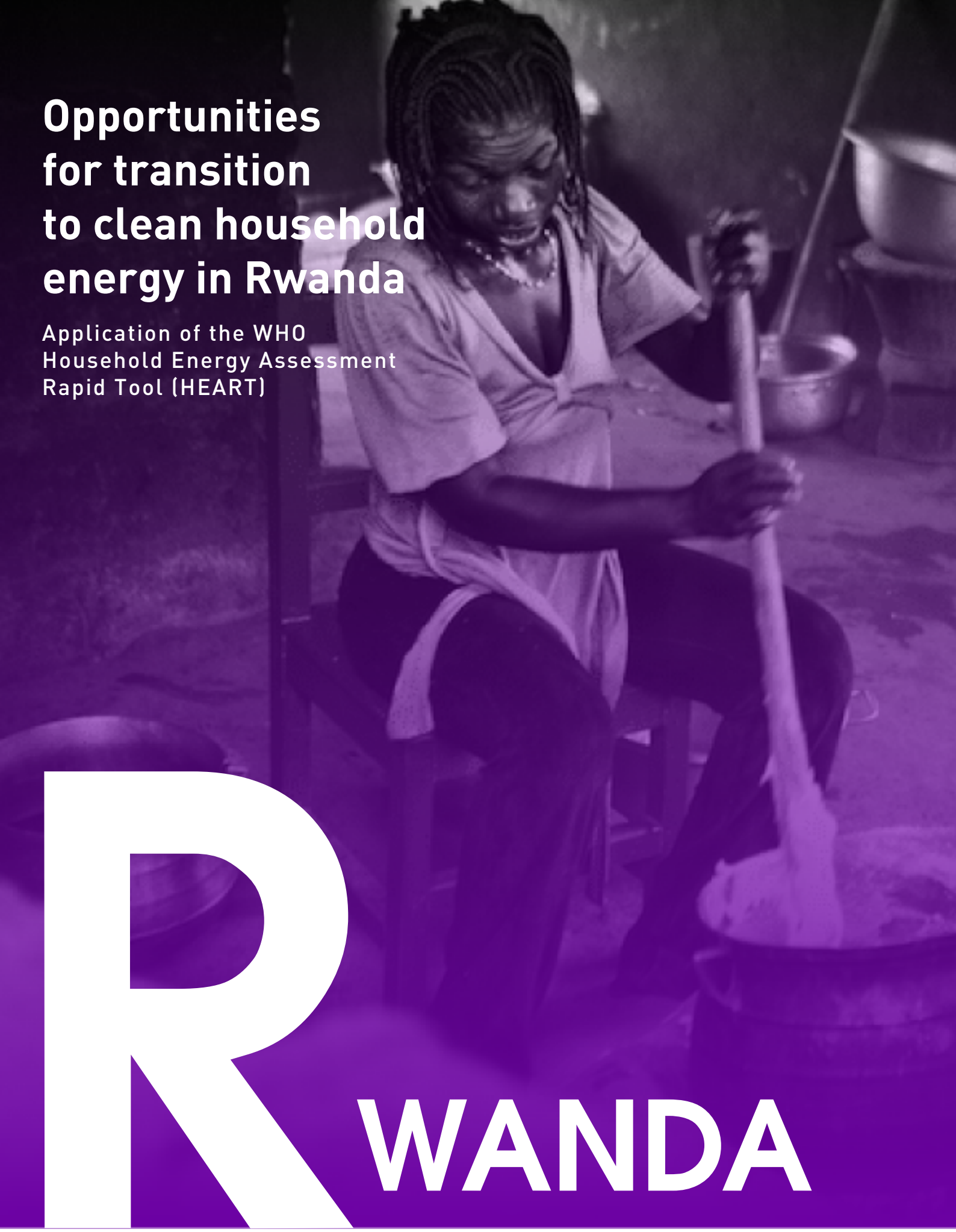

Opportunities for transition to clean household energy in Rwanda

Application of the WHO Household Energy Assessment Rapid Tool (HEART)

RWANDA

CHEST
CLEAN HOUSEHOLD ENERGY SOLUTIONS TOOLKIT

World Health Organization

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Contents

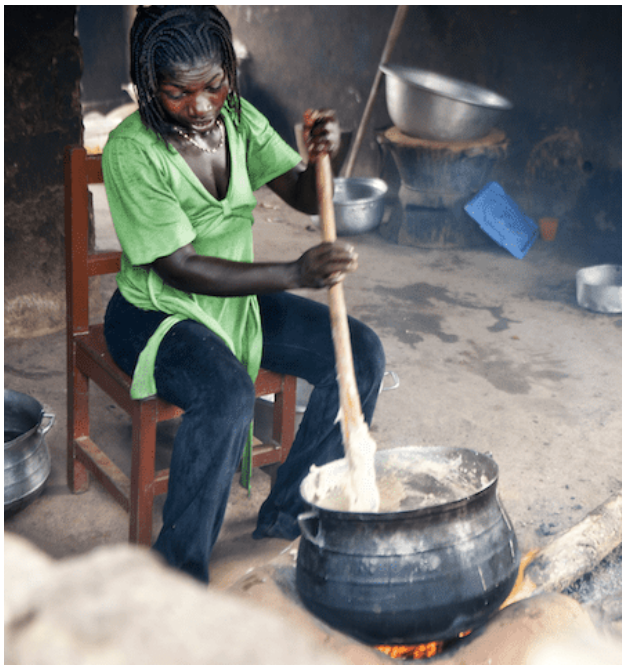
Preface

Household air pollution (HAP) from incomplete fuel combustion is one of the most important environmental health risks today. Kerosene and solid fuels (wood, animal dung, charcoal, crop wastes and coal) are burnt by 2.6 billion people, mainly in low- and middle-income countries, in inefficient, highly polluting stoves to meet their daily energy needs. These include simple necessities like preparing a warm meal or keeping warm on a cold night. Widespread use of polluting cook stoves causes millions of premature deaths among children and adults annually from respiratory illness, cardiovascular disease, stroke and cancer, as well as serious injuries due to scalding, burns and poisoning.

The *WHO guidelines for indoor air quality: household fuel combustion* provide recommendations on the best approaches to reducing HAP by transitioning to clean energy for policy-makers and specialists in energy, health, the environment and other issues. The Household Energy Assessment Rapid Tool (HEART) was developed by the World Health Organization (WHO) to support implementation of the guidelines. It is being used for conducting rapid situational assessments and mapping stakeholders to determine a country's readiness to access clean energy technologies. The tool is used to collect and synthesize information on household energy use and its impact on national public health. Information presented can be used to stimulate informed discussion on the impacts of interventions for household energy, shared responsibilities and coordinated action, country-specific barriers to implementation and opportunities for the public health and other sectors to collaboratively accelerate the transition to clean household energy.

The rapid assessment does not replace the detailed economic evaluation required to identify national energy priorities, national and global mapping of disease prevalence associated with polluting fuels or the social and political considerations required for applying major social interventions to transition to clean energy. The assessment does provide a broad overview of the current situation of household energy and health, identifies key stakeholders and will ultimately support intersectoral cooperation to reduce HAP and improve health. This report presents the results obtained from use of HEART in Rwanda.

A woman cooks with a traditional stove - © Iwona Bisaga



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This report was researched and prepared by Theoneste Ntakirutimana, Tzu-Wei Joy Tseng and Karin Troncoso (consultants), and was reviewed by Kendra Williams (technical officer) and Ryanne Fujita-Conrads (consultant). Heather Adair-Rohani (technical lead) oversaw the development of the report. In country, the initiative was coordinated and facilitated by Innocent Habimana from the WHO Rwanda Country Office. Cynthia Wantee Davis, Brama Koné and Guy Mbayo supported this project from the WHO Regional Office for Africa.

WHO is thankful to the following institutions for their support and cooperation during the assignment: the Rwandan Ministry of Health, Ministry of Infrastructure, Ministry of Environment, Rwanda Environment Management Authority, Rwanda Biomedica Center, Rwanda Energy Group and the World Bank. WHO also thanks Mukamunana Alphonsine, Bihinda Steven, Theophile Dusengimana, Nsengiyumva Jacques, Dr. Francois Uwinkindi, Oreste Niyonsaba and Norah Kipwola for the participation in interviews for this report.

WHO is grateful to Ministry of Foreign Affairs (Netherlands) for funding the project to identify opportunities for transition to clean household energy in countries by application of the Household Energy Assessment Rapid Tool (HEART).

Acronyms and abbreviations

CHW community health worker

HAP household air pollution

HEART household energy assessment rapid tool

LPG liquefied petroleum gas

NDBP National Domestic Biogas Programme

NGO nongovernmental organization

PM particulate matter

REG Rwanda Energy Group

REMA Rwanda Environmental Management Authority

RwF Rwandan franc

SDG Sustainable Development Goal

WHO World Health Organization

Introduction

Exposure to household air pollution (HAP) from inefficient burning of solid fuels is among the main risk factors for morbidity and mortality worldwide *(1)*. Access to clean, sustainable, affordable energy is a basic human right and essential for advancing global sustainable development agendas *(2)*; however, 2.4 billion people (about one third of the global population) still rely on polluting fuels and technologies to meet their household energy needs *(3)*.

In 2021, WHO launched updated air quality guidelines for air pollutants with the aim of reducing the risk of adverse health impacts *(4)*. Many people worldwide, including in Rwanda, are still exposed to pollutant concentrations that do not meet those guidelines. The annual ambient mean concentration of particulate matter (PM) measuring ⩽ 2.5 µm (PM2.5) in Rwanda is 43 µg/m3 *(5)*, which exceeds the interim target of 35 µg/m3 and to an even greater extent the recommended guideline level of 5 µg/m3. The contributors to poor air quality in Rwanda include the industrial sector, vehicle emissions, residential sector and burning of agricultural waste. Kigali has the highest level of air pollution in the country *(5)*.

Almost the entire Rwandan population (98.5%) relies on polluting fuels, particularly firewood and charcoal, for cooking *(6)*. Access to clean energy such as electricity is still limited. In 2022, 70% of the population lived in towns and villages that have electricity – 49% from the national grid and 21% from off-grid (mainly solar) systems *(7, 8)*. When access is defined as connection and use of households to electricity, an estimated 47% of households had access in 2020, representing 86% of the urban population but only 38% of the rural population *(9)*. Electricity could be a clean energy solution for cooking, particularly in urban areas, however less than 1% urban population cooks with electricity. Household air pollution (HAP) from solid fuels is a leading health risk factor for death in Rwanda, with 6932 deaths attributable to HAP in 2019 *(11)*.

A woman holding a child in Rwanda © Unsplash / Stuart Isaac Harrier

Boy in Ruduha Village, Rwanda © Unsplash / Stuart Isaac Harrier

Accelerating household access and adoption of clean energy is essential to achieving better air quality. This requires strong collaboration among stakeholders in multiple sectors. As a first step to improving access to clean fuels for household energy needs in Rwanda, this HEART assessment documents the existing household energy and health situation and identifies relevant stakeholders. This assessment was conducted by a comprehensive review of the literature and data and by interviewing informants in Government ministries, international organizations, nongovernmental organizations (NGOs), the private sector and academics involved in household energy, health and related activities in Rwanda according to the HEART template *(12)*, part of the first module of *WHO's clean household energy solutions toolkit (CHEST) (13)*. Published documents, such as on energy policies and programmes, were searched online with selected keywords, and relevant secondary data were identified. At a consultation workshop hosted by the Rwandan Ministry of Health in May 2022, a preliminary version of the HEART report was circulated to stakeholders in order to obtain their feedback *(14)*. Stakeholders provided additional information, such as data and identified barriers, opportunities and ways forward, to increase access to clean household energy in Rwanda, which were included in the final HEART report.

2

General country context

2.1 Geographical context

Rwanda, which is situated in the equatorial zone of east Africa, is a small, landlocked country with a total area of 26 338 km2, of which 94.7% is land and the rest (5.3%) water *(15)*. Its neighbours are Burundi, the Democratic Republic of the Congo, Uganda and the United Republic of Tanzania *(16)*.

Rwanda has a mountainous terrain (950–4500 m) and a temperate climate characterized by strong seasonality and high interannual variation *(17)*.

The country's topography results in moderate temperatures and rainfall, with large variations over short distances. Rwanda has two rainy seasons, a main season from March to May and another from mid-September to mid-December. The four main climate zones of the country are summarized in Table 1.

Water collection in a village, Rwanda © WHO / Henrietta Allen

↓ ***Table 1.*** *Climatic zones and average rainfall in Rwanda*

Climate zone	Average temperature	Annual average rainfall	Relative climate
Western and northern highlands	15–17 °C	1400–1600 mm	Coolest and wettest
Central plateau	17.5–19 °C	1200 mm	Cooler and wetter
Eastern plateau	20–21 °C	700–950 mm	Warmer and drier
Southwest lowlands	23–24 °C	800 mm	Warmest and driest

Source: Climate risk profile: Rwanda. US Agency for International Development, 2019.

2.2 Demographic and economic context

2.2.1 Population distribution

Rwanda has a population of approximately 14 million *(18)*, composed mainly of young people with a median age of 19.2 years (see Table 2) and an annual population growth rate of 2.3% *(18)*. The average household consist of 4.3 people.

2.2.2 Urbanization

About 17.6% of Rwandans live in urban settlements, with an annual urbanization rate of 3.2% *(19)*. Urbanization is concentrated in Kigali, the capital and largest city of Rwanda; however, other cities are undergoing extensive transformation, especially Musanze, Rubavu, Muhanga, Huye, Rusizi and Nyagatare, which will influence the urbanization rate in the coming years. High movement from rural areas to the capital city has led to an increase in energy consumption, which has resulted in numerous electrical outages in the city, causing many people to resort to using biomass for fuel *(20)*.

Rwandan landscape © WHO / Henrietta Allen

↓ ***Table 2.*** *Rwanda population distribution by age*

Age category (years)	Percentage of the population
0–14	38.89
15-24	20.46
25–49	30.84
⩾ 50	10.23

Source: World Population Prospects. United Nations, 2022.

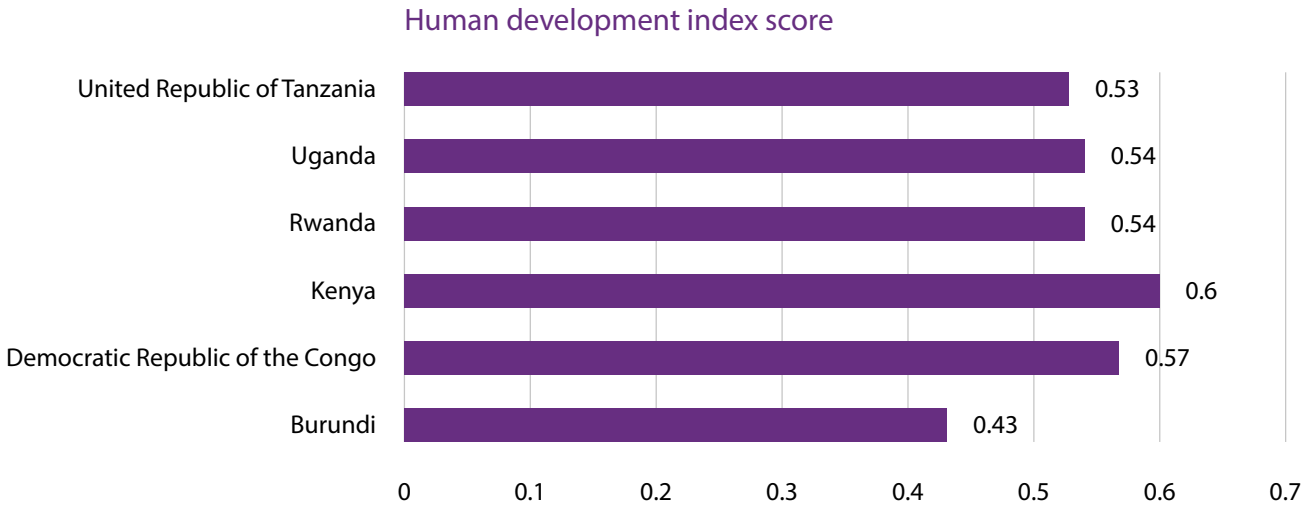
2.2.3 Economic and development context

Rwanda had a national gross domestic product of US$ 10.35 billion in 2019, and the per capita income of Rwanda in 2020 was US$ 797.9, a decrease from US$ 820.1 in 2019 *(21)*. In 2020, the gross domestic product decreased by 3.4%, following a growth of 9.5% in 2019, which is attributed to the preventive measures during the COVID-19 pandemic, such as a lockdown and social distancing measures, which sharply curtailed economic activities in 2020. Poverty in Rwanda, as measured by the international poverty line, fell from 77.2% in 2001 to 55.5% in 2017, while poverty measured by the national poverty line decreased from 58.9% to 38.2% *(22)*. Of those in the poorest quintile, 85% depend on agriculture.

