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TRAIDE

Investment Opportunities in the Rwandan Energy Sector

TRAIDE Rwanda

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May 2020

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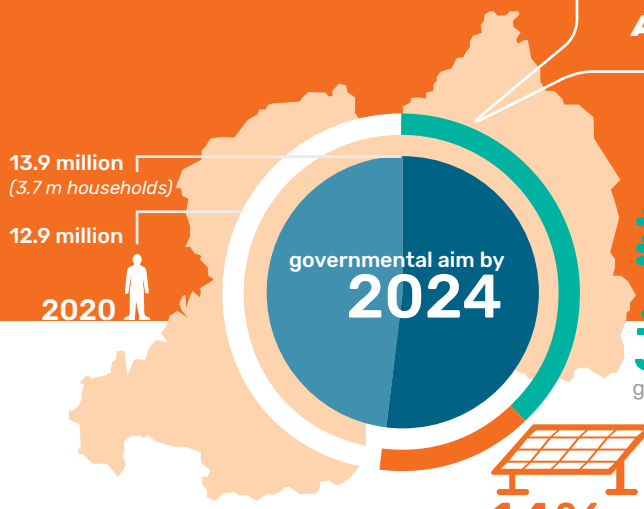
Contents

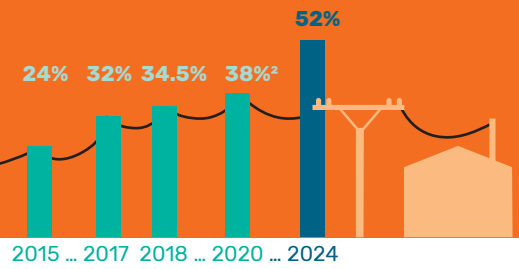
RESILIENCIA RWANDA

TRAIDE

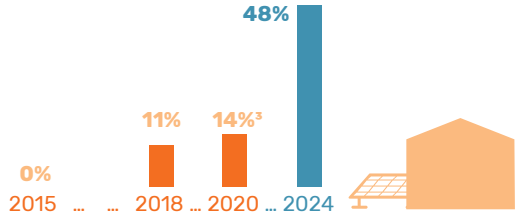
Fact sheet Rwandan energy sector

ACCESS TO ENERGY



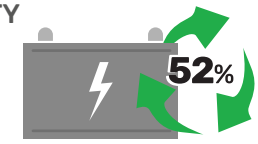


38% access to a grid connection line / aimed **52%**



14% off-grid line[1] connected to an / aimed **48%**

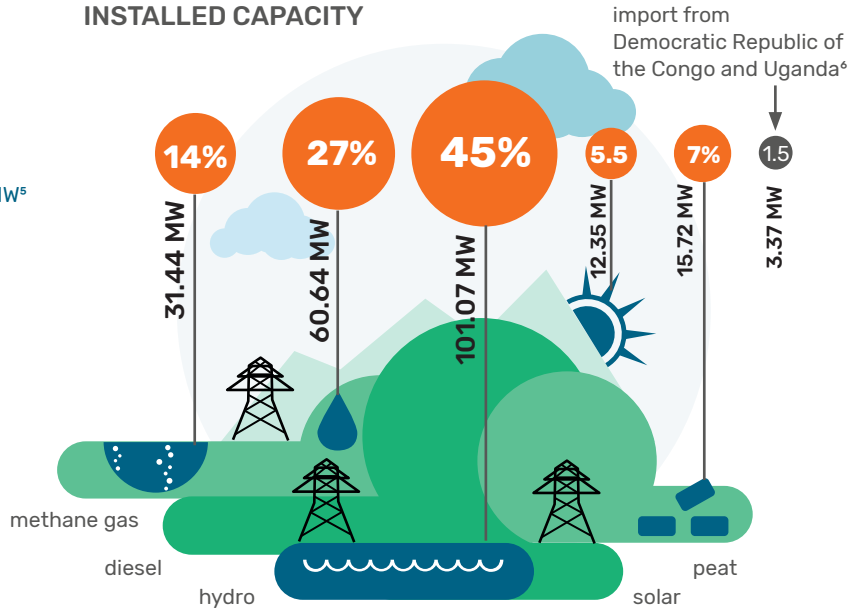
CAPACITY



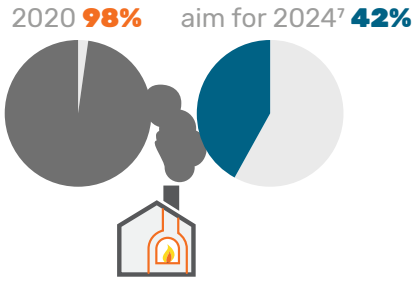
2010	72.7 MW
2019	218 MW
2020	224.6 MW + 19.95 MW[4]
2023-24	556 MW[5]

