Policy and market review

for modern energy cooking in Rwanda

Working paper

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Main authors:

Energy 4 Impact

H. Njiru Nyaga, I. Ndayishimiye, D. Ntivunwa Saulve, J. Baranda Alonso

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Executive Summary

This report was commissioned by Loughborough University, the lead implementing partner on the Modern Energy Cooking Services (MECS) programme.

The purpose of this report is to explore the policy frameworks and national markets in Rwanda around modern energy cooking solutions, in order to understand the existing cooking landscape and the potential of modern energy cooking solutions in the country, particularly electric cooking, providing MECS with recommendations to support the transition towards modern energy cooking services in Rwanda. The report is based on primary and secondary research conducted by Energy 4 Impact (E4I) between January and June 2021, including interviews with clean cooking stakeholders from the public and private sectors in Rwanda.

Over the last decades, Rwanda has experienced substantial socio-economic progress, driven by a long-term political vision to achieve high standards of life for Rwandans. Energy is a cross-cutting area of focus by the Government of Rwanda (GoR) to achieve this socio-economic transformation, with ambitious targets on generation capacity, quality and reliability of supply and energy access.

The main policies setting the strategic framework for Rwanda's energy sector are the Rwanda Energy Policy and the Energy Sector Strategic Plan (ESSP). The ambitious objectives set in these policies have led to 62% of Rwandan households having access to electricity in 2021, from only 9% in 2009. This outstanding progress is aligned with the current goal of the GoR of achieving universal electrification by 2024. The advances in electricity access contrast with the continued reliance on traditional cooking technologies and fuels by the majority of Rwandans, with the subsequent health, economic and environmental impacts.

In the electricity sector, the combination of grid-connected and off-grid solutions, such as solar home systems or mini-grids, have been considered in the road towards universal electrification. While a strong focus has been placed on productive uses of electricity, electricity consumption by households remains low at 20.8 kWh/month, with access limited to low-load appliances for most households, and relatively high electricity tariffs compared to other countries in the region. Rwanda has also introduced targets for the improvement of the reliability and efficiency of the electricity supply in the country, as well as financing schemes to support the off-grid sector, such as the results-based-grants under a joint scheme by Rwanda Renewable Energy Fund (REF) and Rwanda Energy Access and Quality Improvement Project (EAQIP), financed by the World Bank.

Biomass continues to be the main energy source in Rwanda, representing 85% of final energy consumption. The high dependency on biomass by households, mostly for cooking, together with the rapid population growth, is putting pressure on the biomass resources of the country. The Biomass Energy Strategy is promoting a more sustainable management of the biomass resources of the country, together with a reduction in the biomass dependence, favouring alternative fuels for cooking. Some of the challenges faced by the transition needed in the biomass sector are the increasing demand, the low efficiency of biomass production processes resulting in low efficiency products, and the important role that plays in the country's economy. The petroleum sector represents 13% of the primary energy consumption in Rwanda, showing an increasing demand for imported LPG for cooking, but still reduced and concentrated in urban areas.

As a result, the cooking landscape in Rwanda is dominated by traditional cooking fuels, such as firewood and charcoal, and traditional cooking technologies, such as three-stone or mud stoves. Firewood accounts for 93% of the cooking fuel used in rural areas, while charcoal is predominant in urban areas (65% of cooking fuel used). Hence, indoor house air pollution is a leading factor for mortality in Rwanda, estimated to cause over 7,800 premature deaths annually. National policies represent the ambition to reduce the reliance on traditional fuels and cooking technologies, with the ESSP aiming to reduce the number of households depending on traditional cooking fuels from 79% to 42% by 2024. This would also contribute to achieving a balance in the supply and demand of biomass products in the country. A strong emphasis on customer awareness, social and behavioural change campaigns are promoted to achieve this target. Subsidies to clean cooking technologies are encouraged, with a USD 17 million clean cooking results-based-financing (CC-RBF) window funded by the World Bank under the Energy Access Quality Improvement Project (EAQIP) programme (World Bank, 2020b), subsidising the price of eligible clean and efficient cooking solutions for consumers, aiming to reach 500,000 households by 2025 (BRD, 2021a). The clean cooking stream of EAQIP also includes a USD 3 million technical assistance and implementation support programme, that will provide technical assistance and training to local producers to improve local product design and quality production, support awareness raising and behaviour-change campaigns, market facilitation and policy review technical assistance (World Bank, 2020b).

However, Rwandan household cooking practices are still based on traditional fuels and stoves. About only 2% of the population has access to modern cooking fuels and technologies, concentrated in urban areas

and high-income households, while about 15% have access to clean cooking stoves. Three-stone and traditionally manufactured stoves are predominant in rural areas, and 76% of Rwandan households spend more than 7 hours per week acquiring and preparing fuel, posing a high burden on women and girls, who are generally in charge of these activities.

Nevertheless, there is a clear interest from Rwandan households to transition towards more efficient cooking solutions, with half of households using traditional stoves willing to purchase improved cookstoves (ICS) (World Bank, 2018). The market for efficient biomass cookstoves is growing in Rwanda, which can represent a cost-effective solution to transition rural and low-income households away from traditional cookstoves, reducing their fuel use and costs. Charcoal is substantially more expensive than firewood, which can be often collected for free. Charcoal monthly expenditure per household is around USD 10-15, while the monthly expenditure on firewood is USD 2 on average across the country (REG, 2021c). However, if firewood is not collected for free and only purchased at market prices, the high amounts of fuel needed per household can also result in substantial expenditure, of up to USD 11 per month based on current market prices.

The GoR has identified urbanization as an opportunity for socio-economic growth, and acknowledges that a well-planned urbanization may help achieve the proper use of land, other natural resources, and initiate local economic development. The urban population is projected to double from 17.8% in 2017 to 35% in 2024, and based on the recent charcoal use increase in urban areas, from 65.1% in 2014 to 67.4% in 2017, the balance would significantly shift away from firewood use and towards increased use of charcoal. However, the target by GoR to reduce urban charcoal consumption to 32% would provide a potential market for modern cooking solutions, and for electric cooking in particular with the high electricity access in urban areas.

Advanced biomass fuels such as pellets and briquettes are proposed by the GoR as alternatives to displace firewood and charcoal. While the most advanced biomass cookstoves can cost up to USD 65, various private companies are starting to offer innovative stove and fuel subscription models to remove the upfront cost barrier for customers, with 1kg of pellets priced between USD 0.25-0.30.

Modern fuels such as LPG or biogas are also regarded by the GoR as cleaner alternatives for cooking. Biogas has been widely promoted among institutional facilities and households under the National Domestic Biogas Programme since 2008, reaching 3,700 households, 86 schools and prisons across the

country to date. However, the high upfront costs, technical maintenance requirements and availability of waste have hampered a wider adoption. LPG has started to gain traction as an alternative fuel for cooking, and it is currently regarded as one of the fastest solutions to curb biomass demand in Rwanda. However, its presence is mostly limited to urban areas and high-income households to date. There is a growing offer of LPG stoves and cylinders in the country, which still require significant upfront investments by households, between USD 40 and 100.

Electricity for cooking, while included among the potential alternatives to traditional fuels in the Rwandan policies, has received reduced attention to date, highlighting a gap in cooking sector considering the country is aiming for universal electrification. Despite this, a small number of companies are starting to develop and offer products such as electric pressure cookers or electric hot plates, and developing pilot projects to better understand customer behaviour and needs around electric cooking solutions. While upfront costs of electric cooking appliances (from USD 40 to 85) are still in comparative ranges in relation to other clean and modern cooking solutions, the excess electricity generation capacity, the increase of electricity access and electricity supply reliability across the country offer a much more positive prospect for the development of the electric cooking sector. This is particularly relevant if further incentives are set around the importing, manufacture and purchase of appliances or the use of electricity for cooking.

The interviews carried out with various stakeholders in the sector have provided further insights into the role those different actors play in the transition towards modern energy cooking in Rwanda. Financial institutions are playing an important role in the promotion of efficient and modern energy cooking technologies in Rwanda, such as the CC-RBF funded through the World Bank's EAQIP, which is been managed by the Development Bank of Rwanda (BRD) and implemented by the Rwanda Energy Group Energy Development Corporation Limited (REG-EDCL). A growing number of private sector actors are driving the expansion of modern energy cooking solutions, through innovative fuel subscription models for pellets, such as EcoGreen or BioMassters, pay-as-you-go LPG such as Bboxx, or piloting electric cooking appliances to explore the adoption an impact on consumers, such as Electrocook, NESELTEC or Arc Power. Finally, international donors and development partners such as the European Union or EnDev continue to be active in the cooking sector in Rwanda, supporting the creation of enabling environments and stronger markets for efficient cooking technologies.

As part of this research, a stakeholder workshop was carried out in Kigali City, Rwanda, gathering public authorities, regulators, development partners and private sector companies in the cooking sector. The discussions highlighted a number of areas of collective action to facilitate the transition towards modern energy cooking services in Rwanda. These include the introduction of further incentives for modern energy cooking appliances and fuels, closer collaboration among all players, the emphasis on customer awareness and demand side management to promote electric cooking, ensuring progress on financial access, and the promotion of a mix of fuels and clean cooking solutions adapted to rural and urban areas.

The modern energy cooking sector in Rwanda is small and nascent but with potential to grow and expand rapidly over the coming years. This is supported by the clear commitment and targets from the GoR to shift to cleaner cooking technologies and fuels, the active presence of international donors and development partners in the modernisation of the sector, the growing presence of efficient and modern cooking solutions, increasing their availability, and the increasing electrification rates and ambitious electrification objectives in the country. For this transition to succeed, a number of persistent challenges such as low consumer affordability and awareness of modern cooking solutions, minimising fuel stacking, lack of access to finance for modern energy cooking companies and a strengthening of supply chains will need to be addressed.

Finally, based on the review of the policy framework and market dynamics, the report outlines recommendations on how MECS can support and accelerate the transition towards modern energy cooking in Rwanda:

- On a policy level, these include the promotion of the role of electric cooking within national policies, developing extensive awareness campaigns and supporting the introduction of standards, tax incentives and variable electricity tariffs to encourage the use of electricity for cooking.
- On a research level, gather further evidence on customer behaviour around electric cooking through pilot projects, exploring the potential of developing local innovation hubs for electric cooking appliances adapted to local foods.
- On a market level, support awareness campaigns for modern and electric cooking, provide customers with flexible financing solutions and support the strengthening of supply chains for electric cooking appliances.

1. Introduction and background

According to the last SDG7 tracking report (World Bank *et al.*, 2021), it is estimated that some 2.6 billion people lack access to clean and modern fuels and technologies for cooking around the world, representing a third of the global population. The use of traditional cooking fuels and technologies is a leading cause of household air pollution, contributing to 3.8 million premature deaths each year in low- and middle-income countries (WHO, 2021). The lack of access to modern cooking fuels and technologies also has severe implications for gender relations, economic livelihoods, environmental quality and climate.

The Modern Energy Cooking Services (MECS) programme aims to understand and accelerate progress in the transition towards modern energy cooking services across 15 countries in the Global South, with Rwanda being one of them. In order to understand the existing cooking landscape and the market potential for modern energy cooking, a review of the relevant policy areas and national markets in each of the targeted countries is needed. This review together with stakeholder consultations and additional primary research on consumer cooking environments and practices will provide guidance on the design and implementation of activities to help transition towards modern energy cooking services.

1.1. Background of study

Energy 4 Impact (E4I) was commissioned to write this report by Loughborough University, the lead implementing partner of the MECS Programme. The report is based on primary and secondary research conducted by E4I between January and June 2021. E4I carried out interviews with different stakeholders, including government institutions, non-government organisations and private sector companies offering or involved in clean cooking products and services.

This report analyses the existing policies in Rwanda relevant to the energy sectors with a specific focus on modern energy cooking solutions and electric cooking in particular. Through the interviews carried out with relevant stakeholders, highlighting existing initiatives and programmes on clean cooking, this report illustrates the perspectives from institutions, companies and organisations towards modern energy cooking in Rwanda. These perspectives, together with the existing policy and market contexts, are used to provide recommendations to MECS.

This report aims to understand the current state of the Government of Rwanda (GoR) policies, the national stakeholders' perspectives, academic literature and the broader landscape of energy for cooking in Rwanda. As per the World Bank (World Bank, 2020) and the GoR, "clean cooking solutions" in this report refer to the combination of stove technologies and fuels that have higher efficiency and/or produce lower particulate and carbon emissions levels than the traditional cookstoves and fuels used in Rwanda. This report has a particular focus on "modern energy cooking solutions", corresponding to cooking practices conducted using modern fuels such as electricity, liquefied petroleum gas (LPG), natural gas or biogas, with particular attention given to electric cooking (e-cooking).

This report does not look in detail at the historical compilation of energy access initiatives in Rwanda, but rather focuses on the existing policy and market dynamics within the energy sector in the country, in order to identify the opportunities and challenges for the development of e-cooking and more broadly modern energy cooking in the country. Considering the ambitious targets of the GoR and the dynamic energy ecosystem in Rwanda, the stakeholder mapping and the policy framework presented is expected to evolve over time.

1.2. Socioeconomic context in Rwanda

Figure 1. *Map of Rwanda and its main provinces. Source: Worldmap.*

Rwanda is a small land-locked country of 26,338 km^2 in in the Eastern part of Africa. Its territory is divided in five provinces, namely Northern, Southern, Eastern, Western and Kigali City province, corresponding to its capital- the City of Kigali. Despite its small size, it is a densely populated country in comparison to other African countries. The National Institute of Rwanda projects the country population at 12,9 million in 2021 (NISR, 2021). In 2020, Gross Domestic Product was estimated at 823 USD/capita, ranking 180 in the world (Statista, 2021).

Despite a convulse recent history, Rwanda has made significant achievements in its recovery since the 1994 Genocide against the Tutsi. In the last decade, the country has experienced important socio-economic progress with a rapid and consistent economic growth rate (average annual growth of 7.2%,

among the fastest in the world) coupled with substantial progress in poverty reduction, which fell from 77.2% in 2001 to 55.5% in 2017, according to the latest Integrated Household Living Conditions Survey (EICV5) (NISR, 2018). Rwanda has become a frontrunner among African economies in the 'Ease of Doing Business' indicators, moving from a global rank of 148 in 2008 to 38 in 2020, which is second in Sub-Saharan Africa after Mauritius (World Bank, 2020a).

According to Vision 2050 (MINALOC, 2020), the country's long term strategic plan, Rwanda aims to become an upper-middle-income country by 2035 and high-income country by 2050, guided by the Sustainable Development Goals (SDGs), the Africa Union Agenda 2063 (African Union, 2013) and the East African Community Vision 2050 (EAC, 2015). To achieve this long-term vision, the GoR laid out a seven-year implementation instrument, the National Strategy for Transformation (NST) in 2017 (GoR, 2017). The objective of the NST is to lay the foundation for decades of sustained growth and transformation that will accelerate the transition towards high standards of living for all Rwandans. The first phase, NST 1 (2017-2024), continues the efforts set out by the previous Economic Development and Poverty Reduction Strategy (EDPRS 2, 2013-2018) policy (GoR, 2013), with the development of the private sector at the helm (GoR, 2017). The NST 1 is based on three pillars: economic transformation, social transformation and transformational governance. With this new strategy, Rwanda's public policy will focus on developing and transforming Rwandans into capable and skilled people ready to compete in a global environment. The NST 1 is composed of Sector Strategic Plans covering specific areas such as education, energy, health, and agriculture. The NST also includes District Developments Strategies integrating national and sectoral priorities with the local policies and specificities of each province. Energy is a cross-cutting area of focus under both the economic transformation pillar and social transformation pillar, with targets in generation, quality and reliability of supply, and access.

1.2.1. Covid-19 impact and economic recovery

Before the Covid-19 pandemic, Rwanda was in the midst of an economic boom, with the economy expanding by 9.4% in 2019, the highest growth rate on the continent (World Bank, 2021a). However, the latest Rwanda Economic Update by the World Bank (World Bank, 2021b) estimates that the country's gross domestic product dropped by 0.2% in 2020, immersing the country in its first recession and potentially compromising years of gains in poverty reduction. It also estimates that due to the adverse implications of the pandemic, the poverty level is likely to rise by 5.1 percentage points in 2021, disproportionally affecting women and people in rural areas.

To respond to the Covid-19 pandemic, the GoR put together an Economic Recovery Plan addressing key intervention across the hardest hit sectors. Some of its priorities include strengthening the health system, scaling up social protection, ensuring food security, or supporting businesses and job creation. The Economic Recovery Plan also includes a strong focus on further investment and efforts on energy access, and is estimated to cost around USD 900 million between 2020 and 2021 (World Bank, 2021b). Two major initiatives part of the Economic Recovery Plan, the Economic Recovery Fund and the Manufacture and Build to Recover Program were presented in March 2021 to support the business and construction sectors respectively (GoR, 2021).

1.3. Structure of the report

The report is divided into five sections. This first section has introduced the general socio-economic and energy access context in Rwanda, the focus country of the study. The second section includes a comprehensive review of the Rwandan energy sector, divided into main subsectors as outlined in the Energy Sector Strategic Plan (ESSP) and the Rwandan Energy Policy (2015): electricity, biomass, petroleum, with electricity covering energy efficiency and demand-side management. For each subsector, the main policies, market dynamics and challenges are highlighted. The third section explores the cooking landscape in Rwanda, including the status of existing cooking practices, technologies, and policies in the country. The fourth section presents the main stakeholders relevant for the energy and modern cooking sector in Rwanda, exploring the interventions and perspectives of representative actors such as financial institutions, regulatory authorities, private companies and international organisations. The highlights from a clean cooking stakeholder workshop carried out in Kigali in June 2021 are also included. Finally, the conclusions on the modern energy cooking landscape in Rwanda and the recommendations arising from this study are presented.