The poverty rate varies widely by region; in Kigali, 1% of the city's population lives in extreme poverty, as compared with 32% in the Southern Province. Similarly, 64% of the population of Kigali is in the wealthiest category, as compared with only 11% in the Southern and the Northern provinces. Regional differences in poverty reduction rates have also been seen, much of which was seen in Kigali, while poverty has increased in the Western Province, and extreme poverty has increased in the Southern Province *(23)*.

Rwanda's human development index for 2019 as 0.543, similar to other east African countries (Fig. 1) and positioning it at 160 out of 189 countries and territories *(24)*. The score is slightly below the average of 0.547 for sub-Saharan African countries.

↓ ***Fig. 1.*** *Human development index of Rwanda and nearby east African countries, 2019*



Source: Human development report 2020. United Nations Development Programme, 2022.

2.2.4 Health Services

Rwanda has made significant advances towards universal health coverage with its community-based health insurance programme (Mutuelles de Santé) *(25)*. In Rwanda, 85% of the population live within one and a half hours by foot from public primary health centres *(27)*. The country currently has a functioning, decentralized health-care service system comprising eight national referral hospitals, four provincial hospitals, 36 district hospitals, 509 health centres, 885 health posts and other types of health facility such as private facilities and dispensaries (Fig. 2, Table 3) *(30)*. Rwandans have a life expectancy at birth of 69 years (females: 71.2, males: 66.8) (26). The probability of dying under 5 per 1000 live births is 40.47 in 2020, while maternal deaths per 100,000 live births is 248 in 2017 *(28, 29)*.

↓ ***Fig. 2.*** *Entry points for health care services delivery and advocacy in Rwanda*

Source: Rwanda Health Sector Performance Report 2017-2019. Rwanda Ministry of Health, 2020.

↓ ***Table 3.*** *Numbers of public health facilities in Rwanda in 2019*

Type of health facility	No.
National referral hospital	8
Provincial hospital	4
District hospital	36
Health centre	509
Health post	885

Source: Rwanda Health Sector Performance Report 2017-2019. Rwanda Ministry of Health, 2020.

Health facility in Rwanda © WHO / Henrietta Allen

3

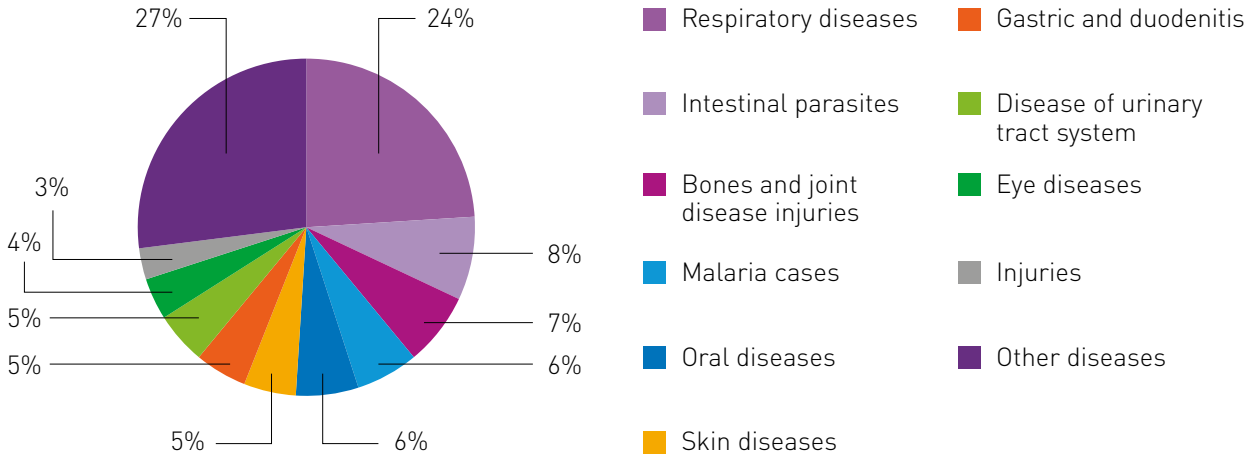
Impacts of household air pollution on health

3.1 Burden of disease due to household air pollution

In Rwanda, the top 10 causes of death are neonatal conditions, lower respiratory infections, stroke, road injury, ischaemic heart disease, malaria, diarrhoeal diseases, HIV/AIDS, cirrhosis of the liver and diabetes mellitus *(10)*. In 2019, acute respiratory infections were the leading cause of morbidity in health-care facilities in Rwanda, accounting for 24.2% of all patients admitted (Fig. 3) *(30)*. Respiratory infections are among the top causes of death in children under the age of 5 in Rwanda, accounting for 14% of all deaths in this age group *(10)*.

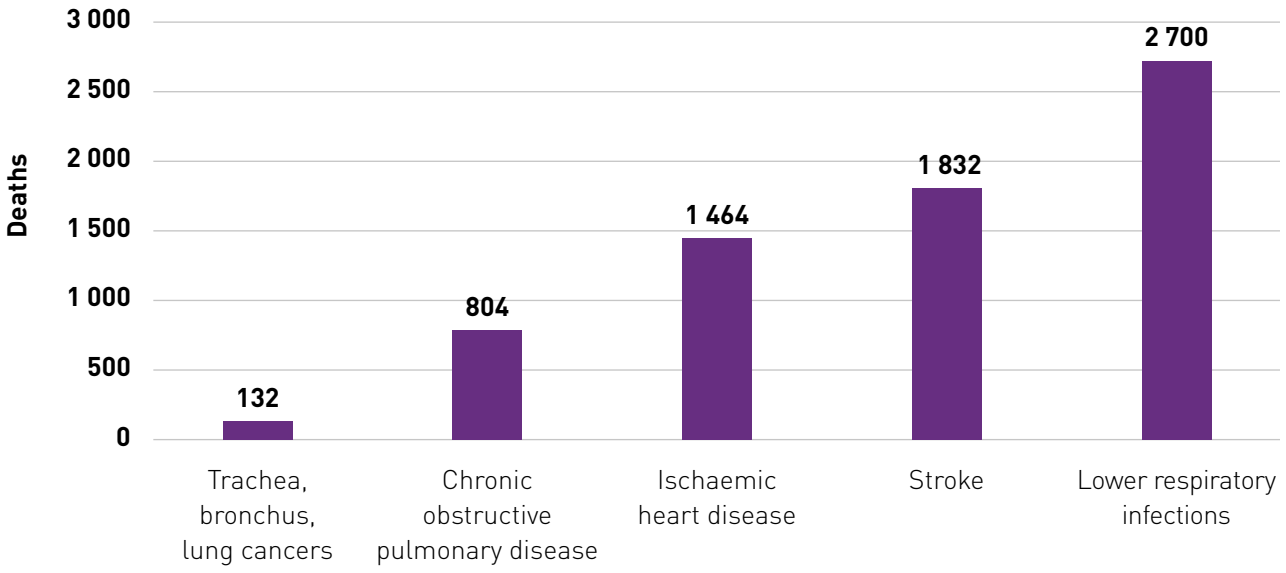
According to the WHO Global Health Observatory database, 6932 deaths and 237 855 disability-adjusted life years were attributable to HAP in Rwanda in 2019 *(11, 31)*. Lower respiratory infections account for the majority of deaths and disability-adjusted life years due to poor household air quality, followed by ischaemic heart disease (see Figs 4 and 5). Acute and long-term health conditions associated with exposure to HAP can strain the health-care system *(32)*.

↓ ***Fig. 3.*** *First 10 causes of morbidity in all health-care facilities, Rwanda, 2019–2020*



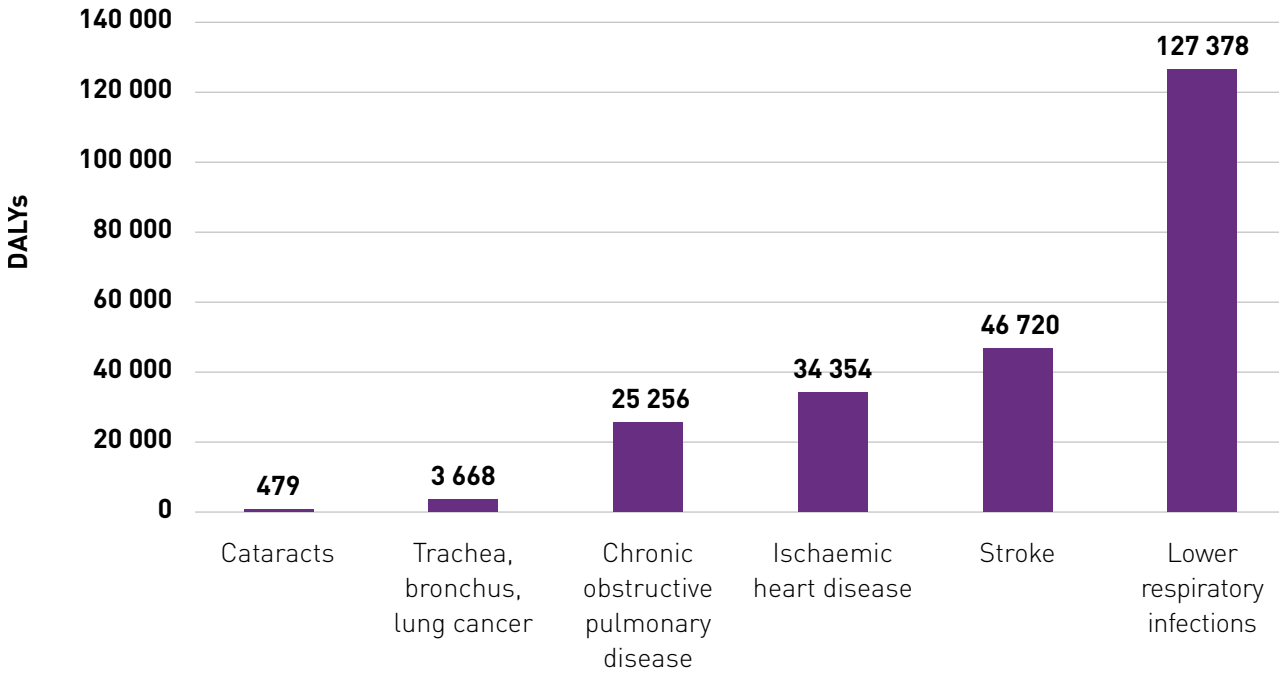
Source: Rwanda Health Sector Performance Report 2019-2020. Rwanda Ministry of Health, 2020.

↓ ***Fig. 4.*** *Deaths attributed to household air pollution in Rwanda, 2019*



Source: WHO Global Health Observatory, 2022.

↓ ***Fig. 5.*** *Disability-adjusted life years attributed to household air pollution in Rwanda, 2019*



Source: WHO Global Health Observatory, 2022.

3.2 Local information on the health effects of air pollution

Health effects of ambient air pollution

Little evidence is available about ambient air pollution in Rwanda. The available studies and reports provide quantification of different air pollutants in various sites in the country. In six studies and reports *(34–39)* of $PM_{2.5}$ and PM_{10} concentrations in different areas of Rwanda, the levels markedly exceeded the WHO interim targets *(4)* for both. The findings show that the pollutants of concern in Rwanda are from various anthropogenic and natural sources, such as industrial and manufacturing activities, residential cooking and transport. The pollutants of concern are:

- PM with aerodynamic diameters ≤ 10 µm (PM_{10}) and ≤ 2.5 µm ($PM_{2.5}$),
- nitrogen oxides, including oxides of nitrogen and nitrogen dioxide (NO_2),
- sulfur dioxide (SO_2),
- ozone (O_3) and
- carbon monoxide

In a study by Subramanian *(39)* between March 2017 and July 2018 in Kigali, the average ambient $PM_{2.5}$ and black carbon were 52 µg/m^3 and 4 µg/m^3, respectively. The $PM_{2.5}$ level exceeded the WHO guidelines (5 µg/m^3)*(4)*.

In a 3-month outdoor gravimetric sampling study in Kigali and Musanze, the $PM_{2.5}$ and PM_{10} concentrations were 133 µg/m^3 and 156 µg/m^3, respectively, in Kigali and 45 µg/m^3 and 54 µg/m^3 in Musanze District *(38)*. The mean 24-h concentrations of $PM_{2.5}$ in Kigali were much higher than the WHO guideline value of 15 µg/m^3. The high concentrations of these pollutants were attributed mainly to vehicle emissions, as the concentrations dropped during holidays and car-free days *(37)*.

In a study conducted in Kigali in which NO_2, SO_2 and carbon monoxide were monitored, the concentrations of these pollutants were acceptable as they were generally below the WHO guidelines and the East African Standards for ambient air quality. There were, however, some higher concentrations of SO_2 during the dry season. The levels of ground-level O_3 were also high, resulting in some exceedances of the 8-h WHO guidelines *(36)*. The East African Standards propose that, in rural and urban residential areas, 24-h mean exposure to the pollutants $PM_{2.5}$, SOX and NOX should not exceed 25 µg/m^3, 80 mg/m^3 and 80 mg/m^3, respectively, and 1-h mean exposure to carbon monoxide should not exceed 4 mg/m^3 *(40)* (see Table 4). Rwanda has not yet established air quality standards; however, an interview with an informant at the Rwanda Environmental Management Authority (REMA) indicated that standards are being prepared.

Household air pollution from domestic combustion of solid fuels © AdobeStock / Dennis Wagewijs

↓ ***Table 4.*** *WHO and East African Community air quality standards (2021)*

Pollutant	Average time	WHO standard	East African Community standard
$PM_{2.5}$ (μg/m^3)	Annual 24-h	5 15	10 25
PM_{10} (μg/m^3)	Annual 24-h	15 45	20 50
Carbon monoxide (mg/m^3)	1-h 8-h	35 10	4 2

Source: WHO Global Air Quality Guidelines. World Health Organization, 2021; Draft Standard, Air Quality. East African Community, 2021.

Nduwayezu et al. *(36)* found that the following factors contribute to high concentrations of particulates in Kigali:

- a high density of vehicles, particularly old vehicles;
- inadequate maintenance facilities;
- poor traffic management systems and road conditions; and
- lack of mass transport systems such as trains.

The contribution of household air pollution to ambient air pollution was not considered in this report. However, globally, household energy is an important source of outdoor air pollution as well. Clean household energy is therefore important for reducing the heavy burden of disease from outdoor air pollution as well. All the studies and reports cited above were conducted in Kigali and secondary cities in the country, some with data that is more than 5 years old. More recent data should be generated by monitoring in different areas of the country to determine whether the concentrations of air pollutants are acceptable for human health.

Studies on the health effects of household air pollution

Limited evidence is available on HAP and its health effects in Rwanda. In the available studies, promotion of improved cook stoves was a part of the study design.

