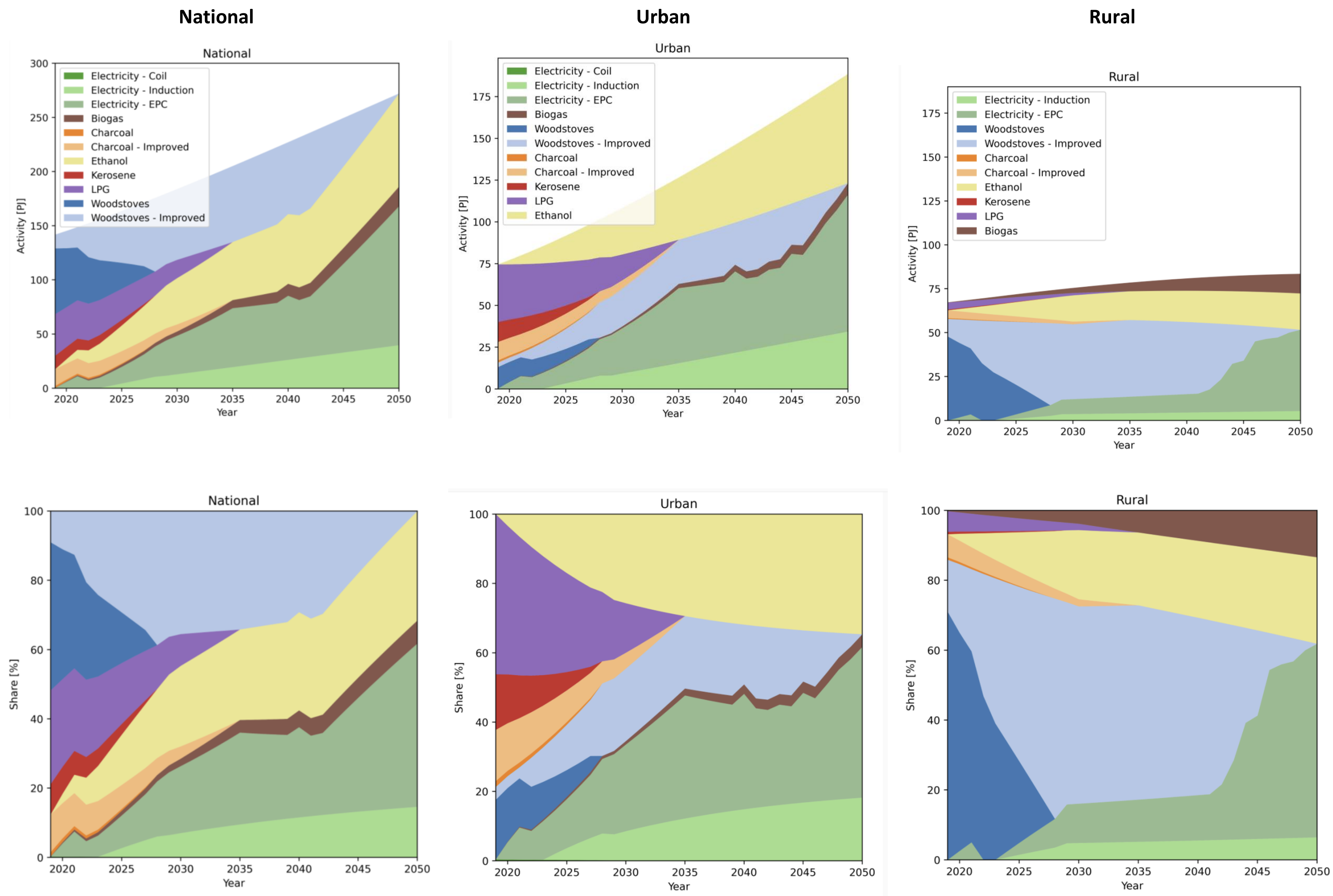
The simulated net-zero hypotheses are as follows:

- Emissions from BAU scenario are gradually reduced to zero by 2050.
- 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 (assumed by 2050) (Bio-energy strategy, 2020).
- 2.3 million biodigesters are deployed by 2050 (Bioenergy strategy, 2020). 42% access to biogas and bioethanol in rural areas by 2030
- There is a strong focus on electrification in urban and rural areas (Ministry of Energy and Petroleum Strategic plan 2023-2027)[2]:
    - 100% access to Tier 3+ electricity by 2030 in urban areas
    - 25% access to Tier 3+ electricity in rural areas by 2030.

A visualisation of the findings is presented in Figure 2.3 below.

[2] The analysis here focuses on Tier 3+ electricity connections that can support eCooking. Existing policy documents do not define the type of connectivity, thus some assumptions are imposed based on extrapolations from current connectivity data from the eCooking baseline study.

Figure 2.3 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. eCooking adoption stands at about 20 percent in 2030.
- **Ethanol**: Though starting from a mere 2% in 2020, it sees steady growth to reach 31% 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 about 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% in 2019 to a peak of 36% 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.

2.4.2. (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.

