DEMOCRATIC REPUBLIC OF CONGO

eCooking Market Assessment: A focus on urban Eastern DRC

2022

AUTHORS
Jacob Fodio Todd, Matthew Leach & Jon Leary

CONTRIBUTIONS FROM
GIZ/EnDev Team: Leonardo Bertero, Lasse Hoffman & Raya Kuehne
AVSI Foundation: Michele Pontonio, Alessandro Galimberti & Martina Raimondi
MECS Leads: Simon Batchelor & Nick Rousseau

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DRC ECOOKING MARKET ASSESSMENT

This study is a publication produced jointly by Energising Development (EnDev) and the Modern Energy Cooking Services (MECS) Programme and aligns with a 2021 series of publications developed in collaboration with **GIZ/EnDev**. The market assessments offer strategic insight on the current state of electricity access and clean cooking in countries across sub-Saharan Africa and South Asia.

This study identifies the key opportunities and challenges to the scale up of electric cooking in the coming decade and concludes with a series of recommendations for targeted interventions that could support the development of the eCooking sector.

The market assessments are structured according to the MECS transition theory of change (TToC), which consists of three interrelated dimensions: **the enabling environment, consumer demand and the supply chain.** This study was conducted via desk research, interviews and primary data collection.

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EXECUTIVE SUMMARY

In recent years, the mini-grid and off-grid sectors in the Democratic Republic of Congo (DRC) have developed rapidly, making use of the country's enormous and largely untapped clean energy resources, and in doing so contributing towards tackling the DRC's low rate of electricity access (estimated at 9-19% of population). President Tshisekedi has indicated that over the course of his presidency he aims to increase electricity access from its low current levels to 30% of the population, which if successful would extend access to between 10-20 million Congolese over the next few years. A draft National Energy Policy was made public in 2022 and if ratified would provide a framework for managing the sector and the country's energy resources, including renewable and biomass energy sources. It could also be a precursor to developing a dedicated clean cooking strategy.

The national grid runs on 99% renewable energy (almost exclusively hydropower), although it suffers from a legacy of underinvestment and disrepair and demand far outweighs supply. Despite this, 2.5% of the population (i.e. around 2.3 million people) already primarily cook with electricity and in some urban areas such as Kinshasa, it is a familiar way of cooking: the national utility offers one of the lowest tariffs in Africa.

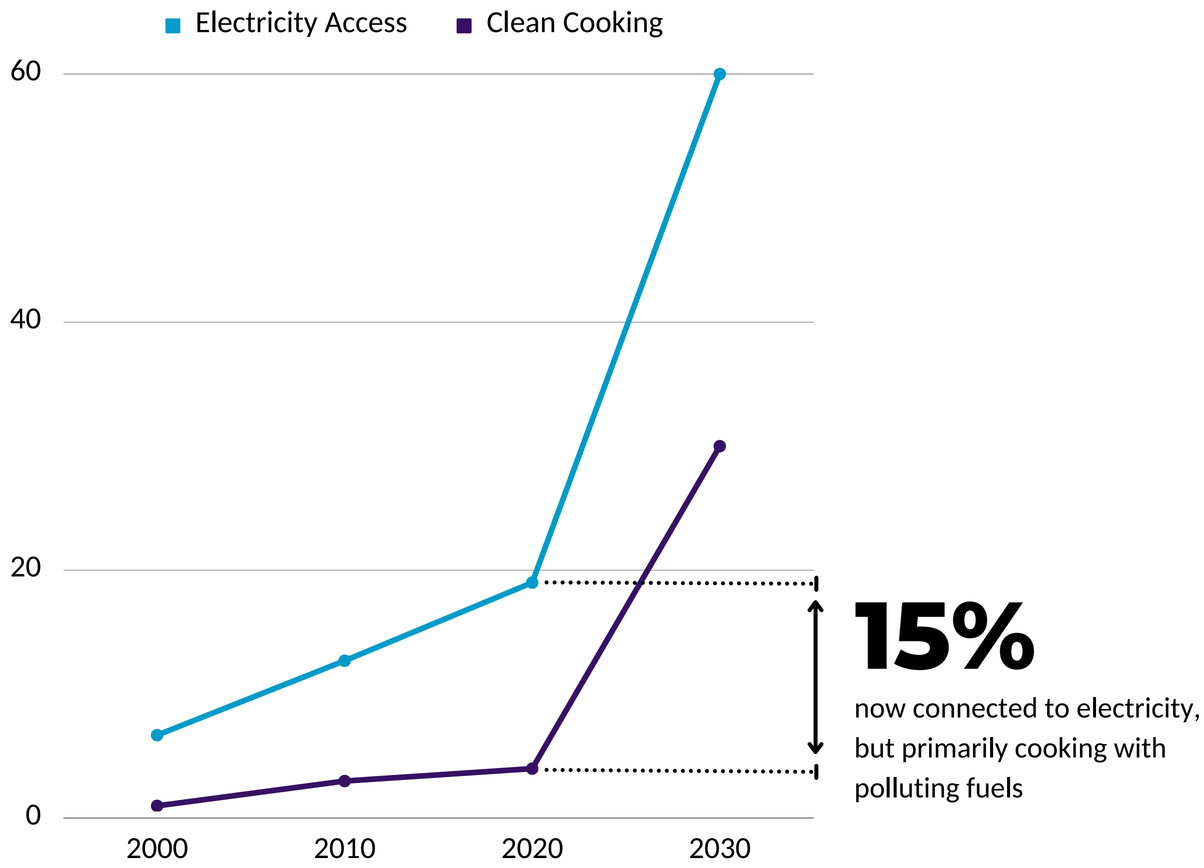
Most of the population (approx. 97%) still rely on polluting fuels such as firewood and charcoal to cook. There are huge disparities between rural areas, where firewood use is abundant and there is negligible access to electricity, and urban areas, where electricity access is far higher (~40%) and charcoal use, a major driver of deforestation, tends to dominate. Large multi-partner initiatives seek ways to tackle deforestation by reforming the wood and charcoal sectors and mainstreaming alternative cooking materials and fuels (such as LPG, green charcoal or electricity) and thus act as a key driving force in pushing forward the clean cooking, and recently in some cases, the electricity access agenda. For example, in Eastern DRC, the Virunga Foundation has been trialing eCooking with electric pressure cookers (EPC) on the Virunga Energy hydro mini-grid, with high device retention and ongoing use, and an extended trial. Similar to many Eastern and Central African cuisines the devices are considered highly compatible with the majority of home cooked Congolese dishes and cooking processes (see section 3).

EXECUTIVE SUMMARY CTD.

EnDev has a strategic focus in the Eastern DRC and as a result, the focus of this market assessment is to identify pathways by which the eCooking transition could be accelerated in the near to medium term in the region. Throughout there is a particular spotlight on primarily urban areas, where opportunities are more compelling, given vast national differences between electricity access of around 40% compared to rural areas at only 1%, and secondly with a focus on the Eastern DRC, particularly Goma and Bukavu. Although both urban centres have historically been hindered by poor electricity access and regional instability, there are promising signs of embracing modern energy cooking services. Firstly, by adopting clean cooking solutions, with eCooking trials and the expansion of LPG initiatives, and secondly, with improving energy access as mini-grid developers, such as Virunga Energy and Nuru extend their networks (although they face bureaucratic and logistical hurdles common to the sector). Modelling in this study shows that with complementary technology, such as energy-efficient appliances or battery support, and adequate financing, **eCooking could be a viable option in off-grid and mini-grid settings, with positive net environmental and health impacts and a relatively short payback period for urban consumers due to high levels of existing expenditures on charcoal.**

More research on understanding current patterns of on-grid eCooking, the viability of expanding access to electric cooking on-grid (including through support from battery storage to mitigate the unreliability of the grid), as well as eCooking on mini-grids and off-grid using solar and batteries will be crucial in developing the evidence base for eCooking in DRC. What is more, **supporting the development of the supply chain for energy-efficient appliances and piloting of innovative business models, such as Paygo or on-bill financing, is a critical next step for building the market for eCooking in Eastern DRC.**

ELECTRICITY ACCESS & CLEAN COOKING ACCESS



Electricity Access statistics (World Bank), Clean Cooking statistics 2000-2020 (WHO household energy database), 2030 clean cooking and electricity access targets (DRC government).

ECOOKING GLOBAL MARKET ASSESSMENT VIABILITY SCORE FOR DRC

The MECS 2021 eCooking Global Market Assessment (GMA) draws on the experience of a range of stakeholders to identify the key factors which influence the viability of a scale up of electric cooking and represents this as a weighted score constructed from 37 indicators covering 130 countries in the Global South. As electric cooking relies on a supply of electricity which is provided in a variety of different ways, the GMA provides a score for national grid, mini-grid and off-grid (standalone) supported electric cooking as well as a combined overall score indicating the viability of a scale up of electric cooking.

Overall: **94th / 130**

On-grid eCooking: **0.35 – 118th/130**

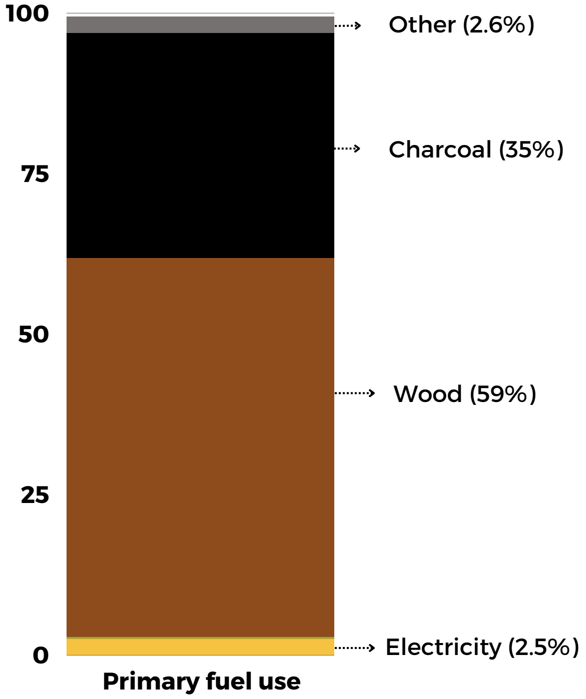
Mini-grid eCooking: **0.41 – 54th/130**

Off-grid eCooking: **0.35 – 99th/130**

DRC's score is reflective of its poor energy access sector indicators, particularly on-grid where it scores 118 of 130 and suffers from a legacy of underdeveloped and badly maintained infrastructure, and a poor outlook. Although similarly low standing in the off-grid (standalone) scenario, its **mini-grid eCooking scenario is more positive, indicating considerable promise.**

COOKING ENERGY: PRIMARY FUEL USE

2.5% cook primarily with electricity



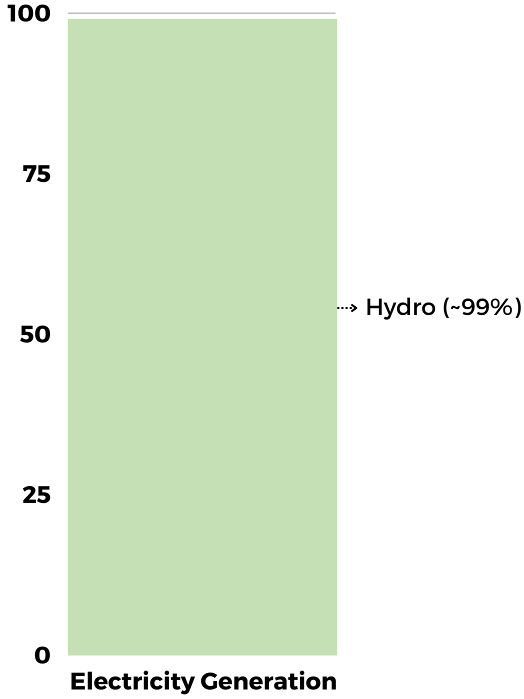
35% cook primarily with **commercialized** polluting fuels (charcoal)

97% cook primarily with polluting fuels

Source: WHO Household Energy Database, Geneva: World Health Organization; 2020.