A randomized controlled trial with multiple phases was set up to investigate the Tubeho Neza ("Live Well") programme in rural Rwanda, where improved cookstoves and water filters were distributed and promoted to the poorest quarter of households (Ubudehe 1 and 2). During the pilot phase, air pollution in the cooking area was monitored in a random subsample of 121 households, of which 61 were control households. An overall reduction of 48% in the 24-h $PM_{2.5}$ concentration was seen in households with EcoZoom Dura improved wood-burning stoves, from 0.905 mg/m^3 in the control group to 0.485 mg/m^3 in the intervention group. A larger reduction was seen in households where cooking was done outdoors (73%) than in those where cooking was indoors (37%) *(41)*. After the pilot phase, a larger study of 1582 households was conducted, which indicated that the intervention had no significant impact on 48-h personal exposure to log-transformed $PM_{2.5}$ concentrations in cooks or children but reduced the prevalence of reported acute respiratory infections by 25% and also of burns in children. Further investigations should be conducted to better understand the unexpected effects on acute respiratory infections in the absence of reductions in $PM_{2.5}$.

A study of baseline data from another randomized controlled trial of an improved household energy initiative in urban Rwanda included 529 households with 694 children under 5 years of age. Children living in clusters of poorly ventilated homes, families that cooked indoors and households near tree cover were at significantly higher risk of respiratory infections, illness with cough and breathing problems *(42)*; however, children living in homes with cemented floors and ventilation holes in the cooking area were less likely to experience respiratory infections.

More data should be made available on levels of exposure and the associated health impacts associated with the use of different types of stoves and fuels in Rwanda. A detailed list and description of studies in which ambient and HAP levels were measured at ground level are provided in Annex 1.

4 National household energy context

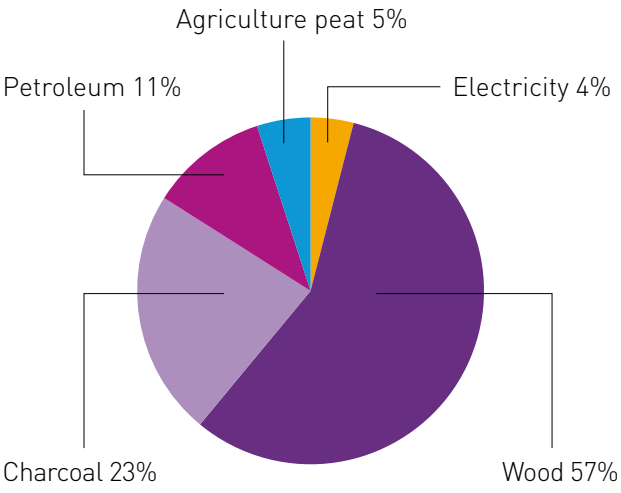
4.1 National energy profile

Rwanda relies primarily on biomass as a source of energy, which contributes about 5% to the gross domestic product. Although there has been a downward trend in use of biomass as a primary source of energy over the past 4 years, in 2018, approximately 85% of primary energy still came from biomass in the form of wood, which is either used directly as fuel (57%) or converted into charcoal (23%), or in the form of crop residues and peat (5%) *(43)* (Fig. 6).

The residential sector consumes the most energy in Rwanda (82%), primarily for cooking and lighting (see Fig. 7). Transport (8%), industries (6%) and other sectors (4%) consume considerably less energy.

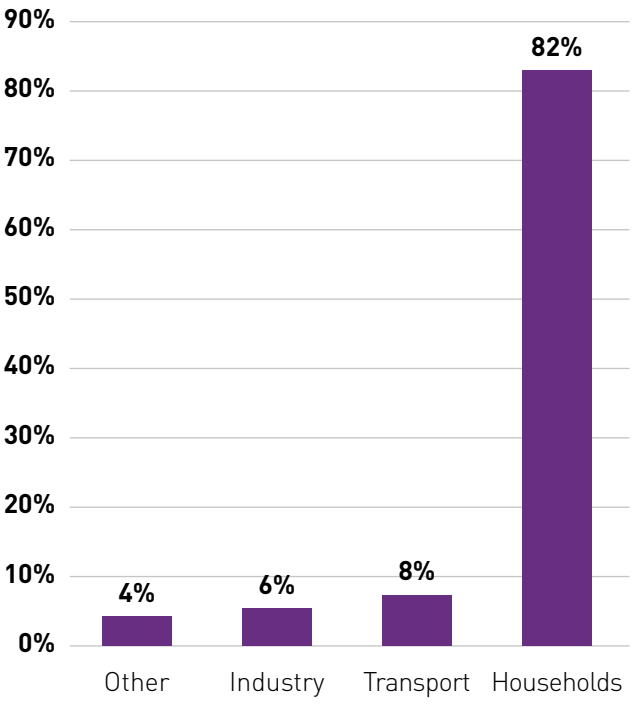
Electrical grid © AdobeStock / Valeriya

↓ ***Fig. 6.*** *Primary energy balance in Rwanda*



Source: Establishing a green charcoal value chain in Rwanda: A feasibility study. World Bank Group, 2018.

↓ ***Fig. 7.*** *Energy consumption in Rwanda by sector*



Source: Niyonteze JD, et al., 2020.

4.2 Infrastructure for fuel and technologies

4.2.1 Electricity

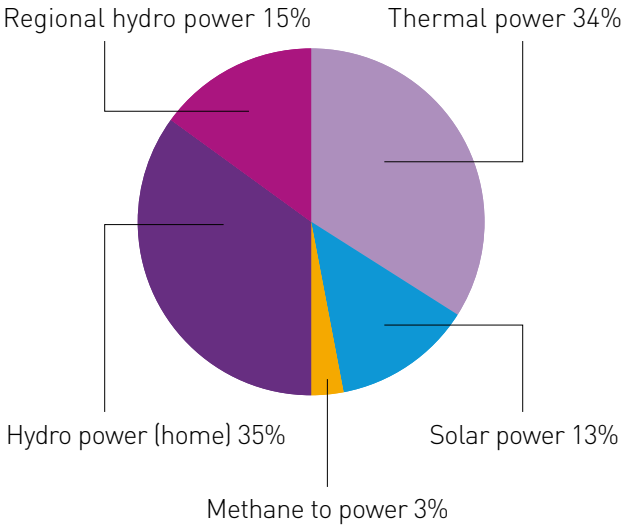
Rwanda's demand for electricity has grown rapidly, by 25% a year, due to rapid urbanization, industrial demands, population growth and increased economic activity *(43)*. The average monthly household consumption of electricity is nevertheless still relatively low, particularly in rural areas: 20.8 kWh nationwide, 29.2 kWh in urban areas and 9.9 kWh in rural areas. Households pay an average of 3514 Rwandan francs (RwF) (USD 4.2) a month for electricity from the grid, and urban households spend twice as much as rural households (4656 RwF (USD 5.6) and 2010 RwF (USD 2.4), respectively) *(7, 45)*.

The electricity supply in Rwanda consists of domestic generation and electricity imported from neighbouring countries and shared regional power plants. Together, these sources currently supply 228.2 MW of electricity capacity. Electricity is generated from hydropower plants, thermal power plants (diesel and heavy fuel generators), methane gas and solar energy (Fig. 8). Today, 70% of Rwandan households live in a village or town with access to electricity, 49% live in a village or town with access to the national grid, and 21% could have access through off-grid systems; however, only 47% of households are actually connected to the grid or an off-grid system *(45)*. The distribution of the households that are connected demonstrates the infrastructure challenges, as 93% of people living in urban areas are connected, but only 26% living in rural areas have some source of electricity *(7, 46)*. To eliminate recent power deficits due to insufficient generation capacity, the Government rented thermal power plants as a provisional solution *(7)*. Rwanda's Government is committed to diversifying the country's sources of energy, and a number of large investments are being made.

The country's electricity supply relies heavily on hydroelectric power, which is affected by changes in seasonal weather conditions and extreme events. Lack of rainfall and unpredictable weather in the past few years caused several electricity shortages, thus rendering hydroelectric power an unreliable source of energy. Although diversification of energy sources is a high priority, the Government continues to develop hydropower as the least costly resource. Rwanda's mountains provide abundant opportunities for hydroelectricity production; however, other sources should be investigated to reduce outages resulting from climate change *(51)*.

The current access target is to ensure that 100% of households have access to electricity by 2024 *(46, 48, 49)*, while users such as industries, agriculture and commercial activities will all be connected before the end of 2022. To achieve this target, Rwanda Energy Group (REG) intends to increase the number of new connections by 500 000 every year, comprising 200 000 on-grid and 300 000 off-grid. The aim is to increase electricity generation for domestic use to 556 MW by 2024, from the current 228.2 MW. There is urban–rural disparity in access to electricity, with 26.2% of households in rural areas and 93.1% of households in urban areas connected to electricity *(7, 46)* (Table 5). Power outages across the country are attributed to seasonal changes, maintenance breaks and sometimes insufficient supply of voltage. Some institutions, such as banks and ministries, have back-up generators fuelled with petroleum in case of outages *(7, 45)*.

↓ ***Fig. 8.*** *Distribution of sources of electricity generation*



Source: Koo BB, et al., 2018.

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↓ ***Table 5.*** *Rwanda electricity profile*

Electricity indicator	
Total installed capacity	228.2 MW
Imported capacity	25.9 MW
Households in towns and villages with access to electricity	70%
Households with electricity service (connected on-grid or off-grid)	47%
Urban access to electricity	93%
Rural access to electricity	26%
Households in towns and villages with access through a national grid	49%
Households in a town or village with access through an off-grid system	21%

Source: Off-grid electrification helping to achieve Rwanda's energy targets. Rwanda Energy Group, 2022; Rwanda Ministry of Intrastructure, Energy division, 2022; Koo BB, et al., 2018.

Kerosene lamp © AdobeStock / Christopher Klein

Although tariffs are subsidized, the cost of electricity is higher than in all other East African countries. Start-up subsidies are given to families in social economic categories 1 and 2, which they are financed from a programme financed by stakeholders that include the World Bank and the US Agency for International Development *(50)*. The Government reduced fiscal tariffs on the electricity sector, halving them for low-income households, making connection significantly more affordable (Table 6).

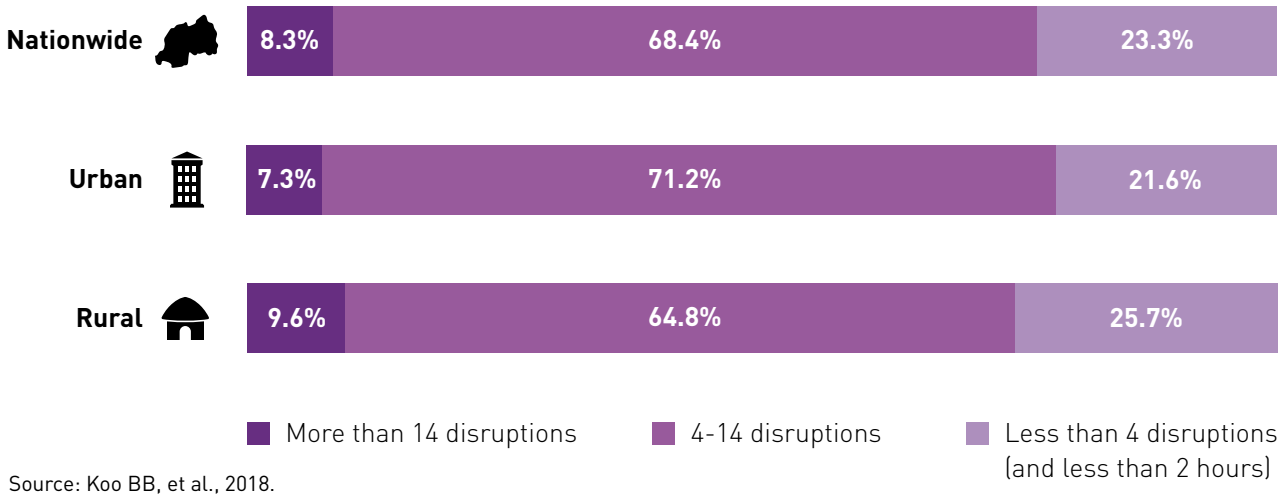
↓ ***Table 6.*** *Electricity prices by consumption category*

Category	Consumption (kWh)	Rfs/kWh (exclusive of VAT and regulatory fee)
Residential	0–15/month 15–50/month > 50/month	89 212 249
Non-residential	0–100/month > 100/month	227 255
Water treatment plants and water-pumping stations	All consumption	126
Telecommunication towers	All consumption	201
Hotels	All consumption	157
Health facilities	All consumption	186
Broadcasters	All consumption	192
Commercial data centres	All consumption	179

Source: Rwanda Energy Group, 2020.

According to the Ministry of Infrastructure in 2018 *(52)*, the average number of power outages per year was 265, for a total annual duration of 44 h without electricity for users; 91.7% of grid-connected households experienced more than four electricity disruptions per week. Reliability is slightly greater issue in urban than in rural areas (Fig. 9), perhaps because of the higher density of grid-connected households in cities. Power outages, resulting in poor reliability, occur when a utility or equipment uses more power than the capacity for generation or electricity transmission lines break down in certain geographical areas *(45)*.

↓ ***Fig. 9.*** *Power disruptions in Rwanda for urban and rural households*



Source: Koo BB, et al., 2018.

4.2.2 Liquefied petroleum gas for cooking

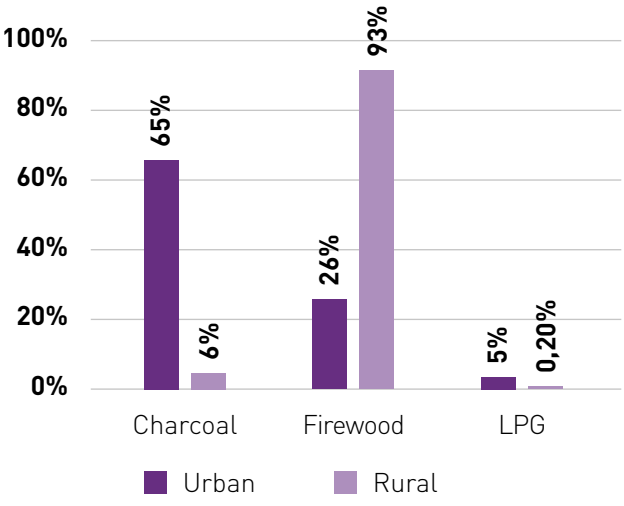
Currently, Rwanda has no domestic production of liquefied petroleum gas (LPG) and relies on imported cooking gas. The LPG market in Rwanda is dominated by 10 importers (Société Pétrolière, Kobil, Sulfo Rwanda, Rwanda Oxygène, Merez, Hashi Energy, Abbarci Petroleum, Safe Gas Lake Petroleum Rwanda, and RUCSA Investment) and four distributors. Retail sales and distribution are assured at service stations, by independent distributors and at supermarkets in various cylinder sizes: 3, 6, 12, 15, 20, 25, 35, 38, and 50 kg. Tanks containing 500–5000 kg are available for large institutions. The average household cooking gas consumption is 12.74 kg per month at a cost of 14 315 RwF (USD 14.08) *(53–55)*. Use of LPG as a source of cooking energy increased from 2 749 572 kg in 2015 to 21 329 751 kg in 2019 *(56)*, but its penetration is still low, at 5% in urban and 0.2% in rural areas (Fig. 10). The Global LPG Partnership master plan *(57)* has identified drivers of demand for LPG in Rwanda:

- ease of access: The closer an LPG retail point is to a consumer, the more the consumer is likely to adopt and use LPG, particularly when cylinders are delivered to the home;
- availability of fuel: Shortages discourage a decision to adopt and rely on LPG;
- demographic factors: Socio-economic status, urbanization and the age, gender and educational level of the head of a household correlate with LPG uptake;
- residence: LPG use is concentrated in Kigali and other urban centres;
- costs: Up-front equipment and continued use (i.e., cylinder refills);
- appropriateness to cooking needs: Factors such as the taste of cooked food and the ability to cook foods for a long time and use large pots.

The Government has promoted use of LPG by various means, including suspension of VAT on LPG imports, subsidizing the cost of investing in the infrastructure, bulk purchase and storage facilities, to ensure the affordability and efficiency of LPG facilities *(57)*.