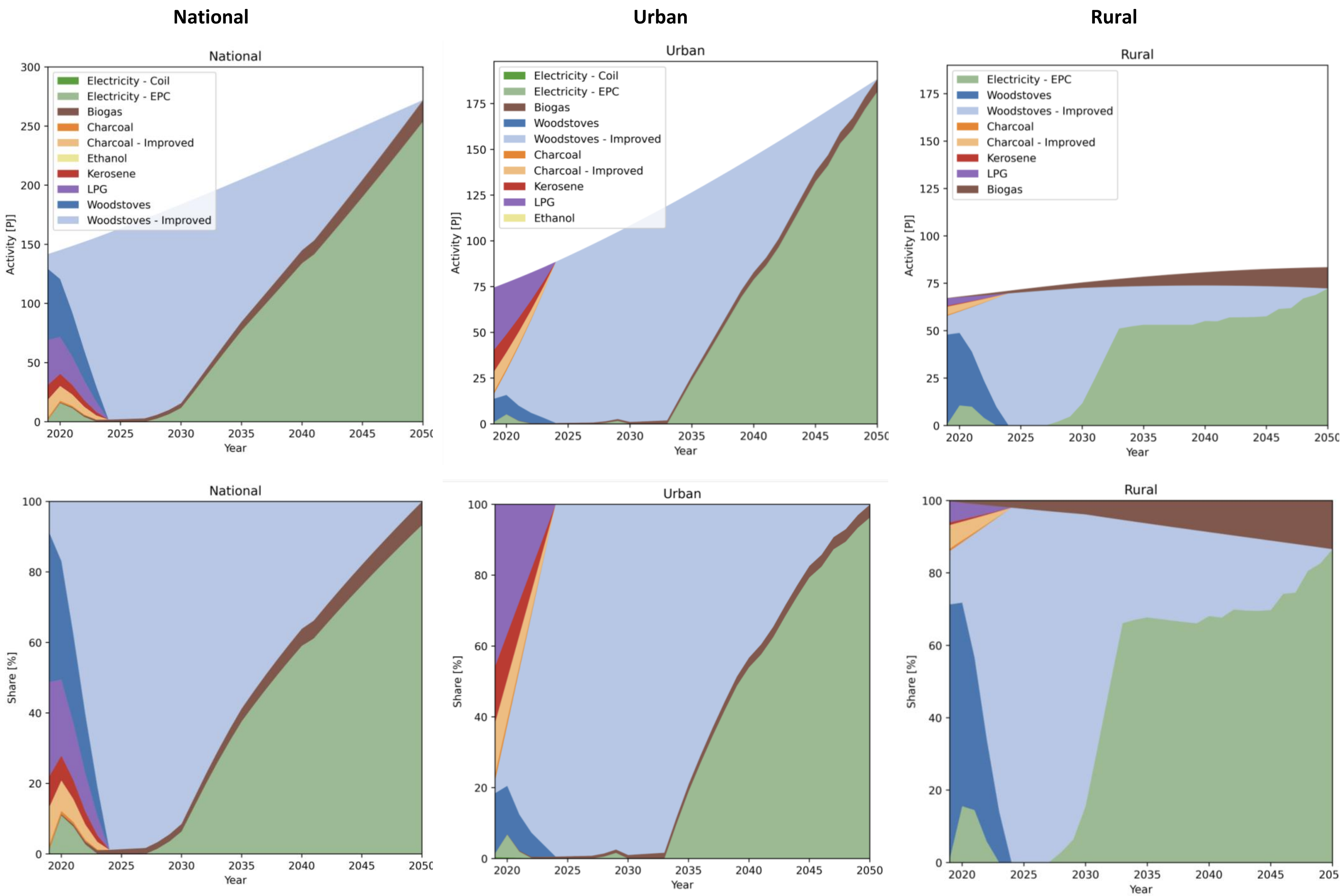
A visualisation of the findings is presented in Figure 2.4 below.

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

Growth Trends:

- **Electricity**: Starting from 0.3% 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 5% in 2050 with the installation of more biodigesters.
- **Improved wood** is a transitional fuel, as it is cheaper or free.

Figure 2.4 Optimised Net Zero Scenario model results



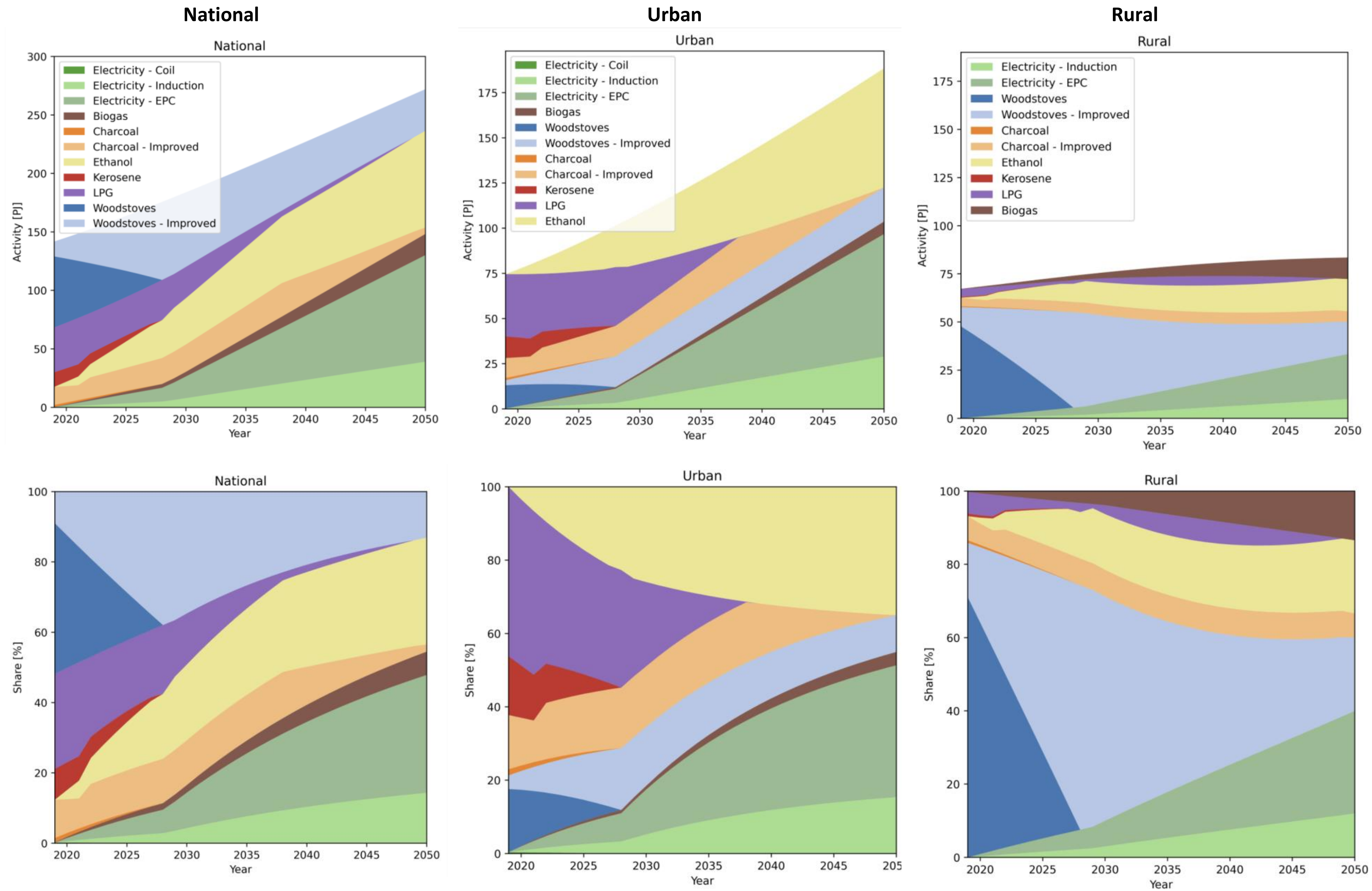
2.5. eCooking Transition scenario

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)
  - Improved biomass decreases to about 10% 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 KNeCS Baseline Study, (2023) , it is argued 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 2.5.