includes a reserve margin of 15%

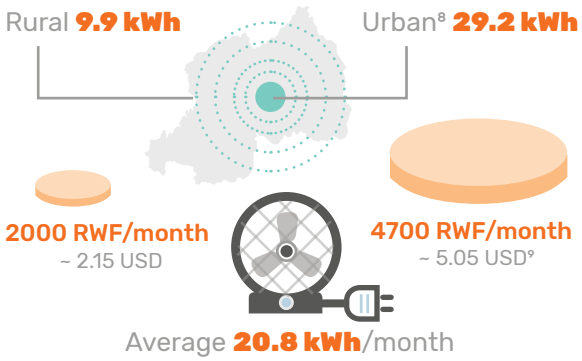
INSTALLED CAPACITY



INEFFICIENT COOKING SOLUTIONS



ENERGY CONSUMPTION



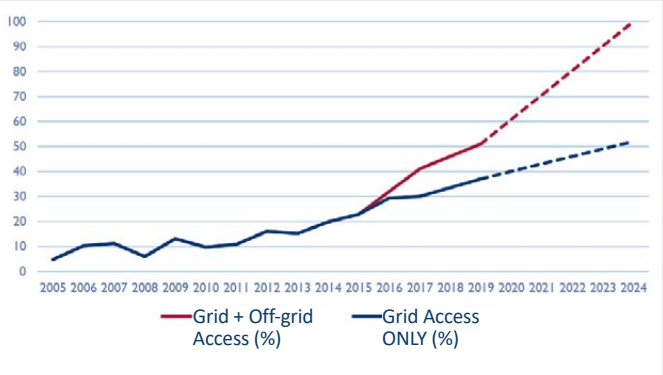
[1] Head of Infrastructure Section Lénaïc Georgelin, 2020; When applying IEA standards, this percentage is 49.1.
[2] These percentages are lower when taking into account the World Bank standard that electricity should be available for at least four hours during the day and one hour at night. Applying these standards, only 26.8 percent was connected in 2020.
[3] MinInfra, 2018; REG, 2019.
[4] REG, 2019.
[5] USAID, 2019; RDB, 2017.
[6] REG, 2019.
[7] Inefficient fuels for cooking are wood, charcoal, coal and kerosene (Clean Cooking Alliance, n.d.); MinInfra: Biomass Strategy, 2019.
[8] Extensive research was conducted for the 'Rwanda Beyond Connections' report based on the multi-tier framework (World Bank in cooperation with AfDB and UN) to study electricity consumption, affordability and willingness to pay in 2017.
[9] World Bank, 2018.

Business opportunities

ON-GRID ELECTRIFICATION

- Rwandan government has awarded nine large-scale (>5 MW) projects and twelve small-scale (<5 MW) projects to increase the MW generation capacity in Rwanda. Two large-scale projects are regional projects, involving other East-African countries.
- At the moment, there are no open tenders. Suppliers might be able to provide services or inputs for projects such as equipment, consultancies and training.
- There are over seventeen projects ongoing aiming to upgrade and expand the transmission line network. Several of these projects still require funding. Opportunities exist in realising the infrastructure development, providing equipment, technical support, projects design and training of technicians.

Figure 1. ENERGY ACCESS RWANDA BASED ON GRID ACCESS VS. GRID + OFF-GRID ACCESS IN THE PERIOD 2005–2024 (SOURCE: WORLD BANK, 2017 AND MINISTRY OF INFRASTRUCTURE, 2018)



OFF-GRID ELECTRIFICATION

Solar Home Systems

Product development

- Explore opportunities to create Solar Home Systems that can be shared by multiple households in terms of design and business model. In 2016, 55.5 percent of the Rwandan population was living below the poverty rate earning 57–59 USD per month. Meanwhile, the price range for a medium-size Solar Home System sold on the local market was 50–100 USD. Most households do not have the means to purchase their own Solar Home System.
- Develop stronger Solar Home System products. There are safety issues with affordable Solar Home System kits on the market: stronger equipment and wires are needed to improve the quality of systems.

Local production

- Explore opportunities to assemble or produce Solar Home System kits locally and obtain investment incentives. Most Solar Home System kits are sourced from China, but one company is currently investigating options for local production.

Financial model

- Benefit from financial support provided to Solar Home System companies and consumers. The Scaling up Renewable Energy Program fund and Ubudehe subsidies will be launched soon providing funds to reach low-income households.

Mini-grids

Product development

- Benefit from falling international market prices of solar PV panels. Improved cost-efficiency thanks to reduced costs of equipment generates opportunities.

Financial model

- Tap into blended finance to fund mini-grid development engaging donors, public and private actors. Financial support for SHS companies will become available via the Scaling Up Renewable Energy Program fund, which is expected to be launched in 2021. The program will fund a maximum of 37 percent of total financing costs.

Clean cooking

Product development

- Develop affordable, safe products for low-income households focusing on tier 0, 1, 2 and 3 Improved Cooking Stoves. For example, companies can add insulation to the stove to increase heat efficiency.

Local production

- Investigate the possibility to produce pellets and briquettes locally, to reduce usage costs of tier 4–5 stoves. The government is willing to facilitate access to raw materials for factories (e.g. providing forest concessions to pellets makers).

Awareness

- Contextualise sales strategies and awareness campaigns to local values. Cooking practices are linked to strong cultural and behavioural values in Rwanda. Consequently, it is difficult to convince people to change their behaviour in both urban and rural areas.

1. Introduction

This report will explore investment opportunities for Dutch and other local or foreign businesses in the energy sector. Sustainable Development Goal (SDG) 7: 'Ensure access to affordable, reliable, sustainable and modern energy for all' is a top priority for the Rwandan government. The Rwandan government aims to reach universal access to electricity for the population by 2024. This agenda offers opportunities for the private sector. Rwanda is moving through a phase of transition. The country seeks to develop equitable relationships with other countries moving from aid to trade. This report seeks to evaluate investment opportunities along the aid and trade spectrum: some of these business models can be market-driven whilst others will require subsidies. Many energy projects depend on external funding, and low-income rural households often need funding mechanisms in order to afford the basic electricity services offered by private energy businesses. Therefore, close collaboration between public and private stakeholders is very important.

RWANDAN CONTEXT

Rwanda is one of the smallest, most densely populated countries on the African continent. Around 12.5 million people live in an area of 26,338 square kilometres.[10] Eighty percent of the Rwandan population lives in remote, rural areas. Therefore, it is difficult and expensive to connect them to the national grid. Also, purchasing power of the Rwandan population remains low. In 2016, 55.5 percent of the Rwandan population was living below the poverty rate earning 57–59 USD per month. Meanwhile, the price range for a medium-size Solar Home System (SHS) sold on the local market was 50–100 USD.

[10] Koo et al.: Rwanda Beyond Borders, 2018.

ABBREVIATIONS

ADF	African Development Fund
AfDB	African Development Bank
DRC	Democratic Republic of Congo
EARP	Energy Access Roll-out Programme
EDCL	Energy Development Corporation Limited
ESSP	Energy Sector Strategic Plan
EU	European Union
EUCL	Energy Utility Corporation Limited
GACC	Global Alliance for Clean Cookstoves
GDP	Gross Domestic Product
ICS	Improved Cookstove
IEC	International Electrotechnical Commission
IEA	International Energy Agency
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
KV	Kilovolt
KW	Kilowatt
KWh	Kilowatt hour
LCPDP	Least Cost Power Development Plan
LPG	Liquefied Petroleum Gas
LV	Low Voltage
MinEcoFin	Ministry of Finance and Economic Planning
MinInfra	Ministry of Infrastructure Rwanda
MoMo	Mobile Money
MV	Medium Voltage
MW	Megawatt
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NEP	National Electrification Plan
PAYG	Pay As You Go
PV	Photovoltaic
RBF	Results-Based Financing
REG	Rwanda Energy Group
RES	Rural Electrification Strategy
RURA	Rwanda Utilities Regulatory Authority
RWF	Rwandan Franc
SACCO	Savings and Credit Cooperative Organization
SDG	Sustainable Development Goal
SHS	Solar Home System
SLS	Solar Lighting System
SREP	Scaling Up Renewable Energy Program
USD	United States Dollar
W	Watt
WHO	World Health Organization
WTP	Willingness to Pay