Liquified petroleum gas for cooking © Ghislaine Rosa

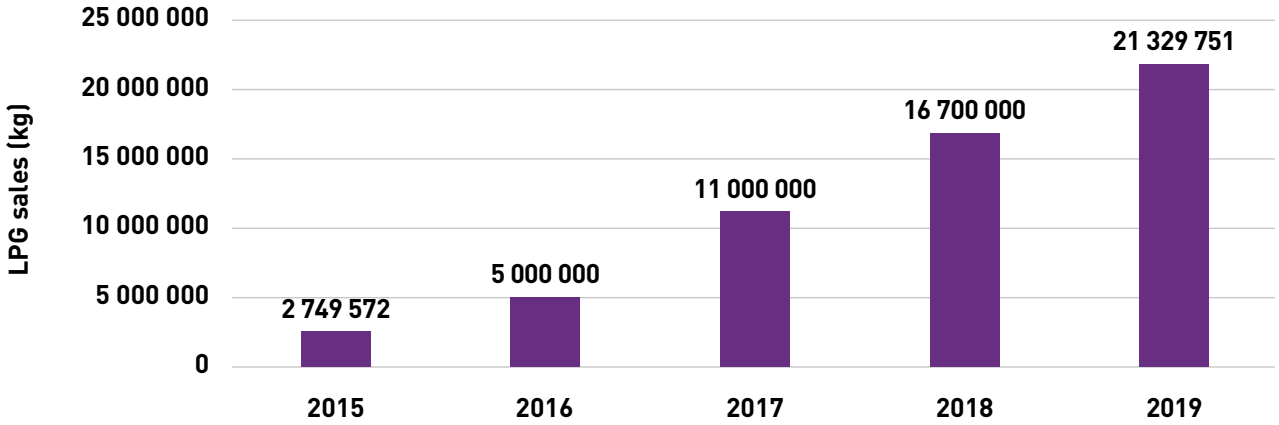
↓ ***Fig. 10.*** *Use of LPG cooking gas and of firewood and charcoal*



Source: Cukic I, et al., 2021.

An incremental increase in adoption of LPG has been seen during the past 5 years, due to the increased availability of LPG, particularly in urban areas *(56)* (Fig. 11), and the Ministry of Infrastructure developed a national LPG master plan to build on the growth *(57, 58)*. The aim of the plan is to scale up LPG use to achieve the 2024 policy target and the 2030 target for universal access to clean, modern energy (SDG 7) and to increase household LPG use from 5.6% in 2020 to 13.2% by 2024 and 38.5% by 2030. If realized, this project could result in a reduction of 7656 premature deaths and 403 664 disability-adjusted life years, as well as 243 million trees saved *(58)*.

↓ ***Fig. 11.*** *LPG consumption, Rwanda, 2015–2019*



Source: Energy Private Developers, 2021.

4.2.3 Natural gas

Carbon dioxide and methane gas are released naturally in Lake Kivu, which is located on the border between Rwanda and the Democratic Republic of the Congo. The lake covers an area of 2700 km2 and contains about 300 billion m3 of carbon dioxide and 60 billion m3 of methane gas. The resource is shared equally between the two countries *(46)*.

An estimated 120–250 million m^3 of methane can be generated annually from the Lake, and the Government has initiated a project to use this resource to develop methane-to-power projects and other uses, such as fertilizer. In project, methane gas from the Lake would be used for cooking by converting it into compressed natural gas for clean burning by the end of 2022. To address the energy deficit and provide all Rwandans with access to power, the Government is attracting private investors. The Union Chimique de Belge began using purified methane gas, with a pilot plant in Rubona, a neighbourhood on the shores of Lake Kivu, in 1963, but it was not until 2015 that methane-to-power projects were set up *(53)*. KivuWatt is a project managed by Contour Global, which extracts methane from Lake Kivu to generate electricity, extend household access to power, lower costs and reduce environmental hazards. The project is currently generating 26 MW of electricity for the local grid. Another project, funded by Gasmeth, is expected to compress methane gas onshore to create natural gas *(60, 67)*.

The Government has established a supervisory body, the Lake Kivu Monitoring Programme, to ensure safe extraction of methane gas and to protect the surrounding population while preserving the Lake's stability. Laws and regulations for methane projects are under review and are expected to be approved shortly. Challenges and risks to sustainable extraction of natural gas from Lake Kivu include lack of financial resources and technical expertise; however, the potential benefits of extraction are considered to outweigh the risks *(60, 68)*.

4.2.4 Biogas

Rwanda launched a national biogas programme in 2009, after an initial pilot programme supported by German Agency for International Cooperation (formerly the German Technical Cooperation Agency) and the Dutch non-profit organization SNV *(63)*. In 2010, the Government took over the biogas programme and helped to establish more than 50 private companies conducting projects in homes and schools. More than 11 000 biogas systems currently provide power to some rural homes based on methane from cow dung and other animal waste. The cost of constructing biogas systems has been a significant barrier to more widespread use of the technology, especially for poor families. In 2016, biogas systems cost 400 000–800 000 RwF (USD 666.6–1333.3, 2016 exchange rate), depending on size. The upfront costs of a biogas system exceed rural household incomes and are the main barrier for adoption of the technology by households. To overcome this barrier, the National Domestic Biogas Programme (NDBP) provides a subsidy for each system installed of about 300 000 RwF (about US$ 350), the farmer being expected to finance the rest, with a possible credit to a bank or a savings and credit cooperative. The subsidy approval scheme has evolved since inception of the NDBP. In its initial form, authorized biogas companies applied for subsidies to local authorities, for final approval by the REG. The subsidy was transferred to the biogas company in three instalments, according to a schedule that included quality control by a local REG technician (one or two REG technicians per district were entitled to conduct quality controls). In mid-2015, the NDBP closed and was transferred to the biogas unit of the Energy Development Corporation Ltd, a branch of the REG under the Ministry of Infrastructure, and subsidy approval and quality control are now decentralized to district authorities. Each district is now responsible for relations with biogas companies for subsidy approval. The NDBP provides a similar subsidy, regardless of the size or type of biodigester. The subsidy may represent 37–54% of the total cost of the system, depending on its size (see Table 7). In addition to subsidies for construction of the biogas system, the NDBP provides, for each constructed biodigester, lighting equipment for households (a biogas or solar lamp) *(43, 64)*.

House in Rwanda using biogas © AdobeStock / Roel

One goal of the NDBP subsidy was to increase the awareness of the population and the capacity and experience of biogas companies. By mid-2015, 6000 subsidized biogas systems had been installed under the NDBP, and little unsubsidized activity was observed. An evaluation of the NDBP performed by SNV in 2013 indicated that the robustness of the technology and its positive outcomes were strengths of domestic biogas systems, but the high upfront cost of the system for households was the main cause of slow uptake. Other causes included insufficient manure, as most households do not have enough livestock to provide the average daily manure requirement of 5 kg/animal per day and time spent on additional trips for collecting manure and water (51). An article posted on Rwanda Today in March 2022 (65) cited the Auditor General's report that 5000 of the 9647 biogas plants constructed in the country since 2007 had failed and that the beneficiaries had returned to using firewood. This failure was attributed to poor workmanship and recruitment of staff without the required technical capacity to implement the project (66).

↓ ***Table 7.*** *NDBP subsidies for total cost of biogas systems*

Biodigester size (m^3)	Total cost of biogas system (RwF)	NDBP subsidy (RwF)	Share of NDBP subsidy of total cost (%)	Remaining upfront cost for end user
4	555 000	300 000	54	225 000
6	624 000	300 000	48	324 000
8	712 000	300 000	42	412 000
10	818 000	300 000	37	518 000

Note: 1 USD=834.63 RwF, 2016 exchange rate.
Source: Domestic Biogas Diffusion in Rwanda. ENEA Consulting, 2016.

4.2.5 Kerosene

Rwanda's average consumption of gasoline and kerosene is about 5300 barrels per day *(45)*, almost all of which is imported through the port of Mombasa, Kenya. Although there is limited information, kerosene appears to be used extensively in rural areas for lighting and to some extent in urban areas for cooking and lighting. In 2018, Kigali and Western provinces used the most kerosene *(67)*.

4.2.6 Peat

The country's peat bogs contain up to 155 million t of dry peat, covering a combined area of 50 000 ha. About 77% of the peat reserves are near the Akanyaru and Nyabarongo rivers and the Rwabusoro plains. One study *(60)* indicated the potential electricity generation from exploitable peat reserves to be about 150 MW for sod peat application and 117 MW for milled peat application for 30 years of operation.

4.2.7 Charcoal

Charcoal is the third most commonly used energy source for cooking in Rwanda, after firewood and agricultural residues. Charcoal is derived from trees planted on Government, private or community land; little charcoal is produced from natural forests. Average wood-fuel production is 2.8 million t/year, and charcoal (converted into wood equivalents) accounts for 40–50% of total wood-fuel consumption *(43)*.

The charcoal production industry has three types of staff: master, foreman and labourer. A charcoal master seeks wood to be carbonized, negotiates with plantation owners and purchases trees. A charcoal master could be a professional charcoal burner with financial backing or a "big" transporter who can buy charcoal or finance onsite production to supply various urban areas. Many plantations are purchased by businessmen, especially in Kigali, who make a profit from the charcoal produced. A foreman works for a charcoal master or, in rare cases, a wood owner and manages the staff. Labourers are paid by an output-based payment system and receive 500-1000 RwF (USD 0.77-1.54, 2013 exchange rate) per sack of charcoal produced *(68)*.

Woman cooks with charcoal © Iwona Bisaga

Kigali alone accounts for an annual charcoal consumption of 120 000 t, equivalent to 1.2 million m^3 or 850 000 t of wood. As households spend an average of 12% of their incomes on energy, the World Bank estimated that the average consumption of fuelwood and charcoal was 1.45 + 0.48 kg or 1.93 kg/person per day in 2018 *(43)*. Charcoal is packaged distinctively in rice or maize sacks and fan palm leaves or twine ropes. A standard bag contains 33–38 kg and a large bag 50–60 kg of charcoal, depending on the species of tree used. The upper visible part of the bag contains larger bricks of charcoal than the rest of the bag in order to attract buyers (Fig. 12). Charcoal producers sell their products to collectors–transporters or wholesalers. A few producers organize transport to urban centres and sell their products directly to wholesalers. The main charcoal combustion techniques used in households are the three-stone fire (Fig. 13), first-generation improved stoves (Fig. 14), second-generation improved stoves and high-efficiency stoves *(43)*.

4.2.9 Firewood and biomass

Firewood and agricultural residues are the two dominant energy sources in Rwanda. Total firewood consumption has been estimated to be 2.8 million t/year *(45)*. As for charcoal production, firewood is produced locally by fuelwood wholesalers, who deal with plantation owners to agree on a price *(45)*. The owner manages the plantation and sells the standing timber stock that can be sold as firewood or used to produce charcoal. On average, a standing timber volume of 100 m3 costs about 300 000 RwF (USD 293, 2022 exchange rate).

A legal procedure for of commercial logging of forests in Rwanda encourages appropriate forest management and prevents deforestation. Firewood wholesalers are responsible for contacting local authorities and applying for the necessary cutting permits. The service fee for issuing a permits ranges from 1500 to 25 000 RwF (USD 1.8-30, 2016 exchange rate) *(45, 55)*. The legal process depends on the size of the plantation. For a plantation < 0.5 ha, no attestation or permit is required; for a plantation of 0.5–2.0 ha, permission is required, which can be obtained at the sector level and is free of charge. For plantations > 2.0 ha, a cutting permit is required that must be obtained at the district level, and a service charge is paid. The permit is valid for 3 months. In addition, the buyer pays a tax of 1% of the value of the standing timber *(45)*.

Firewood is used mainly in traditional three-stone stoves, although improved cookstoves are also common in urban areas. Table 8 summarizes annual per capita wood and charcoal consumption in Rwanda, showing that traditional cooking stoves burn 1642 kg per household per year, and improved cooking stoves burn 1263 kg per household per year *(45, 69)*.

Traditional charcoal stove © Ghislaine Rosa

↓ ***Table 8.*** *Wood and charcoal consumption*

Fuel	Stove	Consumption per household per year (kg)	Consumption per capita per year (kg)
Fuelwood	Traditional three stones Improved	1642 1263	355 273
Charcoal	Traditional Improved	700 538	152 117

Sources: Koo BB, et al., 2018; Rwanda Environment Management Authority, 2018.

4.2.10 Home solar systems

Solar energy is a promising solution for meeting remote rural household demand for electricity. As of May 2022, 21% of electricity in Rwanda is provided by off-grid systems, which are mainly solar. Rwanda's total on-grid installed solar energy is 12.08 MW. Households far from the planned national grid coverage are encouraged to use stand-alone solar photovoltaic cells to reduce the cost of access to electricity *(49)*. The Energy Development Corporation Ltd has signed memoranda of understanding with various private companies to increase the supply of home solar systems, improve the supply chain and bring solar systems closer to clients. Table 9 lists the main solar energy projects and their generation capacity:
To increase the number of installed home solar systems and electrification of households in rural areas, the Renewable Energy Fund and the Rwanda Energy Access and Quality Improvement Project (off-grid component 3a) are being implemented by the Rwanda Development Bank (Figs 15 and 16). In 2020, the Development Bank, in partnership with the World Bank, launched a results-based financing subsidy *(71, 72)*. The objective is to increase access to electricity in Rwanda through off-grid technologies and to facilitate private-sector participation in renewable off-grid electrification. The targeted beneficiaries are households and businesses, which will gain access to off-grid electricity services through solar systems or mini-grids and to replace consumption of diesel, kerosene, dry-cell batteries and other fuels. The financing facility is expected to increase uptake of Renewable Energy Fund funds to connect Rwandan households to off-grid solutions. The subsidy will be channelled through eligible off-grid solar companies.

↓ ***Table 9.*** *Notable on-grid solar power plant projects in Rwanda*

Project	Date started	Capacity	Funding
Mount Jali in Kigali	July 2008	250 KWp	Stadtwerke Mainz (German municipal power company)
Rwamagana Solar Power Plant	February 2015	8.3 MW	Gigawatt Global
Nasho Solar power plant	2017	3.3 MW	Howard G. Buffett Foundation and Ministry of Agriculture
Ndera Solar power plant	2013	0.15 MW	Enforsa Rwanda Ltd (Belgian company)

Sources: Rwanda Ministry of Intrastructure, Energy Division, 2022; Rwanda Energy Group, 2018.

Solar panel in front of rural house © AdobeStock / Kriss75

5

Household energy use

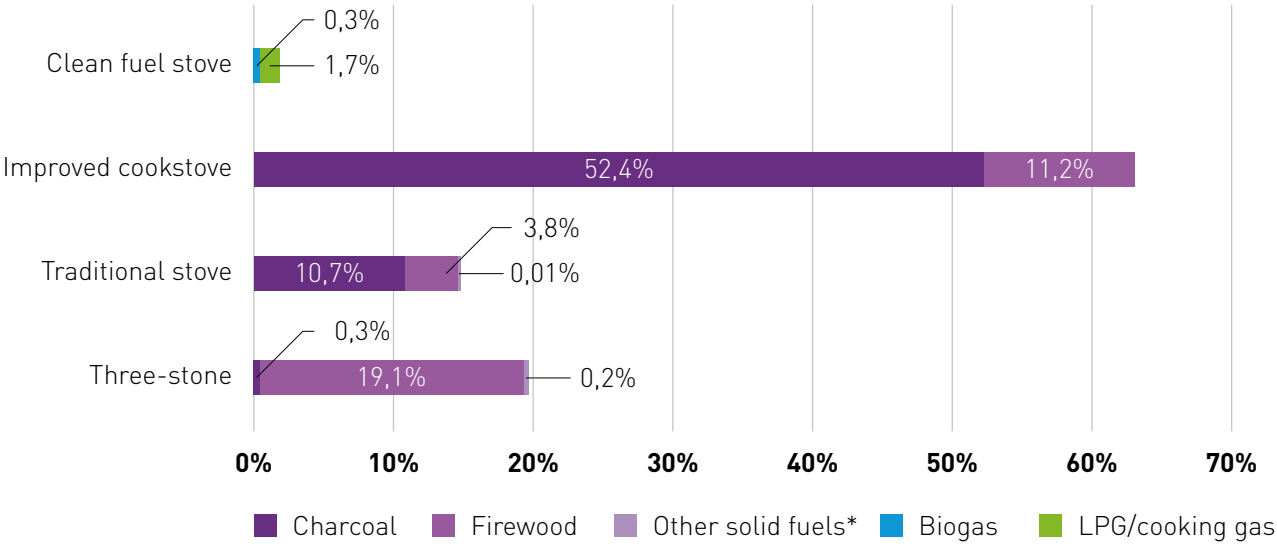
5.1 Cooking

In Rwanda, about 98.5% of the population uses polluting fuels for cooking; the proportion in rural areas is almost 100% *(6)*.