2 Energy sector overview

The GoR, through the Ministry of Infrastructure (MININFRA), has set out policies and strategic documents to guide and influence decisions on the extraction, development and use of Rwanda's energy resources in a transparent and sustainable manner. The Rwanda Energy Policy (MININFRA, 2015) and the Energy Sector Strategic Plan (ESSP) (MININFRA, 2018) are the two main documents setting the strategic framework for Rwanda's energy sector, with mutually reinforcing objectives. The Rwanda Energy Policy outlines the long-term vision for Rwanda's energy sector, providing high-level goals and recommending clear and coordinated approaches for achieving them. The ESSP, on the other hand, outlines the detailed targets and the implementation framework against which to measure the progress towards the goals set in the Rwanda Energy Policy.

In Rwanda, energy access is a critical element of the productive sector, with the potential to catalyse broader economic growth and contribute significantly to achieving the country's ambitious socio-economic transformation agenda. The vision outlined in the Rwanda Energy Policy recognises the integral role of access to modern, sustainable, and affordable energy services to the achievement of Rwanda's ambitious socio-economic transformation agenda. The lack of modern energy services is also highlighted as one of the main barriers to the development of income-generating activities, hampering the provision of basic services such as health care and education. Therefore, the provision of cost effective, appropriate solutions to low-income segments of the population, particularly in rural areas where energy services are scarce or expensive, can contribute to the objectives of poverty reduction of the GoR. This priority is developed in detail in the Rural Electrification Strategy (MININFRA, 2016), which presents the most appropriate form of electricity access according to households across the country, including standalone systems, mini-grids and electricity grid extension.

According to MININFRA (MININFRA, 2015), the energy sector is a driving engine in Rwandan households: families use energy services for cooking, lighting, heating, brewing, firing, boiling, ironing, and operating electric appliances to maintain human security, good health and quality of life. The predominance of the household energy segment is also due to the limited industrial and commercial development in Rwanda, which is crucial to ensure the long-term financial viability of the energy sector. To address this, the GoR has a strong focus on the provision of electricity to all productive users in the country, and is also implementing other initiatives to promote the development of the industrial and commercial sectors, such as the Special Economic Zones (GoR, 2010), providing incentives to investors and businesses to

concentrate their activities in designated areas. As a result, households were the largest category of energy consumer in 2017, accounting for 82% of the total energy consumption of the country, followed by the transport sector at 8%, and the industrial sector at 6%, as illustrated in Figure 2.

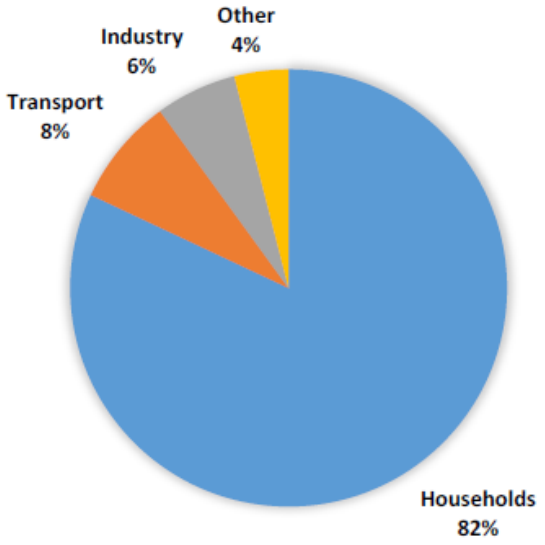

Figure 2. *Energy consumption per user category in Rwanda (MININFRA, 2018).*

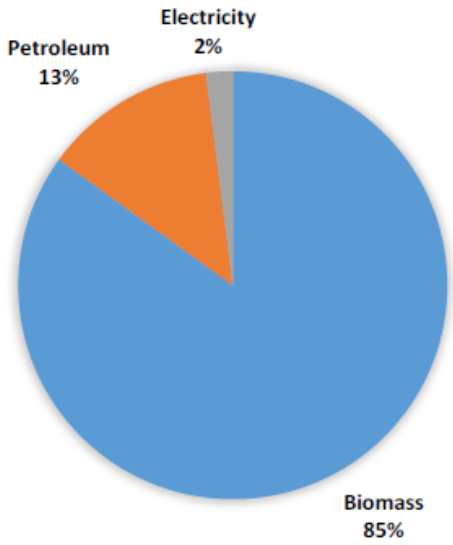

Figure 3. *Energy consumption in Rwanda by subsector (MININFRA, 2018). Electricity consumption refers to electricity consumed not produced from biomass nor petroleum related fuels.*

The ESSP divides the energy sector in Rwanda into three main sub-sectors, namely electricity, biomass, and gas and petroleum, with each playing a key role in Rwanda's transition to a middle-income country (MININFRA, 2018).

Electricity is playing an increasingly important role in Rwanda's economic activity and the ESSP identifies it as one of the main drivers of Rwanda's growth in the next decades. Currently, Rwanda's electricity mix is dominated by hydro and diesel. Energy efficiency across generation and transmission infrastructure, as well as at consumption level, is becoming increasingly important, opening opportunities for significant economic and environmental benefits. The country's continuous efforts to expand the electricity grid access throughout the country and the rise of alternative energy sources and off-grid technologies in recent years have been major contributors to the expansion of electricity access. Under the ESSP, Rwanda aims to reach universal electrification by 2024, from which 48% is projected to be through off-grid technologies, and 52% through national grid connections. The ambitious government targets and policies, together with substantial investments in new energy generation and energy access projects, have led to

over 62.3% of Rwandan households having access to electricity in June 2021, from only 6% in 2009. These include 46% connected to the national grid and 16.3% accessing electricity through off-grid solutions (REG, 2021b).

However, the majority of households continue to rely on traditional fuels and technologies for cooking and heating, and the access to modern energy cooking solutions remains a persistent gap. As a result, biomass is the dominant energy source in Rwanda, with wood-based and biogas fuels accounting for 85% of total energy consumption in the country (Figure 3). Biomass is largely consumed for cooking purposes, with wood mostly used by rural households and charcoal predominantly by urban households. Petroleum and petroleum-related products, such as diesel, kerosene, LPG and natural gas accounted for 13% of total energy consumption in 2017 (MININFRA, 2018). Petroleum is mostly used in transport, electricity generation and in cooking through LPG. The use of LPG in cooking is expected to increase significantly as urban households are encouraged to switch from using firewood to cleaner energy sources for cooking. The GoR is also promoting the use of alternative fuels such as biogas from animal and agricultural waste. In addition to reducing the levels of indoor air pollution, which is a leading contributor to respiratory diseases and death in Rwanda (MININFRA, 2019b) , this shift would also free up the time spent by women and children in collecting firewood, increasing the time available to study and undertake other productive activities. Furthermore, shifting consumption from biomass-based energies to modern sources of energy such as biogas, electricity and LPG for cooking would help to reduce the pressure on forest resources, protecting land arability and helping to mitigate climate change impacts across the country.

In Section 2, the characteristics and challenges of the electricity, biomass and petroleum sub-sectors in Rwanda will be analysed in detail. Section 3 explores the current landscape of the cooking sector in Rwanda and the main opportunities for the development of modern energy cooking solutions, considering the general context of the energy sector presented here.

2.1. Electricity subsector

2.1.1. Electricity generation

In order to achieve the ambitious targets for the electricity sector, including the target of universal electrification by 2024, the ESSP estimates that a target cumulative generation capacity of 556 MW will be needed. As of December 2020, Rwanda had a cumulative installed generation capacity of 238 MW.

This is comprised of domestic generation capacity of 220MW, shared generation of 12MW and imported power of 6MW, compared to the current peak demand of 160MW experienced in the country. Rwanda's power generation capacity tripled between 2010 and 2020 (Figure 4), successfully reducing its reliance on oil-fired power (thermal) due to the investments in hydropower, lake methane-based power, peat-fuelled power and solar power.

Figures from MININFRA (2018) show that in 2017, hydropower represented 45% of installed generation capacity, diesel and heavy fuel oil 27%, methane gas 14%, peat 7% and solar PV 6%. Therefore, further diversification of the technology mix will continue to be a key factor in achieving the target generation capacity, as highlighted in the ESSP. Table 1 compiles the potential of different energy technologies in Rwanda as estimated by MININFRA in 2017. The high hydropower potential of the country indicates that it will continue to dominate electricity generation in Rwanda. However, solar PV technologies have experienced a rapid growth in the last years, totalling 31 MW installed across the country in 2021, from which 19 MW correspond to off-grid systems (IRENA, 2021). As a result, the greenhouse gas intensity of power generation declined from 308gCO2eq/kWh in 2013 to 134gCO2eq/kWh in 2018 (World Bank, 2020b), and expected to further improve due to the increasing weight of clean energy technologies in the electricity mix.

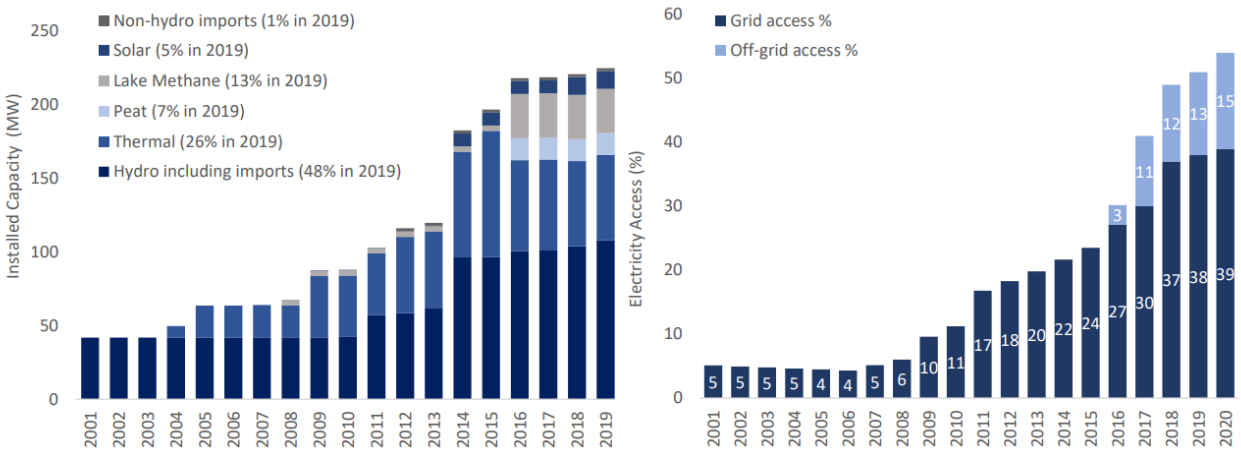

Figure 4. *Progress in generation capacity and electricity access during 2001-2020* (World Bank, 2020b).

Table 1. Overview of Rwanda's electricity sector potential contributors. ESSP, p.32 (MININFRA, 2018).

Resource potential	Summary of current and potential contribution
Hydropower 313-400 MW[4]	Hydropower has generated the bulk of electricity in Rwanda since 1960s. Its overall potential is estimated at up to 400 M W, with the current installed hydro capacity is 98.5 MW. As a result of extremely low operational costs however, hydro is still one of the cheapest forms of generation in the long run.
Methane 140-180 MW	Kivuwatt, a 27 MW generation facility, has demonstrated the commercial and technical viability of extracting methane from Lake Kivu. Further utilisation of methane resources is planned, with significant investor interest.
Peat 121-161 MW	A Peat master plan was first developed in 1993. Estimates of potential capacity have since been revised downwards from the initial 700 MW to 121 MW-161 MW in 2016. About 77% of peat reserves are near Akanyaru and Nyabarongo rivers and the Rwabusoro Plains.
Geothermal (TBD)	Rwanda's geothermal resource is yet to be proven. However, studies have identified Karisimbi, Kinigi, Gisenyi and Bugarama as promising areas, with potentially 47.3 MW of generation available from five promising sites. Further studies, exploration and test sites are required to confirm this.
Solar Energy (TBD)	Rwanda's solar radiation varies between 4.3 and 5.2 kWh per m2 per day over all regions.. There is high interest from the private sector in on-grid solar power development. However, penetration is limited by the technical capacity of the grid.
Biomass (TBD)	Small-scale power generation using agricultural residues (such as bagasse or rice husks) or biomass briquettes (from compacted waste residues or charcoal dust) is feasible at low levels of capacity..
Wind Energy (TBD)	Commercialy wind power resources are not expected to be significant based on past resource assessments and modeling work. However, MININFRA will continue to assess the potential for wind to contribute to the generation mix.

2.1.2. Electricity access

The GoR recognizes the vital role that electricity access plays in accelerating economic development and improving the health and standards of living of Rwandans. Energy, and in particular access to electricity, have long been one of the Government's key priorities. This is reflected in the ESSP, which includes a target to provide 100% of Rwandan households with electricity access by 2024. The ambitious government targets and policies, together with substantial investments in new energy generation and energy access projects, have led to over 62.3% of Rwandan households having access to electricity in June 2021, from only 6% in 2009. These include 46% connected to the national grid and 16.3% accessing electricity through off-grid solutions, mainly solar home systems (SHS) and solar mini-grids (REG, 2021b). Rwanda's progress in electrification during 2010-2016 ranked 11th globally and 3rd in Africa. The geographical distribution to access to electricity by provinces is presented in Table 2. The grid access to public institutions is

remarkably high, reaching as of 2019 100% of hospitals, 93% of health centres, compared to a third on average for Sub-Saharan Africa, and 80% of primary and secondary schools, compared to a quarter for Sub-Saharan Africa (World Bank, 2020b).

Table 2. *Electricity access rate per district in Rwanda as of June 2021. Source: REG (2021a)*

District	Access rate	District	Access rate
Bugesera	70%	Ngoma	66%
Burera	50%	Ngororero	41%
Gakenke	36%	Nyabihu	48%
Gasabo	60%	Nyagatare	55%
Gatsibo	44%	Nyamagabe	50%
Gicumbi	56%	Nyamasheke	47%
Gisagara	55%	Nyanza	51%
Huye	56%	Nyarugenge	56%
Kamonyi	41%	Nyaruguru	88%
Karongi	52%	Rubavu	80%
Kayonza	56%	Ruhango	74%
Kicukiro	95%	Rulindo	51%
Kirehe	65%	Rusizi	70%
Muhanga	53%	Rutsiro	55%
Musanze	71%	Rwamagana	74%
		NATIONAL	63.3%

Under the National Electrification Plan (REG, 2019), the GoR has identified the most economically viable electrification mode for each region of the country, illustrated in Figure 5.

Figure 6 illustrates the resulting contribution of the different electrification modes to the universal electrification target set by 2024. On-grid connections are planned to represent 52% of total connections in 2024, while off-grid connections will represent 48%. Within off-grid technologies, microgrids are expected to serve complete villages accounting for 10% of total connections, with a 21% of connections powered by solar home systems (SHS) or AC stand-alone systems. The ESSP estimates that for 7% of the

total projected connections, both standalone systems and microgrids could be considered at the implementation phase (MININFRA, 2018; REG, 2019).

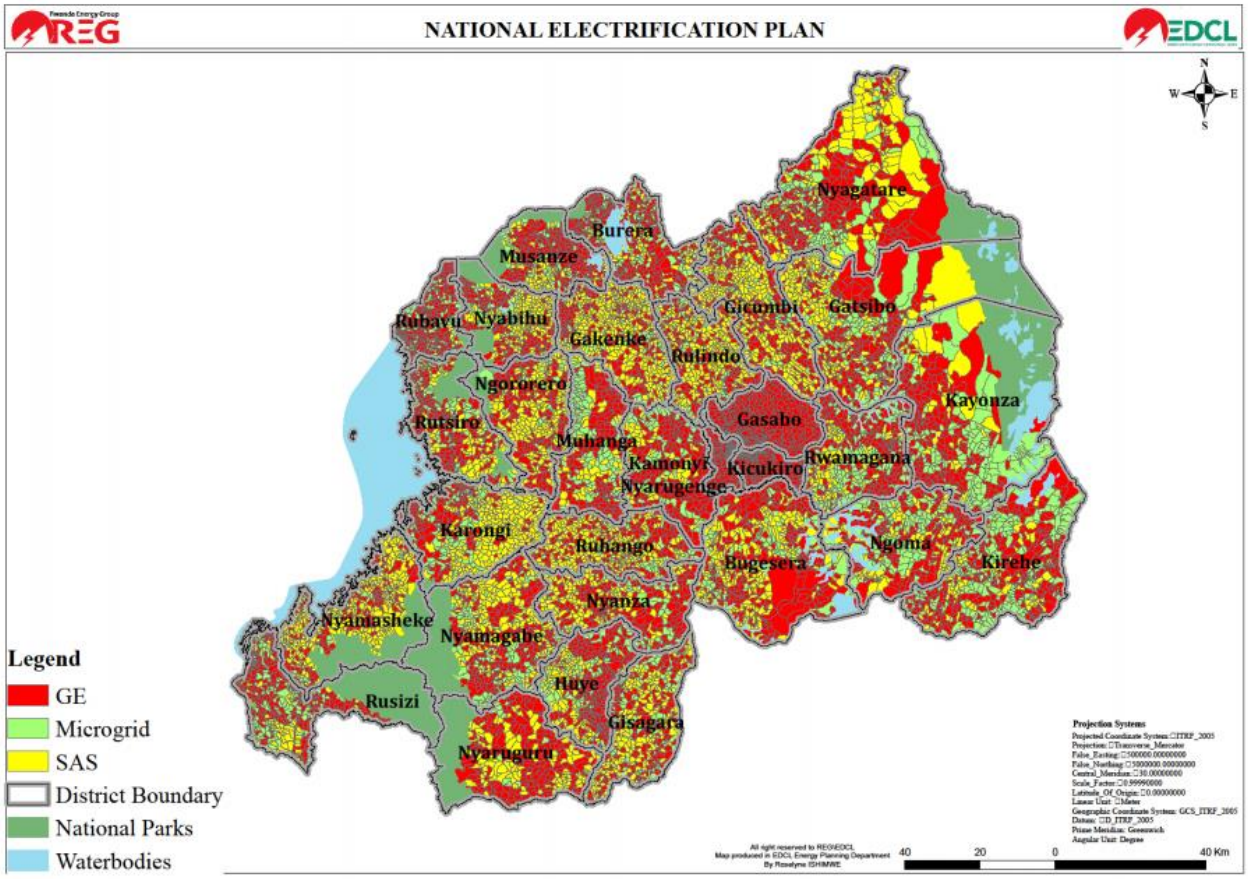

Figure 5. *Geographical distribution of electrification modes under the National Electrification Plan* (REG, 2019)*, including grid extension (GE), microgrids and stand-alone systems (SAS).*

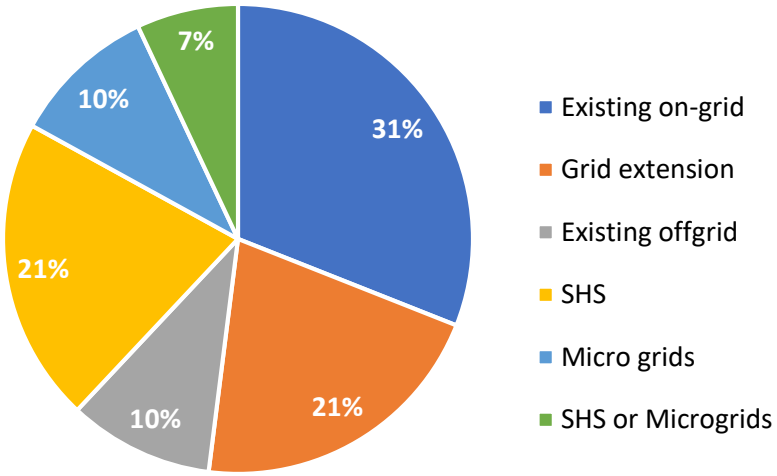

Figure 6. *Share of energy supplied per electrification mode in 2024 as projected by the ESSP* (REG, 2019).