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.

2.6. 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 more in support of LPG. 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 eCooking 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 in the short term is the simulated version, while the optimised version has an initial dampened growth of eCooking due to competing cost of firewood against electricity assuming no policy constraints, but a more optimistic outlook. For the simulated version, the focus is not just on eCooking but on a holistic approach to achieving net-zero emissions at the lowest cost. 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.

3. Impact of Scaling eCooking on the electricity grid

3.1 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 has 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 in 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 Least Cost Power Development Plan, both long term (20 years) and medium term (5 years).

3.2 Approach

The variability of renewable energy sources is modelled, taking into account the anticipated energy demand for electric cooking in Kenya. In the analysis, OSeMOSYS, a Capacity Expansion Model is employed, 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[3] (Howells, et al., 2011).

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., (2024).

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

[3] 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, the present focus remains solely on OSeMOSYS.

3.3 Findings

Projected energy demand growth from eCooking

The results show that by 2028, electricity demand from eCooking will reach 2.54TWh/year. In the long-term, there is a dramatic increase in electricity demand in the residential sector based on new eCooking demand of 18.89TWh/year, as illustrated in Figure 3.1.

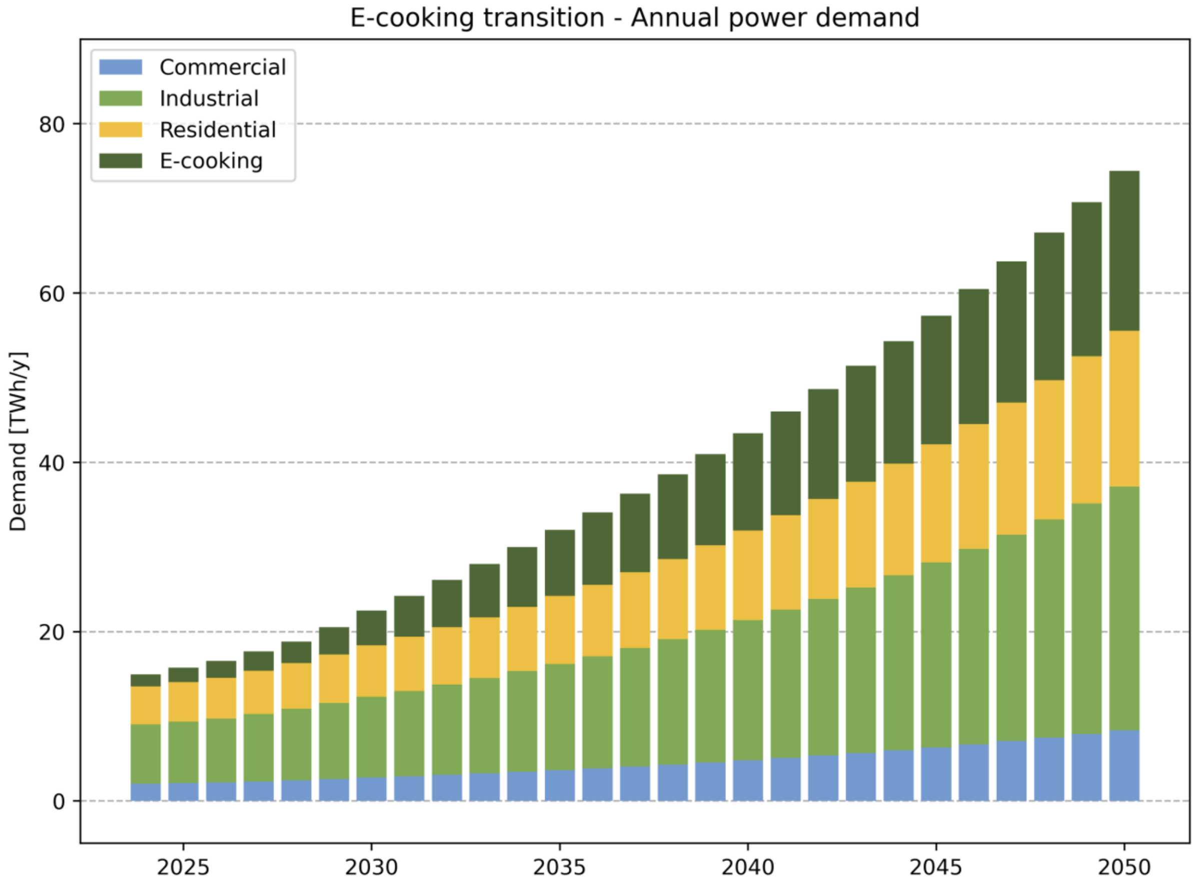


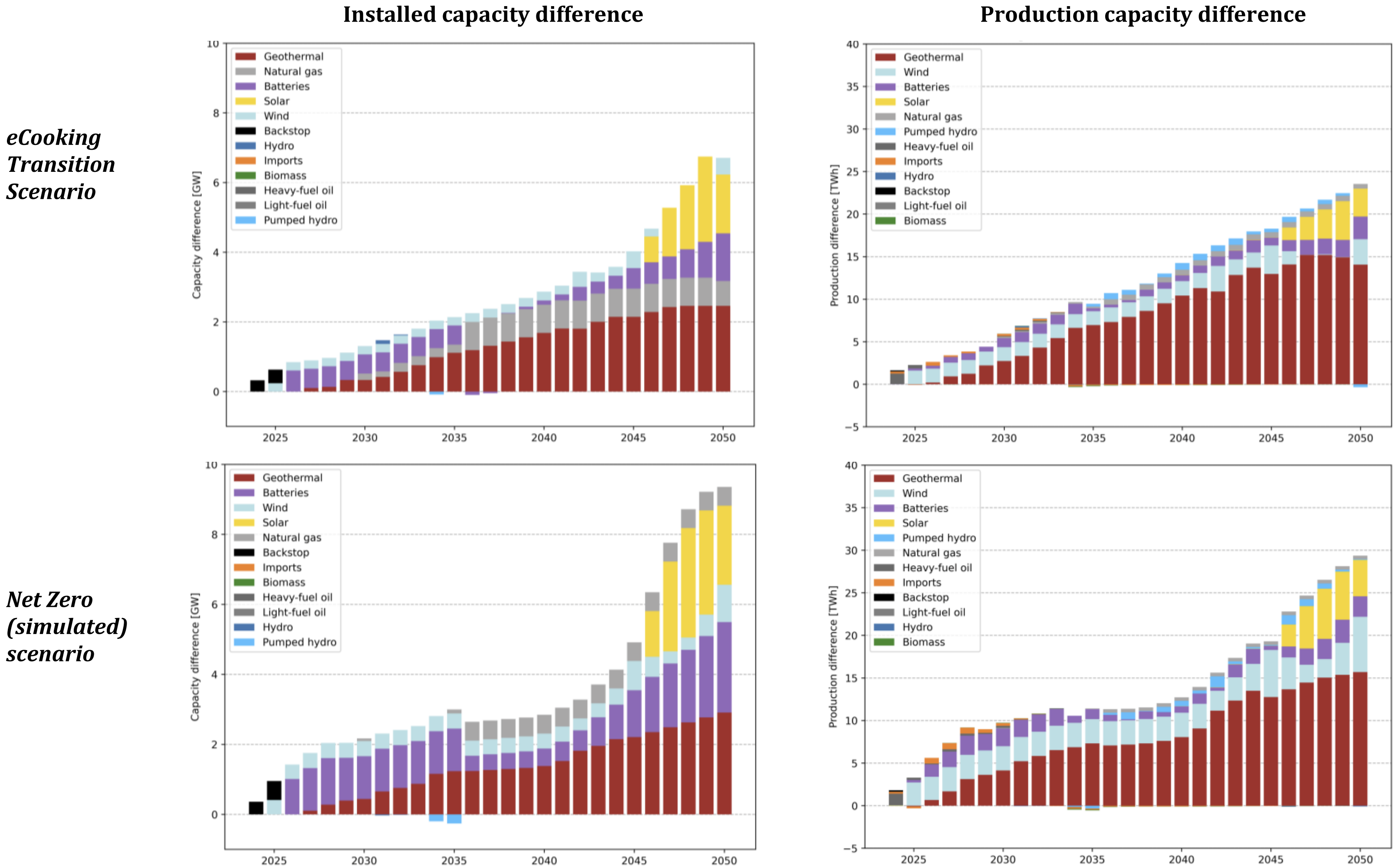
Figure 3.1. Electricity demand growth for the Whole Energy System Model, with new eCooking demand

Figure 3.1 illustrates the projected energy demand growth from 2019 to 2050 for different sectors under the eCooking Transition scenario, including new eCooking demand, residential, industrial, and commercial demands. Starting from a low base, the eCooking demand grows significantly and becomes the largest component of the total energy demand by 2050, surpassing other sectors. Commercial demand remains the smallest component of overall demand in 2050.

Installed and production capacity to meet new eCooking demand

Given the considerable impact of eCooking on electricity demand, investigation is done on how existing and planned capacity and electricity production can meet this demand. The capacity that needs to be built up to 2028 is assessed, and also up to 2050, and examine how the least cost technology mix needed to cover the new demand evolves. The difference between the outcomes of the baseline and eCooking scenarios is calculated. Figure 3.2 below graphically presents the evolution in the energy mix in the power sector both in terms of capacity installed and actual energy production for both the eCooking Transition Scenario and the simulated Net Zero scenario.

Figure 3.2 The evolution in the energy mix in the power sector in terms of capacity installed and production capacity.