ELECTRICITY GENERATION: ON-GRID

99% renewable



Source: 2010 and 2020 electricity data (World Bank, 2022a)

OFF-GRID

Nascent mini-grid & off-grid sectors:

Numerous new projects in the pipeline and a key part of the DRC government electrification strategy

KEY OPPORTUNITIES FOR SCALING ECOOKING

- High proportion of current, and planned, renewable energy generation
- Mini-grid developers and off-grid sector expanding and high potential for growth with recent investment (e.g. Bboxx and Orange) and expansion plans (e.g. Virunga Energy and Nuru Sarlu).
- Electric pressure cookers (EPCs) highly compatible with popular long-cooking dishes such as beans and cassava leaves.
- Low cost of national grid residential electricity: tariffs $0.04-0.10/kWh
- Cooking with EPCs affordable and cost effective compared to LPG, charcoal, and paid firewood, even on some higher minigrids tariffs (e.g. Virunga Energy or SOCODEE in Goma on current rates).
- Political will, and international support, to regulate and decrease charcoal production and use.
- Relatively high existing expenditures on charcoal, creating an attractive market opportunity for eCooking by repurposing as repayments on financed appliances and electricity units.
- Substantial existing use of eCooking as primary cooking fuel (2.5% of the population, i.e. around 2.3 million people).

KEY CHALLENGES FOR SCALING ECOOKING

- Lack of awareness amongst key market actors, end users, and decision-makers, about the affordability and viability of cooking with energy-efficient devices.
- Reliability challenges in on-grid electricity supply and poor and badly maintained current electricity infrastructure.
- Insufficient electricity production on the national grid to meet demand, and potential challenges for any increase in demand if significant uptake of eCook in mini-grid settings occurs.
- Challenging supply chain for electric appliances with complicated, costly and irregular import systems.
- The tax system is difficult to navigate and there are high import taxes for equipment and appliances needed for electric cooking to reach scale.
- No national energy policy or clean cooking strategy in place.
- Draft policy focusses on LPG for cooking futures without exploring the opportunity to leverage electricity access gains and investments for clean cooking.
- Political tensions and cycles of violent conflict, particularly in eastern provinces.

Photo: courtesy of Alessandro Galimberti

1. INTRODUCTION

CLEAN COOKING & ELECTRICITY ACCESS IN DRC

The Democratic Republic of Congo (DRC) is a country with a population of around 92m people, spread across the second-largest country by land mass in Africa. Approximately 49.5m (54%) people reside in rural areas and 42.5m (46%) in urban areas (World Bank). It is one of the poorest and least developed countries in Africa and it suffers from a chronic electricity access crisis, with estimates ranging from around 9% (IEA) to 19% (World Bank) of the population connected to electricity in 2022, predominantly in urban areas (Gnassou, 2019). However, the DRC's location, in the vast Congo Basin, means it has enormous clean energy resources with significant hydropower, solar and geothermal potential as well as other notable other options, such as biogas and methane. Currently 99% of electricity generated for the national grid comes from hydropower.

The DRC has a huge dependence on biomass for cooking, with 97% of the population relying on charcoal and wood (WHO, 2022). There are large differences between rural areas, which favour wood, often collected at little or no cost, and urban areas, where commercialized charcoal tends to be the dominant fuel. The clean cooking sector in the DRC has historically focused on improved cookstoves, where there is a small nascent market, although needs and uptake vary widely according to factors such as location, fuel and financing model availability, quality control and affordability. A market for LPG, which has had negligible uptake and use, has in recent years been stimulated through initiatives such as the CAFI Programme for the Sustainable Consumption and Partial Substitution of Wood Energy that envisions building the market and stimulating its use as a primary fuel in urban areas, and through private ventures. In 2021, UNCDF partnered with Bboxx, with government backing, to scale-up their LPG operation in Goma, Bukavu and Lubumbashi. Inroads are being made with LPG products: the region is Bboxx's largest clean cooking market. Electricity is considered the most common fuel used after charcoal in larger urban areas, however there are constraints to market development due to the instability of supply with the national grid. Recent developments in the off-grid and mini-grid sector are encouraging, with an emerging market, and exploratory eCooking trials, although investors and developers face sectoral legal, regulatory and tax obstacles.

With regards to electricity access, the national utility company SNEL's (Societé Nationale d'Electricité) capacity did not increase significantly between 1990 and 2017 (World Bank, 2020) and therefore the pace of electrification across the DRC has been slow. Access remains low, due to a legacy of a poorly serviced national grid with underdeveloped production, transmission and distribution systems and the disrepair of infrastructure across its main grids in the East, South and West. Service is unreliable and suffers from a lack of maintenance and supply (Power Africa, 2019), thus connected households are regularly subject to load shedding and can be deprived of power for days (Ngongo, 2020). Efforts to vastly upgrade power production for the national grid, by constructing large hydroelectric plants (e.g. Inga III and Grand Inga) have stalled, and planning has been beset by financial, political and technical challenges.

However, SNEL has one of the lowest costs of electricity per kWh in Africa for consumers, with a residential electricity tariff of around US$0.04-0.10 per kWh, and it is often unmetered so many consumers pay a flat rate subscription. There are also high rates of illegal connections. Consequently, in certain grid-connected areas, such as Kinshasa, electricity use for cooking is fairly high (Gazull et al., 2020), as part of a fuel stack alongside primary cooking fuel charcoal, and other energy sources for cooking. However, due to factors such as a low unit price, SNEL fails to cover its costs, and operates at a loss. As a result of these national grid challenges and the task of electrifying the country, in recent years the mini- and off-grid sectors have come to be increasingly important parts of the DRC's electrification strategy (Power Africa, 2019) especially since the electricity sector law promulgated in 2014.

The liberalization of the electricity sector, and the end of the SNEL monopoly of the sector, envisioned an increased role for the private sector. Despite some investment, by for example mining companies, being directed towards SNEL and supporting rehabilitation and development of the national grid, the off-grid (standalone) and mini-grid sectors in DRC have emerged as attractive markets for local and international organizations, with donors making financial commitments. In this regard, in recent years, the Eastern Congo has emerged as a particular area of opportunity, as an area historically underserved by electricity (Kabongo et al., 2020) and the home of the first privately operated mini-grids in the country (SEforALL, 2020), and location of a current eCooking trial for mini-grid users.

Additionally, the Eastern DRC has extensive and rapid deforestation issues mainly due to slash and burn agricultural land clearing, firewood harvesting and charcoal production. Charcoal production especially is tied into complex conflict dynamics, particularly in the forests of the Eastern DRC, for example Virunga National Park, which acts as a barrier to addressing these issues. Exploring complex political and conflict dynamics are out of the scope of this assessment however the global significance and the investment into protecting DRC forests are notable as many international organisations fund large forest protection initiatives that seek ways to reform the charcoal sector and mainstream alternative cooking materials and fuels (such as LPG, pellets, green charcoal or electricity). Thus, they are a key driving force in pushing forward the clean cooking, and in some cases, the electricity access agenda. For example, President Tshisekedi in 2021 signed a second letter of intent (2021-2031) with the Central African Forests Initiative (CAFI) for a results based agreement for USD 500 million which contains a commitment to reduce use of wood energy for cooking in major urban centres by at least 50% by 2031.

2. ENABLING ENVIRONMENT

ECOOKING POLICY OUTLOOK

In October 2022, a draft National Energy policy document was launched for public consultation by the Ministry of Hydraulic Resources and Electricity (MEHR) and supported by a variety of actors. The national utility company SNEL's (Societé Nationale d'Electricité) monopoly on production, transmission, distribution and trading of electricity ended in 2014 with the reform and liberalization of the energy sector. The 2014 electricity sector law incentivized private sector investment and dictated the formation of new agencies, a National Agency for Electrification and Energy Services (ANSER) and an Electricity Sector Regulator (ARE). More recently, President Tshisekedi has outlined his ambition to improve energy access during his presidency. Other recent government statements have indicated a commitment to remove VAT and import duties from the sale of solar systems and clean cooking solutions, although a timescale is not indicated.

With regards to clean cooking, enshrining a National Energy Policy is considered a first milestone towards the development of a clean cooking strategy. There is no coordinating body for clean cooking, such as those in the decentralized and renewable energy sector with for example ACERD (Association Congolese pour les Énergie Renouvables et Décentralisées), a non-profit organization, comprising local, regional and international companies, established in 2018 to promote the development of the renewable and decentralized energy sector, or CORAP (Coalition des Organisations de la Societe Civile pour le Suivi des Reformes et de l'Action Publique). Civil society actors have historically been an important force in driving government policy (Stearns, 2022).

Although there is fairly extensive use of electricity for cooking in urban DRC, there are few studies and pilot projects generating evidence and exploring the challenges and benefits of eCooking, including cost analysis and the impacts of energy-efficient appliances, or looking at cooking on mini-grids. Further research and evidence is required to support scaled uptake and accelerate the change in narrative around eCooking.

Key policy stakeholders: *Ministry of Energy and Hydraulic Resources (MEHR), Ministry of Environment and Sustainable Development (MEDD), SNEL (Societé Nationale d'Electricité), National Agency for Electrification and Energy Services in rural and peri-urban areas (ANSER) Electricity Sector Regulator (ARE)*

TARGETS

ELECTRICITY ACCESS

30% electricity access by 2025 (grid/off-grid)

100% by 2050

CLEAN COOKING

50% reduction of the share of unsustainable fuelwood for cooking in major urban areas

RISE SCORES

Regulatory Indicators for Sustainable Energy (RISE) scores reflect a snapshot of a country's policies and regulations in the energy sector and designates four pillars of sustainable energy (global average in brackets): Electricity Access (53), Clean Cooking (37), Renewable Energy (55) and Energy Efficiency (48). Each pillar is determined from various indicators that are scored on a scale from 0 to 100. These scores provide a picture of the strength of government support for sustainable energy in the Democratic Republic of Congo.

36	32	40	15
electricity access	clean cooking	renewable energy	energy efficiency

KEY INTERNATIONAL DEVELOPMENT PROGRAMMES CREATING THE ENABLING ENVIRONMENT IN WHICH ECOOKING CAN SCALE:

The Modern Cooking Facility for Africa (MCFA) - a financing programme established in 2022 to support the development and scale-up of clean cooking technologies in Africa until 2027, with a focus on DRC and five other countries. Nefco manages the facility and the primary donor is the Swedish Development Agency (SIDA), although further funding and funders are sought. Cooking service providers will receive financial support based on eligibility and achieving milestones.

Power Africa (PAOP) – the Power Africa Off-grid project is a four year program started in 2018 to accelerate off-grid electrification across sub-Saharan Africa. Over 10 focus countries, of which DRC is one, it aims to achieve 30,000MW of newly generated power and reach 300 million Africans.

Beyond the Grid Fund for Africa in the DRC (BGFA) – Sweden, through the Embassy in Kinshasa, is supporting the expansion of BGFA to the Democratic Republic of the Congo with SEK 200 million (~ EUR 20 million). The overall aim of the new country programme is to create access to affordable renewable energy solutions for people living in rural and peri-urban areas in the country.

UNCDF Challenge Fund: investment to quantifiably reduce wood energy consumption in the DRC through a Central African Forest Initiative (CAFI) under REDD+ and implemented by UNCDF and UNDP. Grants of between $50,000-$150,000 USD offered to be implemented between November 2022 and December 2023.

World Bank IFC Scaling Mini-grid Programme – The International Finance Corporation with the government aims to bring clean, solar energy to over 1.5 million homes, businesses, schools, and clinics in the country, starting with an expected USD $400 million initial funding, beginning in 2022/23.

KEY GOVERNMENT PLANS CREATING THE ENABLING ENVIRONMENT IN WHICH ECOOKING CAN SCALE:

DRC REDD+ National Fund (FONAREDD) – Established in 2012 FONAREDD, with committees led by the Ministry of Finance and Ministry of Environment and an Executive Secretariat, is funded by CAFI via a project through UNDP. Its Programme de Consommation Durable et Substitution Partielle au Bois-ènergie seeks to develop alternatives to wood fuel, particularly through ICS and LPG.

Fonds Mwinda – flagship programme of ANSER, launched in 2021, it aims to develop energy access in rural and peri-urban settings in DRC.

Plan National Stratégique de Dévelopment (2019-2023) – sets out a framework for government, and its development partners, interventions from 2019-23. It outlines challenges for the electricity infrastructure and sectoral objectives including an intensification of investment in renewable energy, particularly gas, expanding the grid, and developing and reforming institutional organs of the electricity sector.

Draft National Energy Policy (2022) – Launched for public consultation in October 2022, this policy was developed by the Ministry of Energy and Hydraulic Resources with technical support from UNDP and financed by CAFI via FONAREDD. The document offers ways to manage the energy sector in a number of different subsectors in order to optimize energy resources, and introduce innovative approaches to renewable energy and reducing biomass use, including concerning modern energy cooking. A previous draft energy sector policy paper dated to 2009 was embraced by major stakeholders in the DRC, but never ratified (USAID, 2016).