The ambitious electrification targets included in the current ESSP also includes a 100% of productive users to be connected by 2022. The perspective of the energy sector as the driving engine for economic growth is based on the support and development of productive activities through energy and electricity access. In that sense, the ESSP projects that 100% of productive users in Rwanda will be connected in 2022, up from 72% connected in 2017. Productive users utilise energy for activities that enhance income and welfare, including health and education facilities, public infrastructure and industry. The ESSP recognises that the connection of productive users away from cities will be a key element of rural economic development. Additionally, given their higher ability to pay for energy services than most Rwandan households, their connection would also improve the sustainability of the electricity sector.

Aligned with the objectives for off-grid electrification set in the ESSP, the GoR has put in place a strong policy and regulatory framework for off-grid electricity access delivered through the private sector. Off-grid solutions are promoted as transitionary solutions in areas where extending the grid is not viable in the short term. Some of the supportive actions from the GoR include the allowance of tax exemptions for solar equipment and appliances, enforcing strong quality standards to reduce the presence of low-performance products and counterfeits, setting minimum standards and service-level requirements for solar home systems imported to Rwanda (MININFRA, 2019a), or the design of specific financing mechanisms for off-grid solar in local currency.

2.1.3. On-grid electricity consumption and tariffs

According to MININFRA (2018), households represent the largest consumer group for on-grid electricity, in comparison with industry and the public sector. Households consume 51% of total on-grid electricity, with lighting being the primary use; followed by the industrial sector at 42%, with industrial motor-drivers and lighting as the main applications; and public sector at 7%, mainly for powering public buildings, street lighting and water pumping services.

However, the household's electricity monthly average consumption is still low at 20.8 KWh nationwide, with 29.2 KWh in urban areas compared to only 9.9 KWh in rural areas (World Bank, 2018). In terms of monthly expenditure on grid electricity, urban households spend twice as much as rural households (4,656 Rwandan francs (RWF) compared to RWF 2,009), with an average of RWF 3,513.8 across the country (World Bank, 2018). Figure 7 illustrates the small range of appliances that have a large penetration among grid-connected households in Rwanda.

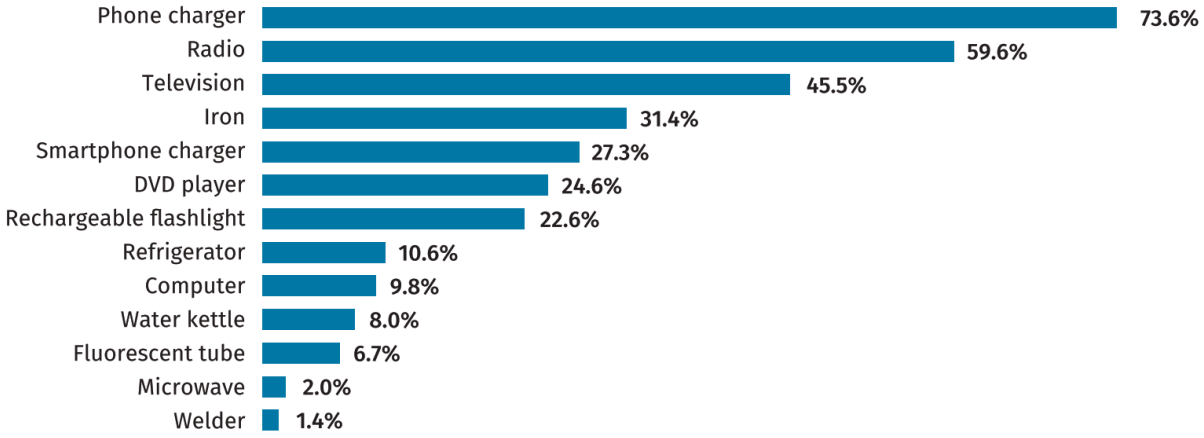

Figure 7. *Most common appliances in grid-connected households in Rwanda (World Bank, 2018)*

The World Bank report also notes that these same grid-connected households do not take full advantage of the performance of the electricity supply received as most of them own only low-load appliances. This accentuates in rural areas, where 66.8% of grid-connected households use only very low-load appliances (mostly for lighting and phone charging), and 20.6% own low-load appliances, such as a television (World Bank, 2018). Medium-, high-, and very high-load appliances, such as refrigerators, are extremely rare in rural areas.

Households using off-grid electricity solutions, mainly solar, use electricity mostly for lighting, phone charging and listening to the radio. Among households using off-grid solar devices, 62.8% own a radio, 48.5% own a mobile charger and 15.8% own a television (World Bank, 2018).

On an annual basis, the GoR provides subsidies amounting to RWF[1] 10.5 Bn to electricity consumers. These subsidies are provided through a variable electricity tariff structure for residential consumers depending on their level of electricity consumption per month. Vulnerable or low-income households, who generally consume less electricity due to affordability constraints, benefit from more subsidised electricity tariffs than residential customers with higher consumption levels. There are three consumption categories within residential customers (REG, 2021): From 0 to 15 kWh/month, from 15-50 kWh/month, or more than 50 kWh/month, with increasing tariffs of 89 RWF/kWh, 212 RWF/kWh and 249 RFW/kWh respectively. Table 2 details the tariff structure for residential, non-residential and other commercial consumers.

Table 3. *Rwandan electricity tariff structure for non-industrial customer by categories (REG, 2021d).*

Category	**Consumption (kWh) / Month**	**RWF[2]/kWh (VAT exclusive)**
Residential	[0-15]	89
	[>15-50]	212
	>50	249
Non residential	[0-100]	227
	>100	255
Telecom towers	All	201
Water treatment plants and water pumping stations	All	126
Hotels	All	157
Health facilities	All	186
Broadcasters	All	192

[1] *Exchange rate: 1 USD= 1010 RWF*
[2] *Exchange rate: 1 USD= 1010 RWF*

Commercial data centres	All	179

Table 4. *Rwandan electricity tariff structure for industrial customer by categories (REG, 2021d).*

Industry category	**Energy charge (RWF/kWh)**	**Maximum demand charge (FRW/KVA/Month)**			**Customer service charge (FRW/Month)**
		Peak (18h-23h)	**Shoulder (08h-18h)**	**Off-peak (23h-08h)**	
Small	134	11,017	4,008	1,691	10,000
Medium	103	10,514	3,588	1,292	10,000
Large	94	7,184	2,004	886	10,000

Flat rates for industrial customers without smart meters:

Industry category	**Flat rate (RWF[3]/kWh, VAT and regulatory fee exclusive)**
Small	151
Medium	123
Large	106

Similar to non-industrial customers, industrial customers, are also subject to variable electricity tariffs based on their level of consumption. They are categorised as small, medium or large customers if their annual electricity consumption is lower than 22,000 kWh/year, between 22,000 and 660,000 kWh/year, or higher than 660,000 kWh/year respectively. The corresponding tariffs are illustrated in Table 3. This tariff structure also includes charges for the maximum power demand used by commercial customers over a given month for each of the three time periods established: peak, shoulder and off-peak. For industrial customers without smart meters installed, a penalising flat rate per category applies (REG, 2021d).

Compared to other East African countries, Rwanda presents relatively high electricity tariffs, followed by Uganda (UEDCL, 2021), while electricity tariffs in Tanzania (TANESCO, 2021) are the lowest, followed by Kenya (Kenya Power, 2021). The corresponding tariffs for each customer category are summarised in Table 5.

[3] *Exchange rate: 1 USD= 1010 RWF*

Table 5. *Comparison of electricity tariffs in East African countries.*

	Electricity tariff prices in USD/kWh			
Consumer category	**Rwanda**	**Kenya**	**Tanzania**	**Uganda**
Domestic (<15 kwh)	0.089	0.093	0.043	0.21
Domestic (15-50 kwh)	0.22			
Domestic (>50 kwh)	0.25	0.15	0.15	
Commercial (<100 kwh)	0.18	0.093	0.086	0.18
Commercial (>100 kwh)	0.25	0.14	0.13	
Industry (KVA < 500, average)	0.15	0.083	0.068	0.16
Industry (KVA >500, average)	0.11	0.071	0.067	0.1

2.1.4. Quality of service and demand-side management

The additional generation capacity and investment in energy infrastructure planned by the GoR to meet its electrification targets is also expected to significantly improve the reliability of electricity supply for residential and productive users, reducing the average number of interruptions in a year from 265 to 92 by 2024, as well as the total duration of those (MININFRA, 2018). The main objectives of the ESSP for the improvement of the electricity sector are summarised in Table 5.

Table 6. *Summary of Rwanda's objectives for the electricity sector under the ESSP, covering the period 2017/18-2023/24* (World Bank, 2020b).

ESSP Objectives	Baseline (2017)	Target (2023/24)
Achieve universal electrification (Tier 1 or more)	40.7 percent (29.7 percent on-grid, 11 percent off-grid)	100 percent (52 percent on-grid, 48 percent off-grid)
Reserve margin	n.a.	15 percent
Average number of interruptions per year	265	92
Average total duration of interruptions per year	44 hours	14 hours
Reduce transmission and distribution network losses	22 percent	15 percent
Expand electricity access to productive users[a]	72.6 percent	2020/21: 100 percent

Over the last years, Rwanda has already made progress on electricity reliability, with the objective to ease doing business and attract investors to the country. The power reliability is often measured by the outage indices based on the duration of each power supply interruption and the frequency of interruption, is defined as the ability of the power system components to deliver electricity to all points of consumption,

in the quantity and with the quality demanded by the consumer (Christie, 2012). This reliability is often measured by outage indices based on the duration of the average power supply interruption, through the System Average Duration Index (SAIDI), the frequency of interruption for customers, through the System Average Interruption Frequency Index (SAIFI) and the average time required to restore the service for interrupted customers, through the Customer Average Interruption Duration Index (CAIDI).

Improvements made in Rwanda include the strengthening of transmission and distribution networks stability to ensure a better quality of power supply to our customers and stakeholders, and an automated computation system was introduced to consistently monitor outages duration and frequency levels in recognized international network reliability measurements, capturing SAIDI, SAIFI and CAIDI measurements (REG, 2018). For the capital city Kigali, over the period from January 2020 to December 2020, the SAIFI, was 2.49; SAIDI was 1.47; and CAIDI was 10.48 (REG, 2021a).

Compared to other regions in East Africa, over the same period (January to December 2020), for Nairobi County in Kenya, SAIFI was 4.5, SAIDI was 11.5, and CAIDI was 2.6 (KPLC, 2021). Although the Uganda Electricity Development Corporation Limited doesn't provide the reliability indices, in 2018, reliability indices were computed as SAIFI at 0.23, SAIDI at 2.99, and CAIDI at 12.7 (Edimu, Serugunda and Kabanda, 2018).

Additionally, the ESSP also aims at reducing the transmission and distribution losses of the electricity system in Rwanda, which in 2017 stood at 22%, significantly higher than the international benchmark of 6 to 8% (MININFRA, 2018). From these, 17% were technical losses, associated with transmission and distribution lines, and 5% were commercial losses, caused by mismanagement of accounts and payments by customers. These losses were equivalent to 128 GWh of energy, resulting in a financial cost of USD 28 million. In 2020, the losses were reported at 19%, with the objective to reduce losses to 15% by 2024 (MININFRA, 2018, 2020). To achieve this goal, the GoR is installing infrastructure to support the more precise quantification of losses, including capacitor banks and advanced metering, as well as upgrading transmission and distribution lines. To reduce commercial losses, the installation of smart metering is being promoted for large industrial customers.

Energy efficiency and demand-side management are recognised in the Rwanda Energy Policy as relevant areas due to the country's limited natural resources and growing electricity demand (MININFRA, 2015). Recent progress in this area includes the adoption in 2020 of minimum energy performance standards for

residential and street lighting by the Rwanda Standards Board, based on the Energy Efficiency Strategy approved in 2018 (MININFRA, 2020). In 2019, with support from UN Environment Programme, the Ministry of Environment also developed a National Cooling Strategy (Ministry of Environment, 2019), identifying key interventions to meet the growing demand in the country in a more efficient manner. The GoR is also implementing demand-side management measures such as the introduction of variable demand charges for large customers (Table 3) or the support of demand-side management programs within national utilities (MININFRA, 2015).

2.1.5. Institutional set up of the electricity subsector

The GoR has pursued several reorganisations of the structure of the electricity sector in order to facilitate governance and clear financial accountability, with the resulting structure illustrated in Figure 8. This structure is organised around the Rwanda Energy Group (REG), a commercially operated state-owned enterprise, with a mandate to develop and operate all public sector energy sector infrastructure and be the interface of all private investments in the sector. REG includes two independent subsidiaries, Energy Utilities Cooperation Limited (EUCL) and the Energy Development Corporation Limited (EDCL), in charge of revenue-generating service functions and non-revenue generating infrastructure development respectively. The holding company, REG, as well as its affiliated companies are governed under company law as opposed to public service law, which entails stricter requirements in terms of transparency and management accountability. REG is overseen by MININFRA and regulated by the Rwanda Utilities Regulatory Agency (RURA), an independent regulator. RURA evaluates the revenue requirements of REG and proposes electricity tariffs accounting for affordability constraints. The cash deficit of REG for both investment and operational purposes is provided through electricity sector subsidies by the Ministry of Finance and Economic Planning (MINECOFIN). The Development Bank of Rwanda (Banque Rwandaise de Développement, BRD), among its services, provides financing support to the off-grid sector through the Renewable Energy Fund (REF), which is one of the main vehicles of the Government in promoting private investment in off-grid energy (World Bank, 2017). Under the REF Window 5, recently approved by the GoR and the Word Bank, the REF offers loans and results-based grants to businesses providing off-grid solar solutions such as SHS, as well as reduced pricing for households according to their income level (BRD, 2021b). MINECOFIN issues budget transfers to the energy sector, while the Economic Cluster of the Cabinet has oversight over higher-level sector policy decisions.

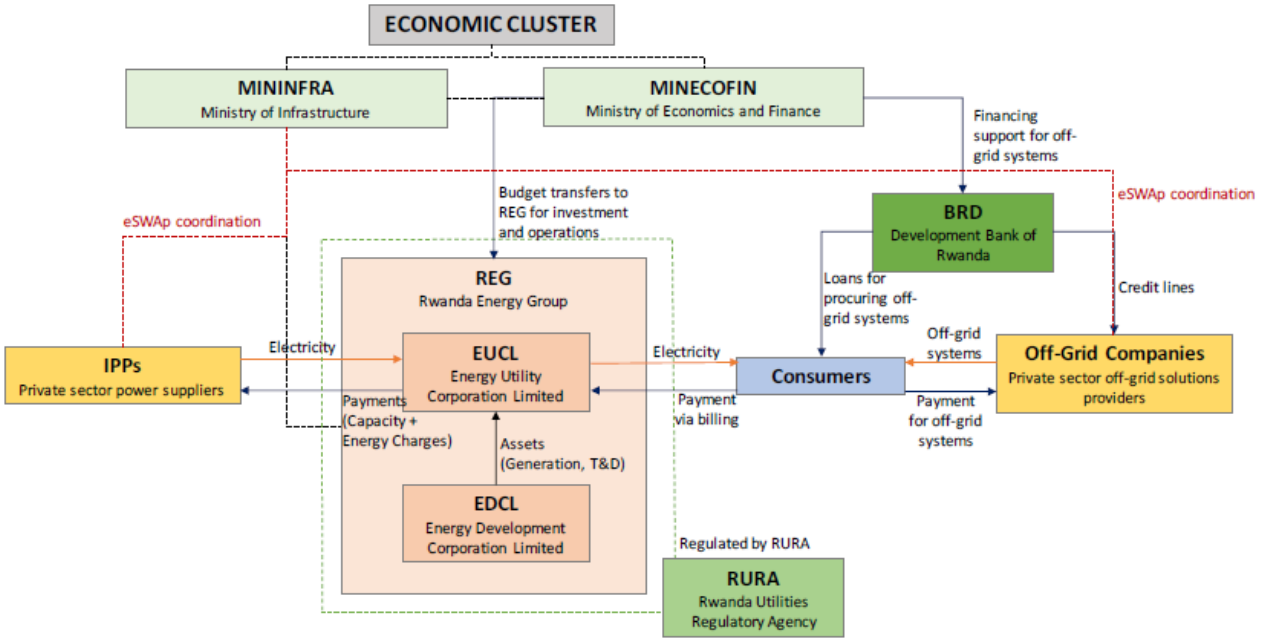

Figure 8. *Institutional setup of the electricity subsector in Rwanda (World Bank, 2020).*

2.1.6. Challenges of the electricity subsector

Some of the key challenges of the electricity sub-sector in Rwanda include the following:

- Insufficient investment to develop energy infrastructure, including electricity generation, transmission and distribution projects, as well as interconnection projects to facilitate electricity trade, coupled with inadequate maintenance of existing infrastructure;
- Access to grid electricity remains concentrated in higher income and urban areas, with 76% access rate in urban areas and over 60% for the highest income quintile, compared to only 5% for the lowest income quintile;
- Gender gaps in electricity access persist, as female-headed households have lower access both to grid and off-grid electricity. According to the EICV5 (NISR, 2018), in 2016/17, only 20% of female headed households had access to electricity compared with 29% of male-headed households;
- High costs of electricity supply, due to the recent increases in flat and high-tier grid tariffs, further contributing to low average electricity consumption across all population;
- Affordability constraints led to a slowdown of the market for off-grid solutions such as SHSs, despite the implementation of a strong regulatory and policy framework by the GoR, which are being addressed through the financing options provided by the BRD's REF Window 5;

- Lack of cost reflective tariffs for non-industrial consumers and demand-side management initiatives, resulting in increasing pressure on the electricity network and contributing to reliability issues;
- Electricity system losses remain relatively high (19% in 2020) and reliability issues remain common, which coupled with poor customer service represents a barrier to service delivery and the modernisation of the sector;
- Inefficient commercial operations due to the lack of appropriate financial planning, accurate customer databases, inadequate systems and controls for meter reading and high accounts receivable, resulting in low operational efficiency.