The Rwandan Gross Domestic Product (GDP) has experienced an average growth rate of 7.5 percent since 2000. In 2019, economic growth even exceeded ten percent. Prior to the global pandemic, growth rates of approximately eight percent were projected until 2022.[11] Disruptions of international trade and travel are likely to suppress growth rates. Moreover, public investments supporting the expansion of (energy) infrastructure such as power plants have been a major driver of growth.[12] Stable energy supply can support industry development and small businesses. At the moment, 72 percent of productive users in Rwanda has access to energy.[13] Considering recent developments, delays in the execution of energy generation projects can be expected.

RWANDAN ENERGY SECTOR

In 2020, the Rwandan Ministry of Infrastructure (MinInfra) estimates that 52.2 percent of the Rwandan population has access to energy. 38 percent of the Rwandan population has access via a grid connection and fourteen percent is connected to an off-grid line.[14] This percentage might be slightly lower when applying the standards of the International Energy Agency (IEA) according to which 49 percent of the Rwandan population had access to basic electricity in 2019.[15] The Rwandan government aims to reach universal access for the population to electricity by 2024. At the moment, consumer electricity demand is rather low because most households still use biomass for cooking, and kerosene for lights. Around 98 percent of the total Rwandan population uses biomass as cooking fuel, which makes the health burden of indoor air pollution exposure one of the largest in the world.[16] The government aims to reduce the number households using biomass for cooking from 98 to 42 percent by 2024.

The Ministry of Infrastructure (MinInfra) has set ambitious targets in the Energy Sector Strategic Plan (ESSP) for 2018/2019–2023/2024.[17] It distinguished between three subsectors: electricity, biomass and petroleum.[18] Whereas, electricity and biomass are prioritised, petroleum is not. All petroleum (including LPG) is imported from neighbouring countries and so far, there is no evidence Rwanda has its own source. Rwanda's ESSP main target is reaching universal access to energy by 2024. Approximately 52 percent of energy generation should come from renewable energy sources. The projected division between on-grid and off-grid access is 52 percent versus 48 percent. Figure 4 shows that on-grid targets for the year 2018/19 were met. However, targets were not met for off-grid access, which is fourteen percent at the moment instead of the projected 23 percent. The main challenge is to reach low-income households in remote areas.

Figure 2. ACCESS TO ELECTRICITY TOTAL POPULATION (SOURCE: POWER AFRICA, 2019)

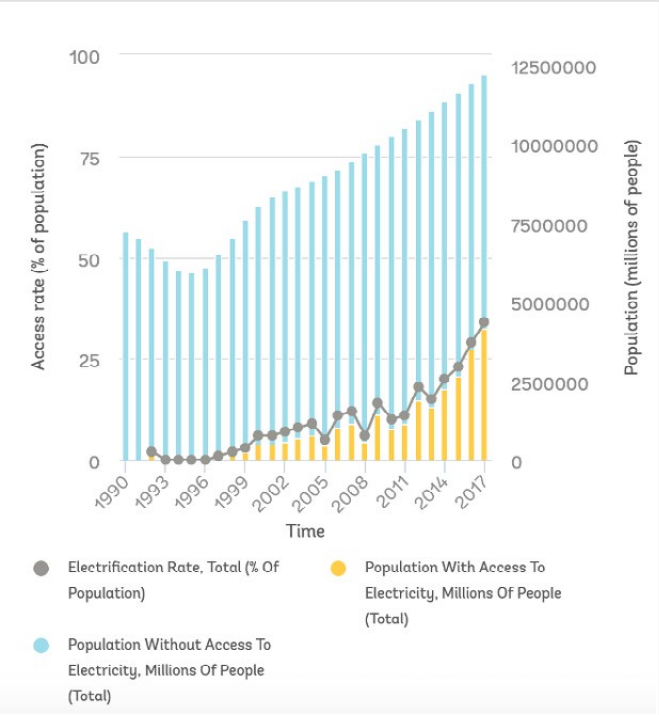
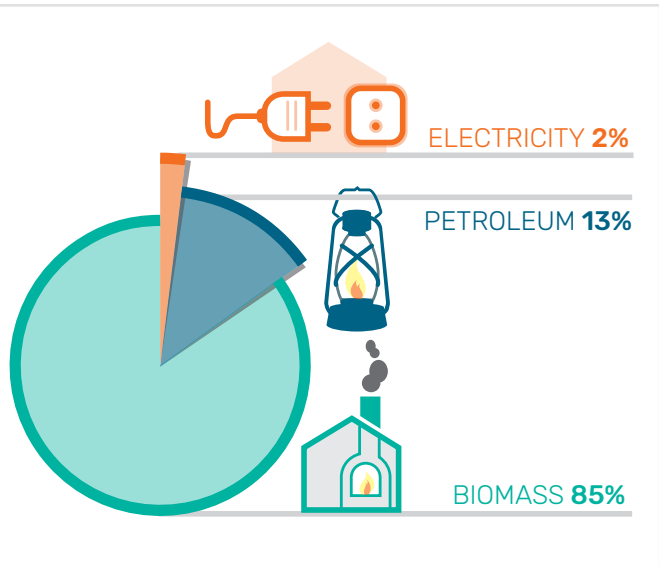
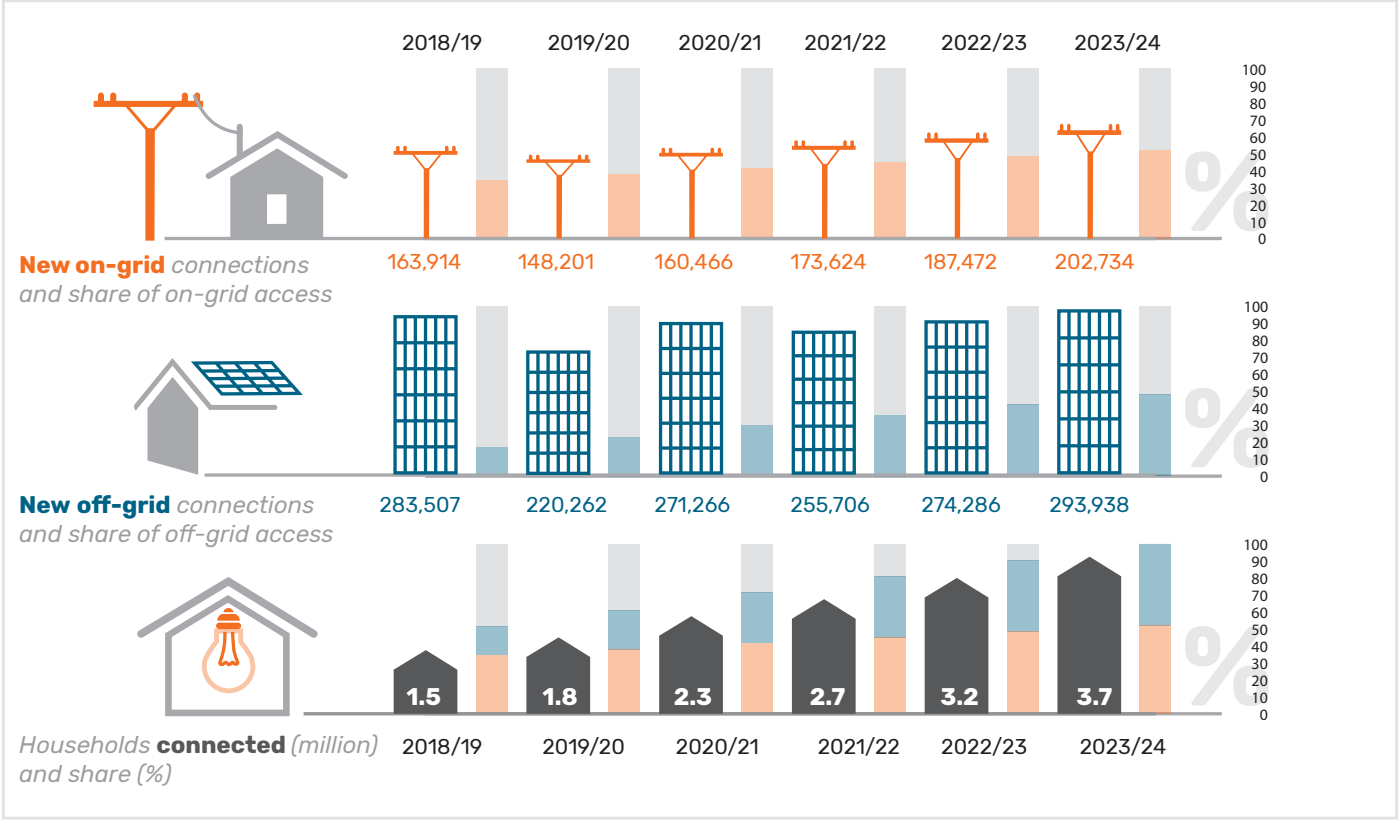