KEY DRIVERS IN THE ENABLING ENVIRONMENT:

- Emerging mini-grid and off-grid markets.
- National Energy Policy has been drafted for public consultation.
- Electricity already the most commonly used clean cooking fuel.
- Low cost of grid electricity: ~0.04-0.10USD/kWh for households.
- Recent statements in support of expanding electricity access to 30% under President Tshisekedi and addressing duty and tax laws by President and CEO of ANSER.
- Decreasing charcoal use is a current policy focus.
- Goma, a major trade hub, has the fastest growing urban population in the Eastern region (World Bank, 2020) and has a relatively high average household expenditure on charcoal, that could be converted to electricity units. With the expansion of mini-grid networks and EPC trials, it presents new opportunities for eCooking.
- Cooking with energy-efficient electric appliances such as an EPC can be much cheaper than popular cooking fuels, yet the high upfront cost of energy-efficient appliances is prohibitive for the low- and middle-income households, that would stand to benefit the most. However high upfront costs can be mitigated by sales on credit, import tax and VAT exemptions, and upcoming innovations such a PAYGO cooking.

KEY BARRIERS IN THE ENABLING ENVIRONMENT:

- Negligible access to electricity outside of urban areas and reliability in grid-connected areas remains an major issue
- Electricity demand far outweighs supply and no clear strategy to improving grid or increasing production in short term
- Lack of knowledge throughout market actors, end users, and decision-makers, about affordability and viability of cooking with energy-efficient devices.
- Lack of national policies dealing with energy or clean cooking, and process of adoption is long-term and complex.
- Low rank (183rd) on ease of doing business index.
- Lack of strong national coordinating body to advocate for clean cooking.
- High import taxes and VAT for clean cooking & renewable energy solutions.
- Lack of quality standards mean quality of electric cooking devices is not controlled.
- LPG has expected regulatory support, but supply and storage issues may hinder uptake as well as leading to ongoing reliance on fossil fuels.

Photo: courtesy of Alex Catherine Nagawa

3. CONSUMER DEMAND

WHAT'S ON THE MENU?

In an average week a typical DRC household might prepare:

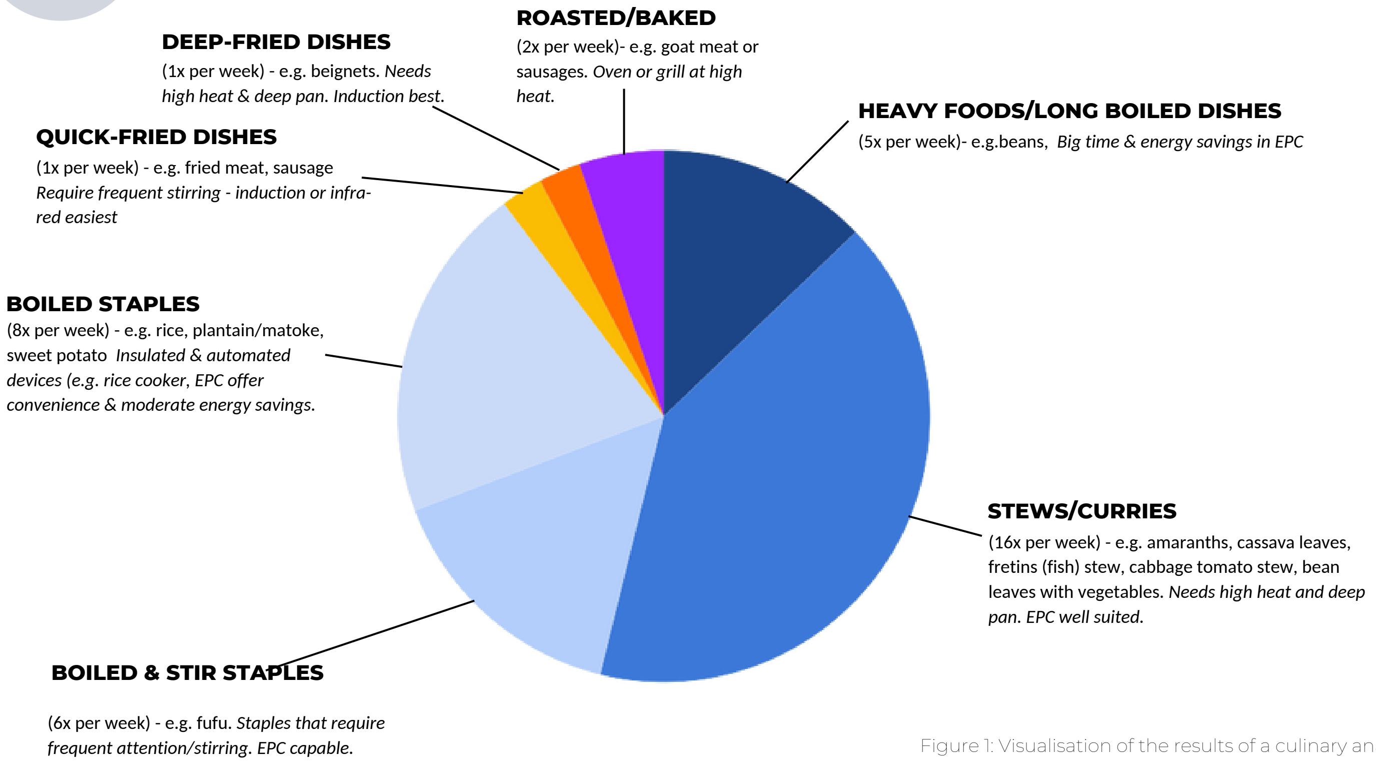


Figure 1: Visualisation of the results of a culinary analysis carried out during this market assessment by asking local team members to map out dishes that a typical Eastern DRC household might prepare in an average week to assess their compatibility with modern energy- efficient appliances.

POPULAR DISHES: 92% of everyday eastern DRC dishes able to be cooked with an EPC

Households in Eastern DRC typically prepare two meals per day on average, using a mix of cooking processes, of which long boiled dishes such as beans, fry and boil/simmer dishes such as stews, and boiled staples (such as fufu or rice) dominate. A high proportion of the depicted weekly menu is compatible with energy-efficient appliances such as rice cookers and EPCs, in line with conclusions from MECS' Eastern and Central African studies.

Fufu –a maize meal, sorghum or cassava (or mix) staple dish that is boiled and vigorously kneaded. *It is simple to cook in an EPC or rice cooker and the non-stick pot is easy to clean.*

Cassava leaves – boiled cassava leaves mixed with other vegetables (such as carrot or aubergine) and finished with oil. *EPCs are well suited to boiled dishes as offer deep pans and insulated lids, and can offer significant savings.*

Beans – different varieties of legumes or pulses, which are boiled for around one hour to several hours. *EPCs are the obvious choice in this category, offering big time and energy savings.*

Rice or Plantain– simply boiled or steamed rice or plantain are common staples. *Easily prepared with rice cookers or EPCs.*

Sauces – stews or sauces cooked using vegetables, such as cabbage or bean leaves, or meat such as pork, goat or beef are common dishes that take around one hour. They are cooked with a frying stage and a longer boiling or simmering stage. *The EPC is well suited to both these processes, with or without pressurizing. Pressurizing accelerates the process.*

KEY ENERGY-EFFICIENT APPLIANCES & MARKETING MESSAGES

Most viable energy-efficient appliances: EPCs, induction stoves, rice cookers, kettles

Key marketing messages: energy-efficient appliances offer substantial time and cost savings and enable multi-tasking, and could form part of fuel stack. EPCs are the cheapest and most convenient way to cook long-boiling dishes such as beans.

KEY ECOOK DEMAND CREATION PROGRAMMES:

- Virunga Foundation are trialing EPCs with customers on their Virunga Energy mini-grid in Goma (described in detail in Supply Chain section).

KEY CONSUMER DEMAND DRIVERS:

- Urbanization driving broader changes in lifestyle: shifts towards urban areas that have better access to electricity, towards purchasing cooking fuel, and towards a wider range of income generating activities driving demand for time savings.
- Energy-efficient appliances could reduce peak demand on grids vis-à-vis inefficient appliances such as hotplates and heating coils.
- From culinary survey findings, over 92% of the everyday Eastern DRC menu can be cooked in an EPC, with big time and energy savings on the most energy-intensive dishes (heavy foods), which make up around 10% of the weekly menu.
- High use and experience for consumers of eCooking in some urban centres, such as Kinshasa, although predominantly using simple low efficiency electric appliances (e.g. hotplates).

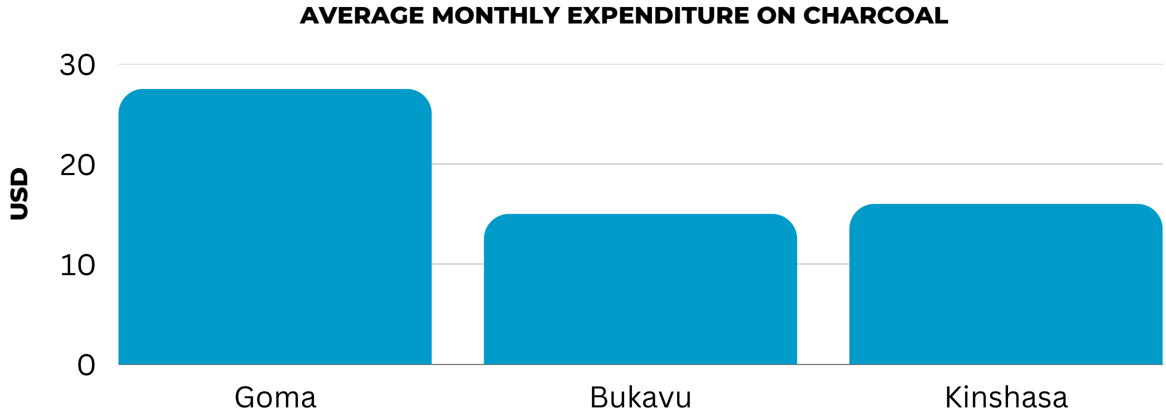
KEY CONSUMER DEMAND BARRIERS:

- Deep-rooted social-cultural perceptions exist, built over histories of biomass dependency and widely-promoted intermediary technologies such as improved biomass cookstoves.
- Limited availability and awareness of the range of the available modern energy-efficient electric cooking appliances and their compatibility with Eastern DRC cuisine.

KEY MARKET SEGMENTS FOR THE ELECTRIC COOKING TRANSITION

The DRC is among the poorest nations in the world and accordingly consumers are price sensitive and interventions must take into account the low average purchasing power of the population. **Consumer financing mechanisms are likely needed to support eCooking, especially for the lowest income urban populations.**

- **Urban charcoal users** – The most important market segment for transitioning to eCooking are charcoal users. In urban areas in Eastern DRC over 90% of households depend on charcoal as a primary cooking fuel. Unlike firewood, charcoal is often purchased and is an existing expenditure that could alternatively be used on electricity units. It is estimated that between 15-30% of household income is used for biomass energy. Energy efficient appliances, such as EPCs, offer a modern alternative that could reduce expenditure on cooking fuels, and the high upfront appliance costs can be mitigated by new business models such as buying on credit and through PAYGO schemes. However, interventions needs to consider varying income differentials and contexts. Most people live below the poverty line ($2.15 per person, per day).



- **Electric cooking users** – Nationally, 2.5% of the population are estimated to cook with electricity. For example, according to a 2020 study conducted in Kinshasa, electricity is used by 66.4% of the Kinois population with significant fuel stacking for households (70%), while 97.7% of households primarily use charcoal, and other fuels equating to under 10% use (Gazull et al., 2020). In Goma there is less fuel stacking (25%) and far more reliance on charcoal alone, with 99.5% primary use, followed by electricity (13.2%), gas (9%), firewood (5%) and kerosene (2.7%). The most popular electric cooking devices are single or multiple hotplates (Laurent Gazull, 2020b). **More knowledge about the current use of electricity for cooking and the potential impact of energy-efficient devices could provide instructive in determining the opportunities and challenges for facilitating wider uptake.**

- **Firewood users** – Around 60% of Congolese rely on firewood as a primary cooking fuel. Many firewood users do not pay for their fuel so there is no direct monetary incentive to shift to eCooking or a modern energy fuel that is paid for. This is especially acute in rural areas where 99% of households use firewood as primary cooking fuel. However, with urbanization and increasing incomes households move away from firewood and it is often substituted for charcoal or additional fuel types in a fuel-stacking pattern. Other factors, such as time and effort spent in collection, and the indirect monetary cost of particularly the time, are potential drivers of behavior change in this segment.