Urban households cook predominantly with charcoal (67%), followed by firewood (26%) *(6)*. In urban areas, 64% of households use an improved cookstove, and 5% use a clean fuel stove (mainly LPG) *(45)* (Fig. 12). While fuel "stacking" was not common in urban Rwanda, as observed from responses to the Integrated Household Living Survey for 2016–2017, in which 81% of households reported not using a second cooking fuel *(73)*, it was more common in areas where new technologies had been introduced. In Gisenyi, where improved cookstoves with biomass pellets have been promoted, about 65% of cooking was still done on charcoal stoves and traditional three-stone stoves.

Familiy using a LPG cookstove © Iwona Bisaga

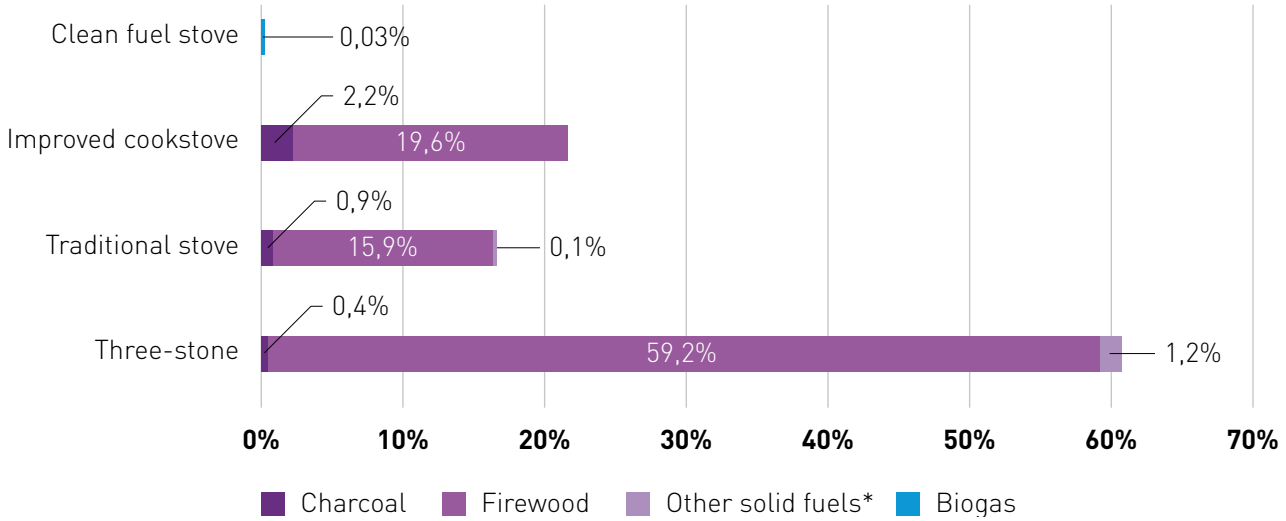
↓ ***Fig. 12.*** *Cooking fuels and technologies used in urban households, 2016*



*Note: Other solid fuels include peat, animal waste/dung, crop residue/plant biomass, sawdust, and processed biomass (pellets/woodchips).
Source: Koo BB, et al., 2018.

Rural households cook predominantly (94%) with firewood *(81)*; 22.4% of households use an improved stove, with negligible use of clean fuel stoves *(45)* (Fig. 13). Stove stacking was similarly found to be common when improved cookstoves were introduced in rural Rwanda; in a pilot programme in the Western province in which improved cookstoves were distributed and use was monitored, 72% of households that used them continued to use traditional cookstoves.

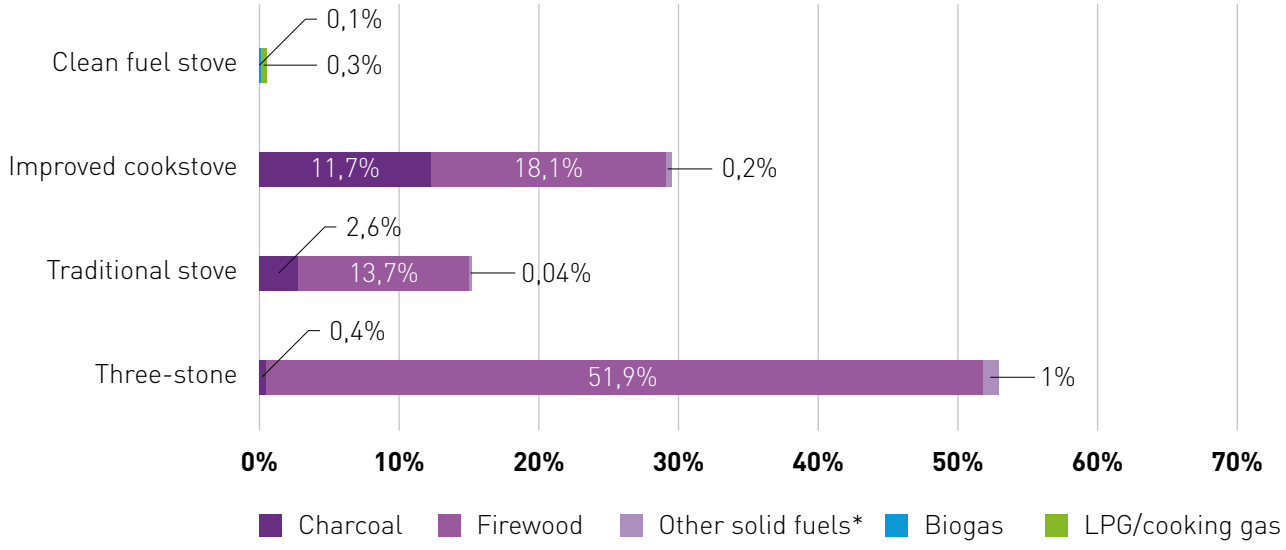
↓ ***Fig. 13.*** *Cooking fuel and technologies used in rural households, 2016*



*Note: Other solid fuels include peat, animal waste/dung, crop residue/plant biomass, sawdust, and processed biomass (pellets/woodchips).
Source: Koo BB, et al., 2018.

Considering both, urban and rural, most (53%) households use a three-stone stove, burning mainly firewood, and 16% use a traditional biomass stove, also burning mainly firewood *(45)* (Fig. 14). Nonetheless, 30% of households use an improved biomass stove, of which 39% burn charcoal. Few households cook with clean technologies and fuels, such as biogas and LPG. In 2016, only 0.4% of all households used them as the primary cooking fuel.

↓ ***Fig. 14.*** *Most households cooked with biomass, mainly firewood, and nearly 70% used a three-stone or traditional stove.*



*Note: Other solid fuels include peat, animal waste/dung, crop residue/plant biomass, sawdust, and processed biomass (pellets/woodchips).
Source: Koo BB, et al., 2018.

Rwanda is one of the few countries in Africa where use of improved cookstoves, including improved charcoal stoves, has penetrated deeply. It is estimated that about 30% of Rwandan households own an improved cookstove; however, 41% of the owners never use them, 11% use them irregularly and 48% use it for all cooking *(45)*. Low income, inadequate training, peer influence and inadequate information about the health benefits associated with adoption and use of clean cooking technologies prevent household from switching from traditional to improved cookstove *(45)*.

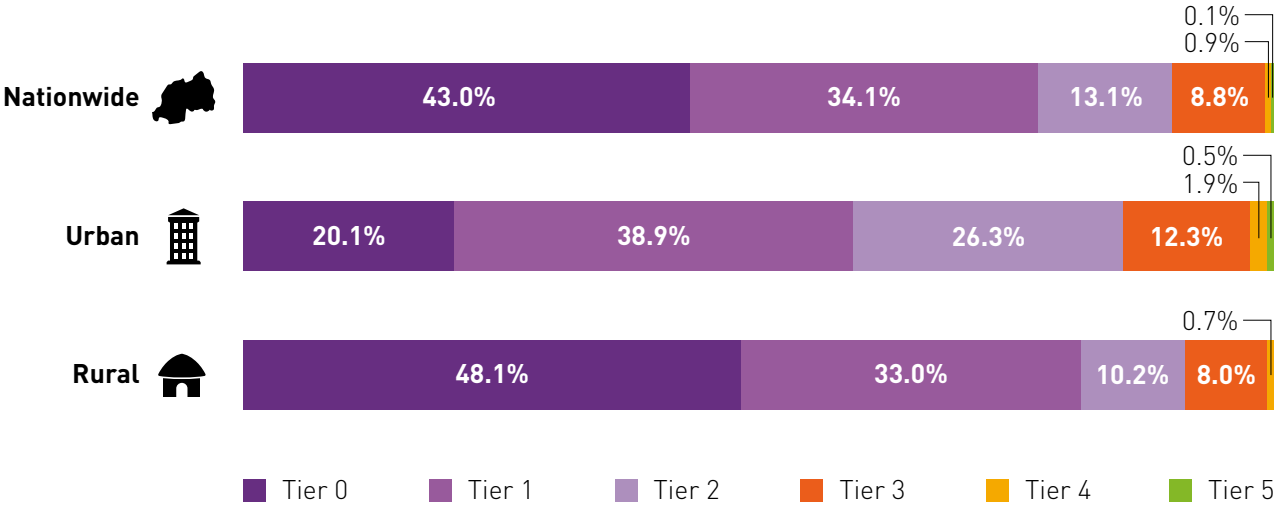
Most kitchens are outside the main living space and are constructed from mud or bricks on a timber frame, although some urban households have modern kitchens with chimneys. Cooking areas are often open spaces (which provides informal ventilation). In most households, the stove is lit three times a day to prepare breakfast, lunch and dinner *(38)*.

A multi-tier framework assessment (MTF) of exposure to cooking fumes in Rwandan households was conducted in 2016 *(45)*. The MTF assigns a tier between 0 and 5, depending on the Cooking Exposure as a function of cookstove emissions (which are a function of the device's characteristics, its use duration and pattern, user adherence to use specifications, maintenance, and fuel quality), kitchen volume, air exchange rate, and ambient pollution. The assessment showed that 43% of households cooked in poorly ventilated spaces for more than 7 h per day and are classified as tier 0 following the MTF methodology (Fig. 15).

Family in Rwanda doing household chores
© Iwona Bisaga / Jean de Dieu / Kayonza

Prepared meal in a pot © Iwona Bisaga

↓ ***Fig. 15.*** *Exposure of households to cooking fumes*



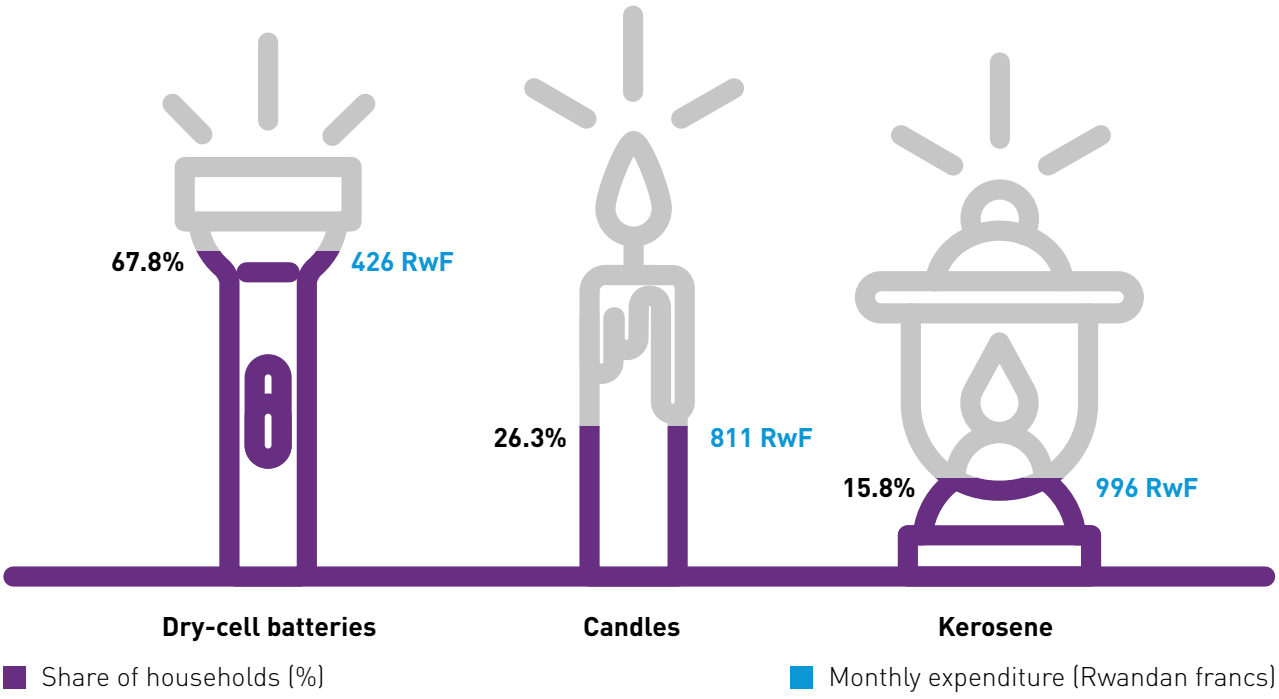
Source: Koo BB, et al., 2018.

5.2 Lighting

Data suggests in households lacking electricity, alternative polluting sources like kerosene or candles are used. For example, in 2016, a Rwandan household survey found that of the 61% without access to electricity, 71.4% used alternatives such as candles, kerosene and torches powered by dry-cell batteries *(45)*. These typically provide less lighting and adversely affect human health and the environment *(45, 74)*. Dry-cell batteries are the most common alternative in households with no access to electricity, particularly in rural areas, followed by candles (popular in urban areas) and kerosene (Fig. 16). Dry-cell batteries are also the least expensive. Despite lack of access to electricity, 14% of unconnected households owned a phone and charged it outside the house. Of grid-connected households, particularly in urban areas, 65.8% used candles as a back-up for lighting, and 24.4%, mostly in rural areas, used dry-cell batteries. The monthly cost of back-up solutions ranged from 113 RwF for candles to 860 RwF for kerosene. Urban households spent three times as much on kerosene as rural households *(45)*.

Use of a homemade kerosene lamp © AFP / Getty Images / Steve Terrill

↓ ***Fig. 16.*** *Most households with no access to electricity use dry-cell batteries for lighting, probably because it is the least expensive alternative.*



Note: One USD per 834.63 RwF, 2016 exchange rate.
Source: Koo BB, et al., 2018.

5.3 Heating

Rwanda's climate is temperate all year round, and there is no need to cool or warm a house at any season, although limited data indicate that some hotels and motels have electric heating and cooling systems to adjust room temperatures *(75)*. The service sector (hotels, motels, hospitals, health centres) and some urban households use solar energy to heat water.