Figure 3. ENERGY CONSUMPTION BY CONSUMERS IN RWANDA (2016)



[11] MinInfra: ESSP, 2018.
[12] African Development Bank Group: Africa Economic Outlook, 2020; World Bank 2020.
[13] Productive users utilise energy for activities that enhance income and welfare. Examples of productive users are health and education facilities, public infrastructure, and industries (MinInfra: ESSP, 2018).
[14] Head of Infrastructure Section Lénaïc Georgelin, 2020.
[15] IEA (2019, p. 36) defines access to energy for households when 'the household has reliable and affordable access to electricity (and clean cooking facilities), which is enough to supply a basic bundle of energy services, and with the level of service capable of growing over time. Basic electricity services are defined as owning a set of several lightbulbs, phone charging, a radio and potentially a fan or television.
[16] IEA, 2019.
[17] MinInfra: ESSP, 2018.
[18] MinInfra: ESSP, 2018.

Figure 4. PLANNED CHANGES IN ON- AND OFF-GRID CONNECTIONS 2018–2024 (SOURCE: ESSP, 2017)



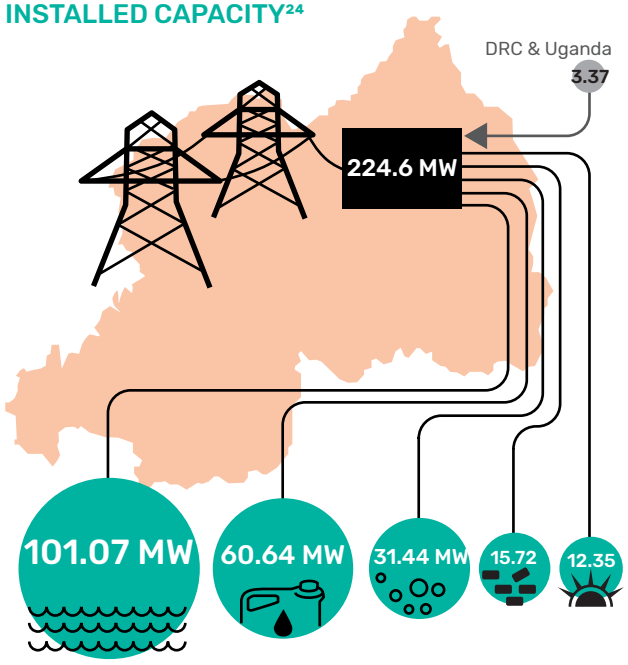
In 2020, Rwanda has an installed on-grid energy capacity of 224.6 megawatt (MW) plus an installed off-grid capacity of 19.95 MW (mostly from SHS).[19] By 2023/24, the combined on-grid and off-grid capacity should reach 556 MW, which includes a reserve margin of fifteen percent.[20]

The Rwandan on-grid generation capacity has tripled since 2010. The current installed capacity of 224.6 megawatt comes from five energy sources: 101 MW installed hydroelectric capacity, 60 MW capacity from diesel resources, 31 MW from methane gas resources, 15.5 MW from peat resources and 12.5 MW from solar resources. An additional 3.5 megawatt is imported from DRC and Uganda.[21]

Installed off-grid capacity is much lower than grid capacity. Off-grid electricity in Rwanda is generated through SHS and mini-grids. The latter type generates energy through solar PV or hydropower. In 2018, there were 27 companies distributing SHS and nine companies installing mini-grids. Overall, the installed mini-grids (both hydro and solar) have a total capacity of 250 kilowatt (KW).[22] The installed capacity of SHS, based on an average of 50 Watt (W) SHS is 12.7 MW. This is based on numbers from 2019.