These plots show the installed and production capacity differences between the outcomes of the baseline and eCooking scenarios, and the baseline and simulated Net Zero scenario[4]

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[4] Please note that the total production in these graphs appears higher than the actual demand because the graph is double-counting the contributions from batteries and pumped hydro. The plot displays the energy produced by the batteries (in purple) and by pumped hydro (in blue), in addition to the energy generated by other sources that is used to charge these two storage technologies.

Current installed generation capacity for commercial, industrial and residential use is roughly 3.6 GW, and the LCPDP projects an installed capacity of 4.2 GW by 2028.

Net Zero (simulated) scenario: According to this power sector model, additional eCooking demand in 2028 under the simulated Net Zero scenario will require about 2 GW of additional capacity, rising to approximately 9 GW by 2050. Geothermal and wind capacities are built to meet new eCooking demand, with solar playing a bigger role after 2045. In 2024 and 2025, the existing and planned renewable energy capacity falls short, necessitating reliance on diesel generators or imports[5, 6]. To address grid capacity issues, the model proposes installing a significant amount of battery capacity. For example, in 2027 alone, the model suggests adding up to 1 GW of *extra* battery capacity to help maintain the reserve margin and ensure grid stability. While battery costs are projected to decrease significantly, heavily investing in battery technology in the short term may not be the best course of action.

eCooking Transition scenario: In this case, 1 GW will be needed to meet additional eCooking demand in 2028, and this will rise to about 6.5 GW in 2050. Just as in the Net Zero scenario, but to a much lesser extent, fossil fuels or imports, and batteries are needed in the short-term to meet peak demand. Starting from 2025, according to the LCPDP projections, more geothermal power plants will be commissioned, complemented by incremental wind capacities. Additionally, more electricity imports can be utilised to add capacity.

In conclusion, under current projections, the eCooking Transition scenario is more feasible than the simulated Net Zero scenario. The eCooking Transition scenario features a much more gradual and manageable increase in installed capacity to meet new eCooking demand. In contrast, the NZ scenario requires a steep and rapid increase in capacity, with an overreliance on batteries, which as discussed, is not sustainable. However, if increased imports from Ethiopia, and potentially Tanzania are deployed in the LCPDP, some of these bottlenecks will be alleviated.

This model presents one of the potential trajectories and capacity mixes for covering additional electricity demand from eCooking, given current capacities and LCPDP projections. The actual energy mix could vary depending on the strategy adopted by the government, e.g. to invest more in geothermal, or natural gas—which in the model is installed but almost not used at all.

Additional revenue for sector utilities

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 3.3 presented below.