The Government encourages use of solar water heating, as this reduces the pressure on the national electricity grid while increasing the energy supply mix *(60, 75)*. In the 2012 population census, the average electricity requirement of most households for water heating was estimated to be 4 kWh/day *(76, 77)*. The Rwanda Energy Group, in collaboration with the World Bank, initiated a 4-year SolaRwanda Programme in 2012 to promote widespread use of solar water heaters in the residential sector through financial incentives and other support measures, with the goal of installing 12 000 solar water heaters by the end of 2015, which would have resulted in a total estimated annual saving of 23 328 MWh. By the end of 2017, only 2464 solar heaters had been installed *(78)*.

5.4 Safety of household energy use

Household reliance on inefficient and unsafe fuels has significant adverse effects on livelihood, in addition to the negative health outcomes related to HAP. In households that rely on firewood for energy, collection of wood requires a significant amount of time *(79)*. Epidemiological data on burns in Rwanda are limited and incomplete; however, a study conducted in the burns unit at the University Teaching Hospital of Kigali, which is currently the only hospital with such a unit in Rwanda, found 1093 records of acute burn injury between January 2005 and December 2019 *(80)*. The commonest type of burn injury was scalding (81.0%), followed by flame injuries (15.4%); the in-hospital mortality rate was 13.0%. Of the 1093 records, 700 (64.2%) had incomplete data; the only variable reported in all patient records was the year of admission. All burn cases should be reported, also from other health-care facilities in the country, with better recording of the causes, including those related to residential energy use.

To reduce the risks of burns and other accidents, the fire and rescue brigade of the Rwanda National Police and the Rwanda Energy Group conduct awareness campaigns to remind households to unplug appliances when not in use and to avoid contact of water with electrical cables *(81, 82)*. The Rwanda Energy Group installs cash power meters and ensures that electrical utilities in urban areas have been installed correctly and safely and are used properly, whereas this is the responsibility of individual households in rural areas.

Dwellers producing household air pollution © AdobeStock / Roel

5.5 Time required for collecting fuel

Acquiring and preparing fuel is time-consuming for most households. The World Bank Global Survey on Energy Access conducted in Rwanda in 2018 in a representative sample of the Rwandan population *(45)* found that 76.5% of households spent over 7 h/week collecting or purchasing and preparing cooking fuel. About 84% of households in the study used firewood as the primary cooking fuel, and most collected it for free, hence spending > 1 h/day collecting and preparing fuel. In rural areas, fuel is collected mainly by children; in other households, men bring dried wood to the house and chop it into lengths that fit into cookstoves. Only 3% of households spent < 0.5 h/week acquiring and preparing fuel, and 38.4% of households spent < 5 min per meal preparing the stove.

Children collecting firewood © AdobeStock / Lunipa

5.6 Role of income

In Rwanda, the choice of household lighting and cooking fuel is linked to income and family size *(45, 73)*. Khundi-Mkomba *(73)* analysed 2434 responses from urban households to the Rwanda Integrated Household Living Survey for 2016–2017 and found that household income, wealth index, house ownership, geographical location, number of rooms, household size and participation of the household head in the labour market significantly affected fuel choices. High-income families were less likely to use traditional fuels (e.g., wood) and more likely to choose clean fuels (e.g., LPG). Larger households with more family members were less likely to choose clean cooking fuels (e.g., LPG).

5.7 Environmental considerations

Deforestation in Rwanda has been driven by requirements for food, medical drugs, charcoal and timber, especially for commercial products. Tree loss has had severe environmental consequences, mainly soil erosion and landslides due to frequent rains and the mountainous terrain. Extraction of charcoal and wood contributed to annual average deforestation of 24.6 ha in 2002–2020. This implies a total consumption of wood for fuel in Rwanda of 2.8 million t/year. Charcoal (converted into wood equivalents) accounts for 40–50% of total wood fuel consumption *(45, 83)*. Because of the massive negative effects of deforestation, the Rwanda National Forestry Policy, implemented in 2018, set a target of increasing forest cover to 30% of the country's land area through afforestation and reforestation by 2020, which resulted in sustainable production of charcoal and avoided a net loss of forest cover *(84)*.

6

National household energy programmes and policies

Rwanda acknowledges the importance of access to modern energy services in order to meet basic social needs, drive economic growth and fuel human development and has elaborated a number of plans to guide national development in a wide range of sectors. These programmes and policies form the basis of the Economic Development and Poverty Reduction Strategy. Energy promotion and diversification are priorities for a medium-term programme for achieving the long-term goals *(59)*.

6.1 Policies related to household energy and air pollution

Vision 2020

Vision 2020 was a Government development programme launched in 2000 by Rwandan President Paul Kagame with the aim of transforming Rwanda into a middle-income country by 2020 *(91, 92)*. Vision 2020 was based on six pillars: good governance and a capable state, human resource development and a knowledge-based economy, a private sector-led economy, infrastructure development, productive and market-oriented agriculture and regional and international economic integration. Into these pillars were interwoven three cross-cutting issues: gender equality, protection of the environment and sustainable natural resource management, and science and technology.

One focus was to increase energy production and diversification to alternative energy sources. The projection was that, by 2020, at least 35% of the population would be connected to electricity and the consumption of wood would decrease to 50% of national energy consumption. To ensure sustainable development, Vision 2020 envisaged adequate land and water management coupled with a sound biodiversity policy. Vision 2020 set the target for forest cover to reach 30% of the national land area by 2020 and the rate of protection against erosion to increase from 20% in 2000 to 90% by 2020.

Rwanda has made remarkable progress since 2000 in achieving vision 2020 indicators. According to the World Bank, in 2020 47% of the population had access to electricity *(9)*. In 2022, 69.8% of the population was living in a town or village with access to electricity *(85)* as compared with 2% in 2000.

Vision 2050

Vision 2050 is designed to increase living standards to upper-middle income by 2035 and to high income by 2050. The objectives are to promote economic growth and prosperity and ensure a high quality of life for Rwandans. The Vision promotes affordable energy available for large commercial enterprises in horticulture, agriculture, abattoirs, dairies and others *(87)*.

Solar panel between traditional houses © AdobeStock / 593

Energy policy

Rwanda's energy policy is based mainly on three documents: the National Energy Policy, the National Energy Strategy and the Biomass Energy Strategy. The rationale of these documents is that increasing energy provision is a prerequisite for strong economic growth, which is seen in turn as a prerequisite for tackling poverty *(88)*. The new National Energy Policy, developed in 2008 by the Ministry of Infrastructure is an update of the 2004 Energy Policy to:

- set the national energy policy within Rwanda's long-term development plans and strategies;
- pay particular attention to requirements for progressive development of the electricity sector;
- focus more on household energy requirements and gender;
- update the 2004 Energy Policy to reflect the latest developments in use of methane and renewable energy and their environmental implications; and
- clarify Rwanda's commitment to private sector participation and regional cooperation in energy.

The national Energy Policy also includes general statements on overall objectives, development of indigenous energy resources, the importance of energy efficiency, energy pricing and subsidy policies, the regulatory framework and sub-sectors. Most attention is paid to increasing access to grid electricity, increasing power supplies and reducing Rwanda's dependence on imported energy.

In the biomass sub-sector, production of wood fuel and charcoal from plantations and woodlots is to be extended and better managed, and use of briquettes made of underexploited forms of biomass (e.g., peat, papyrus and waste) will be promoted for cooking and heating, along with LPG and solar water heating. Small-scale biofuel projects will be supported, and more research will be conducted to assess potential large-scale biofuel production.

Oil exploration is under way in the petroleum sector, and pipeline and rail projects will be considered in order to reduce costs and increase the security of petroleum product supplies. In the electricity sub-sector, access will be enhanced, particularly in rural areas, by reducing costs and diversifying sources. The national energy strategy for 2008–2020 complemented the updated policy by outlining the current and future energy situation and describing the main programmes of the Ministry of Infrastructure for promoting the objectives of the national Energy Policy *(46, 60)*.

National guidelines for promoting energy efficiency

Guidelines were elaborated in 2013 by the Rwanda Utilities Regulatory Authority *(89)* to ensure a safe, efficient, economically productive energy sector. The guidelines supplement work by the Ministry of Infrastructure and the Rwanda Energy Group to educate the public about energy efficiency in general. The guidelines outline measures for efficient use of electricity, that are applicable mainly for businesses, industry, institutional premises and residential consumers. The measures include:

- energy efficiency standards and appliance labelling
- energy management
- energy audit
- equipment for energy audits
- energy-saving tips.

Woman carrying firewood on the beach © AdobeStock / Renate Wefers / EyeEm

6.1.1 Household air quality and household energy

The Rwanda Standards Board is a public body established by the Government with the mandate to develop and publish national standards *(90)*. Other guidelines were developed by the Rwanda Utility Regulatory Agency. Standards for fuels used for household energy are described below.

Solid biomass cookstoves standards

The Rwanda Standards Board and the Cookstove and Energy Efficiency Testing Laboratory have assisted cookstove manufacturers in fabricating S-Mark certified, energy-efficient stoves that reduce smoke and firewood use by over 50% *(91)*. The Cookstove Testing Laboratory was launched on 14 October 2020, when the country celebrated World Standards Day 2020. The Laboratory fills the gap in testing facilities, whereby locally-made cook stoves were sent to regional testing laboratories, which was a financial burden and time-consuming for local manufacturers, obviated approval and certification of local and imported stoves and subsequently affected the cost of stoves.

With subsidies from the Rwanda Energy Group, clean solutions such as cooking stoves made by 28 private companies have been approved by the Rwanda Standards Board.

Liquefied petroleum gas regulations

The Rwanda Utilities Regulatory Agency has regulated LPG since 2012 *(92)*. The regulations stipulate:

- License for LPG business: No person shall conduct a business of importation, transportation, supply, storage, distribution, wholesale or retail sale or sale to industrial consumers of LPG and related activities except under and in accordance with the terms and conditions of a license granted by the regulatory authority under these Regulations.
- Powers of inspection: The regulatory authority or any person acting on its behalf may inspect any vehicle, premises, facility or installation suspected of being engaged in the business of importation, transportation, supply, storage, distribution, wholesale or retail sale of LPG for the purpose of ascertaining whether the provisions of these Regulations are being observed, and, in the case of contravention, may give such directions to the owner, occupier, driver or person in charge of such vehicle, premises, facility or installation as it considers necessary.
- Reporting of accidents and fires: Any accident involving LPG or the transportation of LPG that causes an injury to employees, property damage, injury to other persons, an accidental release of LPG and any fire in which LPG is directly or indirectly involved shall be reported by the licensee in writing to the Regulatory Authority as soon as possible but not later than 48 h after the incident.

Storage of gas cylinders © Ghislaine Rosa

LPG and natural gas accessories and equipment

The Rwanda Standards Board adopted the RS ISO 11119-3, RS ISO 11119-4 and RS ISO 11623 standards from the International Organization for Standardization for LPG and natural gas accessories and equipment. The standards provide criteria for gas cylinders, such as design, and periodic inspection.

6.1.2 Outdoor (ambient) air quality

There are several programmes to reduce ambient air pollution in Rwanda:

- Motor vehicle inspection
- Car-free days
- Kigali green city project
- E-Mobility and non-motorized transport

6.1.3 Climate change and deforestation

Forest policy

Rwanda's first written national forest policy was published in 2004 *(84)*.With rapid socio-economic and political changes, the policy was revised in 2018 to meet new challenges. The goal is to make the forestry sector one of the bedrocks of the economy and to create national ecological balance for sustainable benefits for all segments of the society. The ministries of environment and of infrastructure inherited the policy and strategies from their predecessors, the Ministry of Internal Security and the Ministry of Natural Resources, respectively. The policy advocates for sustainable management of forest and other biomass resources to meet the growing needs for food, fibre, fodder, fuel and environmental services.

Climate change commitment

Rwanda submitted its updated "nationally determined contribution" to the United Nations Framework Convention on Climate Change Secretariat in May 2020 to demonstrate its commitment to building a more sustainable world (109). The aim of the climate action plan is to reduce emissions by 38% below "business as usual" by 2030. Rwanda has set a bold vision to become a carbon-neutral, climate-resilient economy by 2050. Investment in clean energy, clean cooking, forests, wetlands and land are essential to achieve those goals.

Environmental protection agenda

Today, 30.4% of Rwanda is covered by forests and Ministry of the Environment is undertaking border-to-border landscape restoration *(101)*. Energy and transport emissions are addressed by phasing out biomass fuel for cooking and introducing e-mobility incentives, such as lowering the tax on electric vehicles. These initiatives will be supported by a strong carbon market and policies for people and the planet to ensure an inclusive and equitable transition to net zero. The Government created the Rwanda Green Fund, also known as the Fund for the Environment and Natural Resources for Rwanda, in 2012 to finance its climate action plan. To date, the Fund has mobilized US $ 217 million for green investments and supported 45 green projects in the country, which resulted in the creation of > 161 000 "green jobs" building community adaptation to cope with the effects of climate change.

CHEST workshop in Rwanda, May 2022 ↑ © WHO

6.2 Programmes to address access to clean household energy

Tubeho Neza Programme

The large-scale Tubeho Neza Public Health Program *(102)* is a partnership between the Ministry of Health and the social enterprise DelAgua. Its objective is to provide environmental health technologies to the poorest populations in Rwanda. It included a project for distribution of water filters and improved cookstoves to the poorest 25% families (socioeconomic Ubudehe levels 1 and 2) in 2012. More than 100 000 low-income households in 72 of 96 randomly selected sectors in Western Province received improved cookstoves and advanced water filters in autumn 2014. Evaluation of the project showed a reduced burden of disease, measured as disability-adjusted life years, in the population over time *(103)*.

The Program, in partnership with several universities and the Rwanda Ministry of Health, with oversight and approval from the Rwanda National Ethics Committee, is conducting several controlled studies to analyse adoption of the technology, behaviour change and the public health impacts of the interventions.

Rwanda Energy Access and Quality Improvement Project

The aim of this project is to increase access to clean cooking solutions for 500 000 Rwandan households *(104)*. Component 3b of the project established a "clean cooking results-based financing" scheme – a partial subsidy for the purchase of clean, efficient cooking solutions by eligible households to improve the affordability of clean cooking technologies. Socioeconomic Ubudehe levels 1, 2 and 3 are eligible for the program in order to reduce prices for the lowest income populations in Rwanda. The subsidy is co-financed by the World Bank's Clean Cooking Fund. The aim is to provide access to clean cooking technologies to at least 500 000 households, of which 25% are to be headed by a woman, comprising 2.15 million Rwandans. The subsidy is also designed to decrease the dependence of urban populations on wood for fuel, from 86.3% to 50% by 2024. The project aims to attract private sector financing, build more partnerships and engage other stakeholders in promoting green investments for clean cooking.

On 4 November 2021, Rwanda and Sustainable Energy for All launched the Energy Compact on Clean Cooking *(105)*. The compact is a crucial step in transforming the country's energy use towards a greener, more sustainable future by reducing the proportion of households using wood for cooking from 79.9% in 2017 to 42% by 2024. This subsidiary scheme is conducted in a partnership between the Rwanda Development Bank and the Energy Development Corporation.

Improved cookstoves programme for Rwanda

The aim of the improved cookstoves programme for Rwanda is to reduce the use of biomass for cooking in households by promoting improved cookstoves. This 8-year programme (2017–2025) is expected to introduce advanced cookstove technology and standardized fuel to replace inefficient charcoal and wood stoves and to introduce intermediate cookstove technologies in rural areas *(107, 108)*. The project is funded by the World Bank and implemented by two private companies, Inyenyeri, a Rwanda social benefit company, and DelAgua Health Rwanda Ltd. In 2017, both companies signed purchase agreements for reducing emissions with the World Bank, in which companies receive results-based payment for delivered certified emission reductions.

Inyenyeri initially made positive steps; however, its business model became financially unsustainable after it failed to secure sufficient investment to scale up its operation *(102, 109)*. The company declared bankruptcy in April 2020 after attempting to make a debt restructuring deal with its investors, after it had delivered 7700 tier-4 pellet gasifier cookstoves to local households. DelAgua was initially committed to change its business model from free distribution to a retail business model; however, little progress was made after signing the agreement, with only 1200 stoves sold. The company continued to distribute cookstoves for free after realizing that its retail business model was unfeasible.