Photo: Courtest Dieudonnne Magane

4. SUPPLY CHAIN

INNOVATIVE ECOOKING PILOT PROJECT

Virunga Energies EPC trial – In 2021, the Virunga Foundation distributed 50 ECOA electric pressure cookers (EPC) from Burn Manufacturing (Kenya) to customers of Virunga Energies (VE) – who are currently expanding provision of electricity - in Goma. The majority of EPCs distributed were still in use and many participants act as ambassadors for eCooking and EPCs. The next phase of the pilot, started in 2022, entails distributing initially 500 EPCs obtained from Sescom (Tanzania) to VE customers and aims to learn about customer use of EPCs, advantages and disadvantages and cost comparisons with charcoal. Financing options such as microfinancing or on-bill financing will be explored, as the EPCs are being distributed at no upfront cost. In total, the project aims to get data from 1500 households, with the first analyses expected in 2023. It is multipartner collaboration involving the University of Antwerp, funded by the Fund for Innovation in Development (FID), hosted by Agence Française de Développement (AFD), from the Centre for Economic Policy Research (CEPR) and the Foreign, Commonwealth & Development Office (FCDO) through its joint research initiative on Private Enterprise Development in Low Income Countries (PEDL), the Labex CEMEB from the I-SITE MUSE and the National Research Institute for Agriculture, Food and the Environment (France), Centre for Environmental Economics Montpellier in France.

KEY SUPPLY SIDE DRIVERS:

- Pilots for eCooking devices on VE mini-grids show promising early results, with ongoing regular use once introduced to electric pressure cookers.
- Supply chains for importation of eCooking appliances are in place, including for energy-efficient eCooking appliances.
- Early piloting of innovative consumer financing mechanisms underway with LPG appliances enabling low-income households to unlock low-cost clean cooking. Energy-efficient eCooking devices could follow suite.

KEY SUPPLY SIDE BARRIERS:

- Lack of quality standards risk low poor quality devices in the market and risk customer trust.
- Importers and distributers are not aware of the opportunity presented by expanding their range into more energy efficient cooking appliances.
- Most consumers are not aware of modern energy-efficient devices.

KEY ECOOKING APPLIANCE DISTRIBUTORS IN EASTERN DRC

An appliance availability survey was conducted in Goma and Bukavu to determine the extent of availability of different types of electric cooking appliances, profiling variables such as relative price range, brand/model names, power ratings and other relevant features. The survey was undertaken in 7 stores in Goma and 5 stores in Bukavu.

A range of eCooking appliances such as hotplates and electric ovens, as well a limited range of rice cookers and EPCs, by brands such as Zec, Nikura, Saachi, Ramtons, Sharp, Geepas and Super General, are available in city centre shops. They are imported predominantly from the Middle East and China, and distributed through local retail stores. In addition, Burn Manufacturing (Kenya) have supplied EPCs, and SESCOM, who sell an own-brand Global LEAP award winning EPC adapted for the Tanzanian market, have supplied over 500 EPCs to trials to customers in Goma. The orientation of economic activity in Eastern DRC, as is apparent in Goma, appears to lean towards markets in eastern Africa, the Middle East and Asia (Vlassenroot & Büscher, 2009).

ECOOK APPLIANCES IN EASTERN DRC TODAY:

- In urban areas, where electricity is used for cooking, single or multiple hotplates are the most popular eCooking devices (Laurent Gazull, 2020a)(Laurent Gazull, 2020b), and according to the appliance availability survey conducted in Goma and Bukavu, these are the cheapest electric cooking devices (35-45 USD), apart from water heaters (6-10 USD) and kettles (14-30 USD).
- Other commonly available appliances in Goma and Bukavu are mixed LPG and stand-alone electric cookers.
- Microwaves are relatively expensive (120-300 USD), and few households have them.
- Energy-efficient electric appliances, such as rice cookers or electric pressure cookers, are available in shops but use and sale statistics are unknown.

Appliance	Typical retail price range (in Goma & Bukavu)
Hotplate	35-50 USD
Electric Pressure Cooker	90-120 USD
Rice Cooker	85-90 USD
Microwave	120-300 USD
Airfryer	100 USD
Induction Cooker	200 USD
Infrared	35-190 USD
Kettle	14-30 USD
Water Heater	6-10 USD
Electric Oven & hotplate	140-450 USD

Table 1: Typical retail prices for selected eCooking appliances in Goma and Bukavu.from appliance availability survey conducted Nov 2022

RELATIVE COST OF ECOOKING VS. POPULAR COOKING FUELS

At the national tariff, cooking with electricity would be cheaper than using traditional fuels (except collected firewood), and at upto costs of 0.25 USD/kWh (e.g. VE mini-grid tariffs) it can still be competitive to cook with electricity.

GRID ELECTRICITY TARIFFS (2020):

- **SOCIALE (LIFELINE)**: 2.65 USD/100 KWH (0.027 USD/KWH)
- **REGULAR**: 0.039 – 0.087 USD/KWH (RESIDENTIAL 1 – RESIDENTIAL 2)

MINI-GRID TARIFFS (2022):

VIRUNGA ENERGIES/SOCODEE: 0.25 USD/KWH; 0.27USD/KWH

NURU: 0.37-0.45 USD/KWH

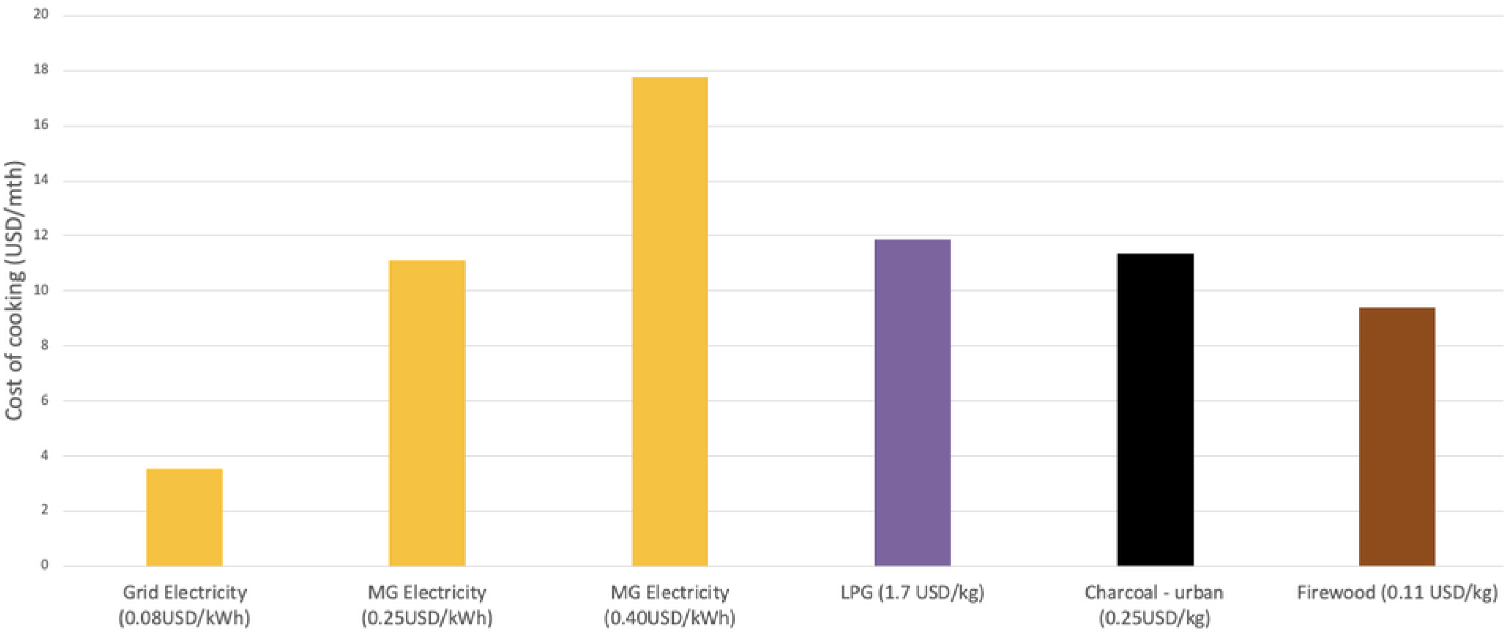


Figure 1: Cost comparison of different cooking fuels based on international averages for cooking energy demand from ESMAP (2020) and local electricity/fuel prices from secondary data and interviews..

5. POTENTIAL IMPACTS OF SCALED UPTAKE IN MOST VIABLE MARKET SEGMENTS IN EASTERN DRC

In the DRC, EnDev has a strategic focus in the Eastern region and as a result, the focus of this market assessment is to identify pathways by which the eCooking transition could be accelerated in the near to medium term in the Eastern DRC through practical interventions that could be made in the near future. There is a particular spotlight on firstly urban areas, where opportunities are more compelling, given vast national differences between electricity access of around 40% compared to rural areas at only 1% (World Bank, 2022b), and secondly with a focus on the Eastern DRC, particularly Goma and Bukavu. Although the two cities share similar characteristics, Bukavu is smaller and largely relies on the national utility company for electricity while Goma has wide active mini-grid electricity provision, is fast growing and seen as an attractive economic centre for business and trade, acting as the base for many development programmes and partners.

Modelling and analysis in this document identify diverging potential paths towards an eCooking transition in the near term, given their different current and historical energy access contexts. There is also a wide range of electricity access solutions for urban areas in the Eastern DRC compared to markets in neighbouring countries, with solar mini-grids and off-grid solution like Solar Home Systems forming part of the current thinking for achieving widespread electrification across urban DRC. With complementary technology, such as battery support, and adequate financing, eCooking could become a viable option in off-grid and mini-grid settings.

Possible scenarios for widespread uptake of electric cooking were explored for Goma and Bukavu. The cases are described below, and the cost and benefit impacts of scaled uptake in these contexts are summarised, with further detail in Appendix A.

SCALED UPTAKE MODELLING

TThe World Health Organisation's (WHO) "Benefits of Action to Reduce Household Air Pollution" (BAR-HAP) tool is used to model the transition from charcoal to electric cooking. BAR-HAP calculates a range of physical impacts of the transition, and also converts those to economic values, allowing an overall 'net social benefit' to be calculated.

The scenarios represent a programme of eCook stove investment, with the capital costs paid by the programme (this could be donor, investor or government funded) and any savings in fuel costs, and avoidance of buying replacement traditional stoves, benefiting the households. The model calculates the changes in those capital and operating costs, but also estimates a much wider set of economic, social and environmental cost and benefits of the transition, such that the overall 'social net-benefit' to the region of the transition can be shown.

Households each receive an Electric Pressure Cooker and a single plate induction stove. Transitioning households are assumed to continue fuel stacking. As this is a key assumption, the scenarios have each been modelled for alternative assumptions on the usage rate of the electric cooking devices, starting from the more optimistic 80% (ie 20% stacking with charcoal) and then a less positive 50% (stacking 50% with charcoal).

Where possible, data from the regions are used, such as charcoal prices and electricity tariffs. Some model parameters are based on evidence from other location; for example the electric stove package is assumed to cost $100, based on experience in other parts of Sub-Saharan Africa and to reflect potential maturing of the appliance market in DRC. The relative energy performance of eCooking compared to charcoal is based on analysis in Scott and Leach (2022) of the specific energy consumption of cooking with charcoal compared to EPCs and hotplates in a wide range of studies in Africa. The resulting energy ratios are 15 and 5.5 respectively.

For battery-supported cooking in Bukavu (case 2), an additional capital cost is included for the batteries and associated equipment used to cushion against grid interruptions. For PV-battery cooking (case 3) there are additional costs for PV panels. Two sources are used for battery and PV costs, based on studies elsewhere in SSA.

These transitions require sufficient electricity supply capacity to support the growing numbers of electric cooking devices. The assumption is made for Goma that the minigrid capacity is increased over time to meet the eCooking demand, alongside other loads. For Bukavu, for the grid-battery-supported case it is assumed that the battery storage implemented as part of the transition can overcome current and future supply deficits by allowing time-shifting cooking loads. For the third case, it is assumed that the PV and battery system is sized to meet the required household cooking demands.