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[5] This is indicated as 'backstop' in Figure 2.2. Backstop capacity is added when the capacity to meet demand is not enough, or if the reserve margin is not met. The reserve margin is the extra capacity needed to handle unexpected increases in demand, or sudden loss of generation capacity. The model requires a 9% reserve margin (excluding solar or wind). In practical terms, this shortfall could result in loss of load, blackouts, load shedding.

[6] Diesel capacities are not shown in the plot in Figure 3.4, as they are not planned for deployment in the LCPCP. Further, as this analysis is based on LCPDP (2022-2041), announced pledges are not taken into consideration, among them, increasing imports from Ethiopia from 200MW to 400MW by 2026, and potential imports from Tanzania once the 400-kilovolt transmission line with the capacity of 2,000 MW is completed.

[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.

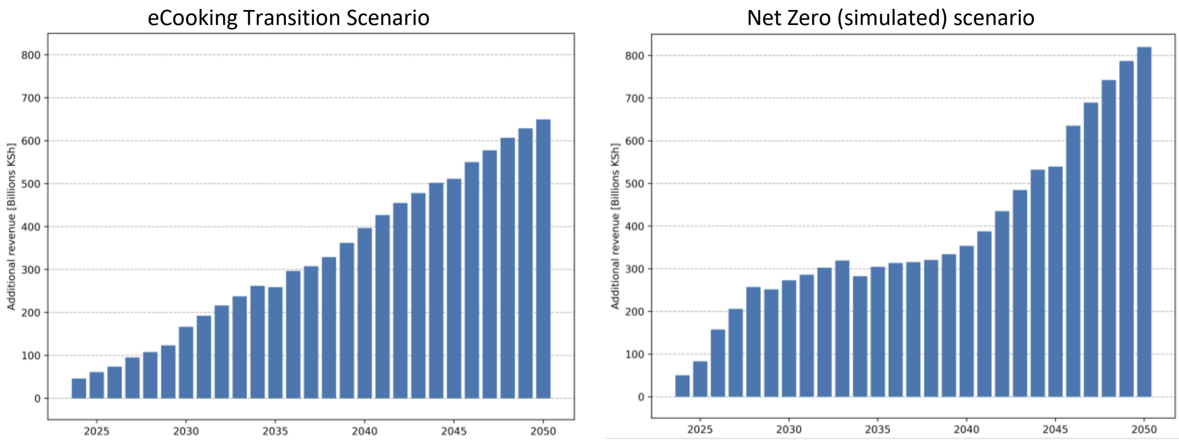


Figure 3.3 Projected additional revenue from the power sector on implementing the eCooking transition scenario and Net Zero (simulated) scenario

For context, Kenya Power's total revenue for the 2022/2023 financial year was 190.98 billion shillings[9]. The model indicates that the Net Zero simulated scenario is projected to yield approximately KShs 120 billion in 2028 based on the current tariff rates, and approximately KShs 800 billion in 2050. Alternatively, the more conservative eCooking Transition Scenario is projected to yield an estimated KShs 100 billion in additional revenue for Kenya Power by 2028, and approach KShs 650 billion by 2050. Thus, the additional revenue from eCooking demand will increase Kenya Power's current revenue by 2028 by about 63 percent in the Net Zero scenario, and 52 percent in the eCooking transition scenario. As expected, in 2028, the Net Zero scenario generates about KShs 20 billion more in additional revenue compared to the eCooking Transition scenario, and an additional 100 billion in 2050.

Both scenarios demonstrate that eCooking serves as a potent demand stimulation tool, potentially yielding considerable revenue that could further strengthen the grid infrastructure.

[9] Statistics from Kenya Power Audited Financial Report for the year ended 30 June 2023. Available here: https://www.kplc.co.ke/img/full/Audited%20Financial%20Report%20for%20the%20Year%20Ended%2030th%20June%202023.pdf

4. Modelling Stacking and eCooking Transitions

This section outlines the methodology used to model households cooking behavior and also assesses the potential impact of market development interventions, such as behavior change communications, subsidies, and financing solutions, on the transition to eCooking. Additionally, it aims to estimate the likely costs and benefits of transitioning to eCooking as a result of these interventions

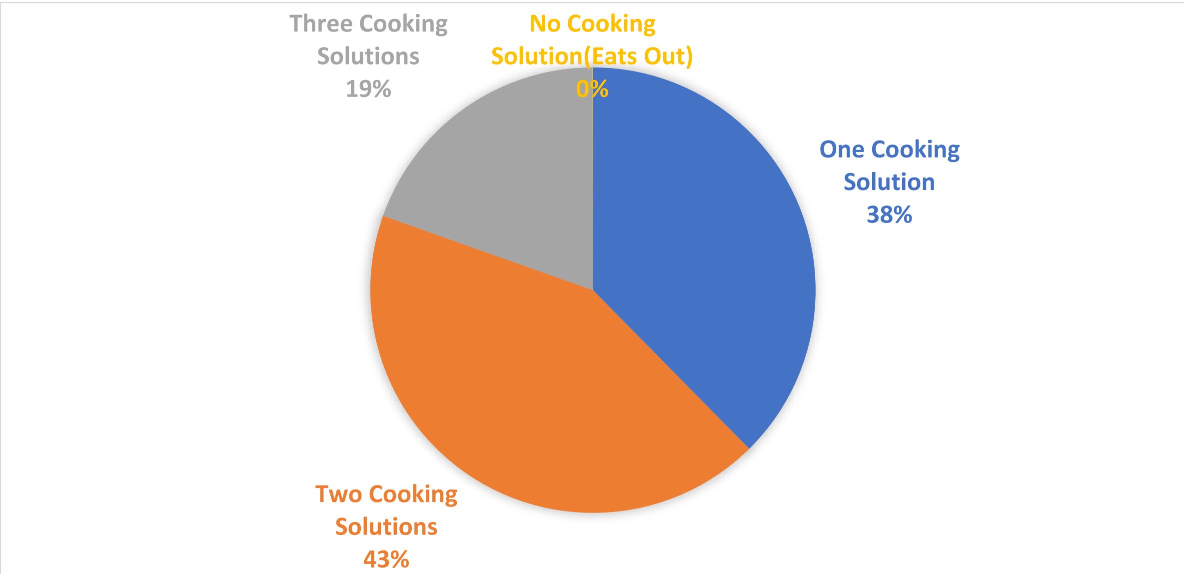
The methodological approach in this note is predominantly built on the KNeCS Baseline Study (2023)'. The KNeCS Baseline Study (2023) was commissioned by the Ministry of Energy and Petroleum, and is part of the broader efforts aimed at developing the Kenya National Cooking Transitions Strategy. The KNeCS Baseline Study (2023) 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.