2.2. Biomass subsector

2.2.1. Overview of the biomass subsector

Rwanda's forest resources cover approximately 600,000 hectares, corresponding to 22% of the country's land area (MININFRA, 2018). This area is comprised of 260,000 ha of natural forest, mainly protected forest areas and natural parks, and 340,000 ha of public and private plantations for forest use. Most of the biomass resources of the country are located in the Eastern, South and Western provinces, as illustrated in Figure 9.

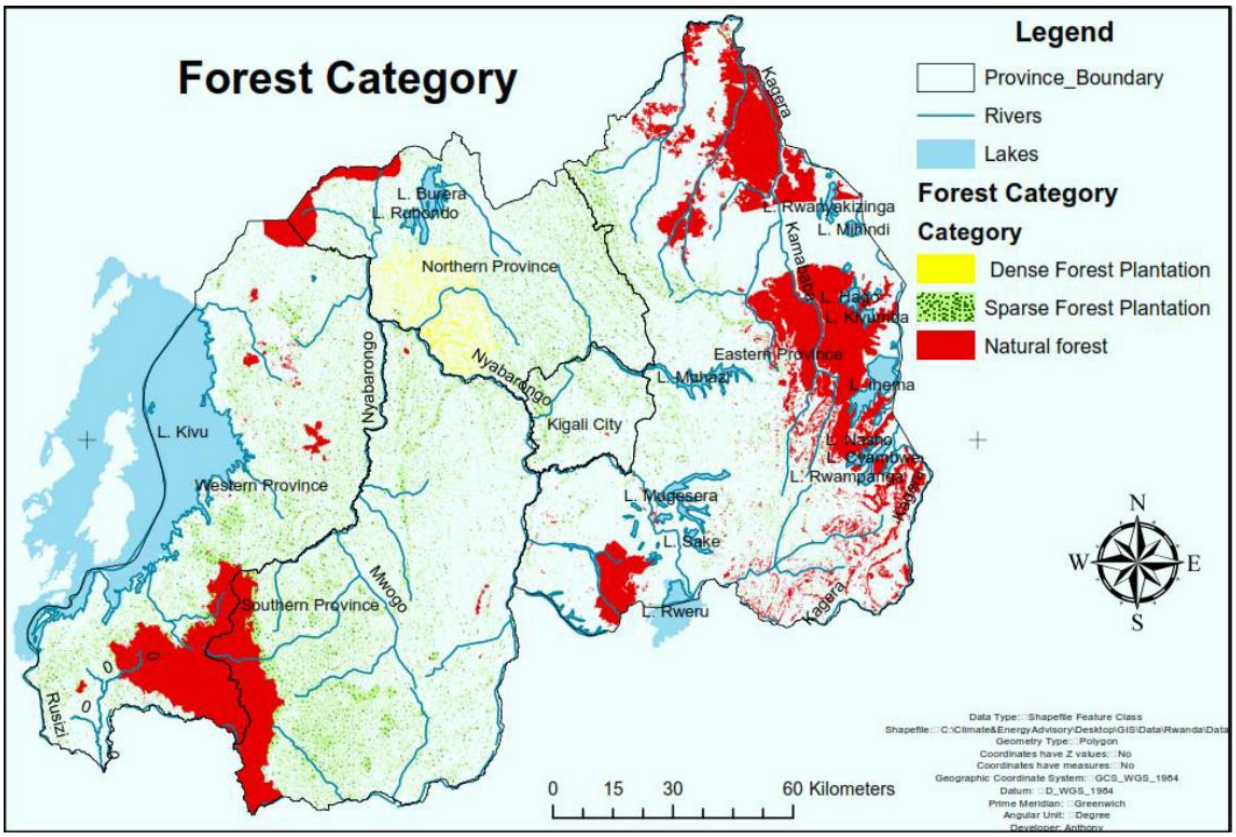

Figure 9. *Map of biomass forest resources in Rwanda.*

However, the high reliance on biomass for energy consumption in the country, together with the increasing demand due to rapid population growth, resulted in an imbalance between supply and demand of biomass products. For the case of firewood and charcoal, this annual demand imbalance is estimated to be of 5,718,000 m3 in 2021, and expected to increase up to 6,591,000 m3 by 2026 (Ministry of Natural Resources, 2017).

The Rwanda Biomass Strategy, recently updated in 2019 (MININFRA, 2019b), already identified in 2009 the need of promoting a more sustainable sourcing of biomass and improving the management of natural resources in the country. It addresses both supply and demand aspects of the biomass sector, aiming to achieve a balance between supply and demand of fuel wood by 2030 (MININFRA, 2019b). However, the progress has been slow and reliance on non-sustainable biomass continues, particularly in rural areas. Most Rwandans live in rural areas where traditional biomass, mainly wood fuel has remained the leading source of energy for cooking (REG, 2021c).

The ESSP defines the five key market segments for biomass energy usage for cooking, heating and drying processes in Rwanda as: household sector (rural and urban), commercial food industry, public institutions and processing and production sectors. The main user types within each segment are illustrated in Table 6. Biomass represents 85% of final energy consumption in Rwanda, from which households are responsible for 91% of energy consumption. The remaining biomass consumption is shared between industry (4%), using biomass for drying processes in tea industries and small-scale brick making, non-energy usage (2%), commercial food industry (1%) and public sector, including schools or prisons (1%).

Table 7. *Main Biomass market segments in Rwanda* (MININFRA, 2018).

Segment	User Types
1. Rural Households	Rural consumers who rely mostly on firewood for cooking and heating purposes
2. Urban Households	Urban consumers who rely heavily on charcoal for cooking and heating purposes
3. Commercial food industry	Hotels, bakeries and restaurants who rely on charcoal and firewood for cooking
4. Public institutions	Schools, prisons, military, refugee camps relying on charcoal and firewood for cooking purposed
5. Processing and Production sector	Tea factories utilise firewood for tea curing, and brick making processes utilise firewood for brick making

The Rwanda Energy Policy and ESSP recognise that the use of biomass energy has potentially serious environmental implications and may be non-renewable unless properly managed. The Rwanda Energy Group (2021b) projects that biomass energy will remain dominant for household cooking and small-scale industry processes in the short-term. Thus, it also highlights that it is imperative that forests and woodlots are more productively managed, and charcoal more efficiently produced across the country. The failure in this realm could result in accelerated deforestation as the demand for energy increases due to the rapid population growth. To address the challenge of deforestation and unsustainable use of biomass resources, the GoR developed a National Forest Policy (Ministry of Natural Resources, 2017), first presented in 2004 and revised in 2011 and 2017, as well as a Forest Sector Strategic Plan (2017-2021). The National Forest Policy includes high-level policy objectives aimed at increasing the capacity of public institutions and private sector actors to manage the country's forest resources more efficiently. The Biomass Energy Strategy translates these high-level objectives into specific targets to be achieved by 2024 and 2030 (MININFRA, 2019b). The GoR is also aiming to diversify away from traditional wood fuel to look at other forms of biomass such as papyrus, rice and coffee husks, as well as biogas, which benefits from

the 'One cow per poor family' scheme. This is a program set up by the Rwandan government aimed at cutting poverty and improving health and nutrition in rural areas. Through it, the GoR has provided more than 130,000 cows to low income families, allowing for new sources of income for the household through the sale of milk and the use of manure as fertiliser (Nilsson et al., 2019). The Government has also put in place strict tree harvesting regulations; through which only licensed persons are allowed to cut trees, including those from private lands. These measures have helped to reduce deforestation rates in Rwanda, reaching its goal of increasing forest cover to 30% in 2019 and becoming one of only a handful of countries in Africa where the relationship between charcoal consumption and deforestation no longer exists (REG, 2021c).

Coupled with the more sustainable management of natural biomass resources, the GoR has also tried to raise awareness among its citizens on the unsustainable use of biomass. The National Leadership Retreat[4] of 2017 called for sensitising Rwandans and setting up sound mechanisms to shift from traditional biomass fuels to cleaner, environmentally-friendly, and more efficient energy solutions for cooking. This is supported by the objectives set in the Rwanda Energy Policy (MININFRA, 2015), which recommends more efficient production and use of biomass energy by households, complemented by the promotion of alternative sources of energy, including biogas, pellets, briquettes and LPG. Similarly, the ESSP establishes a target to halve the number of households dependent on biomass fuels for cooking, from 83% in 2018 to 42% by 2024 (MININFRA, 2018).

The predominant cooking practices, including cooking technologies and fuels used in Rwanda, and the landscape for biomass-based and modern energy cooking technologies are explored in further detail in Section 3.

2.2.2. Challenges of the biomass sector

The existing biomass resources in Rwanda have not been adequately managed and effectively utilised in the provision of modern energy for a variety of reasons:

- Continued over-dependence on unsustainable wood fuel, biomass residue and other forms of biomass as the primary sources of energy to meet household energy needs;

[4] Refers to a tradition in Rwandan culture whereby leaders would convene to reflect on issues affecting their communities.

- Rapid population growth, increasing pressure on biomass resources and leading to unsustainable practices, including early harvesting and planting on marginal and less productive soils;
- Uneven distribution of biomass resources across the country and lack of capacity to manage and monitor the large number of small forest holdings existent;
- Lack of advanced technologies for biomass fuel production, leading to low efficiency and high levels of waste in timber manufacturing. Most of charcoal in Rwanda (86%) is produced through traditional and inefficient carbonisation techniques, such as earth mound kilns, with extremely low average thermal efficiency, around 12% (World Bank, 2020b).
- Low energy efficiency of traditional biomass cooking technologies used, due to the lack of local manufacturing capacity for higher quality products and absence of effective awareness campaigns to encourage households and institutions to adopt more energy efficient equipment and practices;
- Failure to exploit the opportunities for transforming wastes from agricultural production and processing into locally produced modern energy (e.g., biogas, ethanol);
- Critical role of the biomass sector in the Rwanda's economy, generating between USD 120 to USD USD 150 million in economic activity, representing around 5% of GFP and a primary source of income for farmers in rural areas (Ministry of Natural Resources, 2017);

2.3. Petroleum subsector

The petroleum sector represents 13% of total energy consumption in Rwanda. Despite the prospects of petroleum reserves in the Lake Kivu belt, Rwanda currently relies on imports of petroleum related products from Kenya (7.1%) and Tanzania (92.9%). According to the ESSP, the demand for petroleum products in Rwanda has experienced a strong growth over the last years, with an average annual increase of 8% (MININFRA, 2018). The Rwanda Utilities Regulatory Authority (RURA) holds the regulatory responsibilities over petroleum products and MININFRA is responsible for the development of the strategic petroleum reserves in the country. In the ESSP, the GoR has set the objective to increase the country's petroleum and gas reserves to cover at least three months' supply by 2024, from 74 to 198 million litres of storage, in order to ensure the availability of supply and mitigate price fluctuations.

The key demand segments for petroleum products are road transportation, thermal power generation and aviation. The ESSP includes objectives to reduce the reliance on petroleum-based (diesel) generation, developing the electricity mix to minimise the use of diesel away from peak demand hours. However, natural gas and particularly LPG demand have increased substantially in recent years, with LPG consumption increasing by over 50% from 2012 to 2018, to over 10,000 tonnes per year, and expected to reach 240,000 tonnes by 2024 (MININFRA, 2018). LPG is imported by road tankers of 10-20 metric tons from either Kenya or Tanzania by large importing corporations, and retail distribution is done through service stations, independent distributors and supermarkets in cylinder sizes ranging from 1kg to 50 kg. RURA is in charge of the regulation of the downstream petroleum sector and introduced in 2012 regulations to grant LPG business and installation licenses, subsequently updated in 2017 (RURA, 2012; MININFRA, 2018). Additionally, the Rwanda Energy Policy (MININFRA, 2015) highlights the need to improve LPG market and distribution infrastructure to cater to the expected increase in LPG demand for cooking by consumers.

LPG is currently promoted as one of the alternative modern cooking technologies to displace the use of traditional cooking fuels such as charcoal or firewood, and it is currently considered as one of the fastest solutions to curb the demand for biomass resources. Despite this, its penetration is still reduced and mostly concentrated in urban and peri-urban areas. Further details on the use of LPG and other modern energy sources for cooking are presented in Section 3.

3 Cooking landscape in Rwanda

3.1. Cooking in national policies

In Rwanda, the huge reliance on traditional fuels for cooking and slow progress towards cleaner cooking solutions has limited improvements in health outcomes and deforestation. In rural areas, firewood accounts for 93% of the fuel used for cooking. In urban areas, firewood still represents 26.3% of the cooking fuel used, with charcoal being the most common fuel (65% of total cooking fuel used). With firewood and charcoal as the prevalent cooking fuels, the use of traditional cooking technologies is also common in Rwanda. Traditional stoves are the most commonly used cooking stove (53%) by households, followed by charcoal or open fire stoves (with 16%). The EICV5[5] also shows that 53% of the households set up their stoves in a separate dwelling indoors, while 20% of the households install their stoves outdoors and 5% in the same dwelling in a sleeping area (NISR, 2018).

As a result, access to clean cooking remains a significant bottleneck in improving the health and well-being of Rwandan households. The GoR, through its Rwanda Energy Policy, recognizes both environmental and health threats brought by the overexploitation of biomass, in particular firewood and charcoal. Household air pollution (HAP) from solid fuel use is the fourth leading risk factor for morbidity and mortality in Rwanda, and respiratory infection the leading cause of life lost (IHME, 2021). It is estimated that more than 7,383 premature deaths in Rwanda are attributable to HAP annually, with total welfare losses of USD 674 million per year (World Bank and IHME, 2016). Seventy-six per cent of households spend at least 7 hours per week acquiring fuel on average, either by collecting or purchasing it and preparing the fuel for their stoves, with a disproportionate burden on households using firewood. Women and girls also disproportionately bear the burden of fuel collection and cooking-related activities. As a result, women and children are more susceptible to HAP and associated adverse health effects, and chores relating to cooking take a considerable amount of their time, which otherwise could have been used for other productive areas such as education or employment (World Bank, 2020).

Thus, the Rwanda Energy Policy proposes an extensive fuel switching among households to modern energy technologies and carriers including biogas, LPG, and biomass pyrolysis stoves. It outlines various

[5] The Fifth Integrated Household Living Conditions Survey, conducted in 2017 among Rwandan households.

measures to be adopted to ease the transition to modern energy cooking technologies. The existing landscape for each of these modern technologies is presented in the following sections.

However, the incentives for most households to switch to modern cooking technologies are limited by the fact that they are able to collect wood fuel and biomass residues at no cost. For that reason, MININFRA proposes a much stronger emphasis to be placed on social and behavioural change campaigns and partnership with financial institutions in implementation approaches. These include the promotion of new technology standards and regulations (building upon existing technical guidance, in some instances like biogas digesters). To increase consumer choice and affordability, the Rwanda Energy Policy also proposes the development of subsidies for clean cooking technologies in order to improve the impact and scale-up potential of existing programs. An example of these subsidies is the establishment of the results-based-financing scheme under the Energy Access and Quality Improvement Project by the World Bank (World Bank, 2020b), which has a specific subcomponent to support clean cooking solutions in addition to the support for off-grid electrification solutions provided through the Rwanda Energy Fund Window 5 (BRD, 2021b). The USD 17 million clean cooking results-based-financing (CC-RBF) window will partially subsidize the price of clean and efficient cooking solutions for eligible customers. The initiative expects to trigger at least 500,000 households to gain access to clean cooking technologies until 2025, of which 25% are supposed to be female-headed households, benefitting a total of 2.15 million people in Rwanda (BRD, 2021a).

The ESSP reflects the ambition to promote a more sustainable management of natural resources and the shift away from traditional cooking sources, with the target to reduce the number of households depending on traditional cooking fuels from 79.9% in 2017 to 42% by 2024 by replacing wood and charcoal with clean cooking options. An estimated investment of USD 170m will be needed until 2024 to halve the number of households using these traditional cooking technologies (World Bank, 2020).
These targets are supported by the implementation of the Biomass Energy Strategy (MININFRA, 2019b), which in addition to improving the sustainable management and supply of biomass resources in the country, aims to reduce the demand for biomass fuels by promoting the switch to modern cooking fuels. This includes raising customer awareness, the strengthening of value chains of clean fuels and cooking technologies and the strengthening of the coordination and capacity of public institutions in the sector. Table 7 indicates the main targets for 2024 and 2030 outlined in the Biomass Energy Strategy for the reduction in biomass dependence for cooking.

Additionally, in May 2020, the Government updated its Nationally Determined Contributions (NDCs) under the Paris Agreement, which includes promoting the use of efficient cookstoves as a mitigation measure, given that cooking-related emissions account for 14 percent of the GHG emissions from the energy sector in Rwanda (GoR, 2020). With that aim, Rwanda NDC's mitigation measures include the dissemination of modern efficient cookstoves to 80 percent of the rural population and 50 percent of the urban population by 2030, with an estimated investment of USD 380 million (GoR, 2020).