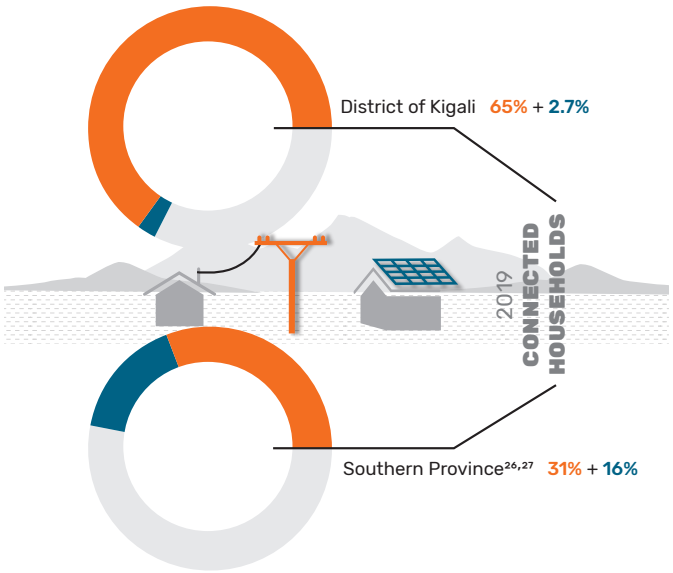
Most investment opportunities for the private sector seem to exist in the off-grid electrification. The Rwandan government is investing in on-grid projects to raise the electrification rate. In remote, rural areas, it is too expensive to establish grid connections and hence, innovative solutions are required. The government has called upon the private sector to help provide energy access for all Rwandan residents and businesses.[23] Businesses can develop technologies and business models suited for these challenging target groups in the electricity and biomass subsector.

INSTALLED CAPACITY[24]



[19] REG, 2019.
[20] RDB, 2017; USAID, 2019.
[21] REG, 2019.
[22] REG, 2019.
[23] MinInfra: ESSP, 2018.
[24] The website of REG (2020) states the 'available capacity' (rather than the installed capacity) is currently: 88.41 MW hydro (39%), 43.07 MW thermal (diesel) (19%), 56.68 MW methane gas (25%), 24.94 MW import (11%), 4.53 MW solar (2%), 9,07 MW peat (4%). The data regarding installed capacity was collected during an interview with REG.

2. Stakeholders and enabling environment



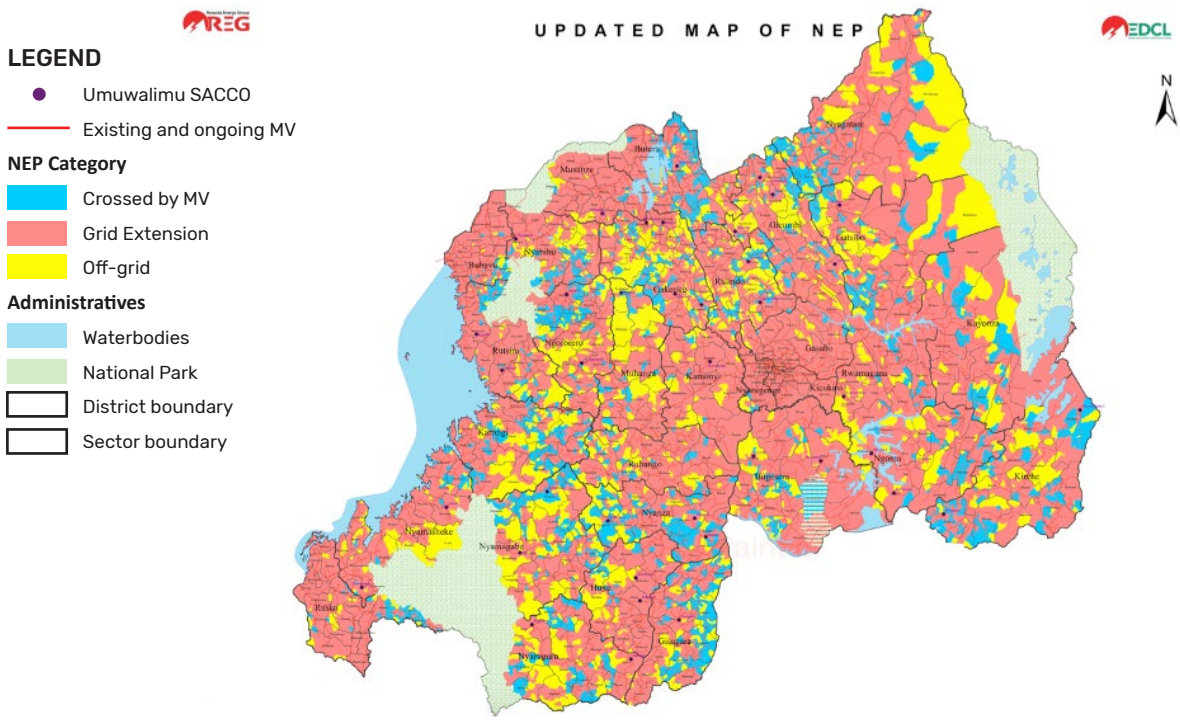
Three types of stakeholders can be distinguished in the energy sector, namely: public sector, independent power producers (IPPs) and consumers. On-grid projects are generally large-scale investments managed by the government (in collaboration with a foreign IPP) and funded through loans. These projects include the construction of new plants as well as the upgrading of existing plants and transmission lines. Off-grid projects tend to be small-scale and are frequently aid-based implemented by IPPs in rural, remote areas. Please review Annexe 1 for an overview of categorized donors for off-grid, on-grid and clean cooking. Please review Annexe 2 for an overview of development organisations supporting energy projects in Rwanda.