The Save80 project

The Save80 stove is a stainless-steel stove on which a meal can be cooked with a handful of firewood or twigs. Cooking is completed in a "wonder box" without a burning fire or a supervisor *(110)*. With its partners Safer Rwanda, Rwanda Women's Network, the Office of the United Nations High Commissioner for Refugees (UNHCR) and Energie Domestique Sarl and Atmosfair, a German non-profit organization, traditional charcoal stoves and three-stone fires are replaced with highly efficient biomass stoves such as the Save80 cook stove *(111)*. The components are fabricated in Germany, and the stoves are produced in Rwanda. The project targeted densely populated areas where mainly charcoal is used for cooking, such as Kigali and UNHCR refugee camps. More than 28 000 Save80 stoves were distributed to private households and refugee camps as of March 2017.

Beneficiaries appreciate the stoves, as they are easy to use intuitively. The Save80 stove uses up to 80% less wood than a three-stone fire for the same performance. Moreover, the Save80 stove lasts for > 10 years. Replacing a charcoal stove with a Save80 stove results in even greater savings of wood, given the large amount of biomass necessary to produce charcoal (9 kg of wood is required to produce 1 kg of charcoal) *(111)*.

Sustainable Household Energy Adoption in Rwanda

The SHEAR is a 3-year project that was started in August 2019 in partnership with Colorado State University, USA, the University of Rwanda and MeshPower Ltd to deliver full clean-energy interventions in rural households *(112)*. These include LPG for cooking and solar energy for lighting and power. A randomized controlled trial of LPG stove and fuel distribution combined with solar energy use will be conducted in 650 households in two villages (Isangano and Karambi) in Eastern Province, Kayonza district, Ndego Sector. A 3-month pilot study has started with 40 households, all of which have been given an LPG stove kit and fuel. They will be asked to pay a discounted price (10–90% of the actual cost) in order to determine the incentive necessary for use of LPG for cooking.

Solar panel for household energy use © AdobeStock / Kriss75

6.3 Social interventions

Umuganda

Umuganda, or social community work, is a set of traditional tools for mutual aid rooted in Rwandan culture *(113)*. The practice was re-invented after the 1994 genocide of the Tutsi by the Government as one of Rwanda's "home-grown solutions" to societal challenges. Umuganda helps solve these challenges in two ways: by contributing to socio-economic development of the community through infrastructure development, environmental protection and cleanliness, and the implementation of Government programs; and secondly through meetings where information is shared and social cohesion and peace-building are fostered. Umuganda is mandatory for able people aged 18–65 years; it is nationwide and takes place from 08:00 to 11:00 on the last Saturday of every month. Participation is required by law, and failure to participate can result in a fine. Expatriates residing in Rwanda are also encouraged to participate.

The General Directorate in charge of Social Welfare and Community Development in the Ministry of Local Government coordinates Umuganda. It is regulated by the law on community work, and a Prime Minister's Order determines the attributions, organization and functioning of supervisory committees and their relations with other organs. Committees are established at each level of administration, from village level (Umudugudu), which are responsible for planning and supervising activities. No budget is allocated for Umuganda; instead, activities conducted during Umuganda are attributed a monetary value. For activities that require tools that the population may not find, the committee provides the tools. An impact assessment of Umuganda showed a significant increase in Umuganda monetary value, from 4 billion RwF in 2007 to 19 billion RwF in 2016. The economic benefit of Umuganda was thus multiplied almost five times in just one decade *(113)*.

Community-based environmental health promotion programme

A programme for community environmental health promotion was launched in December 2009 within the Health Sector Strategic Plan to "reduce the national disease burden through community-based hygiene behaviour change and improved sanitation" *(114)*. The programme involves the holistic approach of community health clubs for positive hygiene behaviour change and mobilizing village communities. These voluntary clubs transfer knowledge about health through a participatory approach to improve community health, hygiene and sanitation. The goal is to create a "culture of health" in a community, which is reinforced by positive peer pressure.

The programme reaches all communities and empowers them to identify personal and domestic hygiene and environmental health problems (including drinking-water and sanitation) and to participate actively in solving them. Significant challenges are bridging the gap between policy and implementation and inadequate funding. Most of the current funding is from donations and international NGOs.

Family consultation in Rwanda © Iwona Bisaga

Community health workers

The Rwanda community health worker (CHW) programme was established in 1995 to increase uptake of essential maternal and child clinical services by educating pregnant women, promoting healthy behaviour and follow-up and ensuring links to health services *(115, 116)*. When the Ministry of Health endorsed the programme in 1995, there were approximately 12 000 CHWs; by 2019, there were > 45 000. Three CHWs with clearly defined roles and responsibilities work in each village of approximately 100–150 households. Although CHWs in Rwanda are volunteers, in 2009, the Ministry of Health introduced performance-based financing to motivate them. CHWs form cooperatives that receive and share funds from the Ministry of Health according to achievement of targets established by the Ministry. By linking incentives to performance, the Ministry hoped to improve the quality and use of health services.

Cell coordinators (sometimes with an assistant) visit CHWs every quarter to monitor their activities, supplies and drugs, compile reports and submit the information to the person in charge of community health. During such supervision, they also make house visits to monitor the performance of CHWs and verify the reports sent by CHWs by mobile phone text messaging (SMS) health centres.

Vision 2020 Umurenge programme

This large social protection programme is owned and led by the Government *(117)*. It was conceived during a high-level leadership retreat in February 2007 to address worrying poverty trends in the country and is a flagship programme in the economic development and poverty reduction strategy 2008–2012. The goal was to help meet the national target to reduce extreme poverty from 36.9% in 2005–2006 to 24.0% in 2012. The programme was launched in 2008 with three components: direct support, public works and financial services. The programme targeted communities using the Ubudehe categorization system. It provides direct support to poor families who are unable to work (such as disabled and very elderly people) and public works for poor families who can work. Women are a target, as they are often poor and can be empowered by working outside the home; they are also important contributors to national productivity. Implementation of the programme appears to have increased the empowerment of women through job creation, increased household income and inclusion in the banking system, which contributes to less violence in the home and less conflict over decisions *(118)*. The programme is funded by the Government through the community development fund in the Ministry of Local Government.

Rwandan market © Iwona Bisaga

7

Stakeholder organizations and coordination

7.1 Role of government agencies in addressing household air pollution

Energy systems in Rwanda are managed by the ministries of Infrastructure, Natural Resources, Local Government, Finance and Economic Planning and Trade and Industry, the Rwanda Energy Group, REMA, the Rwanda Utilities Regulatory Agency and independent power producers *(119)*. The Ministry of Infrastructure is responsible for developing national policies and strategies for energy generation, focusing on the off-grid sector, including training, strategy and development of technical specifications for equipment and recommending strategies for the development of the private sector, while regulation of the sector is the responsibility of the Rwanda Utilities Regulatory Authority. The Rwanda Energy Group (REG) is a private company established in 2014, which is wholly owned by the Government.

7.1.1 Ministry of Local Government

Local government authorities address HAP by monitoring and enforcing compliance with environmental laws and coordinating environmental management. The Ministry leads and coordinates multi-sectoral activities to reduce environmental pollution, including indoor air pollution, and supports local interventions *(120)*.

Portable gas stove © Ghislaine Rosa

7.1.2 Ministry of the Environment

The mandate of the Ministry of the Environment is to ensure a safe, sustainable environment. It is responsible for developing environmental rights, goals and objectives, and to set up policies *(121)*. The Ministry has set a national environment and climate change policy, which stipulates the coordination of appropriate measures, the establishment of systems and the design of programmes for a safe environment. It is also responsible for implementing and following up on international and regional environmental agreements to which Rwanda is a signatory, including those on hazardous chemicals, industrial waste and environmental hazards. The Ministry ensures that all relevant central and local institutions include climate change indicators in their plans by sending them a checklist, which in turn is part of the documentation considered by the Ministry of Finance and Economic Planning when approving planning and budgets of institutions. The Ministry established a law on the environment in 2018, which includes elements on air pollution, although it is not specific to HAP.

The Ministry of the Environment works with various partners on clean household energy solutions. For instance, it is conducting a project with the Fund for the Environment and Natural Resources for Rwanda to reduce reliance on biomass fuel by distributing improved cookstoves in Gicumbi district *(122)*. An interview with an informant at the Ministry indicated that the Ministry has signed a memorandum of understanding with an international NGO, DelAgua, to provide 2 million households with improved cookstoves within 5 years.

7.1.4 Rwanda Energy Group

The REG is responsible for regulatory policy, decision-making, energy operations, implementation and supervising other government agencies in the energy sector, and it is responsible for coordination within the sector according to the biomass energy strategy document *(123)*. REG has a focal person to monitor the implementation of an action plan for energy, and particularly electricity. It is also responsible for developing and providing reliable, affordable energy. It oversees the accreditation of private institutions that provide energy technologies for Rwandans. So far, 28 private institutions have been accredited to provide clean energy solutions. Various parameters are considered in the accreditation of equipment, such as thermal efficiency and $PM_{2.5}$ and carbon monoxide emissions. REG is developing various operation manuals and strategies (subsidies, incentives) to increase adoption of clean energy according to socio-economic category (Ubudehe).

7.1.5 Ministry of Infrastructure

The Ministry addresses HAP in Rwanda through the National Strategy for Transformation, with the goal of reducing the use of technologies that emit particulate matter in the community *(124, 125)*. It has paved the way for a biomass energy strategy with structured approaches to reducing reliance on inefficient fuels *(126)*. The Ministry takes the lead in developing policies and strategies and ensuring their implementation and mobilizes resources with support from the Ministry of Finance and Economic Planning. The Ministry of Infrastructure, as a central Government institution, implements energy strategies down to the lowest local entity (district, sector).

An interview with an informant at the Ministry indicated that several programmes on clean household energy are being implemented with partners. A € 5 million project to disseminate over 2 million cookstoves, funded by the European Union and the German Agency for International Cooperation, is being implemented by DelAgua. Other programmes supported by the European Union will install improved cookstoves in schools, which are priorities of the Ministry of Education. The Ministry of Infrastructure also provides technical assistance to local producers to upgrade their energy technologies to meet standards.

7.1.5 Rwanda Environment Management Authority

REMA considers addressing air pollution and climate change as critical to enhancing the well-being of the Rwandan people *(127)*. Although there are no guidelines, REMA plays an important role in improving indoor air quality. The Ministry of Health, Rwanda Biomedical Centre and REMA have formed partnerships to conduct health risk assessments associated with HAP. REMA is involved in country-wide programmes to promote the use of clean cookstoves in order to minimize the amount of firewood used and to reduce emissions; it also facilitates access to LPG. An interview with an informant at the Authority indicated that REMA is forming a collective programme with civil societies, NGOs and Government institutions to make domestic clean energy more accessible by providing an enabling environment for businesses and investors and, when possible, advocating for all taxes on such activities.

REMA is also responsible for monitoring air pollution through a national network *(128, 129)*, and data can be accessed on their website. The network monitors black carbon and identifies sources in the community and levels of emissions in urban and rural areas. The data are used to inform communities about the relation between air pollution and health risks.

7.2 Role of the health sector in addressing household air pollution

The health sector is governed by the Ministry of Health and its implementing partner the Rwanda Biomedical Centre *(130, 131)*. Studies supervised by the Ministry show that HAP is a serious issue linked to health-related risks such as low birth weight and high blood pressure. The role of the health sector in addressing HAP is to formulate policies, document and assess the effects of HAP, oversee public health protection from the health effects of indoor air pollution, address the consequences of air pollution, oversee curative, preventive and environmental health services and raise awareness about the health risks of exposure to HAP and the benefits of using clean energy sources.

An interview with an informant at the Ministry indicated that it considers HAP to be a multisectoral issue that should involve various Government and nongovernmental institutions. The Ministry is a member of a technical working group to address HAP, which includes the ministries of Infrastructure and Energy, the Rwanda Environment Management Authority, the Rwanda Utility Regulatory Authority and Rwanda Energy Group. The Ministry of Health advocates for the use of improved cookstoves in households. Certain organizations, such as the Society for Family Health, DelAgua Health Rwanda Ltd and World Vision Rwanda, are working with the Ministry to promote clean household technologies by distributing water filters to reduce the prevalence of diarrhoeal diseases and improved cookstoves to reduce exposure to HAP.

The human resources of the Ministry include those at health centres, including community and environmental health officers who implement interventions related to HAP *(132)*. The Rwanda Biomedical Centre offers training in assessing household energy. The health sector has highlighted the importance of financial and technical support to ensure capacity-building on HAP in communities.

Children working with maize seeds © Iwona Bisaga

7.3 Roles of nongovernmental organizations, the United Nations system and cooperation agencies in addressing household air pollution

Non-governmental organizations (NGOs), the United Nations system and cooperation agencies provide technical support, mobilize funds and support programmes to address HAP. Some locally produced clean household energy products are substandard, and NGOs often advocate for clean household energy by conducting or funding studies on various aspects of HAP and seeking financial opportunities to promote clean energy solutions. Some charitable NGOs that provide food, shelter and clean drinking-water also support clean household energy programmes by including them in their projects, such as providing improved cookstoves to vulnerable families. WHO and other United Nations agencies active in household energy in Rwanda include the United Nations Environment Programme, the United Nations Children's Fund and the Food and Agriculture Organization of the United Nations. The NGOs involved include DelAgua, Inyenyeri and the Global Green Growth Institute. The cooperation agencies include the World Bank, the German Corporation for International Cooperation, SNV (Netherlands Development Organization) and the US Agency for International Development.

7.4 Coordination mechanisms

Coordination of actors in household energy is led by the Ministry of Infrastructure, although an interview with an informant at the Ministry indicated that a number of ministries and Government agencies are also involved in coordinating the energy sector. The Ministry is, however, mainly responsible for setting the overall policy and strategy of the energy sector and for coordinating development of the electricity sub-sector. The Ministry is also responsible for the development of clean energy (LPG, electricity, solar and wind energy), although some of these resources are distributed throughout the country and the Ministry of Local Government and local government structures are also involved in their development.

There is no national coordination mechanism, and some ministries coordinate household energy activities internally. Coordination is required to bring all the actors together. Identification of key stakeholders is also important, as well as close consultation and joint planning to ensure that clean household energy programmes benefit all citizens.

Electricity supply in a village in Rwanda © Iwona Bisaga

8 Discussion

8.1 Barriers to adoption of clean fuels and technologies

Use of clean energy in households could improve health, safety and livelihoods by reducing exposure to harmful smoke and freeing time spent collecting, preparing and cooking with firewood. Despite its benefits, clean household energy is not widely used in Rwanda. The barriers to uptake include weak coordination among Government institutions, an unreliable electricity service, little investment in access to clean technology, lack of affordability of clean cooking fuels and technologies, misperceptions about them and poor technical capacity of local manufacturers.

Weak coordination mechanism

Rwanda's national policies on health, environment and energy, such as Vision 2050, could be leveraged to support clean household energy use. Better coordination among different sectors is, however, necessary to incorporate this cross-cutting issue into policies and to implement them.

Ministries and authorities such as the Rwanda Environmental Management Authority and the Ministry of Infrastructure, which are responsible for adoption of clean energy, could lead the work and involve financial institutions to provide incentives. Collaboration between or integration of the Government, the private sector, financial institutions and NGOs in the household energy sector should be strengthened.

Affordability of clean cooking technologies

The high cost of LPG cylinders and the price of electricity are major barriers to adoption of clean fuels *(57)*. Low-income consumers tend to use biomass, which is free but collection of which is time consuming, or buy charcoal daily. The need for adequate appliances and installation makes the use of clean fuels even more difficult. The unattractive financial terms offered by micro-finance institutions (e.g., high interest rate on loans, long reimbursement) also discourage wider adoption of clean household energy. Cooking fuels and technologies tend to be a low priority among household investments, and the interest rate currently charged discourages borrowing for household appliances such as stoves. Subsidizing the cost of appliances or providing the option of paying start-up costs in instalments could increase adoption of clean energy. Urban households that spend part of their budget on charcoal could instead spend it on LPG or electricity if the price was competitive *(133)*.