Table 8. *Key indicators of the Biomass Energy Strategy on the reduction of biomass dependence for cooking, p.11* (MININFRA, 2019b).

Indicators	Baseline values and second-level targets
› Percentage of population shifting from use of firewood to modern improved cooking solutions (LPG, Biogas, improved biomass fuels (pellets & briquettes) and Improved high efficient Cookstoves, etc.).	Baseline value 2017: 79.9 %[9] Target value 2024: 42 % Target value 2030: 0 %
› Percentage of Urban Households shifting from cooking with charcoal to alternative improved cooking solutions. (LPG, Biogas, improved biomass fuels (pellets & briquettes) and Improved high efficient Cookstoves, etc.).	Baseline value 2017: 65.1 %[10] Target value 2024: 32% Target value 2030: 1%
› Percentage of population using inefficient cooking technologies;	Baseline value 2017: 72.5% [11] Target value 2024: 36 % Target value 2030: 20 %
› Percentage of public biomass high consuming institutions (e.g. schools, prisons, police and military camps) shifting from traditional woody biomass to clean cooking solutions/Productive use.	Baseline value 2017: NA% Target value 2024: 100 % Target value 2030: 100 %
› Percentage of commercial institutions (Hotels, Restaurants, Tea factories, brick factories) shift from using inefficient wood and charcoal to clean cooking solutions	Baseline value 2017: NA % Target value 2024: 100 % Target value 2030: 100 %

3.2. Household cooking practices and technologies in Rwanda

The EICV5 (NISR, 2018) provides information on the primary sources of fuel used for cooking in Rwanda, summarised in Table 8. Between 2013 and 2017, the dependency on firewood for cooking has declined slightly across the country, from 83% to 79.9%, but remains the most commonly used cooking fuel by 93% of the households in rural areas. The decrease in firewood use by households over this period was compensated by an increase in the use of charcoal, from 15% to 17% across Rwanda, being the predominant source of cooking fuel in urban areas at 65%. It can be highlighted that between 2013 and 2017, there was a low but tangible uptake in the use of gas fuels (from 0.2% to 0.9%), mainly derived from the increased use of gas fuels in urban areas and concentrated in the higher income segments of the population. As an example, in Kigali City, the use of gas fuels for cooking incremented from 1% in 2013 to 6.2% in 2017. The gender gap is also reflected in the primary cooking fuels used by households, with female-led households relying more on firewood (85%) than male-led households (78%).

Table 9. *Primary fuel used for cooking, by province, urban/rural, consumption quintile, habitat, disability status and sex of head of household (HH). Source EICV5 (NISR, 2018)*

EICV 5		**Main type of cooking fuel**				
		Firewood	**Charcoal**	**Crop waste**	**Gas/Biogas**	**Other**
All Rwanda		79.9	17.4	0.6	1.1	0.9
Urban/rural	Urban	26.3	65.1	0.1	5	3.4
	Rural	92.7	6.0	0.8	0.2	0.3
Province	Kigali City	22.4	68.1	0	6.2	3.3
	Southern	92.6	6.5	0.2	0.2	0.5
	Western	87.2	12.2	0	0.1	0.4
	Northern	91.7	7.3	0.4	0.3	0.8
	Eastern	89.3	7.6	2.1	0.3	0.8
Sex of head of HH	Male	78.3	18.9	0.6	1.2	1.1
	Female	84.7	13.0	0.8	0.9	0.6
All Rwanda (EICV4[6], 2013)		83.3	15.2	0.8	0.2	0.6

[6] The fourth Integrated Household Living Conditions Survey, conducted in 2013 among Rwandan households

A study carried out by the World Bank identified various fuel types for cooking in Rwanda and grouped them into biomass and non-biomass fuels. Biomass fuels include firewood, dung, twigs, leaves, charcoal, rice husk, pellets and briquettes; while non-biomass fuels include LPG, biogas, and electricity.

The cookstoves identified during the study are classified into four categories (Figure 10):

- **Three-stone stove:** A pot balanced on three stones over an open fire. Fuel use and emissions are high, and thermal efficiency and safety are low. Three-stone stoves usually use firewood, but other solid fuels may also be used.
- **Traditional biomass stove:** Locally manufactured using mud, metal, or other low-cost materials and following cultural practices. Traditional biomass stoves use biomass fuels. In Rwanda six types of stoves were identified as traditional (Figure 10): round mud stove, rocket stove, gisafuriya, double and triple movable metal charcoal stove, all metal stove, and Muyaga.
- **Improved biomass stoves:** Use more advanced stove technology to improve efficiency, cleanliness, and safety. Improved biomass stoves, also known as improved cookstoves (ICS) use less energy to deliver a given amount of usable heat than three-stone and traditional stoves do, also reducing air pollution levels. Thus, improved biomass stoves may enable cleaner and more efficient delivery of traditional fuels, though they may not meet the strictest emissions or efficiency standards. In Rwanda nine types of improved stoves were identified (Figure 10): Darfour 1, Darfour 2, canarumwe, canamake ivuguruye, canamake itavuguruye, fixed canamake itavuguruye, double and triple movable (canamake itavuguruye), and sawdust/rice husks stove.
- **Clean fuel stoves:** Use fuels with very low levels of polluting emissions, such as biogas, LPG/cooking gas, electricity, ethanol, natural gas, and solar. Such fuels often provide high technical performance in emissions and efficiency, which is largely “stove independent.”

Figure 10. *Types cookstoves found in Rwanda, classified between three-stone, traditional, improved and clean stoves. (World Bank, 2018)*

The EICV5 (NISR, 2018) shows that in 2017 the three-stone stove is the most commonly used stove by households in Rwanda, with 53% of households. Additionally, 16% of the households use other traditionally manufactured stoves. This results in almost 70% of Rwandan population using low efficiency stoves that emit high levels of pollutants. Improved cookstoves (ICS) using charcoal and biomass are used

by 6.2% and 13.5% of households respectively (Table 9), while the use of other stoves, including clean cooking stoves such as LPG, biogas or electricity, is reduced to only 1% of households.

Table 10. *Distribution (%) of households by type of cooking stove, by province, urban/rural, consumption quintile, and sex of head of household (HH). Source EICV5 (NISR, 2018).*

EICV 5		**Type of cooking stove**					
		Three stone	**Self-Built Stove**	**Manufactured Stove**	**Charcoal/fire stove**	**Efficient cookstove**	**Other**
All Rwanda		53.2	14.8	1.3	16.2	13.5	1.0
Urban/rural	Urban	18.0	3.5	5.5	56.1	14.0	3.0
	Rural	61.6	17.5	0.3	6.7	13.4	0.5
Province	Kigali City	20.2	1.7	6.5	61.7	7.0	3.0
	Southern	64.3	12.9	0.2	7.9	14.3	0.4
	Western	60.3	12.4	0.5	9.3	17.1	0.4
	Northern	70.8	12.5	0.3	6.8	9.0	0.5
	Eastern	45.9	28.0	0.5	8.2	16.4	1.0
Sex of head of HH	Male	51.5	15.2	1.4	17.3	13.5	1.1
	Female	58.5	13.6	1.0	13.0	13.5	0.6

Regarding the installation of the stove in Rwandan households, the EICV5 shows that the majority (53%) of the households set up their stoves in a separate dwelling. The data also illustrate that 20% of the households install their stoves outdoor and 5% in the same dwelling than a sleeping area. The percentage of households cooking in a separate dwelling is much higher in rural areas (57%) than in urban areas (39%).

The results of the EICV5 are aligned with the World Bank study, which also highlights the low penetration of modern cooking technologies in Rwanda. According to this study, cooking with clean technologies and fuels, such as biogas, LPG or electricity in Rwanda remains rare, with only 0.4% of households using them as their primary cooking fuel (Figure 11).

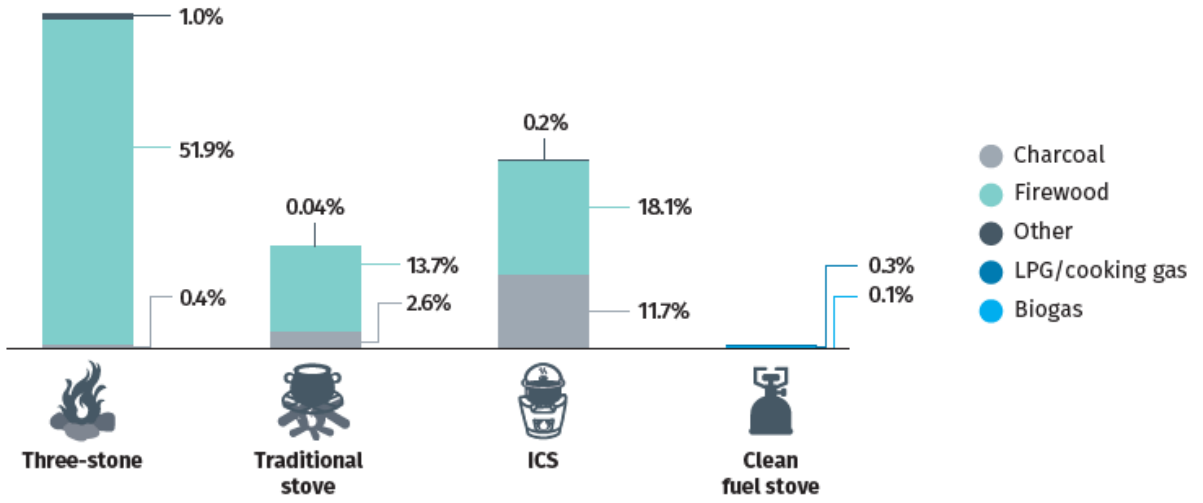

Figure 11. *Breakdown of cooking stoves and fuel types used in Rwanda (World Bank, 2018).*

Different cooking patterns can also be identified between rural and urban households. In urban areas, 63.9% of households use an ICS, and 2% use a clean fuel stove (mainly LPG). Higher availability and convenience of charcoal make it the predominant cooking fuel in urban areas (65%). In rural areas, the penetration of clean fuel stoves is negligible, and the access to ICS is also reduced, with only 20% of rural households using one. As a result, traditional and three-stone stoves are dominant for rural households (79%), and firewood accounts for the large majority of cooking fuel used.

Stove stacking, or using multiple cookstoves, occurs in 6.6% of households, being slightly more common in urban areas (10.7%) than in rural areas (5.6%). For the majority of households that use various cookstoves, the additional or secondary stoves are lower performing than the primary stove. For instance, most households that use an ICS as their primary stove use a three-stone stove as a secondary stove, while the households using clean stoves as their primary stove continue relying on ICS as secondary stoves (World Bank, 2018).

The predominance of traditional fuels and stoves in Rwanda results in a significant burden for the acquisition and preparation of the cooking fuel for households. The study by the World Bank found that 76.5% of Rwandan households spend over 7 hours per week in the acquisition and preparation of cooking fuel, with only 3% of households spending less than 0.5 hours per week (Figure 12). In rural areas, where 93% of the population rely on firewood for cooking, up to 84% of households spend more than one hour per day on average collecting and preparing fuel. In contrast, in urban areas, due to the higher penetration of clean cooking solutions such as LPG and the higher accessibility to charcoal, 9% of households spend

less than 0.5 hours per week on these tasks. However, a large part of the urban population (42%) still devotes more than one hour per day to fuel acquisition and preparation. Households using an ICS as their primary cooking stove achieved substantial time savings in fuel acquisition and preparation compared to households using three-stone or traditional stoves, with time savings of 24% and 18% respectively.

In addition to this, more than 60% of Rwandan households spend over 5 minutes per meal preparing the stove for cooking, with a third of rural households spending more than 15 minutes per meal (World Bank, 2018).

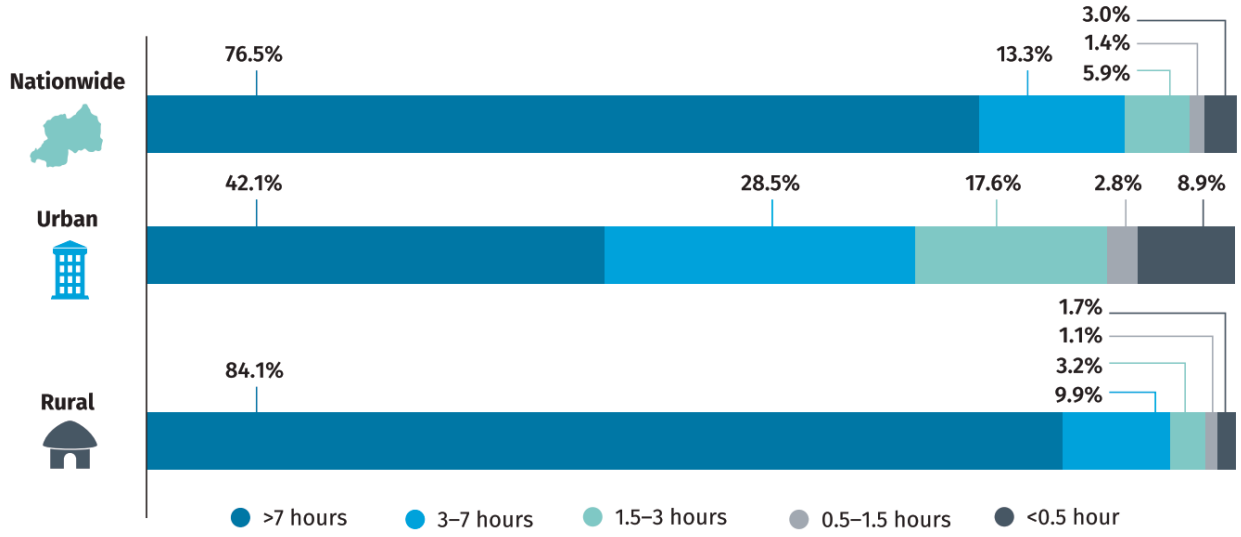

Figure 12. *Average time spent by households acquiring and preparing fuel per week (World Bank, 2018).*

3.3. Modern energy cooking landscape

3.3.1. Efficient biomass cookstoves

The predominant role of traditional fuels, mainly firewood and charcoal, as well as low efficiency cooking technologies in Rwanda indicates that the transition towards modern and cleaner energy cooking solutions has not materialised yet. A large part of the Rwandan population still relies on firewood and three-stone or traditional stoves.

However, the World Bank study estimates that half of the Rwandan households are interested in using more efficient cooking solutions and willing to purchase a conventional ICS (priced at RWF[7] 3,000) to replace their three-stone and traditional stoves. This figure rises to over 70% of households using traditional stoves if allowed to pay over six months in monthly instalments, or offered the ICS at a subsidised price of RWF 1,000 (World Bank, 2018). While market development for clean fuels should be the long-term goal of Rwanda, ICS represent a cost-effective solution to transition many rural and low-income households away from traditional cookstoves with minimal disruptions on cooking practices, while providing time and fuel savings as well as health benefits.

Table 11. *Market cost for different cooking technologies in Rwanda. Source: Market assessment conducted by E4I.*

Type of cooking stove	**Market price (RWF)**
Conventional ICS (firewood)	5,000 – 15,000
ICS: Umucyo 2 (can use charcoal and pellets)	20,000
Advanced ICS: Songa stove (can use charcoal, briquettes and plant residues)	40,000
Advanced ICS: Nguvu stove (can only use charcoal)	45,000
Advanced ICS: Nguvu Plus stove (can use charcoal, firewood, and briquettes)	65,000
Advanced ICS: Nguvu Fan stove (can use charcoal and pellets)	100,000
LPG stove (1 burner)	18,000 – 20,000
LPG stove (2 burner)	27,000 – 45,000
Electric Hotplate stove (1 burner)	35,000
Electric Infrared stove (1 burner)	85,000

Table 12. *Market cost for different cooking fuels in Rwanda. Source: Market assessment conducted by E4I.*

Type of cooking fuel	**Market price (RWF)**
Firewood (7kg) in Kigali / Provinces	1,200 / 800
Charcoal (1kg pan) in Kigali / Provinces	300 / 250
Charcoal (35kg bag) in Kigali / Provinces	11,000 / 9,500
Pellets (1kg / 30 kg / 40 kg / 60 kg)	250 / 4,000 / 6,000 / 8,000

[7] *Exchange rate: 1 USD= 1010 RWF*

Briquettes (1kg)	200
LPG empty cylinder (6 kg / 12 kg / 15 kg)	20,000 / 30,000 / 45,000
LPG refilling cost per cylinder (6 kg / 12 kg / 15 kg)	7,000 / 13,500 / 17,000

There is a wide range of ICS available in the Rwandan market, with some of them represented in Table 10. The prices can range from USD 5 for the most basic stoves, generally using firewood, to more than USD 40 for the most advanced and efficient models, that can also use charcoal, briquettes or pellets as fuel. An increasing number of companies and organisations are active in Rwanda in the manufacture and distribution of ICS, with some of the main actors listed in Table 12. However, the adoption of ICS is hampered by the limited awareness and enforcement of standards and quality control systems, resulting in most stoves on the market not being tested by accredited institutions.

Charcoal fuel is predominant among urban and high-income households, but its availability and cost limit its use by lower income and rural households. According to the World Bank, average monthly consumption of charcoal was 36 kg for households with an ICS, compared with 50 kg for households using a traditional stove, translating in between USD 10 and USD 15 per month on charcoal at current market prices. This contrast with a monthly average expenditure of USD 2 per month on households using firewood, which can be often collected at no cost (REG, 2021c). REG estimates that the average household uses around 1.8 tons of firewood each year to satisfy its cooking needs with a traditional stove, equivalent to 150 kg of firewood per month or 5 kg per day (REG, 2021c). Therefore, despite the lower cost of firewood compared to charcoal, if it is not collected for free and only purchased at market prices, the high amounts of fuel needed per household can also result in substantial costs, of up to USD 11 per month. The current market prices of different cooking fuels are summarised in Table 11. For firewood and charcoal, market prices are higher in Kigali City due to the existing supply constraints in comparison to rural areas. The availability and market price of charcoal, which is the primary cooking fuel for 68% of the population in Kigali, could be further affected by the aim of the GoR to ban the use of charcoal in Kigali City (The New Times, 2020). Additionally, the lack of regulation of charcoal production and the use of inefficient traditional carbonisation techniques difficulties the control of the supply and quality of charcoal produced in Rwanda. The World Bank estimates that switching from a three-stone stove using firewood to the most efficient firewood ICS available in the market (around USD 30) could result into annual savings

of USD 15 for Rwandan households, while switching from a traditional charcoal stove to an advanced charcoal ICS (around USD 35) could lead to annual savings of USD 20 per stove (World Bank, 2020b).