CASE STUDIES IN URBAN EASTERN DRC

REGIONAL CASE STUDY 1: RENEWABLE MINI-GRIDS IN GOMA

Until recently, regional instability meant that few people in this city of around 1-2 million people had reliable access to electricity, however several private developers have established renewable (or hybrid) mini-grids in the city in the last few years (for example Nuru, Virunga Energies and SOCODEE) in addition to the national utility SNEL. Unsustainable charcoal production is a major environmental challenge in the region and eCooking is a possible solution, with Virunga Energies already piloting eCooking with their customers using EPCs sourced from MECS partners in Tanzania and Kenya. This case study explores both the potential impacts that the uptake of eCooking could have amongst the current customer base of these mini-grid developers, as well as the longer-term potential impacts that eCooking could have if their plans to scale these mini-grids are achieved.

POTENTIAL IMPACTS OF SCALED UPTAKE IN MOST VIABLE MARKET SEGMENTS

If 40% of Goma grid-connected charcoal users (est. 230,000 people, 34,000 households) switched to eCooking, the WHO's BAR-HAP tool suggests that:

	Case Study 1a: Goma 80% of current mini-grid connected users transitioning to eCook	Case Study 1b: Goma 50% of current mini-grid connected users transitioning to eCook
Net social benefit	$2.1 million/yr	$1.2 million/yr
DALYS/yr	34	34
CO2 Emissions reduced	38,000 tonnes/yr	23,905 tonnes/yr
Reduction in unsustainable wood harvest	12,105 tonnes/yr	7,566 tonnes/yr
Time saved	2.8 million hours/yr	1.7 million hours/yr
Electricity demand stimulated	1615 MWh	1009 MWh
Payback	6 months*	9.5 months

*$100/HH upfront cost, $196/HH/yr savings on fuel energy costs, For further detail, please see Appendix A: Impact of Scaled Uptake.

REGIONAL CASE STUDY 2: BATTERY-SUPPORTED ECOOKING IN BUKAVU

In Bukavu, the national utility, SNEL, offers access to low cost, but unreliable electricity to some (~69%) of the city's around 1 million people. Hydropower generation offers low tariffs in line with the national rates, however there is insufficient supply to meet demand and load shedding is common practice. Around 10% of the grid-connected households are estimated to already own eCooking appliances (Laurent Gazull, 2020a), however the usage of electricity for cooking is severely limited by power availability. This case study explores the role that household battery storage could play in buffering supply and demand, enabling households to cook with electricity even when there are blackouts.

POTENTIAL IMPACTS OF SCALED UPTAKE IN MOST VIABLE MARKET SEGMENTS

If 40% of Bukavu's grid-connected charcoal users (est. 430,000 people, 66,000 households) switched to eCooking, the WHO's BAR-HAP tool suggests that:

	Case Study 2a: Bukavu national grid and battery, 80% use of eCook	Case 2b: Bukavu grid + battery, 50% use of eCook
Households transitioning	26,470	26,470
Net social benefit	$3.9 million/yr	$2.1 million/yr
DALYS/yr	148	148
CO2 Emissions reduced	74,372 tonnes/yr	46,483 tonnes/yr
Reduction in unsustainable wood harvest	23,537 tonnes/yr	14,711 tonnes/yr
Time saved	5.4 million hours/yr	3.4 million hours/yr
Electricity demand stimulated	3141 MWh	1963 MWh
Payback	*1.7-2.7 years	2.7-4.3 years

*2430-700/HH upfront cost, $258/HH/yr savings on fuel energy costs. For further detail, please see Appendix A: Impact of Scaled Uptake.

REGIONAL CASE STUDY 3: PV & BATTERY SUPPORTED ECOOKING IN BUKAVU

Case study 2 relies on regular availability of the grid to recharge the battery, which can then support cooking at any time, including periods of the day when the grid is not available. This third case study explores an alternative scenario in which households are either not in reach of the grid, or the grid is either not reliable enough, or is of insufficient capacity, to support the rollout of battery-supported eCooking. Instead households use self-contained solar home systems sized to meet the cooking demands (subject to some fuel stacking). The capital costs are higher but households have no ongoing energy costs for cooking.

POTENTIAL IMPACTS OF SCALED UPTAKE IN MOST VIABLE MARKET SEGMENTS

If 40% of Bukavu's charcoal users (est. 430,000 people, 66,000 households) switched to eCooking, the WHO's BAR-HAP tool suggests that:

	Case Study 2a: Bukavu PV and battery, 80% use of eCook	Case 2b: Bukavu PV + battery, 50% use of eCook
Households transitioning	26,470	26,470
Net social benefit	$3.7 million/yr	$1.8 million/yr
DALYS/yr	148	148
CO2 Emissions reduced	74,372 tonnes/yr	46,483 tonnes/yr
Reduction in unsustainable wood harvest	23,537 tonnes/yr	14,711 tonnes/yr
Time saved	5.4 million hours/yr	3.4 million hours/yr
Electricity demand stimulated	n/a	n/a
Payback	*1.7-3.3 years	2.8-5.3 years

*$499-950/HH upfront cost, $289/HH/yr savings on fuel energy costs. For further detail, please see Appendix A: Impact of Scaled Uptake.

RESULTS: IMPACTS OF SCALED MODELLING

The overall social benefit-cost is strongly positive for all cases, as when the physical impacts are monetised, the benefits far outweigh the costs.

The DRCs electricity mix is mainly renewable and hence the greenhouse gas emission benefits of switch from charcoal to electricity are large. The social benefits from avoided time spent cooking are similarly large, reflecting mainly time savings using an EPC. The reduced fuel costs to households shows a large positive benefit, resulting from use of more efficient stoves, even for the Goma case in which the minigrid electricity tariff is relatively high. The largest element of cost is for the purchase of modern stoves, and this is much larger for Bukavu with the added cost of batteries. Adding PV increases the initial capital cost, but removes the ongoing cost of fuel for households. The overall results are similar to the other two cases, showing that the issue for solar electric cooking is not about the overall cost but about how capital costs are spread out and who pays. Payback time (effectively the capital cost of the stoves divided by fuel cost savings) is much shorter than stove lifetime for all cases, showing that even on financial grounds eCook can be agood investment case.

The assumption about the usage rate of the electric cooking devices affects savings in fuel, health benefits, time, GHG emissions and unstainable biomass use. However, while benefits are reduced by the less optimistic case, with 50% continued fuel stacking, the net social cost benefit is strongly positive for all cases analysed and the effects on financial payback time are modest.

This is an impact analysis for some simple broad scenarios in two regions of DRC and for just one particular segment (grid connected charcoal users). However it demonstrates very significant net benefits that could be achieved, for all three approaches to eCooking, based on the WHO's physical impact and impact monetisation methodologies.

6. RECOMMENDATIONS FOR INTERVENTIONS

Table 2: Decision matrix/board highlighting key factors and viability of specific interventions.

		Current status (incl. summary of key opportunities and challenges)	Recommended interventions
Market segments	**On-grid**	Electricity is a common fuel for cooking in urban areas, although regular supply is a constraint.	Work to better understand current eCooking conditions and cultural and financial implications of energy efficient appliances. Trial battery supported eCooking.
	Mini-grid	In Eastern DRC, mini-grids and off-grid solutions are a reliable source of electricity. Pilots have started in Goma with eCooking on mini-grids, with encouraging preliminary results.	Work with minigrid companies to support promotion of eCooking and distribution of eCooking devices. Support the development and trialing of financing mechanisms, to bridge affordability gap for low-income users.
	Off-grid(SHS)	Financing models pioneered with solar home systems and LPG are successfully broadening the reach of novel technologies and payment means.	Encourage SHS companies to pilot eCooking; lobby government to reduce import tariffs on DC eCooking appliances and battery storage sized for cooking; explore innovative financing mechanisms.
TToc dimensions	**Supply chain**	Energy efficient eCooking devices available in retail stores indicate a fledgling market. EPCs have been imported for trials gathering data on consumer preferences with positive early feedback.	Explore the viability of Results Based Financing (RBF) in stimulating market for energy efficient devices with consumer financing mechanisms to bridge affordability gap for low-income users.
	Consumer Demand	Once introduced EPCs are retained appliances, and trials show that their use extends past trial periods.	Awareness raising campaigns, involving key stakeholders in the government, using mediums with greater reach – such as news, TV, radio and video clips of demonstrations to express the potential of energy-efficient appliances.
	Enabling environment	A draft framework for national energy policy led by MEHR with technical support from UNDP and funding from CAFI has recently been developed. However, lack of integrated energy planning, eCooking and energy access policy are not interlinked, and there is no detailed support for eCooking in policy or strategy documents. Civil society actors support and advocate for off-grid and mini-grid sectors.	Support MEHR and other government offices to develop strategies relating to clean and eCooking. Bring ministries and relevant organizations together at eCooking demonstrations to raise awareness. Support network building and coordination for civil society actors and organizations in mini- and off- grid sectors. Advocate for energy-efficient appliances import duty and VAT exemption.

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7. APPENDIX A: THE WHO'S BENEFITS OF ACTION TO REDUCE HOUSEHOLD AIR POLLUTION (BAR-HAP) TOOL: APPLICATION TO DRC MARKET ASSESSMENT

1.INTRODUCTION

For the DRC market assessment, we want to estimate the impacts that will occur if electric cooking is implemented at scale, in certain regions, compared to continued use of current cooking appliances and fuels. Impacts include costs and changes in subsidies (to the consumer, to government and to other funders etc); health benefits; climate and other environmental impacts; reduction in use of non-renewable biomass; and reductions in time spent gathering fuel.

This requires (a) defining one or more scenarios for level of uptake of eCooking in the region(s) of interest and (b) methods to calculate associated impacts.

The World Health Organisation (WHO) released a revised version of their "Benefits of Action to Reduce Household Air Pollution" (BAR-HAP) tool in July 2021, as part of their Clean Household Energy Solutions Toolkit (CHEST). BAR-HAP tool offers an excellent platform for impact assessments for scenarios of transitions to modern energy cooking at scale. The tool has been applied previously by MECS for each of eight countries in an assessment of eCooking markets for GIZ, plus for two other countries.

The BAR-HAP tool includes databases of demographics, population health, current cooking methods and national energy systems for all low- and middle-income countries, and technical assumptions for all of the traditional cooking appliances and fuels and for clean cooking options including LPG and electricity. The tool could be applied without any input from the rest of this country assessment. However some of the data built-in to the tool lack detail and/or may not represent the segments of the country's population that the market assessment is focused on; some data for DRC are also absent in the tool completely, and in that case wider averages are applied. MECS have added an additional front-end to the tool, allowing input of more detailed data on eCooking, and allowing for easy input of key country or region specific data.

2. CASE STUDIES OF ECOOKING SCALE-UP

2.1 REGIONAL CASE STUDY 1: RENEWABLE MINI-GRIDS IN GOMA

Until recently, regional instability meant that very few people in this city of around 1 million people had access to electricity, however several private developers have established renewable mini-grids in the city in the last few years. Unsustainable charcoal production is a major environmental challenge in the region and eCooking is increasingly being seen as a viable solution, with Virunga Energies already piloting eCooking with their customers using EPCs sourced from MECS partners in Tanzania and Kenya. This case study explores both the potential impacts that the uptake of eCooking could have amongst the current customer base of these mini-grid developers, as well as the longer-term potential impacts that eCooking could have if their plans to scale these mini-grids are achieved.

2.2 REGIONAL CASE STUDY 2: BATTERY-SUPPORTED ECOOKING IN BUKAVU

In Bukavu, the national utility, SNEL, offers access to low cost, but unreliable electricity to some of the city's around 1 million people. Hydropower generation offers low tariffs in line with the national rates, however there is insufficient supply to meet demand and load shedding is common practice. Many of the grid-connected households already own eCooking appliances, however the usage of electricity for cooking is severely limited by power availability. This case study explores the role that household battery storage could play in buffering supply and demand, enabling households to cook with electricity even when there are blackouts.

2.3 REGIONAL CASE STUDY 3: PV + BATTERY ECOOKING IN BUKAVU

Case 2 relies on regular availability of the grid to recharge the battery, which can then support cooking at any time, including periods of the day when the grid is not available. This third case study explores an alternative scenario in which the grid is either not reliable enough, or is of insufficient capacity, to support the rollout of battery-supported eCooking. the role that household battery storage could play in buffering supply and demand, enabling households to cook with electricity even when there are blackouts. Instead households use self-contained solar home systems sized to meet the cooking demands (subject to some fuel stacking). The capital costs are higher but households have no ongoing energy costs for cooking.