Poor reliability of electricity services

The quality and reliability of electricity must be improved to make it a more feasible option for cooking *(45)*. Other economic incentives, such as subsidies, should be considered to increase use of clean fuels and technologies for cooking *(134)*.

Inadequate information

Clean energy technologies could provide a number of benefits, including cleaner indoor air, better health, lower costs for cooking, shorter cooking times, less deforestation and less greenhouse gas emissions. Lack of awareness among households of the negative effects of inefficient combustion of biomass fuels is still a barrier to transition to cleaner alternatives *(57)*. Consumers who are aware understand the benefits of clean energy and the cost of inaction. Consumers could be educated through road shows, discussion forums and radio campaigns. Other clean energy alternatives, such as solar energy products for rural areas, should also be promoted.

Perceptions of clean cooking technologies

LPG is sometimes perceived as dangerous, particularly after reports of accidents associated with LPG leakage from cylinders, which have resulted in massive destruction of property and injuries *(135)*. In some households, it is believed that use of gas can attract monsters or ruin to their houses. These misconceptions dissuade adoption of gas for cooking.

Little investment in clean technologies

Increasing access to clean fuels and technologies requires a large investment, particularly in the electricity sector. To achieve universal access to electricity, the Government should invest in extending the grid and improving the transmission and distribution of electricity. Other, non-grid alternatives should be explored for isolated regions. Bankruptcy and little return in investment have been documented for some interventions to increase adoption of clean energy *(9)*. Limited distribution networks for LPG in rural areas is another issue. Small-scale entrepreneurs providing clean cooking solutions have limited access to investment capital for their businesses, and they operate with low profit margins.

No harmonized retailing network for LPG cylinders

In Rwanda, LPG cylinders are marked with the name of the company, and consumers cannot refill at any retailer but must find one with the corresponding brand of cylinder. Consumers find this a challenge, as most retailers do not have branches in all neighbourhoods, with cost implications for time and transport *(57)*.

Production of low-standard technologies by local manufacturers

The quality of locally produced clean household energy products is sometimes sub-standard. The provision of technical support to local manufacturers could lower the cost of clean household energy technologies, thus making them more affordable to consumers. Some hesitate to invest in clean household energy because of reports that local manufacturers produce poor-quality products that do not meet the standards set by REG and the Rwanda Standards Board. This limits use of local technologies and increases the cost to consumers as technologies are imported from aboard.

Little use of electricity

In Rwanda, the average electricity consumption is less than 21 kWh/month per household *(45)*. Increasing use of electricity is linked to prosperity and well-being and will also require increasing production capacity. Use of electricity for cooking, for example, consumes 15-100 kWh/month, depending on the efficiency of the appliance, cooking practices and family size *(133)*. The electricity infrastructure should be considered before promoting electricity for cooking in Rwanda.

Little use of LPG

Little usage of LPG is associated with the high upfront cost of the cylinders, product quality, safety and distribution, lack of pay-as-you-go options for LPG refills and lack of behaviour change campaigns. Full transition to LPG might, however, require more than just changing behaviour and is related to affordability, availability, accessibility and acceptability *(64)*. Of these drivers, ease of access was most strongly correlated with adoption of LPG by households in a national survey *(57)*.

8.2 Opportunities for increasing access to clean fuels and technologies

Leverage government programmes for clean energy

The Government of Rwanda intends to provide universal access to electricity by 2024 by increasing its production capacity to 556 MW, of which renewable energy will constitute 60% of the energy mix, derived mainly from hydro projects and solar energy *(46, 48, 49)*. The plan to increase the electricity supply should include electricity for cooking. There is also a national plan to scale up use of LPG (*57, 58)*.

Coordination with social welfare programmes such as Vision 2020, the Umurenge Programme and Vision 2050 could provide resources and communication strategies to increase access by vulnerable and marginalized communities. The UNHCR project to distribute improved cookstoves in refugee camps and clean energy through social cash transfers could include access to clean fuels *(111)*.

The Government is investing in road, rail and water transport infrastructure, which will reduce the cost of transporting petroleum and LPG *(136)*. Rwanda encourages people to move to areas with higher population concentrations to ensure access to jobs and public services such as education and health. This plan has implications for the design and distribution of energy services, including electricity infrastructure and clean fuel and technologies for cooking *(136, 137)*.

Capacity-building

The ministries of Infrastructure and Health are those best suited to support strengthening the capacity in household energy. Demonstrations for consumers and subsidized training of entrepreneurs in clean energy technologies could increase adoption of clean fuels and technologies. The Ministry of Health could train health-care workers and staff in clean household energy, and the Ministry of Infrastructure could provide technical assistance and undertake sector studies, policy evaluation, monitoring and evaluation. The Government could include household energy activities in performance-based contracts and build the capacity of administrators.

Research institutions should be provided with up-to-date equipment for monitoring air quality, and research should be conducted on the health impacts of HAP.

Use of community health workers to promote clean cooking stoves

CHWs are one of Rwanda's "home-grown solutions" *(115, 116)*. The programme has been empowering communities for two decades. It has been extended to all villages in Rwanda since its inception and employs about 45 000 CHWs, who provide health-care services, which has contributed to the country's remarkable progress in the health sector. The community-based environmental health promotion programme approach, led by village CHWs in responsible for disease prevention, can address HAP by including the topic in community health clubs *(114)*. CHWs should be trained and involved in the development and design of awareness campaigns on HAP.

Mobile phone penetration

Mobile phone penetration is at 79.8%, while smartphone penetration is still low, at 14.6% *(138)*. Mobile phones can be used for payment of refills of LPG for cooking, and Rwandans who are on the national grid can also pay for electricity. Private telecommunication companies and some banks allow their clients to pay for electricity by dialling in codes and following the instructions *(139)*.

International cooperation

Rwanda has active international support in achieving its goal of universal access to clean energy by 2030. Rwanda has already made remarkable progress in promoting improved cookstoves, with over 20% penetration *(45)*. It is important document this experience and use it to promote clean fuels and technologies.

8.3 Suggestions

- *Improve coordination.* A coordinated strategic action plan from central government to local administration level could help the transition to clean household fuels. This includes seeking a joint understanding about accelerating access to clean household energy between the different involved ministries and setting it as a national priority. Strategies such as governmental incentives to engage private sector for promoting clean energy technologies can play a critical role.

- *Follow the Rwanda national LPG master plan for feasibility and investment.* The master plan describes three means for developing the market for LPG.

  - A "low intervention" option, potentially reaching 45% of the target population by 2024, would require the Government to design new policies to improve access to LPG by imposing in law and regulation the branded cylinder recirculation model (the global best practice for LPG market structuring, bankability and safety), to direct public institutions to transition to LPG use from firewood and charcoal, to mobilize industry and the financial sector to expand the inventory and distribution network for LPG cylinders and to promote the switch to LPG nationally.

  - A "high intervention" option, potentially reaching 50% of the target population by 2024, would require the Government to implement all elements of the "low intervention" option and also require stimulation measures, including creation of consumer financing and subsidy schemes for LPG equipment.

  - An option within the National Strategy for Transformation, which would achieve the target by 2024, requires the Government to implement all the "high intervention" elements and also requires urban residential and institutional users to switch to LPG and to prohibit biomass supply and use for cooking in those markets; implement the branded cylinder recirculation model, including swapping filled cylinders for users' empty ones, which are recirculated to a responsible filling plant for safety checks, refill and return to the distribution network; and defining marketers who are exclusively responsible for investing in branded cylinders, importing LPG, developing distribution and sales networks and safely refilling and adequately maintaining their cylinders. Implementation and enforcement of the model are essential to achievement of the safety, growth and financing of the LPG sector.

- Define, publish, implement and enforce an enabling environment for the LPG supply chain. The environment should include:

  - regulations for the distribution of branded cylinder that (a) allocate roles, rights, obligations and sanctions for licensing marketers, intermediate distributors and local and home delivery retailers, and (b) include effective enforcement mechanisms;

  - enhanced LPG safety requirements, including the specifications, standards, norms and rules for the construction, certification, repair, maintenance, filling, transport and handling of LPG in cylinders and in bulk; and

  - competitive, predictable consumer pricing and industry margins, as modelling indicates for acceptable rates of return if recommended policies are enacted and enforced.

- Leverage current Government policies and programmes and nongovernmental activities to increase access to clean energy:

  - The Umuganda, the community environmental health promotion programme could leverage resources for their target populations.

  - Community health clubs could be used for uptake of new cooking technologies and for teaching about the health risks associated with HAP.

  - The Village Savings and Loan Association component of community health clubs could help members to pay for clean cookstoves and their installation.

- Provide incentives.
    - Consider incentives to promote a transition to clean technologies and fuels, such as targeted subsidies, reduced taxes and a financing option for the acquisition of appliances.
    - Provide incentives to the private sector to retail clean energy in rural areas.
- Train the health sector at all levels on HAP and its impacts on health, so they can become agents of change.
- Consider cooking in planning the expansion of the electricity grid and off-grid solutions.
- Improve the evidence on HAP, its impacts on health and monitoring strategies to mitigate health risks through collaborations between the Ministry of Health and academic and other institutions to conduct more studies.
- NGOs and United Nations agencies could provide capacity-building to local technicians and investors to improve the quality of their technologies.
- Increase resources for the use of clean energy.
- Among urban households that use charcoal for cooking, promote a switch to LPG or electricity.

Traditional cooking with wood © Ghislaine Rosa

8.4 Conclusion

Adoption of clean household energy is a cross-cutting issue. It requires prioritization and intervention by the Government in an integrated framework to coordinate the work of different stakeholders and partnerships. Nongovernmental organizations and private sector federations should also play their part by providing more funding, such as loans and grants, and technical assistance, training and community awareness campaigns.

The meeting of Rwanda's stakeholders in May 2022 resulted in three messages.

- Convert the national biomass strategy into a clean cooking strategy to ensure that other fuels and technologies, such as LPG and electricity, are promoted. The goal of the Rwanda Biomass Energy Strategy is to ensure a sustainable supply of biomass energy (e.g., firewood and charcoal) and to promote access to modern fuels and efficient biomass combustion technologies for households and small enterprises. To ensure that the Strategy promotes use of efficient alternative clean cooking technologies and to establish sustainable use of energy, it should be revised to include all strategies for accelerating a transition to clean energy. This revised strategy should be known as the National Clean Cooking Strategy.

- Reform the technical working group on energy for cooking to create a steering committee that includes the health sector and other relevant stakeholders. The national energy steering committee promotes sustainable energy in Rwanda. It should be expanded to include the health sector and other stakeholders to ensure that health is at the centre of their work.

- Conduct training for the health sector, and complete the introduction of the Clean Household Energy Solutions Toolkit (CHEST) in Rwanda.

Advocacy should be conducted for policy on HAP. The Government should consider including the WHO air quality guidelines *(4)* in national policies in order to prioritize the transition to clean fuels such as electricity and LPG for cooking while promoting transitional technologies such as improved cookstoves for burning biomass where access to and the affordability of cleaner solutions are challenges. Incentives such as tax cuts and subsidies and awareness-raising campaigns should be considered to increase the use of LPG, electricity and solar energy. Communication programmes on household energy, such as cooking shows with well-known personalities as guests, could also raise awareness about the advantages for health of clean household energy and demonstrate alternative ways of cooking.

The Government already has a detailed master plan for promoting LPG, which includes an estimate of US$ 94 million for 2021–2024 to extend LPG use to an additional 2 million households in order to serve 20% of the Rwandan population by 2024. Further financing of US$ 103 million in 2025–2030 would extend LPG use by an additional 4.4 million people, meeting the projection of 45% of the Rwandan population served by 2030.

Kigali and perhaps other cities could produce renewable LPG from the biogas emitted by properly handled municipal solid waste. The LPG would be "green", would obviate financing for importation and probably cost less than imported LPG. It also would confer additional supply security, as it would be produced within Rwanda.

Promotion of electricity for cooking should be explored and included in national plans for extending grid and off-grid electrification, particularly for populations that depend on bought charcoal or firewood. This would require improving the distribution and the quantity and quality of electricity.

Depending on the options the Government chooses, a transition to cleaner fuels and technologies would result in substantial, measurable progress towards achievement of the SDGs for mitigating climate change, preserving scarce forest resources, reducing harmful air pollution and providing nationally determined contributions. Promotion of LPG, electricity, biogas and ethanol should be considered a priority in achieving SDG 7 indicator 7.1 that addresses the proportion of the population using clean fuels and technologies for cooking.

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Annex. Studies of levels of ambient and household air pollution in Rwanda

Reference no.	Study site	Pollutant	Method	Concentration	Conclusion/findings
1	Kigali	$PM_{2.5}$, PM_{10}	3-month gravimetric sampling	133 µg/m^3, 156 µg/m^3	The ambient $PM_{2.5}$ and PM_{10} levels exceeded the 2005 WHO guideline levels (now interim target 4 in the 2021 WHO guidelines). During public holidays and Kigali car-free days, air pollution was lower than during working days, as there were fewer cars on the road. The authors advised the Government to consider implementing car-free days, not just as temporary events but more widely.
	Musance	$PM_{2.5}$, PM_{10}		45 µg/m^3, 54 µg/m^3	
2	Kigali	$PM_{2.5}$ BC	1 month use of real-time affordable multi-pollutant	52 µg/m^3 4 µg/m^3	The ambient average $PM_{2.5}$ in Kigali was 52 µg/m^3, significantly higher than the 2005 WHO guideline level of 10 µg/m^3, and average black carbon was 4 µg/m^3. A sharp diurnal profile was observed in both $PM_{2.5}$ and black carbon. The absorption angström eponent indicated that the morning peak is associated with air pollution related to rush-hour traffic,while the late evening peak can be attributed to both traffic and domestic biofuel use.
3	Kigali	NO_2 SO_2 O_3 CO	Gray wolf-advanced sense heating, ventilation and air conditioning	0.119–0.050 ppm 0.014–0.000 ppm 0.033–0.009 ppm 3.148–0.000 ppm	Large amounts of air pollutants are released into the atmosphere of Kigali City by both petrol and diesel vehicles. Planting suitable tree species, frequent monitoring of imported fuel quality and establishment of new fuel quality regulations and guidelines, national ambient air quality standards and national air quality emission standards are crucial to ensure that future generations have access to a high quality of life and living environment.
4	Kigali	PM_{10}	2-month gravimetric and scanning electron microscope testing	650 µg/m^3	The concentration of PM_{10} in Kigali is considerably higher than the limits set by the 2005 WHO guideline. The airborne particles were from the combustion of biomass and traffic.
5	Muhanga, Karongi districts of Southern and Northern provinces, respectively	$PM_{2.5}$	Randomized controlled trial; cooking area monitoring with a Berkeley particle and temperature sensor (UCB-PATS®)	Mean $PM_{2.5}$ concentrations of intervention and control households are 0.485 mg/m^3 and 0.905 mg/m^3, respectively	Indoor cooking with the EcoZoom Dura improved wood-burning stove as opposed to the traditional stove was associated with a 37% reduction in 24-h $PM_{2.5}$, which was of borderline significance
	Western province	$PM_{2.5}$	Randomized controlled trial; personal exposure monitoring with integrated gravimetric methods	Mean 48-h time-integrated $PM_{2.5}$ exposure of cooks was 218 µg/m^3 in the intervention arm and 223 µg/m^3 in the control arm. The mean $PM_{2.5}$ exposure of children was 224 µg/m^3 in the intervention arm and 231 µg/m^3 in the control arm.	Provision and promotion of the EcoZoom Dura improved wood burning stove had no significant impact on household primary cooks' or children's exposures to $PM_{2.5}$.
6	Kigali	PM_{10}	2 months of mobile measurement	1013µg/m^3	PM_{10} concentrations in Kigali were over the WHO limits.

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