The promotion of pellets and briquettes is also one of the proposed interventions from the GoR to reduce the dependence on biomass by 2024 (MININFRA, 2019b). This initiative includes the provision of financial and technical support to pellet and briquettes producers, as well as carrying out extensive awareness campaigns promoting pellets and briquettes as a replacement to charcoal and firewood. A number of private companies, such as EcoGreen and BioMassters, are commercialising a different range of efficient cookstoves that can use pellets and briquettes as fuel, in some cases in addition to firewood or charcoal. The price of these efficient biomass stoves can range between USD 20 and 65, and the highest tier can provide a performance close to modern fuels such as LPG in terms of pollutants emitted. On average, 1kg of pellets can burn for 2.5 hours and a household of 5 people in Rwanda consume 30 kg of pellet fuel per month, with a kilogram of pellets costing between USD 0.25 and 0.3. Innovative fuel and stove subscription models, or Pay-as-You-Cook models, are being used by some of these companies to remove the upfront cost barriers associated with the stove purchase, by providing it at reduced or no cost and signing minimum fuel consumption contracts with customers. A study carried out by Inyenyeri, a Rwandan company that provided ICS micro-gasifier stoves under a similar model, showed that this solution can offer cost savings for consumers in comparison to charcoal use. Inyenyeri offered a micro-gasifier pellet stove for an upfront fee of USD 5, with monthly pellet fuel contracts with customers depending on the number of cookstoves and the size of the household. The study indicated that pellet fuel prices per kg were up to 40% lower than charcoal for consumers, and that using exclusively pellets reduced the amount of fuel used per month by 15-20 kg compared to charcoal (Seguin, Flax and Jagger, 2019). The World Bank indicates that switching from a basic charcoal stove to an advanced pellet stove can bring significant cost savings for Rwandan households, estimated at USD 20 per year (World Bank, 2020b). Despite the growing popularity of pellets and briquettes, their production and general customer awareness remains limited, with fuel producers not coordinated and majority of use constrained to the areas close to production sites (MININFRA, 2019b).

3.3.2. Potential of modern energy cooking technologies

To reduce the reliance on traditional fuels for cooking, the GoR has put in place a number of initiatives and pilot projects to test new products and business models and promote the use of alternative clean

fuels for cooking. In general, there is a need to promote technology development, technology transfer, and localisation based on local cooking culture, and to provide financing and knowledge support.

Modern fuels such as biogas or LPG are regarded as alternatives to transition away from traditional fuels and reduce the biomass demand in Rwanda. For instance, the potential biogas market in Rwanda is estimated at 150,000 households, primarily in rural areas. In 2008, after a pilot project supported by GIZ and SNV, the GoR launched its National Domestic Biogas Programme, targeting the introduction of biogas digesters in institutional facilities and households (MININFRA, 2007). To date, 86 institutional biodigesters have been constructed in secondary education schools and prisons, reducing firewood consumption by 60% and 40% respectively along with improved hygienic conditions. Additionally, over 3,7000 domestic biodigesters have been installed in households across the country since 2007 (MININFRA, 2018). A 50% subsidy was provided to households to acquire domestic biogas plants of 4 m3, 6m3 and 10 m3, and the remaining financed through local credit institutions. The GoR also helped establish more than 50 private biogas companies to support the development of the sector, and over 400 masons, supervisors and manufacturers were trained by SNV as part of the program (REG, 2021c). Some of the main actors in the biogas sector in Rwanda are presented in Table 12. However, the high investment required despite the subsidy scheme, which ranged from USD 300 to USD 500, the maintenance requirements and the access to the necessary levels of human or animal waste remain a challenge for the wider adoption and sustainability of biogas systems (Bedi, Pellegrini and Tasciotti, 2015; Mukeshimana *et al.*, 2021).

Another promoted alternative cooking fuel in Rwanda is LPG. Rwanda has no domestic production of natural gas, but has seen a substantial increase in the import demand for LPG in the last years, mostly for cooking purposes. Gas is promoted by the GoR as a clean cooking fuel alternative to reduce the dependence on biomass fuels in urban areas, and it is currently considered as one of the fastest solutions to curb the growing demand for biomass resources. While LPG for cooking has started to attract the attention of consumers, mostly in urban areas, its penetration has not yet reached a sufficient level to translate into a significant reduction of biomass use at the national level (MININFRA, 2018). Table 10 compiles the upfront cost associated with different models and quality levels for LPG stoves, which can range from USD 18 to USD 45. In addition to the stove, upfront investment in the LPG cylinders is also required, with costs from USD 20 to USD 45 for cylinders between 6 and 15 kg. These products are often sold in bundles, with the upfront cost of 6 Kg cylinder including a burner costing around USD 40, a 12 kg cylinder including a 2-burner stove around USD 82, a 15 kg cylinder with a two burner stoves around USD 92, and a 20 kg cylinder with a two-burner stove cost around USD 120. The current fuel prices for LPG in

Kigali stands at USD 1.24 per kg as of May 2021, and the refilling costs for each cylinder size are summarised in Table 11. As a result, the adoption of LPG for cooking present significant upfront costs for consumers, and financing programmes are needed to make them accessible for most of the population. The World Bank estimates that switching from a basic charcoal stove to an LPG stove in Rwanda would only result in a reduced increase of annual fuel expenditure for households, of around USD 0.2 per year (World Bank, 2020b). The GoR is promoting the use of LPG through exempted import taxes for the fuel as well as VAT exemptions for LPG equipment. Innovative approaches such as the PAYGO LPG pilot project carried out by BBOXX (Perros, Buettner and Parikh, 2021) can make LPG more competitive with traditional fuels such as charcoal. In recent years, a growing number of companies have started commercialising LPG stoves, mostly in urban areas. Some of the main actors involved in the LPG sector in Rwanda are included in Table 12. Given the positive prospects for the sector, most of the main LPG importing companies in Rwanda, such as Safe Gas, have started providing LPG stoves through partnerships with local distributors. Some of the barriers remaining for a wider adoption of LPG include a limited distribution capacity and presence of LPG companies outside urban areas, the limited storage capacity at national level, which the GoR is planning to expand, and the absence of regulation regarding the cost of LPG fuel (MININFRA, 2019b).

Electricity is also considered among the alternative sources of energy for cooking in the Biomass Energy Strategy (MININFRA, 2019b), particularly for the hospitality sector and high income segments of the population. Progress in electricity generation and electricity access in the last years has resulted in Rwanda experiencing significant surplus of energy during off-peak hours, while power supply and demand get close to each other in peak evening hours. According to REG, the generation capacity is 238 MW, compared to the current peak demand of 160 MW. This, in addition to the challenge of low electricity demand across the country, indicate that the use of electricity for cooking through “smart” electricity tariffs around meal hours might offer an opportunity to absorb the excess baseload electricity available in the daytime, while also contributing to reducing the dependence on biomass. However, the introduction of electric cooking in the current policies in Rwanda is limited to superficially mentioning it as one of the potential modern energy solutions to be explored (together with other modern cooking technologies such as biogas or LPG), without providing specific objectives, recommendations or practices for its development and implementation. A positive development has been the inclusion of electric cooking appliances within the recent clean cooking results-based-finance window by the BRD (BRD, 2021a).

Despite the lack of initiative by the GoR, a few private actors, such as Electrocook and NESELTEC LTD, are starting to develop and offer electric cooking solutions such as electric pressure cookers (EPC). The cost of these appliances is indicated in Table 10, with EPCs around USD 85, and electric hot plates priced around USD 35. Electrocook estimates that the use of EPCs by grid-connected households can result in USD 5-10 savings per month on cooking fuel for households, and identified an initial urban market of 124,000 households (with an income of over USD 165 per month) for their EPC product, which could be expanded with the increasing electrification of rural areas. ARC Power, a Rwandan mini-grid developer, is also exploring the viability of EPCs and electric hot plates in off-grid mini-grid systems. The activity of these actors, as well as the main barriers and opportunities for electric cooking, are further detailed in the following sections, but the high upfront costs, together with the limited access to electricity and awareness about electric cooking solutions stand as the main barriers for the expansion of electric cooking solutions.

Table 13. List of relevant companies and organisations active in different segments of the clean cooking sector in Rwanda. Source: E4I market assessment.

ICS	Briquettes and pellets	Biogas	LPG	Electric cooking
AJDR	GENI Green Solutions	Earth Systems	BBOXX	Electrocook
BILLEM INNOVATION	ENEDOM	ACSES-International	Ecogreen	Arc Power Ltd
BRIDGE2 RWANDA SERVICES Ltd	ISOKO FOUNDATION Ltd	CRET	SAFE GAS	Neseltec Ltd
CO2 BALANCE	Biomasters Solutions	ENVIROTECH	ABBARCI	Ecogreen
COOFOHU	Ecogreen	RECONS Ltd	City Gas Dealers Ltd	
Dynamic Energy	ECOMAKE Ltd	SOC (Save Our Climate)	Country Gas Trading company Ltd	
Ecomarge Services Ltd	Habona	Vets without Borders Belgium	Hashi Energy Rwanda	
Entreprise Multi-Service (EMS)	Bamboo River Side Ltd	VIECO	JENVA Suppliers Ltd	
Green Growth Solutions Ltd	RNRA/BTC	SNV	LAKE PETROLEUM RWANDA	
Here and Now Group Ltd	ECOMAKE Ltd		MEREZ	
Millenium Villages Project Rwanda	Habona		MOUNT MERU PETROLEUM (R) LTD	
Muyaga Project	Bamboo River Side Ltd		RUCSA Investment	
RNRA/FNC	RNRA/BTC		Rwanda Oxygen	
SaferRwanda			SP Ltd	
TEKUTANGIJE			SULFO RWANDA Ltd	
TOGETHER FORGERS			Yes Gas Ltd	
VI –AGROFORESTRY				
WORLD VISION				
Delagua				

3.3.3. Financial inclusion for clean cooking

A FinScope survey conducted in 2020 in Rwanda (Access to Finance Rwanda, 2020) recognises the potential of modern fuels such as LPG, ethanol, biogas or electricity to empower women and reduce negative impacts on health and the environment. However, it highlights that one of the biggest barriers to accessing them is the high upfront cost associated with modern cooking technologies. Currently, a significant part of the Rwandan population lacks options to access credit or appropriate financial support to face such investments. This lack of financial inclusion does not only affect access to clean cooking, but many other areas, including the ability to educate their children, start income generating activities and improve their general living conditions. The FinScope study argues that access to clean cooking and financial inclusion is a challenge faced by many households in sub-Saharan Africa (SSA) particularly, affecting low-income people who lack formal employment, financial literacy or assets to act as collateral for credit. About 77% of the Rwandan population have access and use formal financial products, including those that are provided by the banking sector and non-bank financial institutions such as insurance firms, mobile network operators, microfinance institutions and Savings and Credit Co-Operative Societies (SACCOs) (Access to Finance Rwanda, 2020). In parallel, more than 87% of the population in Rwanda have access to a mobile phone, with women (84%) having lower access compared to men (90%). The expansion of mobile money in Rwanda has been significant in the last years, with 3 in 5 adults using mobile money, and 68% of men having mobile money accounts, compared to 56% of women. The access to mobile money is a crucial factor for the affordability of different services that are provided through Pay-As-You-Go models, including advanced biomass and LPG solutions commercialised by various private sector players in Rwanda. The key barriers to the uptake of mobile money are generally related to lack of product knowledge and lack of interest in the product. Informal financial mechanisms continue to be common in Rwanda, with about 78% of adults using them, and 80% of women belonging to a savings group. The gender gap is also present in the access and use of formal financial services, with only 34% of female adults in Rwanda use bank services or products compared to 39% of their male counterparts (FinScope, 2020). While significant progress has been achieved through non-bank avenues such as mobile money and SACCOs, formal banking would see more Rwandans not only able to better manage their savings and personal finances but to more easily access the credit services needed to afford modern cooking solutions. For these reasons, the GoR has introduced a number of initiatives to promote financial inclusion, including the implementation of the National Inclusion Financial Strategy (NFIS).

3.4 Urbanisation plan and its impact on modern cooking services

3.4.1. Urbanisation and modern cooking services

In its vision to become a middle-income country, both from the previous Vision 2020 or the current Vision 2050, the GoR has identified urbanization as an opportunity for socio-economic growth, and acknowledges that a well-planned urbanization may help achieve the proper use of land, other natural resources and of investment into infrastructure services, and may help initiate local economic development (MININFRA, 2015b). From 21 urban areas, in 2012, and only one city among those, urban areas have been increasing in Rwanda with the creation of six secondary cities, namely Rubavu, Musanze, Huye, Rusizi, Nyagatare, and Muhanga which were selected for the promotion of urban development outside of the capital city (GoR, 2012). Law No. 10/2012 of 02/05/2012 governing urban planning and building in Rwanda defines a city to have a population of at least 200,000 inhabitants; a municipality at least 30,000 but less than 200,000 inhabitants; and an agglomeration at least 10,000 inhabitants but less than 30,000 inhabitants (MININFRA, 2015b). Prioritization of the six secondary cities to serve as sub-national centres of service provision and economic growth, with socio-economic impact or influence beyond district borders is outlined among the key urbanization objectives to spur the country's socio-economic growth.

The GoR targets a 35% urban population by 2024 from 17.8% in 2017 (GoR, 2018). Some specific targets such as the 100% of the population using basic improved sanitation facilities shows the willingness by the GoR to develop simultaneously both urban and rural areas. Others such as households with access to improved water source within 200m of their proximity, show skewed trends towards heavy investments in urban areas, with a target of 95% households, against 16% in rural areas by 2024. As part of modernising rural settlements, the GoR has since 2007 agreed to adopt a comprehensive strategy, known as the Integrated Development Programme (IDP), to fast-track broad based income generation and economic expansion (RHA, 2021). Dubbed 'model villages', the modern settlement sites connect to essential infrastructure like roads, water, electricity, schools, health posts, and local markets. They are in line with the GoR's target of 80% of rural households settled in integrated, planned, green rural settlements, by 2024 (GoR, 2018). One model village was established in each district for indigent people living in high-risk zones, and other well-off residents allowed to build their own homes in the proximity to take advantage of the infrastructures in place. Infrastructure development to improve access to affordable electricity as support to economic transformation and access to other forms of energy (peat, biogas, solar) for improved welfare and environmental protection, is one of the eleven pillars around which IDP model villages are designed (RHA, 2021).

Urbanization is expected to reduce dependence on inefficient biomass for cooking through adoption of ICS, LPG, efficient biomass (pellets, briquettes, etc.) biogas, and electricity. The EICV5 (NISR, 2018) shows 8.5% adoption of these efficient fuels in urban against 1.3% in rural areas, in 2017. This is also coupled with a reduction in firewood consumption by 3% in urban areas, from 2014 to 2017, against 1.7% in rural areas. However, despite the firewood consumption reduction, charcoal use increased, in the same period, from 65.1% to 67.4% in urban areas and from 4.4% to 6% in rural areas. A comparative argument from EICV3 and EICV4 has shown a correlation between poverty and access to utilities, with utilities and services being more accessible to non-poor than to poor households, but also more accessible to the urban than to the rural population; this especially concerns levels of access to electricity (GoR, 2018). Between EICV3[8] and EICV4, electricity use for lighting has almost doubled country-wide from 11% to 20%, with 71.8% of households in urban areas using electricity compared to 9.1% in rural. This trend has continued with 75.6% of urban households using electricity, in 2017, compared to 15.5% in rural areas (GoR, 2018).

Considering the urban population is projected to double from 17.8% in 2017 to 35% in 2024 (GoR, 2018), the high charcoal consumption in urban areas would significantly shift the balance towards inefficient biomass use. However, the high electricity access in urban areas, coupled with the target to reduce urban charcoal consumption to 32% (MININFRA, 2019), provides a potential market for e-cooking, should e-cooking be promoted like other fuels, particularly LPG for urban areas. Nevertheless, this raises a compelling argument on urbanization impact on modern cooking and would give reason to a focus on urban areas when it comes to promoting a shift towards modern cooking solutions.

Urbanisation is also expected to improve on health issues resulting from low efficiency biomass cooking and cookstoves installation place. In Rwanda, for instance, the EICV5 stated that 82.4% of rural households cooked in a dwelling compared to 48.5% in Kigali city. Cooking inside dwellings increases exposure to emissions affecting indoor air pollution resulting in detrimental health impacts. Among the above-mentioned households cooking in dwellings, 20.5% in rural areas cook in the same dwelling they live in, and 5% within the same area they sleep in, compared to 11.5% and 2.3% respectively for Kigali City. The issue gets exacerbated by the fact that only 2.6% of rural households, compared to 6% in Kigali City, use chimney or any other exhaust system while cooking. Although the cooking solutions' efficiency effect was not included in these above-mentioned percentages, one would have to remember that in rural areas the low efficient fuels were used at almost 99% of households while in the City of Kigali that number stood at

[8] The third Integrated Household Living Conditions Survey, conducted in 2011 among Rwandan households

90%. Subsequently, urbanization, with its potential impacts in switching to clean cooking solutions, would help reduce the consequential heath impacts caused by inefficient cooking solutions.

3.4.2. Densification efforts

The population growth continues to make the land more scarce through increased demand of land for both urban and rural settlement, to the extent of affecting agricultural, grazing, forestry, wildlife, tourism and other land resources. In addition to the population pressure, inadequate settlements significantly contribute to the country's general development.

In the context of its broad urbanisation plan, the GoR outlined densification efforts together with mixed land use and green housing approaches as necessary steps to promote the long-term sustainability of the nation's valuable natural, urban and rural environments. Densification is defined, in MINIRENA (2017), as the increased use of space, both horizontally and vertically, within existing areas and new developments, accompanied by an increased number of units and/or population threshold. It contributes to place-making and the development of attractive and safe urban environments, and the GoR is promoting it in all urban areas (MINIRENA, 2017). MINIRENA (2017) also says that Rwanda aims to achieve a minimum average net density of 70 Hu/ha for Kigali City, 40 Hu/ha for Secondary cities, 30 Hu/ha for other urban, as well as rural settlements.