3. ASSUMPTIONS AND PARAMETER VALUES

3.1 HOUSEHOLDS AND COOKING FUELS

To model the scenarios above, estimates are needed of the number of households in each region that are connected to the grid or minigrid, and that are currently cooking primarily with traditional/polluting fuels. Table 1 shows that there are approximately 150,000 households in each region, with 23% of those connected to a minigrid in Goma and 45% connected to the national grid in Bukavu. Whilst the data on fuel use shown are for the overall fuel use mix, and so do not indicate which are the primary cooking fuels, in both regions charcoal dominates to such an extent that it is a reasonable approximation to use 99.5% and 97% respectively for the proportion of households suitable for transition from charcoal to eCooking. For this analysis, a conservative assumption is made that only 40% of these households transition from primary charcoal to primary eCooking; this is consistent with the MECS programme's suggested "40, 60, by 2030" goals, which includes a target of 40% of all households connected to grid or off-grid electricity in Low and Middle Income Countries to be using it for cooking by 2030. The final row in the table shows the modelled numbers. This transition is assumed to take five years to complete and then a further five years of operation is modelled. Charcoal price assumptions are taken from the individual reports by Gazull et al. (2020) for Goma (1kg: 0.27 - 0.36 USD observed; average of 0.315 USD/kg assumed), Bukavu (1kg: 0.28 - 0.30 USD observed, average of 0.29 USD/kg assumed).

	DRC (national)	Goma	Bukavu
Number of people	92 million	1,001,690	985,562
People per household	5.3	6.6*	6.5**
Number of households	17.4 million	151,700	151,600
Shares of different cooking fuels or types in use in the region(s)***	2.5% electricity 59% wood 35% charcoal 0.3% gas 0.3% kerosene	99.5% Charcoal 13.2% Electricity 2.7% Kerosene 5% Wood 9% Gas	97% Charcoal 15% Electricity <1% Kerosene 13% Wood <1% Gas
Percentage of grid connected households	19%>	23%	45%
Charcoal-using, grid connected households		34,730	66,180
Households modelled as transitioning (40% of above)		13,890	26,470

*(Dubiez et al., 2021)
**(Imani et al., 2021)
***National shares from WHO HH Energy Database; regional shares from Dubiez et al (2021) and Imani et al (2021)
>World Development Indicators

3.2 ECOOKING ASSUMPTIONS

BAR-HAP has been implemented here using its policy option of a ban on charcoal use, which comes in gradually from 2020 to 2030. Other policy options could have been modelled (eg fuel or stove subsidies), but BAR-HAP incorporates behavioural models to simulate the response of household decision makers to such policy incentives (with not all choosing to transition), and whilst interesting in its own right, this is not the purpose of the current analysis of impacts attributable to a particular scale up of eCooking. The scenarios represent a programme of eCook stove investment to replace charcoal stoves, with the capital costs (and administration) paid by the programme (this could be donor, investor or government funded) and any savings in fuel costs, and avoidance of buying replacement traditional stoves, benefiting the households. The full costs of the new eCooking devices have been assumed to be paid for by the programme: this improves the clarity in final results, as the capital costs and changes in running costs are clearly divided out between the different parties. In practice such a stove programme might offer a partial stove subsidy with households paying the balance, or some form of lending. Different policies or business models for a stove programme would elead to a different distribution of stove and fuel costs and savings between parties. Payback period is included in the results to show how the savings in fuel costs compare to the full cost of stoves, irrespective of who pays.

Households each receive an Electric Pressure Cooker and a single plate induction stove; this package is assumed to cost $100 (to reflect potential maturing of the appliance market in DRC, based on experience in other parts of Sub-Saharan Africa). The relative energy performance of eCooking compared to charcoal is based on analysis in Scott and Leach (2022) of the specific energy consumption of cooking with charcoal compared to EPCs and hotplates in a wide range of studies in Africa. The resulting energy ratios are 15 and 5.5 respectively. As discussed in their report, a simple efficiency metric cannot be used for an EPC as it cooks food faster and without boiling water.

Transitioning households are assumed to continue fuel stacking. As this is a key assumption, the scenarios have each been modelled for alternative assumptions on the usage rate of the electric cooking devices, starting from the more optimistic 80% (ie 20% stacking with charcoal) and then a less positive 50% (stacking 50% with charcoal).

Cooking 100% of the food with charcoal is assumed to take 2.6 hours cooking per day. eCooking is assumed to be 30% faster than cooking with charcoal, saving that proportion of the cook's time, but the absolute saving in hours is reduced by the fuel stacking assumption.

For battery-supported cooking in Bukavu (case 2), an additional capital cost is included for the batteries and associated equipment used to cushion against grid interruptions. For PV-battery cooking (case 3) there are additional costs for PV panels.

There is limited evidence from the field of the costs of batteries, controllers and PV for these applications, which are considerably higher capacity than regular Solar Home Systems. Given the pre-commercial nature of the market, supply chains are not fully developed, import taxes and margins vary, and few devices are available that are optimised for these purposes. Two sources have been used here, one a recent study for Uganda for GIZ (Quigley et al., 2021), based on the Pesitho PV-battery-stove, and the other from a cost analysis by Village Infrastructure Angels.

The tables shows the data from the two sources. VIA break the costing down into sub components whilst the data on the Pesitho stove is aggregated into the different system combination that they market, inclusive of appropriate controls.

	Source:	VIA (AC system)		Quigley et al	
Component	*Life*	*Battery only*	*Solar+ battery*	*Battery only*	*Solar+ battery*
1.2kWh Li-ion battery	10 yrs	400	400	205	205
Inverter	10 yrs	100	100		
Charge regulator	20 yrs	100	100		
PV	20 yrs		250		64
Stove	10 yrs	100	100	230	230
Total capcost		**700**	**950**	**435**	**499**

The results for cases 2 and 3 below show the outcomes of using the less-optimistic of the two sets of assumptions on costs of battery and PV, from VIA. However the simple payback times shown below are calculated using both sets of data, to give a range.

3.3 ELECTRICITY SYSTEM ASSUMPTION

These transitions require sufficient electricity supply capacity to support the growing numbers of electric cooking devices.

- The assumption is made for Goma that the minigrid capacity is increased over time to meet the eCooking demand, alongside other loads
- For Bukavu, for the grid-battery-supported case it is assumed that the battery storage implemented as part of the transition can overcome current and future supply deficits by allowing time-shifting cooking loads
- For the third case, it is assumed that the PV and battery system is sized to meet the required household cooking demands, less 20% of that which is to be met by stacking with charcoal.
-

DRC's national electricity supply system is dominated by hydropower: the IEA report 11,045 GWh from hydro in 2019, 27 from biofuels, 29 from solar and just 5GWh from oil-fired generation. Hydro is expected to continue to dominate the mix. The minigrids in Goma are almost exclusively renewable too, mainly solar PV.

Given the high share of renewables in power generation, the GreenHouse Gas emissions associated with electricity use will be very low. Emission factor values are adopted for the three Kyoto protocol GHGs (CO2, CH4, N2O) from the DRC electricity consumption emission factors in Brander et al (2011).

For PV-battery cooking, emissions at point of use are zero.

Electricity tariffs used are:

- Goma: 0.27USD/kWh - average of 3 minigrid suppliers (USAID, 2019)
- Bukavu, case 2: the national tariff of 0.07 USD/kWh (SNEL)
- Bukavu, case 3: households pay nothing for use of the electricity from their solar home cooking system

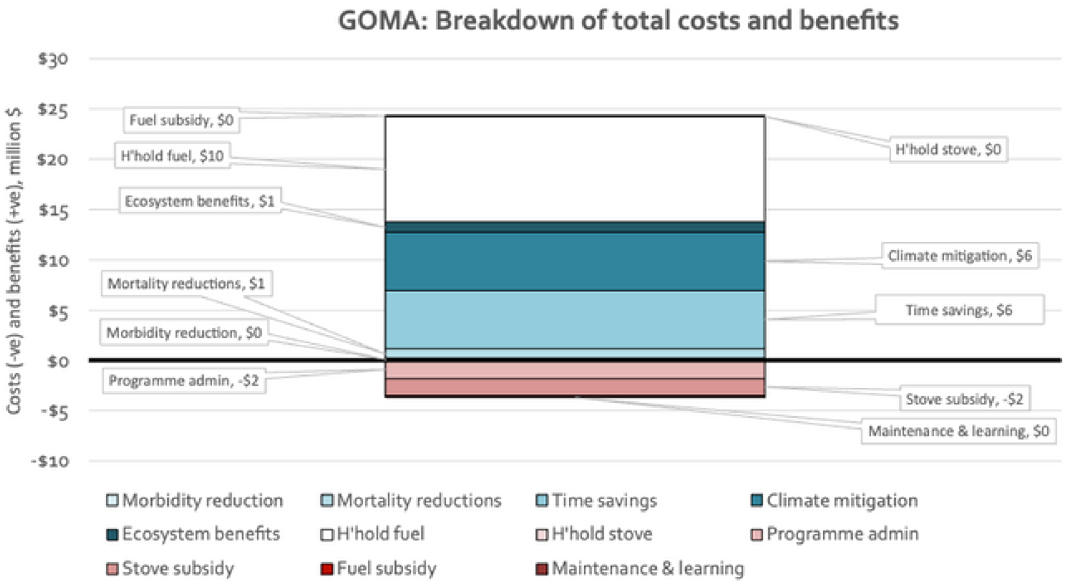
3.4 RESULTS

The simulation results for Goma and then Bukavu are shown below. The upper part of each table shows the number of households transitioning and the lower part shows the outputs of BAR-HAP for the modelled scenario, in both physical units and in economic terms, per household and for the overall transition. The charts show the same total economic values, stacked as costs (-ve) and benefits (+ve), and hence more clearly showing the net social economic impact.

For each of the three cases there are two sets of results, reflecting the alternative fuel stacking assumptions.

3.4.1 Case 1a: Goma minigrids, 80% use of eCook

GOMA						
Grid connections projections and eCook target	Population (million)	housholds (million)	% grid connected			
Regional population, 2022	1.00	0.152				
Electricity connections, 2022	0.23	0.035	23%			
Of which, using charcoal as main fuel	0.23	0.034				
Scenario modelled						
Transition from charcoal to eCooking	0.09	0.014				
Costing (costs are -ve, benefits are +ve)			$/yr	$/yr per household transitioning	$M total for 10yrs	$total per household transitioning
Total present value (ie net social benefits of the transition)			2,062,146	153	21	1530
Total costs of transition			686,461	51	7	509
Private cost to housholds: total			1,034,792	77	10	768
Stove			*5,416*	0	0	4
Fuel			*1,049,081*	78	10	778
Maintenance			*-19,706*	-1	0	-15
Costs to programme: total			-348,331	-26	-3	-258
Stove			*-169,263*	-13	-2	-126
Fuel			*0*	0		
Admin			*-179,067*	-13	-2	-133
Health, Time, and Environmental Benefits: total		**Physical: change/year**	1,375,685	102	14	1021
Health impacts total: DALYs avoided	**DALYs**	**34**	118,189	9	1	88
Mortality reduction	*YLL*	*21*	*96,381*	7	*1*	72
Mortality reduction	*Lives*	*2*				
Morbidity reduction	*YLD*	*12*	*21,807*	2	*0*	16
Morbidity reduction	*Cases*	*63*				
Time savings	**Hours**	**2,785,816**	573,206	43	6	425
Time savings per adopting household	*Hours/HH*	*207*				
Electricity use	**MWh**	**1,615**				
CO2-eq reduction (CO2,CH4,N2O)	**Tonnes**	**38,249**	584,007	43	6	433
Unsustainable wood harvest reduction	**Tonnes**	**12,105**	100,284	7	1	74
Note: costs are discounted across programme period.						
Totals are Net Present values; costs/year are NPV divided by the ten years of the programme						