4.1 Modelling Stacking

4.1.1. Definition and prevalence of stacking

Stacking in KNeCS Baseline Study (2023) 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 4.1. The implication is that nearly 2 in every three households in Kenya have at least two cooking solutions.

Figure 4.1: Household Stacking in Kenya Based on 2023 Kenya National eCooking Study



Household stacking estimates in Figure 4.1 above are based on the household cooking solutions presented in Table 4.1.

Table 4.1 Household Cooking Solutions Considered in 2023 Kenya National eCooking Study

<table>
<tr>
<td rowspan="2">Charcoal-Based Cooking Solutions
• Improved Charcoal Stove (Ceramic lined stoves)
• Metallic charcoal stove
• Nyama Choma Grill</td>
<td>Kerosene Based Cooking Solutions
• Kerosene stove</td>
<td rowspan="4">Electric Cooking Solutions
• Water Heater Coil
• Electric Kettle
• Microwave
• 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</td>
</tr>
<tr>
<td>Biogas Based Cooking Solutions
• Biogas Stove</td>
</tr>
<tr>
<td>Firewood Based Cooking Solutions
• Three stone open fire
• Improved firewood stoves (e.g., Kuni mbili stove, gasifier stoves)</td>
<td>LPG Based Cooking Solutions
• LPG stove
• Mixed LPG-Electricity stove</td>
</tr>
<tr>
<td>Biofuel Based Cooking Solutions
• Biofuel Stove</td>
<td>Solar Based Cooking Solutions
• Solar Cooker</td>
</tr>
</table>

The KNeCS Baseline Study (2023) 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.

4.1.2. Methodology: Classification and Estimation

In modeling household stacking, the categories primary, secondary, and tertiary cooking solutions are considered. To ensure that households are assigned to distinct groups based on their cooking solutions, the use of permutations is employed 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, the modelling of stacking is restricted 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 4.2: 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
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

29) Improved Charcoal Stove - Traditional Firewood Stove
30) Improved Charcoal Stove - Improved Firewood 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
60) Liquified Petroleum Gas (LPG) - Improved 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 4.2 and the household responses in the eCooking Baseline Study, Table 3.3 presents the prevalence of household stacking.

Table 4.2: 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%
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%

14	Traditional Charcoal Stove Only	47	1.669%
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%

44	eCooking-Kerosene	1	0.089%
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%

4.2 Modelling eCooking Transitions

Modelling households' transitions to eCooking is built on the KNeCS Baseline Study (2023) , 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.

4.1.1 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 (KNeCS) 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[10]. 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 KNeCS Baseline Study, 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.

[10] 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 69.09 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 69.09 percent of the households as shown in Figure 3.2.

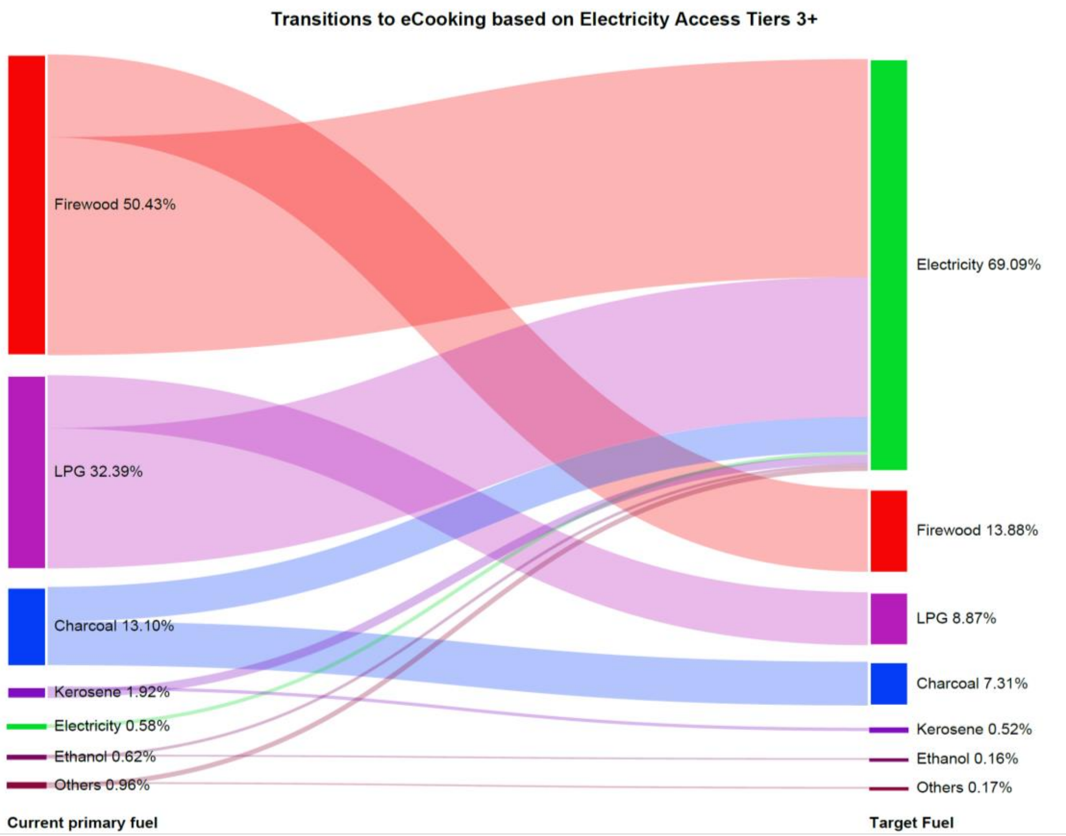


Figure 4.2: MTF Tier 3+ Supply Side Assessment of eCooking Potential

Table 4.3: 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	**69.09%**

5. Using the BAR HAP Tool: Modelling eCooking Transitions

The impact of household transition to eCooking is modelled using the Benefit of Action to Reduce Household Air Pollution (BAR-HAP) tool[11]. 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[12].

5.1 The BAR HAP Tool – A Primer

5.1.1. 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 environment. 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 involves 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[13]. Figure 4.1 summarizes the 16 transitions considered in BAR-HAP tool.

[11] For comprehensive introduction to BAR-HAP tool see WHO (2021), Das, et al., (2021),, and the references therein.