MINIRENA (2017) argues that existing and continuous low-density development is a threat to the long-term sustainability of land use development, and is creating various challenges, mainly the rapid consumption, by urban development, of good agricultural land and valuable biodiversity resources. Difficulties in developing a viable public transport system due to fragmented and dispersed urban activities is another key challenge posed by the low-density development. MINIRENA (2017) also notes that the unit cost of providing the necessary infrastructure required to service low-density forms of urban development is far greater than the unit and operating cost of servicing medium to higher-density forms of urban development.

Densification guidelines outlined by the GoR ensure optimal and efficient use of infrastructure, services, facilities and land; support the development of a viable public transport system and improve levels of access to the urban areas' resources and services; and protect, manage and enhance the natural and built environment and significant cultural landscape. Medium and high-density forms of urban development pursued by the GoR will significantly impact on modern energy cooking. Firstly, high density urban areas will mean a lesser unit cost for essential services (MINIRENA, 2017) including electrification, road networks and business activities which in turn provide improved opportunities for electric cooking, availability and affordability of LPG and other cooking technologies. Secondly, as stated in the previous

section, EICV5 reports an already existing inverse relationship between firewood consumption and urbanization. MININFRA's (2019) target of no more than32% urban charcoal consumption already provides a significant push towards modern energy cooking over inefficient fuel.

3.4.3 Densification and mini-grid

In addition to the traditional grid connection, densification efforts in rural areas attracts a variety of off grid solutions that have wide range of technologies such as a basic solar lantern that can charge a phone or radio to a solar home system that can light an entire house and power appliances such as a television, and Mini-grids that can provide higher levels of electricity to both households and small and medium businesses (MININFRA , 2016). There are already 10 companies operating mostly solar and hydro mini-grids in Rwanda's rural areas (table 14) with a generation capacity of 413 kWp.

***Table 14**: Existing mini-grid in operation in Rwanda, (Source: E4I)*

No	Company	Technology	Location	Size
1	Neseltec	Solar	Kirehe	30 Kwp
2	ECOS	Hydro	Muhanga	11 kwp
3	RENERG	Solar	Nyamasheke	30 kwp
4	MeshPower	Solar	Bugesera, Ngoma	1 kwp each, 57 sites
5	MeshPower	Solar	Bugesera	4 kwp AC/DC
6	Absolute Energy_Rutenderi minigrid	Solar	Gatsibo	50 kwp
7	Ducane Kabrud_Nyankorogoma minigrid	Hydro	Kirehe	13 Kwp
8	Hobuka ltd_Mudasomwa Minigrid	Hydro	Nyaruguru	38 Kwp
9	Arc power	solar	Bugesera 1	20 kwp
		solar	Bugesera 2	40 kwp
10	Equatorial power_gakagati Minigrid	solar	Nyagatare	120 kwp

Mini-grids are considered as solutions that focus on the location, income, and required consumption level, which isn't the case of the traditional grid, and the GoR is implementing their promotion strategy through

private sector, with particular focus on increased competition within private sector which will lead to reduced costs and improved choice of technologies on the market (MININFRA , 2016). Although mini-grids are promoted as solutions that provides choice on required consumption, a number of them (including those already installed in Rwanda) are still able to power electric cooking appliances, thus, increasing e-cooking opportunities.

However, a study conducted by Energy 4 Impact in 2020, to develop a financial model to show the viability of e-cooking in rural mini-grids in Sub Saharan Africa, estimated that at current tariffs (case of Arc Power), the monthly average e-cooking cost per household would be twice the cost of charcoal, and four times that of firewood.

4 Main stakeholders in the cooking sector

This section explores the efforts by relevant financial, regulatory and private sector stakeholders in Rwanda in the promotion of clean cooking solutions in the country. It presents some of the existing clean cooking initiatives, the learnings extracted and the alignment of these interventions with the MECS programme objectives. Most of the information in the section was gathered through interviews with the respective stakeholders, complemented with desk-based research.

This section also presents the insights from a workshop carried out with national stakeholders involved in the cooking sector to understand and share different perceptions on the modern energy cooking landscape and potential in Rwanda.

4.1. Financial institutions

4.1.1. Development Bank of Rwanda (BRD)

BRD recognizes that access to reliable and affordable energy remains a considerable challenge in Rwanda, and that for Rwanda's private sector to be competitive, the energy issue must be addressed, since it is a crosscutting driver of economic growth. For this reason, over the next five years, BRD will invest USD 185 million in the energy sector and catalyse additional USD 638 million from other stakeholders. BRD's interventions have been designed to address key constraints in the sector such as high start-up costs and risks involved (BRD, 2021). BRD also notes that the challenges in the energy sector are mainly related to insufficient financing, lack of infrastructure, risk aversion of financial institutions, or human capital challenges among other factors. It has set up a Department of Energy Financing which oversees the implementation of the Bank's interventions in the energy sector.

BRD interventions are aligned with MECS's objectives in two ways: On one hand, BRD is currently managing the Results-based Financing (RBF) subsidy called "REF Window 5", which is facilitating access to electricity by increasing SHS installations and electrification of households in rural areas of Rwanda. The USD 15 million subsidy window, funded by the World Bank, is designed to address the affordability constraints of rural households to acquire SHS through reduction of prices for the systems at varying amounts allocated for Ubudehe 1, 2, and 3 categories (these categories provide a socio-economic stratification system according to which the GoR support poor Rwandans with social protection

schemes since 2000). Through this RBF scheme, BRD aims to reach some of the lowest income population in Rwanda, and it is expected to trigger at least 182,000 new off-grid connections (BRD, 2021).

Secondly, BRD is managing a USD 17 million RBF subsidy window co-financed by the World Bank's Clean Cooking Fund through the Rwanda Energy Access and Quality Improvement Project (EAQIP). The clean cooking RBF (CC-RBF) window, open for applications until September 2025, will subsidize the price of clean and efficient cooking solutions for eligible customers, with the objective of reaching the poorest population in Rwanda while attracting private sector investment in the clean cooking sector. The predefined subsidy levels, ranging from 45% to 90% to the stove cost, and the triggers for payment are available under the programme's operations manual (BRD, 2021a).

The CC-RBF window will initially support Tier 2+ solutions, as defined within the Multi-Tier Framework for access to cooking solutions developed by the World Bank (ESMAP, 2015), with the objective to gradually increase the minimum performance level requirements as affordable Tier 3+ solutions become widely available. The RBF window will support both urban and rural households. In urban areas, the focus of the clean cooking RBF will be to reduce and eventually phase out charcoal as a cooking fuel and replace it with Tier 3+ clean cooking solutions. In rural areas, the focus will be on reducing the reliance on firewood as a cooking fuel, by gradually introducing more efficient (Tier 2+) and clean cooking (Tier 3+) solutions (BRD, 2021b). The two focus areas will contribute to the objectives of phasing out charcoal use in urban areas; and reducing the reliance on firewood. The performance of eligible cooking technologies will need to be demonstrated through laboratory testing and/or field-based data. RBF incentives will be linked to the verified output, outcome, and impact level results; differentiated by cooking technology performance levels and consumer income categories (Ubudehe categories); reviewed and adjusted periodically.

In addition to the promotion of clean cooking, BRD has taking additional steps to address gender inequalities, recognising the importance of clean cooking in providing a healthy and pollution-free cooking environment for women. For that reason, the BRD is setting gender balance requirements for companies applying for its RBF schemes, on top of the existing guarantee scheme which promotes female-owned projects (75% guarantee level provided) against (50% guarantee level provided) male-owned ones.

4.1.2. World Bank

The recently launched Rwanda Energy Access and Quality Improvement Project (EAQIP) project funded by the World Bank, aims to increase access to modern energy for households, enterprises and public institutions , while enhancing the efficiency of electricity services in Rwanda (World Bank, 2020b). The project notes that the market for efficient and clean cooking solutions is small and nascent but has the potential to grow and expand. Limited financing options and high interest rates, a lack of promotion or incentives to entrepreneurs, and dedicated support to clean cooking enterprises have been found to be the main reasons behind the current artisanal production process of improved cookstoves with limited manufacturing and scale. As a support to private enterprises to move forward and scale, cooking enterprises are eligible for value added tax and import duty exemptions.

One of the components of the project focuses on the increase of access to off-grid electricity and clean cooking solutions in Rwanda. Under the clean cooking component, the project outlines the basis for the setup of the CC-RBF window currently implemented by BRD and EDCL. Additionally, it also devises a US 3 million grant from ESMAP's Clean Cooking Fund to support market development and technical assistance for the clean cooking sector, including: awareness raising and behaviour change campaigns, market facilitation and policy review and improvement, product testing and development, monitoring and verification support for the RBF operation, and innovation (World Bank, 2020b).

Additional households, beyond the current EAQIP's target of 500,000, are expected to access clean cooking solutions from the results-based payments through the purchase of emission reduction credits by the Carbon Initiative for Development (Ci-Dev), which is expected to be processed as additional financing for EAQIP. The RBF from Ci-Dev would complement the output- and outcome-based payments made for clean cooking solutions.

4.2. Regulatory authorities

4.2.1. Energy Development Corporation Limited (EDCL)

The Rwanda Energy Group (REG), overseen by MININFRA, has the mandate to develop and operate all public sector energy sector infrastructure in Rwanda. EDCL is an independent subsidiary of REG in charge of non-revenue generating infrastructure development. The mandate of EDCL includes the investment in the development of new energy generation projects, development of transmission infrastructure or planning and executing energy access projects. EDCL is generally tasked with the implementation of

internationally funded energy access programmes, as well as on the development of economic and technical studies needed for the development of generation, transmission and energy access projects. EDCL also plays an important role in the development of customer awareness campaigns on energy access and alternative cooking solutions, which will be crucial to support the transition towards modern energy cooking in Rwanda.

Under the EAQIP project in collaboration with the World Bank, the clean cooking component is being managed by MININFRA, and REG/EDCL have the mandate to implement it. The Rwanda Standards Board (RSB) is tasked with certifications and setting standards for cooking products, and a testing lab is currently under development (BRD, 2021a). The CC-RBF window financed through the clean cooking component of EAQIP is being implemented by BRD and EDCL, and Figure 13 highlights its main implementation arrangements. As the leading institution in the CC-RBF implementation, EDCL main responsibilities include issuing calls for clean cooking technologies, coordinating with testing facilities on eligibility tests for clean cooking technologies, manage cooperation agreements with clean cooking companies (CCCs), managing the Independent Verification Agents for the execution of payments (IVA) and supervising the verification process. It is also responsible for keeping record of qualified cooking technologies and the corresponding CCCs, providing technical review, policy studies and share the findings of the programme with the World Bank, government agencies and other relevant stakeholders, among others.

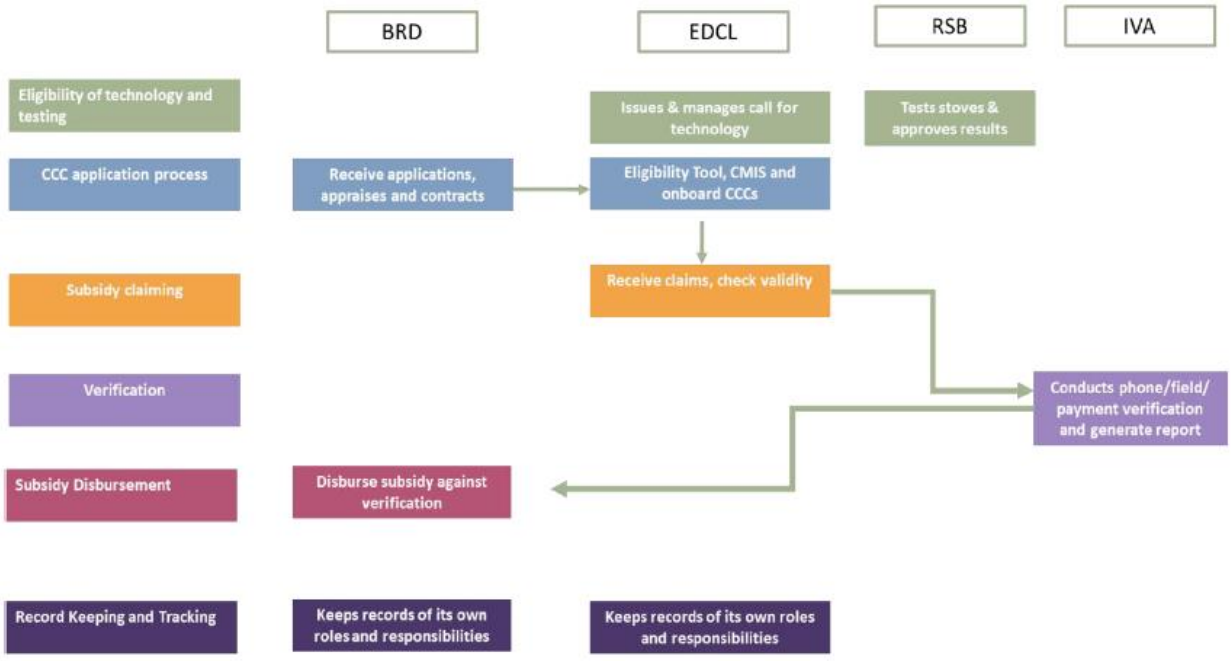

Figure 13. *CC-RBF implementation arrangements (BRD, 2021b).*

4.3. Private sector

4.3.1. Electrocook

Electrocook is an Electric Pressure Cookers (EPC) developer aiming at transforming communities and increase their well-being through replacing charcoal and firewood with electricity for daily cooking activities. While their EPCs are not commercially available yet, Electrocook estimates that they represent an affordable and convenient solution for cooking that can lead to savings between 5-10 USD monthly, providing an expected payback of the initial investment of USD 85 within 12 months. For reference, this is approximately the same cost of a 2-plate LPG stove with a 12kg cylinder at current Rwandan market prices. By reducing the time spent on firewood collection and supervision in terms of fuel stacking (thanks to the automatic switch-off functionality of the EPC) and halving the time for long-boiling staples, Electrocook's EPCs provide clear benefits to reduce the gender gap burden in cooking activities.

According to Electrocook, there could not be a better timing for the e-cooking market in Rwanda than now. The reasons behind this confidence include the increasing access to electricity (universal access targeted by 2024), the political will on banning charcoal use in Kigali (The New Times, 2020), opening up market opportunities for alternative technologies, and the progress of clean cooking initiatives both at governmental institutions level, such as REG, and at public or private institutions level, such as at schools. Electrocook identified an initial urban market of 124,000 households (with an income of over RWF 165,000 per month) for their EPC product, which could be expanded with the electrification of rural areas. As a market penetration and validation tool, Electrocook plans to roll out two pilot studies. The first, partnering with ARC Power, will consist of 100 households connected to one of ARC Power's mini-grids in Bugesera district. In this pilot, Electrocook will be testing an innovative financing mechanism by which the pre-paid EPCs costs will be incorporated by the mini-grid developer in the electricity tariff over a determined period. Within the same period, the second pilot, in partnership with Access to Energy Institute (A2EI), will be conducted for on-grid connection with 150 households. These projects will provide evidence on the potential adoption of e-cooking both in off-grid and on-grid contexts, and show the willingness from different stakeholders in the energy sector to engage in the scale-up of modern energy cooking solutions in Rwanda.

4.3.2. NESELTEC LTD

NESELTEC LTD is a company working in off-grid electrification and clean cookstoves distribution in rural areas of Rwanda, mostly working with underserved communities. The company also sells LPG in Rwanda where the focus is given to 3, 6 and 15 kg LPG cylinders. The company develops various biomass projects like briquetting plants and gasification as well as biogas related projects. The company has recently started distributing an EPC of 8 litres of capacity , after being awarded a research grant by the MECS Electric Cooking Outreach (ECO) challenge fund competition (MECS, 2021). This pilot study will be carried out with three communities in Rwanda: customers of an existing solar mini-grid; rural grid-connected customers, and peri-urban inhabitants of Kigali. The study will determine the willingness of beneficiaries to switch from non-clean cooking energy to efficient electric cooking, focusing on accelerating the uptake of the EPCs in the three communities targeted. The study will target 500 households with the results helping investors and donors make informed decisions in further financing of electric cooking in Rwanda.

4.3.3. Arc Power Ltd

During the last quarter of 2020, under MECS and in partnership with E4I, Arc Power developed a financial model to show the viability of e-cooking for rural mini grids in Sub Saharan Africa.

Using Arc Power's mini-grid financial model, and overlaying it with on-grid e-cooking usage data from MECS, household energy consumption and traditional cooking data from a mini-grid operated by Arc Power in Rwanda, the impact of e-cooking for mini-grid operators and households was verified. In October 2020, ARC Power ran functional tests on five EPCs and five Electric Hot Plates, and in November 2020 gave the appliances to their customers for piloting e cooking on the mini-grid, customers appreciated the e-cooking solution however the tariff makes the solution non-competitive compared to the cost of existing traditional cooking fuels (firewood and charcoals). In that analysis, other benefits of e-cooking e.g., time saving, reduced drudgery of women, improved air quality, fewer accidents were not considered.

4.3.4. Bboxx

In May 2020, Bboxx conducted a research study in collaboration with MECS and University College London, aimed to investigate the characteristics and cooking practices of Bboxx's Pay-As-You-Go LPG customers, soon after the launch of their new cooking service (Perros, Buettner and Parikh, 2021). During this study, a particular focus was put on fuel stacking, analysing the simultaneous use of various cooking fuels, in this case mostly charcoal alongside LPG. The objective was to assess the level of mitigation of the negative health and environmental impacts of cooking with biomass, and the impact of its continued use on the adoption of new cooking technologies.