NATIONAL ELECTRIFICATION PLAN

The division of grid and off-grid connections in Rwanda is strictly regulated by the National Electrification Plan (NEP). The NEP determines in a highly detailed manner where grid connection lines have been and should be installed. The Plan shows grid lines are already present or planned in most areas. By contrast, off-grid areas are scattered; mini-grid areas are also scarce because the number of permits is limited. In 'grid extension zones,' investors must refrain from the instalment of off-grid connections. Hence, the NEP clarifies in which areas IPPs can and in which areas they cannot target potential customers. The NEP only distinguishes between grid and off-grid areas. Hence, the type of off-grid source, a mini-grid or SHS, does not matter.[25] This means that off-grid energy suppliers 'share' these areas.

[25] Personal communication GIZ, 2020.
[26] REG, 2019.
[27] REG, 2019.

Figure 5. NATIONAL ELECTRIFICATION PLAN 2018



PUBLIC SECTOR

The public sector actors are the Ministry of Finance and Economic Planning (MinEcoFin) and MinInfra; policymakers shaping the enabling environment. MinEcoFin allocates the budget for energy investments and operations. MinInfra develops energy policies and targets, which must be aligned with the SDGs. Subsequently, projects are executed by the Rwanda Energy Group (REG). REG is the national utility company in Rwanda and owned by the government. REG is divided into two departments: Energy Utility Corporation Limited (EUCL) and Energy Development Corporation Limited (EDCL).

EUCL is responsible for the operationalisation and maintenance of grid connection lines in Rwanda. They generate, transmit, and distribute energy to customers. EDCL is in charge of public investments in new energy generation projects. EDCL is the main contact for private energy investors that want to operate in the field of energy, both on-grid/off-grid and clean cooking. Rwanda Utilities Regulatory Authority (RURA) sets the tariffs for energy prices in Rwanda.

Furthermore, EDCL develops the Energy Access Roll-out Programme (EARP), in which the expansion of access to electricity in Rwanda is planned. The EARP is funded by the Rwandan government and development partners like African Development Bank (AfDB) and the European Union (EU). There are additional non-governmental funds supplied by grants or loans from independent donors.[28]

INDEPENDENT POWER PRODUCERS

IPPs are of crucial importance to the Rwandan government in helping to achieve its 2024 goals. There are on-grid and off-grid producers. There are only a couple of on-grid IPPs; foreign companies facilitating large-scale grid investments. IPPs have supported the development of the methane gas generation facility at Lake Kivu as well as large solar and peat generation sites. By contrast, off-grid electrification is done via several smaller projects scattered throughout the country by a variety of companies. Off-grid IPPs are mostly involved in renewable energy projects: solar and hydro power. There are also several IPPs involved in the clean cooking sector.

CONSUMERS

Consumer groups in Rwanda are highly diverse in terms of consumption rates. This is the reason why there are fixed electricity tariffs for different consumer groups. A distinction is made between residential, non-residential (public institutions, offices and hospitals) and industrial consumers. A second categorisation is made within the three consumer groups on the basis of monthly consumption rates. Major differences exist between the charged tariffs for the low-income, low-demand households versus the high-income, high-demand households. Moreover, small industrial users pay a higher price than large industrial users; businesses receive major discounts on energy tariffs as an investment incentive.[29] In 2016, households accounted for 82 percent of total energy consumption in Rwanda.

Figure 6. OPERATIONAL FRAMEWORK ENERGY SECTOR RWANDA

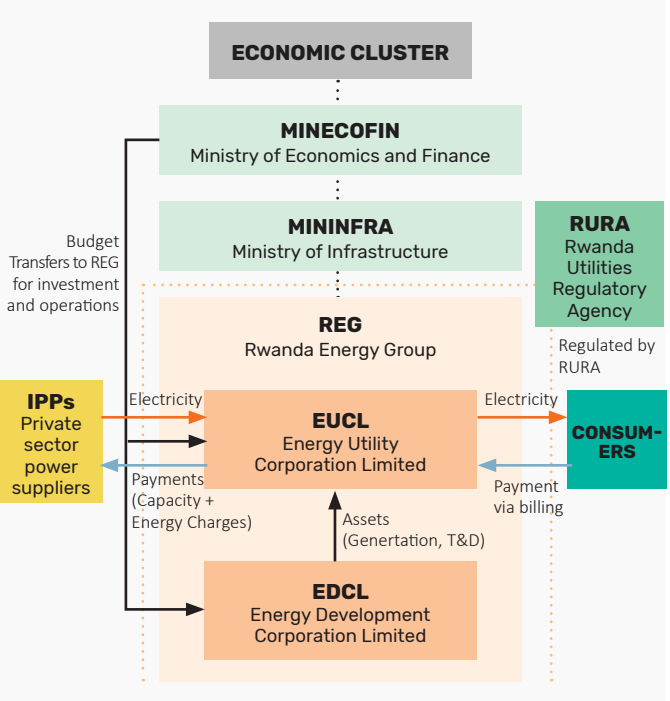
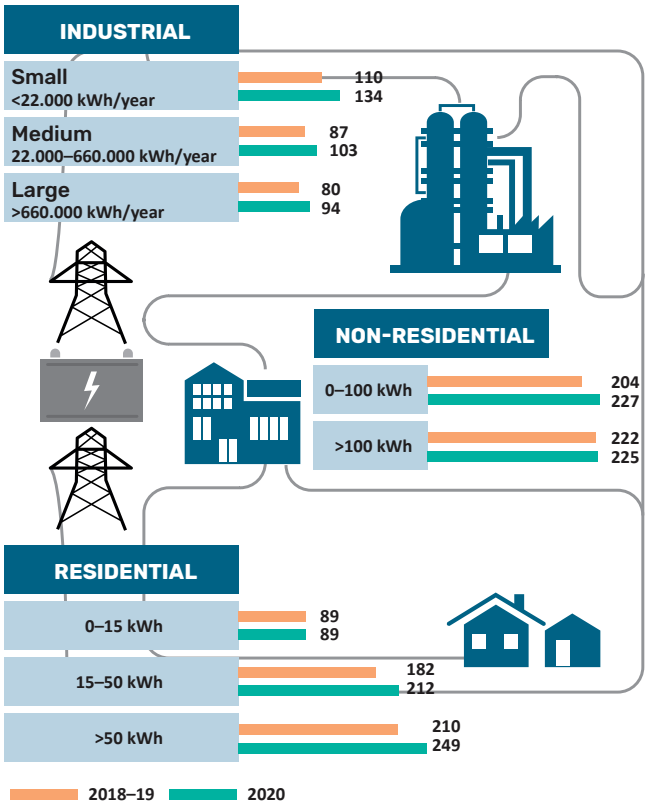


Figure 7. ELECTRICITY TARIFFS FOR DIFFERENT CONSUMER GROUPS IN 2018–19 AND 2020 (PRICE PER kWh in RWF) (SOURCE: REG, 2020)



[28] MinInfra, 2018.