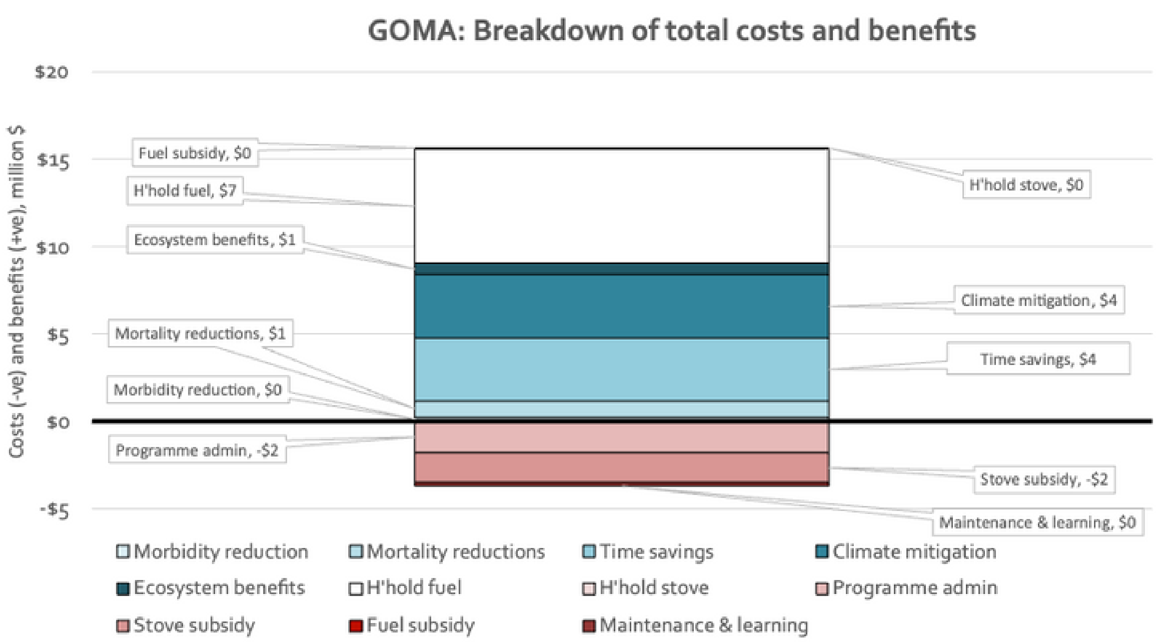


3.4.2 Case 1b: Goma minigrids, 50% use of eCook

GOMA			
Grid connections projections and eCook target	Population (million)	housholds (million)	% grid connected
Regional population, 2022	1.00	0.152	
Electricity connections, 2022	0.23	0.035	23%
Of which, using charcoal as main fuel	0.23	0.034	
Scenario modelled			
Transition from charcoal to eCooking	0.09	0.014	

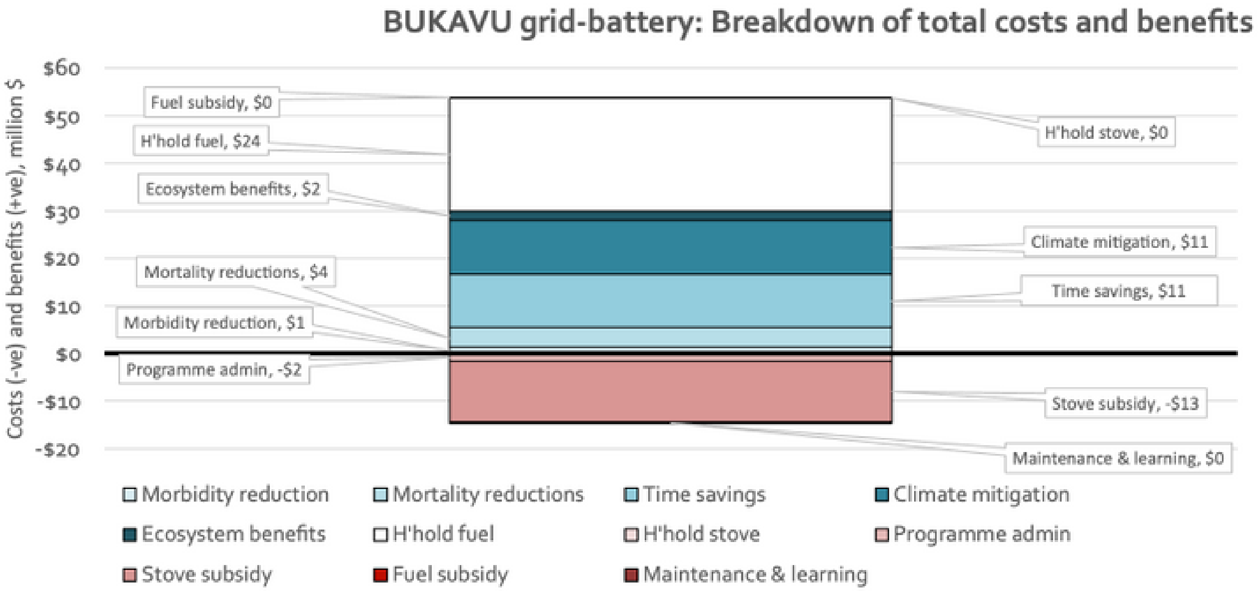
Costing (costs are -ve, benefits are +ve)			$/yr	$/yr per household transitioning	$M total for 10yrs	$total per household transitioning
Total present value (ie net social benefits of the transition)			1,197,180	89	12	888
Total costs of transition			293,056	22	3	217
Private cost to housholds: total			641,386	48	6	476
Stove			*5,416*	0	0	4
Fuel			*655,676*	49	7	486
Maintenance			*-19,706*	-1	0	-15
Costs to programme: total			-348,331	-26	-3	-258
Stove			*-169,263*	-13	-2	-126
Fuel			*0*	0		
Admin			*-179,067*	-13	-2	-133
Health, Time, and Environmental Benefits: total		**Physical: change/year**	904,124	67	9	671
Health impacts total: DALYs avoided	**DALYs**	**34**	118,189	9	1	88
Mortality reduction	*YLL*	*21*	*96,381*	7	*1*	72
Mortality reduction	*Lives*	*2*				
Morbidity reduction	*YLD*	*12*	*21,807*	2	*0*	16
Morbidity reduction	*Cases*	*63*				
Time savings	**Hours**	**1,741,135**	358,254	27	4	266
Time savings per adopting household	*Hours/HH*	*129*				
Electricity use	**MWh**	**1,009**				
CO2-eq reduction (CO2,CH4,N2O)	**Tonnes**	**23,905**	365,004	27	4	271
Unsustainable wood harvest reduction	**Tonnes**	**7,566**	62,678	5	1	46

Note: costs are discounted across programme period.
Totals are Net Present values; costs/year are NPV divided by the ten years of the programme



3.4.3 Case 2a: Bukavu grid + battery, 80% use of eCook

BUKAVU: grid-battery						
Grid connections projections and eCook target	Population (million)	housholds (million)	% grid connected			
Regional population, 2022	0.99	0.152				
Electricity connections, 2022	0.44	0.068	45%			
Of which, using charcoal as main fuel	0.43	0.066				
Scenario modelled						
Transition from charcoal to eCooking	0.17	0.026				
Costing (costs are -ve, benefits are +ve)			$/yr	$/yr per household transitioning	$M total for 10yrs	$total per household transitioning
Total present value (ie net social benefits of the transition)			3,916,845	149	39	1494
Total costs of transition			922,603	35	9	352
Private cost to housholds: total			2,353,906	90	24	898
Stove			*5,793*	0	0	2
Fuel			*2,382,227*	91	24	909
Maintenance			*-34,114*	-1	0	-13
Costs to programme: total			-1,431,303	-55	-14	-546
Stove			*-1,267,124*	-48	-13	-483
Fuel			*0*	0		
Admin			*-164,179*	-6	-2	-63
Health, Time, and Environmental Benefits: total		**Physical: change/year**	2,994,242	114	30	1142
Health impacts total: DALYs avoided	**DALYs**	**148**	549,110	21	5	210
Mortality reduction	*YLL*	*97*	*417,301*	16	*4*	159
Mortality reduction	*Lives*	*8*				
Morbidity reduction	*YLD*	*51*	*131,808*	5	*1*	50
Morbidity reduction	*Cases*	*253*				
Time savings	**Hours**	**5,416,865**	1,114,567	43	11	425
Time savings per adopting household	*Hours/HH*	*207*				
Electricity use	**MWh**	**3,141**				
CO2-eq reduction (CO2,CH4,N2O)	**Tonnes**	**74,372**	1,135,569	43	11	433
Unsustainable wood harvest reduction	**Tonnes**	**23,537**	194,997	7	2	74
Note: costs are discounted across programme period.						
Totals are Net Present values; costs/year are NPV divided by the ten years of the programme						



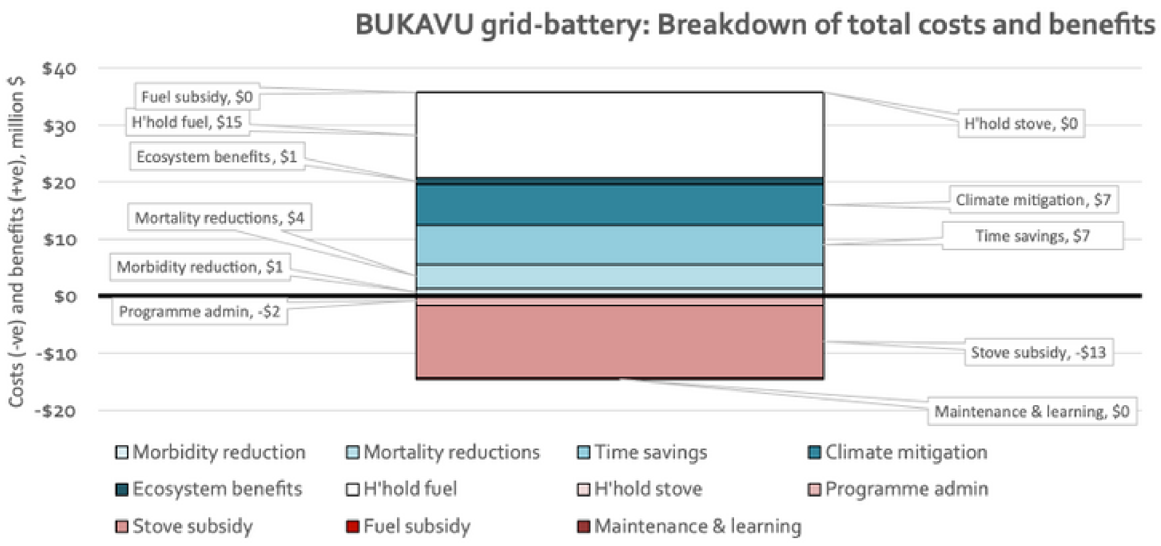
3.4.4 Case 2b: Bukavu grid + battery, 50% use of eCook

BUKAVU: grid-battery

Grid connections projections and eCook target	Population (million)	housholds (million)	% grid connected
Regional population, 2022	0.99	0.152	
Electricity connections, 2022	0.44	0.068	45%
Of which, using charcoal as main fuel	0.43	0.066	
Scenario modelled			
Transition from charcoal to eCooking	0.17	0.026	

Costing (costs are -ve, benefits are +ve)			$/yr	$/yr per household transitioning	$M total for 10yrs	$total per household transitioning
Total present value (ie net social benefits of the transition)			2,106,585	80	21	804
Total costs of transition, government+private			29,268	1	0	11
Private cost to housholds: total			1,460,571	56	15	557
Stove			*5,793*	0	0	2
Fuel			*1,488,892*	57	15	568
Maintenance			*-34,114*	-1	0	-13
Costs to programme: total			-1,431,303	-55	-14	-546
Stove			*-1,267,124*	-48	-13	-483
Fuel			*0*	0		
Admin			*-164,179*	-6	-2	-63
Health, Time, and Environmental Benefits: total		**Physical: change/year**	2,077,317	79	21	793
Health impacts total: DALYs avoided	**DALYs**	**148**	549,110	21	5	210
Mortality reduction	*YLL*	*97*	*417,301*	16	*4*	159
Mortality reduction	*Lives*	*8*				
Morbidity reduction	*YLD*	*51*	*131,808*	5	*1*	50
Morbidity reduction	*Cases*	*253*				
Time savings	**Hours**	**3,385,541**	696,604	27	7	266
Time savings per adopting household	*Hours/HH*	*129*				
Electricity use	**MWh**	**1,963**				
CO2-eq reduction (CO2,CH4,N2O)	**Tonnes**	**46,483**	709,730	27	7	271
Unsustainable wood harvest reduction	**Tonnes**	**14,711**	121,873	5	1	46

Note: costs are discounted across programme period.
Totals are Net Present values; costs/year are NPV divided by the ten years of the programme



The main differences between the input assumptions for the first two cases are:

- Goma electricity tariffs are four times as high
- Bukavu eCooking requires battery support, adding $600 initial cost for each household
- Twice as many households are modelled as transitioning to eCooking in Bukavu

The overall results for each case are however similar, with each having one cost advantage over the other. The total values for Bukavu are larger as more people transition, but per household the net economic benefit is slightly higher for Goma.