[12] See Lauer, Morton, Culyer, and Chalkidou (2020) s

[13] For comprehensive description of the improved cooking solution see WHO (2021), Das, et al., (2021), and the references therein.

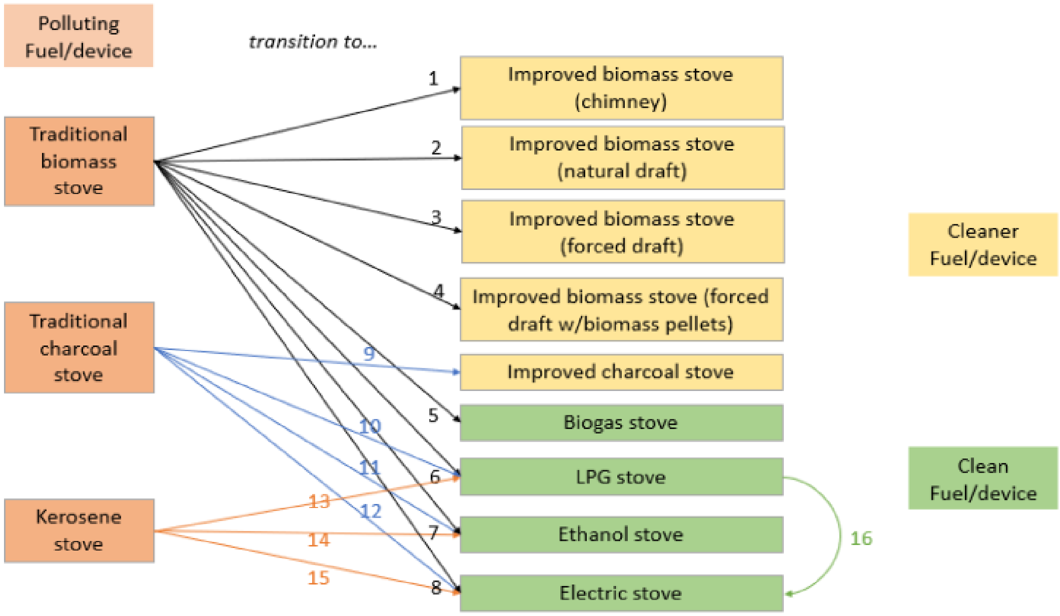


Figure 5.1 16 transitions considered in BAR-HAP tool Source: BAR-HAP user manual.

5.1.2. 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.

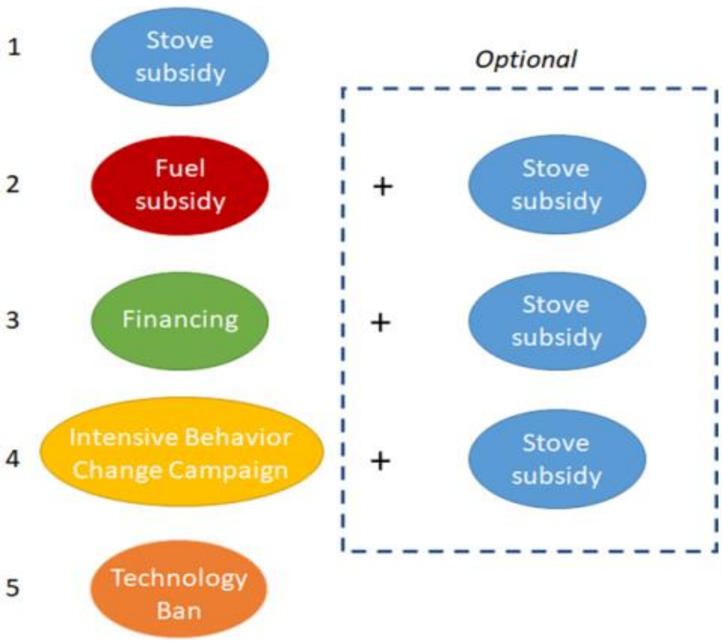


Figure 5.2 Possible policy interventions in BAR-HAP Source: BAR-HAP user manual

5.1.3. 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 5.1 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)	

5.1.4. Some considerations based on the eCooking Study

- **Analysis of eCooking Transitions:** Although the BAR-HAP tool analyzes multiple cooking transitions 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 KNeCS Baseline Study (2023) 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 the share of energy use contributed by both primary and secondary solutions. The energy shares are computed as follows:

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

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

Where:

$$useful\ Energy = Fuel\ Energy\ Content\ (calorific\ values)\ \times Stove\ Efficiency$$

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

5.2 BAR-HAP Transition Analysis Results

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

5.2.1 eCooking Transition Scenario

Interventions for the eCooking Transition Scenario

The eCooking transition 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), appliance subsidy, financing, tax waivers, and subsidy on tariff.

In the eCooking transition 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).
- **Appliance 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 appliance. The appliance 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 appliances 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 based on the BAR-HAP tool are presented tables below. The tables capture the indicative government costs for implementing the interventions and the potential costs to the households occasioned by a shift to eCooking. Additionally, they highlight 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[14]. In addition, the estimations rely on BAR-HAP default assumptions[15] but also incorporate specific estimates from the KNeCS Baseline Study (2023) regarding baseline fuel distribution, appliance, and fuel costs. For example, the cost estimation for eCooking appliance 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 30-100 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 5.2.

Table 5.2 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%
Appliance 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 eCooking Transition Scenario

Table 5.3 presents the overall costs and benefits of the eCooking Transition scenario, while Table 5.4 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

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

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

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 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 5.3 Overall costs and benefits of the eCooking Transition scenario

			eCooking Transition 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
	Appliance subsidy costs	USD	-12,379,594.75	-15,954,378.11
	Fuel subsidy costs	USD		
Private Costs	Fuel Cost	USD		
	Appliance 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 5.4 Costs disaggregated by intervention

	Item	eCooking Transition 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
	Appliance 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
	Appliance 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
	Appliance 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
	Appliance 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
	Appliance 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
	Appliance 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
	Appliance 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
	Appliance 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**		

5.2.2 Speculative scenario - Planned interventions

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

- **Kenya Power Press Release:** this part of the speculative scenario, is building upon Kenya Power's initiative to transition 500,000 households to primary eCooking within three years. The assumption here is that this plan will take a financing structure akin to the ongoing Kenya Power pilot program with PowerPay.
- **Ambitions of eCooking manufacturers:** Ambitions of eCooking appliances manufacturers of distributing 3 million appliances across East Africa by 2026 is incorporated into the 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 is expected to influence the demand for eCooking appliances by lowering their prices.