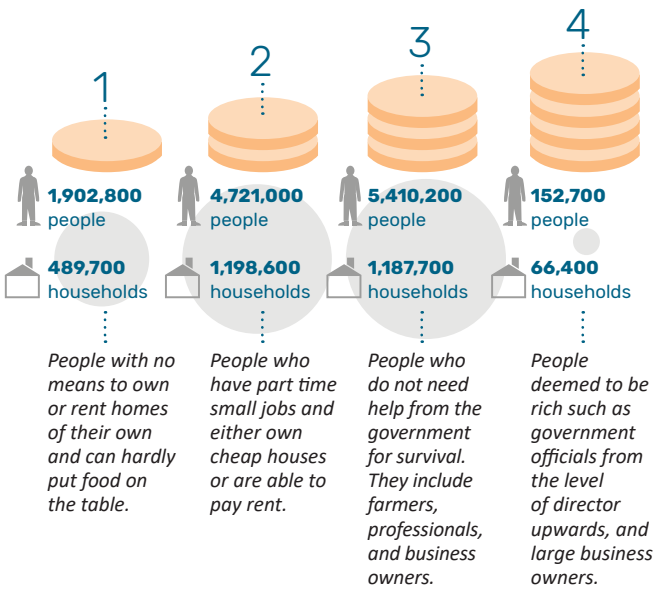
[29] These prices are based on industrial users with a smart meter. Without a smart meter, a flat rate is charged which increases costs per kWh with approximately fifteen percent, 2020.

Categorisation of residential consumers is based on their energy consumption rates as well as the national social stratification system: *'Ubudehe categories.'* Ubudehe means *'collective action and mutual support to solve problems within a community.'* In the tier system, Rwandans are categorised on the basis of their socioeconomic status; one's category determines the level of support provided by the government.[32] There are four Ubudehe categories; the first category includes the poorest people in society while the fourth category is for the wealthiest members of society. Electricity consumption rates are linked to the Ubudehe category: people in tier four have the highest consumption rates ('load') and use most appliances.

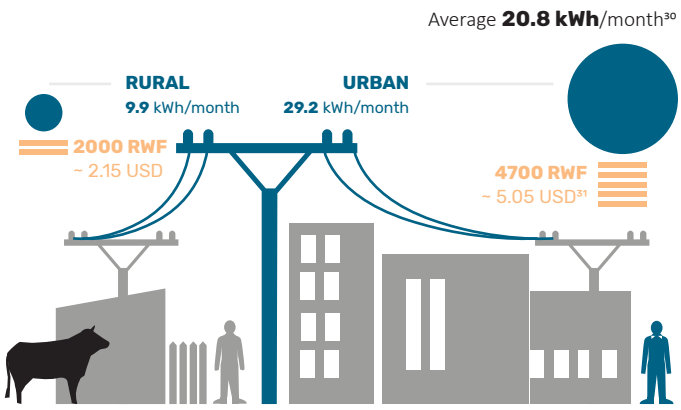
Table 1. LOAD LEVELS, INDICATIVE ELECTRIC APPLIANCES AND ASSOCIATED CAPACITY TIERS (SOURCE: RWANDA BEYOND CONNECTIONS, 2018)

Load level		Indicative electric appliances	Capacity tier tipically needed to power the load
Very low load	**3–49 W**	Task lighting, phone charging, radio	TIER 1
Low load	**50–199 W**	Multipoint general lighting, television, computer, printer, fan	TIER 2
Medium load	**200–799 W**	Air cooler, refrigerator, freezer, food processor, water pump, rice cooker	TIER 3
High load	**800–1999 W**	Washing machine, iron, hair dryer, toaster, microwave	TIER 4
Very high load	**2000 W or more**	Air conditioner, space heater, vacuum cleaner, water heater, electric cookstove	TIER 5

THE FOUR UBUDEHE CATEGORIES[33]



ENERGY CONSUMPTION



[30] For the 'Rwanda Beyond Connections' report based on the multi-tier framework (World Bank in cooperation with AfDB and UN), extensive research was done on electricity consumption, affordability and willingness to pay in 2017.
[31] World Bank, 2018.
[32] Government of Rwanda, n.d.
[33] Local Administrative Entities Development Agency, 2020.

3. Major trends in on-grid electrification

In 2020, Rwanda has an installed on-grid energy capacity of 224.6 MW.[34] Rwandan on-grid energy capacity has tripled since 2010. 52.5 percent comes from renewable energy sources. The government expects on-grid energy demand to peak around 2024, reaching 282–376 MW.[35] Around this time, the government expect on-grid capacity to be around 290 MW (52 percent of the total capacity of 560 MW). In 2019, REG developed the Least Cost Power Development Plan (LCPDP), which defines the generation extension plans for 2019–2025. There are ongoing projects for which construction has started. Most projects are still in the pipeline and some projects are on hold because the funding phase has not been completed.