The tables for Goma shows that over the ten years of the transition (and incorporating discounting) while this transition would cost the programme on average some $250 per household for equipment and programme costs, it would save households almost $100 per year in reduced energy bills. The picture for Bukavu is similar, although the values are higher: the programme pays more than $500 per household to fund eCook devices (including the battery) but households make a higher cooking cost saving, as electricity is less expensive. These numbers are all on an annualised basis from the full ten year period modelled, and are thus not easy to relate to specific investments: payback times are set out below.

The tables also show the range of non-financial impacts in physical terms. In Bukavu for example, more than 250 cases of disabling morbidity would be avoided per year; some 23 thousand tonnes of unsustainable wood harvesting would be avoided and greenhouse gas emissions would be reduced by almost 75 thousand tonnes per year.

The tables show the valuation of impacts too, but the charts summarise more clearly how the financial and economic valuations of other impacts relate. The DRCs electricity mix is mainly renewable and hence the greenhouse gas emission benefits of switch from charcoal to electricity are large. However the social benefits from avoided time spent cooking are similarly large, reflecting mainly time savings using an EPC, and the opportunity cost for peoples' time, as used in BAR-HAP. The reduced fuel costs to households shows a large positive benefit, resulting from use of more efficient stoves, even for the Goma case in which the minigrid electricity tariff is relatively high. The largest element of cost is for the purchase of modern stoves by the stove programme, and this is much larger for Bukavu with the added cost of batteries.

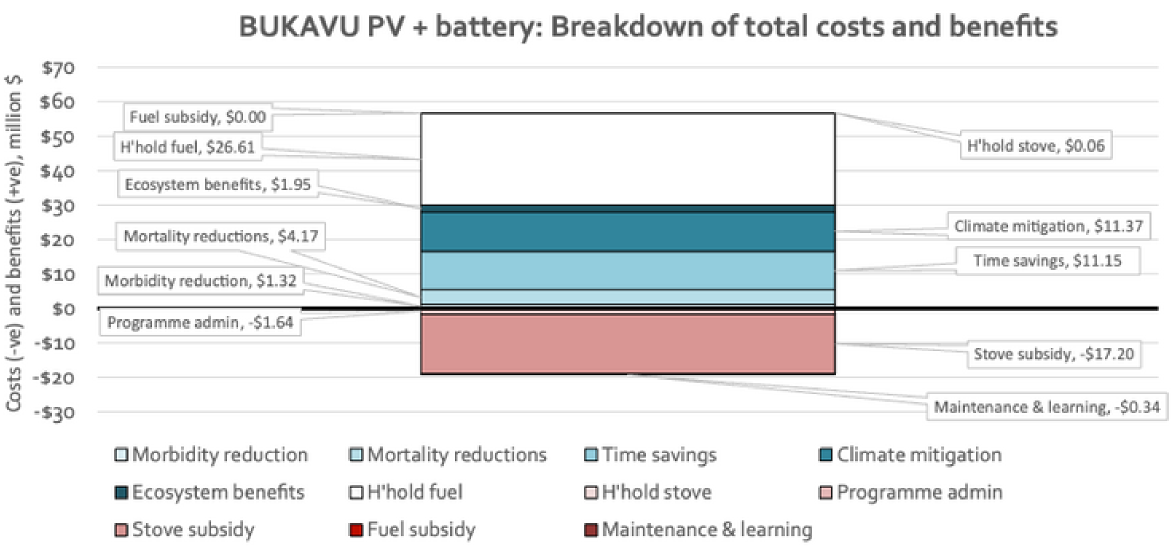
The assumption about the usage rate of the electric cooking devices affects savings in fuel, health benefits, time, GHG emissions and unstainable biomass use. However, while benefits are reduced by the less optimistic case, with 50% continued fuel stacking, the net social cost benefit is strongly positive for all cases analysed. The effects on financial payback time are explored later.

3.4.5 Case 3a: Bukavu PV + batteries, 80% use of eCook

BUKAVU: PV + battery			
Grid connections projections and eCook target	Population (million)	housholds (million)	% grid connected
Regional population, 2022	0.99	0.152	
Electricity connections, 2022	0.44	0.068	45%
Of which, using charcoal as main fuel	0.43	0.066	
Scenario modelled			
Transition from charcoal to eCooking	0.17	0.026	

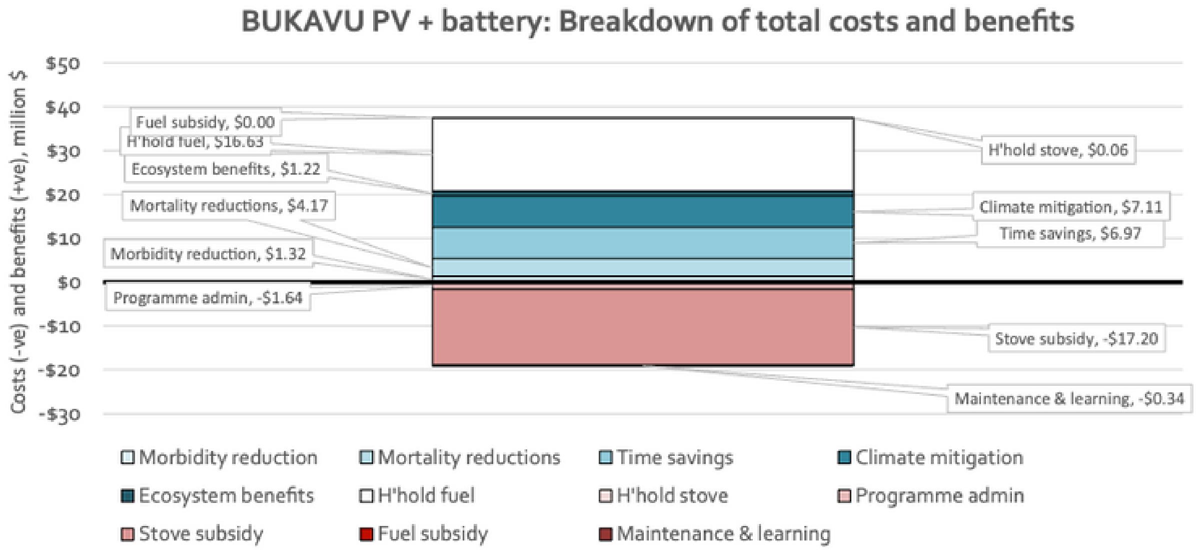
Costing (costs are -ve, benefits are +ve)			$/yr	$/yr per household transitioning	$M total for 10yrs	$total per household transitioning
Total present value (ie net social benefits of the transition)			3,744,544	143	37	1429
Total costs of transition			748,465	29	7	286
Private cost to housholds: total			2,632,313	100	26	1004
Stove			*5,793*	0	0	2
Fuel			*2,660,634*	102	27	1015
Maintenance			*-34,114*	-1	0	-13
Costs to programme: total			-1,883,848	-72	-19	-719
Stove			*-1,719,669*	-66	-17	-656
Fuel			*0*	0		
Admin			*-164,179*	-6	-2	-63
Health, Time, and Environmental Benefits: total		**Physical: change/year**	2,996,078	114	30	1143
Health impacts total: DALYs avoided	**DALYs**	148	549,110	21	5	210
Mortality reduction	*YLL*	*97*	*417,301*	16	*4*	159
Mortality reduction	*Lives*	*8*				
Morbidity reduction	*YLD*	*51*	*131,808*	5	*1*	50
Morbidity reduction	*Cases*	*253*				
Time savings	**Hours**	5,416,865	1,114,567	43	11	425
Time savings per adopting household	*Hours/HH*	*207*				
Electricity use	**MWh**	3,141				
CO2-eq reduction (CO2,CH4,N2O)	**Tonnes**	74,493	1,137,405	43	11	434
Unsustainable wood harvest reduction	**Tonnes**	23,537	194,997	7	2	74

Note: costs are discounted across programme period.
Totals are Net Present values; costs/year are NPV divided by the ten years of the programme



3.4.6 Case 3b: Bukavu PV + batteries, 50% use of eCook

BUKAVU: PV + battery						
Grid connections projections and eCook target	Population (million)	housholds (million)	% grid connected			
Regional population, 2022	0.99	0.152				
Electricity connections, 2022	0.44	0.068	45%			
Of which, using charcoal as main fuel	0.43	0.066				
Scenario modelled						
Transition from charcoal to eCooking	0.17	0.026				
Costing (costs are -ve, benefits are +ve)			$/yr	$/yr per household transitioning	$M total for 10yrs	$total per household transitioning
Total present value (ie net social benefits of the transition)			1,829,193	70	18	698
Total costs of transition			-249,272	-10	-2	-95
Private cost to housholds: total			1,634,575	62	16	624
Stove			*5,793*	0	0	2
Fuel			*1,662,896*	63	17	634
Maintenance			*-34,114*	-1	0	-13
Costs to programme: total			-1,883,848	-72	-19	-719
Stove			*-1,719,669*	-66	-17	-656
Fuel			*0*	0		
Admin			*-164,179*	-6	-2	-63
Health, Time, and Environmental Benefits: total		**Physical: change/year**	2,078,465	79	21	793
Health impacts total: DALYs avoided	**DALYs**	**148**	549,110	21	5	210
Mortality reduction	*YLL*	*97*	*417,301*	16	*4*	159
Mortality reduction	*Lives*	*8*				
Morbidity reduction	*YLD*	*51*	*131,808*	5	*1*	50
Morbidity reduction	*Cases*	*253*				
Time savings	**Hours**	**3,385,541**	696,604	27	7	266
Time savings per adopting household	*Hours/HH*	*129*				
Electricity use	**MWh**	**1,963**				
CO2-eq reduction (CO2,CH4,N2O)	**Tonnes**	**46,558**	710,878	27	7	271
Unsustainable wood harvest reduction	**Tonnes**	**14,711**	121,873	5	1	46
Note: costs are discounted across programme period.						
Totals are Net Present values; costs/year are NPV divided by the ten years of the programme						



Adding PV increases the initial capital cost, but removes the ongoing cost of fuel for households. The overall results are similar to the other two cases, showing that the issue for solar electric cooking is not about the overall cost but about how capital costs are spread out and who pays.

3.4.7 PAYBACK TIMES

The BAR-HAP tool has been applied here using the crude assumption that a stove programme pays the full cost of initial investment in eCooking equipment; hence the capital costs (shown as 'Stove subsidy') and the benefits in reduced running costs (captured as 'Household fuel') are clearly separated. In practice the initial capital cost of stoves, batteries and PV (as appropriate to the case considered) could be paid for in a number of ways. Further exploration of that is beyond the scope of this work. However the clearest way to compare the investment costs to change in operating costs is the payback time. The above tables involve discounting to give a sense of the overall costs and benefits of a long project where the time value of money is important. Here the simple (or undiscounted) payback is shown. The assumption about the usage rate of the electric cooking devices makes an obvious difference here: payback is calculated by dividing capital cost by annual fuel cost saving, and the latter scales almost linearly with usage rate.

		Goma	Bukavu			
			VIA (AC system)		Quigley et al	
	% electric cooking	*Stove only*	*Stove+battery*	*Stove+battery +PV*	*Stove+battery*	*Stove+battery +PV*
Simple payback (years)	80%	0.5	2.7	3.3	1.7	1.7
Simple payback (years)	50%	0.8	4.3	5.3	2.7	2.8

So with more optimistic assumptions about fuel stacking, the required purchase of an EPC and induction hob could be paid back in around 6 months in Goma, due to avoided charcoal purchase, despite the need to pay for electricity from a minigrid. Reducing the use of electric cooking to 50% pushes the payback period up from 6 months to around 9 months. Two sets of result are shown for Bukavu: the first set use the cost assumptions from VIA (as also used in the main results above) and the second use the lower cost estimates from Quigley et al for the Pesitho stove system. The results show that adding a battery causes payback to stretch out into year 2 or 3, and adding PV can stretch it into year 5. The Pesitho-based paybacks are however both well below 2 years.

3.5 OVERALL CONCLUSIONS

The overall social benefit-cost is strongly positive for all three cases, with benefits (above the zero line) far outweighing costs (below the line).

This is an impact analysis for some simple broad scenarios in two regions of DRC and for just one particular segment (grid connected charcoal users). However it demonstrates very significant net benefits that could be achieved, for all three approaches to eCooking, based on the WHO's physical impact and impact monetisation methodologies.