Certain assumptions are imposed in order to delve into the potential impact of these upcoming sector programs. These programs are expected to affect eCooking transitions by providing financing and subsidizing the cost of eCooking appliances. It is assumed that these initiatives will cut the appliance cost by 50 percent. It is worth noting that these interventions overlap, such that, carbon financing may be used to subsidise Kenya Power or eCooking appliance manufacturers strategic plans. Similarly, Kenya Power plans to roll out an RBF programme as part of its 500,000 appliance initiative.

Expanding upon the anticipated interventions, here is the quantified contribution foreseen from the sector programs:

Potential Additions	No. of households
KPLC	500,000
Ambitions of eCooking appliance Manufacturers (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, it is anticipated that the percentage of households using eCooking in 2028 will be 16.5%.

Table 5.5 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 5.6 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
	Appliance subsidy costs	USD	-38,858,753.45	-66,341,332.88
	Fuel subsidy costs	USD	-	-
Private Costs	Fuel Cost	USD	-	-
	Appliance 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 5.7 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	-	-
	Appliance 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
	Appliance 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	-	-
	Appliance 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
	Appliance 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	-	-
	Appliance 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
	Appliance 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	-	-
	Appliance Cost (After Subsidy)	USD	-1,823,792	-5,979,302
	Maintenance Cost	USD	-1,323,120	-4,184,095
	Total Private Cost	**USD**		

5.2.3 Experimental eCooking Tariff speculative scenario

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

Interventions for the 'eCooking Tariff Scenario'

It is estimated that the percentage of households using eCooking in 2028 will be 17.06% with a halved tariff.

Table 5.8 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 5.9 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
	Appliance 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	-	-
	Appliance 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 5.10 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
	Appliance 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	-	-
	Appliance 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
	Appliance 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	-	-
	Appliance 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
	Appliance 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	-	-
	Appliance 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
	Appliance 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	-	-
	Appliance Cost (After Subsidy)	USD	-1,825,252	-5,997,144
	Maintenance Cost	USD	-1,323,120	-4,188,976
	Total Private Cost	**USD**		

5.3 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 5.11 below summarises the findings.

Table 5.11 Comparing the costs and benefits of the baseline eCooking transition scenario against the two speculative scenarios

Benefit	Measure	Unit of Measure	eCooking Transition Scenario (10.76% eCooking)	Speculative/ Planned Activities Scenario (16.46% eCooking)	Experimental Tariff (17.06% eCooking)
Costs	Enablers and market development costs	USD	58,009,437	106,033,141	108,465,884
		KES	9,281,510,400	16,965,303,327	17,354,542,101
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 eCooking transition 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 during the strategy implementation period 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 eCooking transition 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.

In conclusion, the experimental tariff scenario offers the most significant benefits in health, time savings, and environmental impact, even though it has a lower net present value due to high subsidization costs. The planned activities scenario could achieve the highest net present value but provides slightly lower overall benefits relative to experimental tariff scenario. The eCooking transition scenario is a conservative and cost-effective option with less impact. The choice of eCooking transition strategy should balance optimizing benefits with resource constraints. The planned intervention scenario is the more feasible despite the higher benefits of the experimental tariff, while the baseline scenario sets a lower bound for transition target.

6. Conclusion

The modelling exercise in the Kenya National Electric Cooking Strategy used two modelling tools: the Open Source energy Modelling SYStem (OSeMOSYS) tool and the Benefits of Action to Reduce Household Air Pollution (BAR-HAP) tool. Specifically, the OSeMOSYS tool was employed to analyse and forecast trends in energy demand and fuel shares across four scenarios: Business as Usual, Net Zero, Stated Policies, and the eCooking Transition. The eCooking Transition Scenario was identified as the most feasible intervention, serving as the foundational blueprint for the Kenya National Electric Cooking Strategy. This scenario will guide Kenya's journey towards a sustainable, equitable, and climate-friendly cooking future. The OSeMOSYS tool examined the implications of shifting from traditional fuels to electric cooking, assessing the impact on grid capacity and energy demand. It also guided the assessment of the transition's implications for utility revenue. Conversely, the BAR-HAP tool complemented the OSeMOSYS tool by evaluating the effectiveness of policy interventions to encourage households to transition to eCooking and assessing the associated costs and benefits. Specifically, the BAR-HAP tool was used to assess the impact of Behaviour Change Communication, Appliance Subsidy, Appliance Financing, and Tax Waiver policies. The OSeMOSYS and BAR-HAP tools were used iteratively to identify the most feasible pathway for scaling eCooking in Kenya.

The modelling exercise estimated that about 10.8% of households will transition to eCooking during the strategy period, resulting in an additional eCooking demand of 1 GW in 2028, rising to about 6.5 GW in 2050. In the short term, this may necessitate the use of fossil fuels, imports, and batteries to meet peak demand. However, starting in 2025, according to the LCPDP projections, more geothermal power plants will be commissioned, complemented by incremental wind capacities. Additionally, increased electricity imports can be utilized to add capacity.

The eCooking Transition Scenario is projected to generate an estimated KShs 100 billion in additional revenue for Kenya Power by 2028, approaching KShs 650 billion by 2050. Thus, the additional revenue from eCooking demand will increase Kenya Power's current revenue by about 52 percent by 2028, relative to the 2022/2023 financial year's revenues. The eCooking transition scenario thus demonstrates that eCooking serves as a potent demand stimulation tool, potentially yielding considerable revenue that could further strengthen the grid infrastructure.

At the microlevel, the transition to eCooking is associated with savings in fuel expenditure over the 5-year analysis period. Health benefits include saving more than 1,213 lives. Other benefits include a reduction in unsustainable wood harvesting and time savings for households. Additionally, the transition would significantly reduce greenhouse gas emissions. The social benefits from reduced cooking time are substantial, primarily reflecting time savings. Furthermore, using the eCooking transition scenario as the lower bound for the transition target, the sensitivity analysis indicated that more ambitious targets, such as planned activities and a dedicated eCooking tariff, have the potential to amplify the benefits of the eCooking transition even further. This could result in more pronounced demand stimulation, health benefits, environmental benefits, and a reduction in the impact of drudgery.

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