This study presents relevant insights for the development of other modern energy cooking technologies such as e-cooking. Like potential e-cooking users, the surveyed customers had a higher income than the average Kigali citizen, being mostly educated (47% had university degree), and the majority (83%) able to financially afford a modern cookstove. Consequently, the high upfront cost of the LPG stoves was not an issue for the surveyed group. The study analysis showed the LPG being more advantageous in a number of areas, particularly in safety, delivery, and affordability. Most importantly, two thirds of the surveyed group experienced a decrease (although modest) in cooking fuel expenditures since adopting LPG, with the remaining third noting an increase. The main cooking practices recorded in the cooking diary study were water heating and food cooking at 51% and 49% frequency respectively. Water heating was done for drinking water purification, bathing water, and water used to make hot drinks. Food cooking consisted of heating components of meals prepared at home with an average of 2 dishes per meal. The main components heated were green vegetables, rice, ugali, potatoes, banana, and beans (74%). A single dish cooking took 42 minutes on average, except for beans taking up to 89 minutes, and majority of cooking events were recorded around mealtimes at 1pm and 8pm. The study indicates that 91% households surveyed still had charcoal stoves, with 61% confirming they still used them. However, the study questions the latter figure suggesting an underreporting. Interestingly, the study noted that charcoal cooking was not driven solely by the unavailability of LPG, since LPG and charcoal were both used on 34% of days and in 12% of meals. Additionally, meals cooked with a single fuel were composed of 2.1 cooked components on average versus 2.7 components for meals cooked with both fuels, implying that the need to cook multiple elements of a meal simultaneously could have driven stacking.

This study provides a useful perspective into fuel stacking practices among Rwandan customers, and in order to reduce the stacking recommends an introduction of multiple stoves with the product to allow

more dishes to be cooked simultaneously, as well as introduction of pressure cookers. The latter would considerably reduce the time spent cooking heavy foods such as dry beans and cassava leaves, otherwise considered incompatible with LPG fuelled cooking. These findings show how the understanding of cooking practices can inform the most suitable approaches to implement other modern energy cooking technologies such as e-cooking, as well as recommendations to address the fuel stacking challenge.

4.3.5. EcoGreen

EcoGreen Solutions Ltd, a privately owned Rwandan-based company, is an emerging company dedicated to the manufacturing, research, development and commercialization of innovative efficient cooking technologies. EcoGreen is also an official distributor of Safe Gas products (LPG) and Mount Meru Gas in Rwanda. The company manufactures and distributes gasifier stoves that use biomass pellets as fuel, promoted by the GoR as one of the alternatives to charcoal and firewood. While currently the company sources the pellets from other producers in Rwanda, it intends to start its own pellet production.

One of the main challenges that the company faces is the lack of modern stoves suppliers in Rwanda, particularly in rural areas or close to refugee camps, where EcoGreen has been actively involved and which represent one of its focus markets. Cooking habits and the behavioural change needed to switch from charcoal and firewood for cooking, both in refugee camps as well as in host communities, has been highlighted as another crucial challenge for the scale up of their solutions.

EcoGreen currently provides two different types of efficient stoves, both of which work with biomass wood pellets. Their highest tier product, named “Umucyo 1”, presents 51% of efficiency, including solar, an internal battery and an optional electricity connection as power sources in addition to the pellets, corresponding to a Tier 4 under the MTF Framework. This stove can also use charcoal as an alternative fuel, and is currently priced at USD 65. Their second product, the “Umucyo 2”, utilises an air draft technology to provide an efficiency above 25%, corresponding to Tier 2-3. It doesn’t include any additional battery, solar nor electricity power source, and can also use charcoal as a fuel. The “Umucyo 2” is priced at USD 20. The pellets used by EcoGreen have a diameter between 6-12mm, with a moisture content of 10%, an ash content lower than 1.5%, and a calorific value higher than 16MJ/kg. Currently, 1kg of these pellets is sold at USD 0.25 to their customers.

EcoGreen suffers from the additional costs associated with t long supply chains when trying to deliver their products to the remote areas where refugee camps and host communities are located. To address this, they are planning to engage rural and refugee households that own shops in order to distribute or

sell EcoGreen products to their respective communities. For this purpose, EcoGreen is considering setting up cooperatives, engaging with reputable shops that can pay in advance for the stock, or grant them seed capital and request a payback on a monthly or bi-monthly basis. They are also planning to complement this approach with the installation of EcoGreen stores providing both stoves and pellets in nearby communities of the refugee camps where they are active. Those stores will have technicians able to perform necessary maintenance services on the stoves sold.

4.3.6. BioMassters

BioMassters is a Rwandan-based and female-led company, dedicated to the development and commercialisation of wood pellet fuel and biomass gasification stoves in Rwanda. The business emerged from a previous clean cooking venture in Rwanda, Inyenyeri, which successfully piloted ICS in the country. The company operates on an innovative stove and fuel subscription model, through which consumers receive a pellet stove for a USD 5 one-off subscription fee, and pay exclusively for the fuel by signing a minimum fuel consumption contract with BioMassters. The pellet fuel provided is produced in Rwanda and priced at RWF 300 per kg, below the price of charcoal in the Rwandan market, which can represent an attractive alternative for existing charcoal users. The average revenue per customer for the company is between USD 138 and USD 143 per year, and the consumption trends of customers are monitored remotely and used for the verification of carbon credits, generated for the pellet sales. The PAYGO model allows to remove upfront investment barriers from customers as well as reducing the marketing resources associated with the fuel supply. However, in comparison with the off-grid solar industry, this business model proves to be more capital intensive due to the costs associated to sourcing of biomass pellets and setting up the pellet and cookstove manufacturing facilities. Therefore, the profitability of this business model requires a large base of customers, estimated by the company at 30,000, achieved thanks to the contributions of economies of scale in biomass sourcing, pellet production and logistics.

4.4. Donors

4.4.1. Energising Development (EnDev)

Energising Development (EnDev) is a partnership between SNV and GIZ with the overall objective to support sustainable access to energy through a market-led approach. The same market-led approach is used to promote the development of clean and efficient cooking solutions in their countries of operation, including Rwanda. This is done through interventions aimed at stimulating demand, strengthening supply,

and creating an enabling environment for efficient cooking solutions. A special focus is placed on supporting the ICS value chain, involving support to producers and their brands, supporting them on stove production, establishing a retailing system and stimulating demand at the consumer level. The project, with a funding of EUR 1 million and scheduled to end in December 2022, targets 120,000 people accessing clean cooking through the sale of 80,000 improved stoves. The technologies targeted include all ICS types, from gasifiers to clay stoves. Another component of the project focuses on labelling, testing and other complementary activities.

This project is aligned with the extensive experience of EnDev on market-based approaches and creating enabling environments around improved cooking solutions across Africa and Asia. Their activity on modern energy cooking technologies in Rwanda is mainly centred around biogas. EnDev supported the National Domestic Biogas Programme during its first phase between 2007 and 2012 (EnDev, 2020). While the current work of EnDev in Rwanda is mostly targeting ICS, the experience and learnings obtained from their work can help to inform the best approach to create enabling environments for more efficient modern energy cooking technologies in Rwanda.

4.4.2. European Union

The European Union, through its flagship climate programme Global Climate Change Alliance Plus (GCCA+), is funding an EUR 5 million programme called “Reducing Climate Impact of Cooking in Rwanda through improved cooking systems” (Global Climate Change Alliance+, 2019). The program targets to disseminate 500,000 stoves by 2024, aiming to increase the local stove production capacity to 250,000 stoves per year by 2024. While the focus of the initiative is on ICS, specific criteria for the performance of the ICS supported apply to ensure the impact on fuel and cost reduction by beneficiaries. Additionally, the European Union is in discussions with MININFRA to promote the introduction of clean cooking in schools with a potential funding of EUR 10 million (BRD, 2021a).

4.5. Stakeholder workshop

4.5.1. Objective and attendants

As part of the partnership between MECS and E4I to understand the existing economic and policy environments around modern energy cooking in Rwanda, a workshop with national stakeholders was carried out in Kigali in June 2021 to understand and share different perceptions on the modern energy cooking landscape in Rwanda. The workshop involved public authorities and policymakers, energy sector regulators, development partners and donors, and private sector companies in the energy and clean cooking sectors. A detailed list of the participant organisations can be found in Table 14.

***Table 15**. List of participants in the clean cooking stakeholder workshop developed in Kigali.*

n.	Name of institution	Type of institution
1	RURA (Rwanda Utilities Regulatory Authority)	Government institution
2	ACE – ESD/ UR (African Center of Excellence in Energy for Sustainable Development)	Government institution
3	BRD (Development Bank of Rwanda)	Government institution
4	MININFRA (Ministry of Infrastructure)	Government institution
5	Ministry of Environment	Government institution
6	REG/ EDCL (Rwanda Energy Group / Energy Development Corporation Limited)	Government institution
7	SNV	Donor
8	GIZ EnDev	Donor
9	DelAgua	Private company (clean cooking stoves developer)
10	Enedom	Private company (clean cooking stoves developer)
11	Biomassters	Private company (clean cooking stoves developer)
12	Tecnoverde	Private company (clean cooking stoves developer)
13	NESELTEC LTD	Private company (clean cooking stoves developer)
14	Arc Power ltd	Private company (Mini-grid developer)
15	EPD (Energy Private Developers)	Private sector association
16	MECS	Research institution

The main objectives of the workshop were the following:

- Understand participants' perspective on the existing clean cooking landscape in Rwanda, in order to evaluate potential opportunities and challenges for promoting e-cooking in the country;
- Evaluate if there are policy and market gaps that need to be filled to stimulate the adoption of e-cooking in Rwanda;
- Share direct experiences and insights from different players in the clean cooking sector in Rwanda.

4.5.2. Highlights from participant discussions

The event involved the presentation of the preliminary findings included in this report, followed by presentations from different research, public and private sector players related to their clean cooking activity in Rwanda. Group discussions among the participants were organised to explore challenges, barriers, and potential initiatives to support the development of modern energy cooking solutions in Rwanda.

The main highlights arising from these discussions are the presented here:

- **Further incentives and knowledge sharing can benefit the development of the clean cooking private sector in Rwanda.** Additional support from the government to the private sector could be provided in the form of incentives on taxes. For instance, introducing tax exemptions like the one currently applying to SHS, complemented with awareness campaigns for emerging cooking technologies. Additional incentives to investors who want to setup factories for clean cooking technologies (appliances or fuels) could also be considered. The GoR should also promote and facilitate data sharing on the status of the sector, reducing the risk and facilitating long-term prospects for the private sector.

- **Close collaboration across all players is needed to develop effective interventions.** Although the government has relevant policies in place addressing clean cooking, there is a need to incorporate all modern cooking technologies in the existing programmes, and the mechanisms designed for implementation should be realistic to the socio-economic context in the country. Insufficient communication and collaboration among stakeholders have resulted in somewhat fragmented approaches and limited the effectiveness of the implementation of existing policies. Therefore, stronger partnerships and closer collaboration between the GoR, private sector, development partners and beneficiaries are needed.
- **Key role of customer awareness and demand side management for the development of e-cooking.** There is a consensus that e-cooking presents potential for a large part of the country as electricity access tends to universal access by 2024. However, there is a need to educate customers about e-cooking, its benefits and the use of efficient cooking appliances. Actors such as EDCL and RURA could support this process through national awareness campaigns and the exploration of possible incentives on electricity tariffs, such as tariff reductions during cooking hours. Electric cooking could be monitored remotely easily and tariff breaks for households transitioning to electric cooking could be an encouraging factor for increasing adoption. The GoR is in a position to review the current tariff structure to help facilitate that transition. The same applies for mini-grid providers, who could offer tariff breaks to their customers who purchase electric cooking appliances and use them on their mini-grids. This could incentivise the power consumption and make the electricity provision more profitable despite of the reduced tariffs.
- **Financial access at customer and supplier level is key to ensure progress in the clean cooking sector**. Various financing options that can stimulate uptake of e-cooking technologies should be explored. These could include PAYGO models, bank financing for vendors and users, carbon credits, subsidy programmes credits from local financial institutions, and other innovative financing mechanisms. The government has a key role to play in supporting the private sector to mitigate financial risks.

- **The transition towards clean cooking in Rwanda will involve a mix of fuels and technologies**. The future of clean cooking is expected to be a mix of fuels and technologies. The challenges faced, technologies adopted and fuels used will vary between rural and urban areas. The clean cooking mix could evolve towards a combination of ICS and LPG in rural and peri-urban areas, and a combination of electricity and LPG mostly in grid-connected and urban areas.

The insights arising from this workshop, which are aligned with the previous findings presented in this report, as well as the development of common spaces for discussion among the various clean cooking stakeholders, will contribute to the promotion of modern energy cooking solutions in Rwanda.

5 Conclusions and recommendations

5.1. Opportunities for modern energy cooking

Despite the limited penetration of modern energy cooking in Rwanda to date, the existing initiatives and growing national and international attention indicate that the market for clean and modern cooking solutions is small and nascent but with potential to grow and expand rapidly over the coming years.

Based on the current state of the market and policy frameworks in Rwanda, we can identify multiple factors that provide a positive outlook in the development of modern energy cooking technologies in the country:

- The GoR is committed to reduce the use of biomass for cooking across the country, and has set clear targets for the shift towards cleaner cooking technologies and fuels in the coming years. A particular strong emphasis is placed on the development of awareness campaigns aimed at encouraging people to switch from biomass and firewood.
- International donors and players are actively involved in the modernisation of the cooking sector in Rwanda, with internationally funded projects such as the Clean Cooking Results-Based Financing window funded by the World Bank.
- Growing presence of enterprises and private actors providing modern energy cooking solutions, notably LPG and biogas, but also including a small number of e-cooking companies starting to develop pilot projects that could demonstrate the viability of scaling up e-cooking in Rwanda.
- The conducive policy framework and the increasing activity in the modern energy cooking sector provides a favourable environment for the research on the cooking behaviour and preferences around modern cooking technologies by households in Rwanda, which can in turn inform and accelerate the progress in the sector.
- Increasing financial inclusion of Rwandan population through the expansion of services such as mobile payments, with a larger financial sector penetration in rural areas, that support the introduction of innovative financing schemes and business models for the adoption of otherwise costly modern energy cooking solutions.
- While the market has been dominated by traditional and artisanal cooking technologies, there is progressively higher availability of more efficient stove technologies, as well as an increasing offer of modern and efficient appliances due to improvements in supply chains.

- Particularly for e-cooking, the rapidly increasing electrification rates and ambitious plans by the Rwandan Government, targeting universal electrification by 2024, would increase the potential customer base market for e-cooking, both in grid and off-grid electrified areas. This, coupled with the increasing generation capacity and the improving reliability of the electricity supply, provides a positive prospect in the development of e-cooking in Rwanda.

5.2. Challenges for modern energy cooking

Nevertheless, there are remaining challenges to be addressed to facilitate the penetration and scale up of modern energy cooking solutions:

- Low affordability and energy consumption levels of customers, particularly in rural areas, represents a critical barrier for the adoption of modern energy cooking solutions and promotes the continued collection and use of biomass fuels such as firewood.
- Limited awareness of customers of modern energy cooking solutions, together with dominant beliefs and perceptions around their use, which need to be addressed through extensive awareness campaigns addressing health and economic benefits associated.
- The biomass sector continues to play an important role in Rwanda's economy, with firewood and charcoal representing a key source of income for farmers in rural areas.
- Appropriate measures need to be taken to avoid or minimise fuel stacking when promoting the use of modern energy cooking solutions, to fully achieve the environmental and health benefits of clean cooking.
- The modern energy cooking private sector is still in early stages of development, composed by established players testing the expansion of their product offering with modern and more efficient technologies, and smaller actors developing pilot projects for modern cooking solutions.
- The number of active suppliers of certain modern cooking technologies, such as electric cooking appliances, is still reduced in Rwanda. For LPG, the development of increased storage capacity and stronger distribution infrastructure is required to scale up its provision beyond urban areas.
- Clean cooking enterprises have limited financing options at high interest rates, temporarily exacerbated by the economic impact of the pandemic.

- In the case of electric cooking, while it is mentioned as one of the potential modern energy cooking solutions to replace biomass use, it is not as widely promoted as other fuels such as LPG, biogas or pellets. It is considered a niche solution due to limited electricity access, high power consumption, and relatively high electricity tariffs.
- The high costs of current electricity tariffs further limit the affordability of Rwandan households to use electricity as their main source of energy for cooking.
- Lack of specific policies favouring e-cooking appliances, similar to the reduced import tariffs and VAT that other products benefit from.

5.3. Recommendations for MECS

Various actions can be taken at policy, research, and market levels to promote the development of modern energy cooking solutions in Rwanda, with particular attention to e-cooking.

On the policy framework, promote the introduction of specific policies that:

- Highlight the role of electric cooking as a suitable alternative to traditional fuels, making sure it is also supported through existing future financing programs such as the recent Clean Cooking RBF.
- Include awareness campaigns that help customers to understand the benefits of electric cooking and minimise behavioural change barriers.
- Encourage the development of a strong supply chain for electric cooking appliances, through tax exemptions and development of standards, as done with other products such as SHS.
- Allow variable electricity tariffs according to the hour of use, setting preferential tariffs around meal hours to encourage the use of electricity for cooking.

On the research and development area, gather and disseminate further evidence on:

- Household cooking behaviour and characteristics of electric appliances that will be acceptable for Rwandan consumers.
- Affordability and adoption of electric cooking among Rwandan customers through pilot projects.
- The possibility to set up innovation hubs for the research development of efficient electric cooking appliances adapted to local Rwandan foods, partnering with institutions such as the Africa Centre of Excellence of Energy for Sustainable Development, in the University of Rwanda.

On the market and consumer sector:

- Develop and support customer awareness campaigns, including product demonstrations, advice on how to cook local foods, or advice on other energy efficiency practices for the use of electricity for cooking.
- Provide customers with financing solutions to access electric cooking appliances, such as flexible repayment schemes.
- Support establishment of strong supply chains and customer support services for electric cooking appliances.

For private sector enterprises in the cooking space:

- Promote their participation in the whole supply chain of electric cooking, including the assembly and manufacture of electric cooking appliances.
- Support them in demand stimulation campaigns, through community cooking demonstrations, development of recipe books for local foods, etc.
- Provide technical support on product development and testing, as well as business operations and financial strategy to support their establishment and growth in the Rwandan market.

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