Figure 8. ON-GRID GENERATION MIX RWANDA 2019 (SOURCE: REG, 2019)

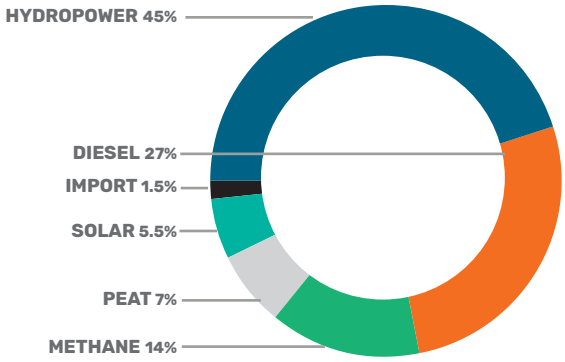
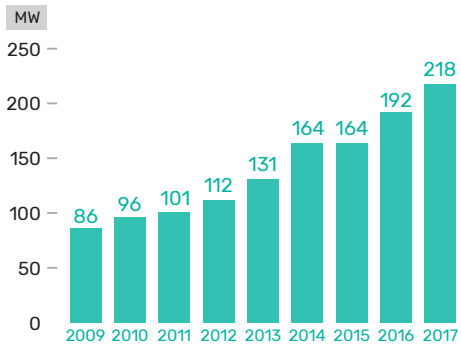


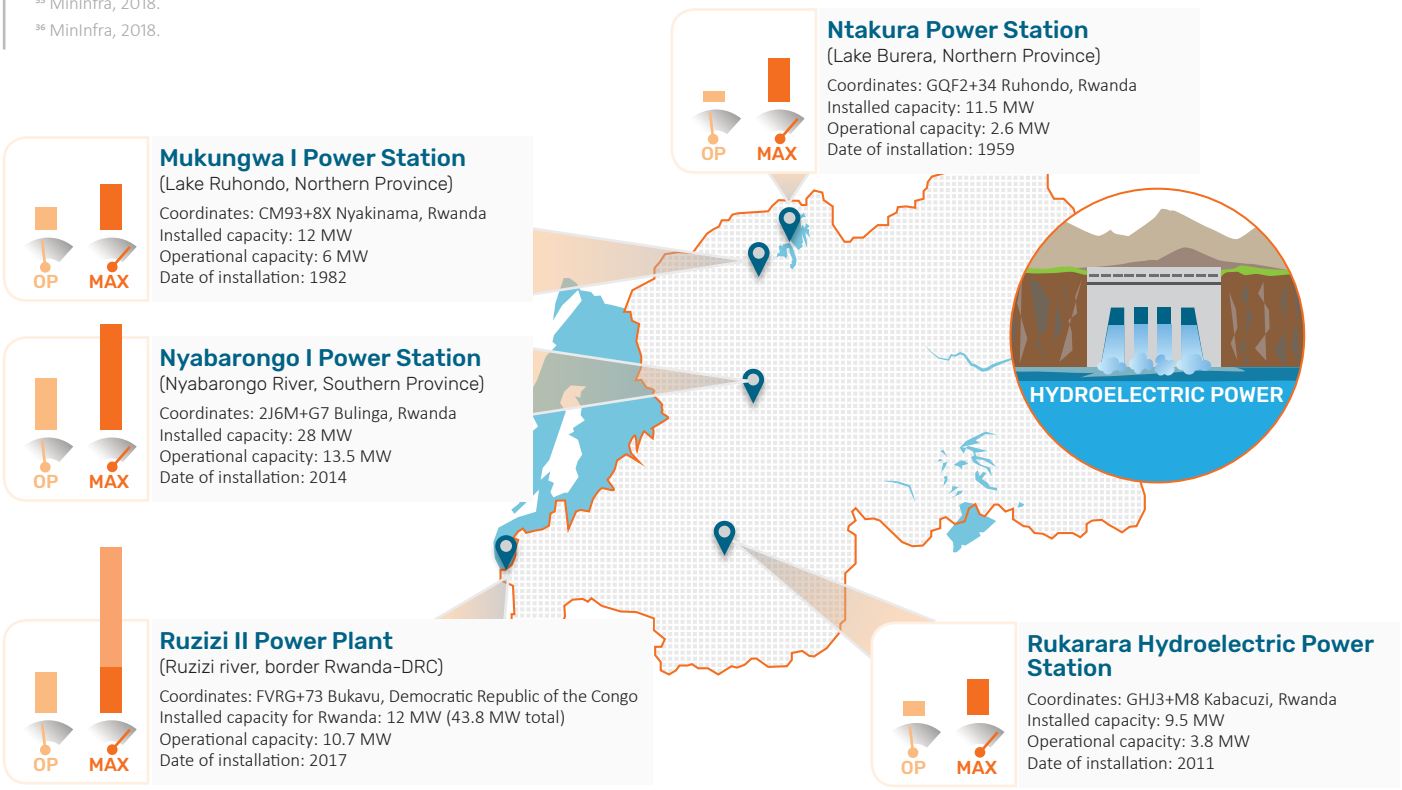
Figure 9. INSTALLED CAPACITY NATIONAL GRID 2009–2017 (SOURCE: MININFRA, 2018)



HYDROELECTRIC POWER

The total current installed capacity of all hydroelectric power plants in Rwanda is 98.5 MW. About 45 percent of on-grid energy in Rwanda is generated by hydroelectric power.[36] There are five large operational power plants with a total capacity of around 73 MW. The large power plants are not working on full capacity due to several reasons such as weather conditions influencing water levels. The large hydro power plants are generating power from river runs and lakes, and their details are visible in the map below:

[34] REG, 2019.
[35] MinInfra, 2018.
[36] MinInfra, 2018.



Total Rwandan potential for hydropower has been estimated at 400 MW. The domestic potential is 250 MW and there is an additional regional potential of 150 MW when the use of shared water resources is optimised. In the coming five years, full domestic capacity of 250 MW should be realised following the development of new and more efficient hydroelectric power plants. These projects will raise hydropower generation by 173 percent.

In the LCPDP, five large hydroelectric power plant projects are mentioned to be developed with a total MW capacity of 137.5 MW: Nyabarongo II (43.5 MW), Ruzizi III (48.33 MW), Giciye III (7.2 MW), Rukarara VI (6.7 MW), Rusumo (26.7 MW) and Bihongore (5.4 MW).[37,38] The first four projects are extensions of current installed plants. Additionally, 31 MW will be installed through eighteen smaller and micro hydro projects; of which 7 MW will be installed by IPPs in 2020.[39] Moreover, the LCPDP states existing power hydro-plants will remain operational. However, there is no indication in the plan whether the government is planning to improve their capacity or not.

THERMAL POWER

Thermal power accounts for 27 percent of total energy capacity in Rwanda.[40] Diesel is the main source used to meet demand during peak hours. Diesel is relatively expensive because it is imported and inefficient, which makes the generation of electricity costly. Industrial users are charged slightly higher prices during peak hours. Improved affordability is expected when extra supply is provided during peak hours following the completion of new hydro and peat projects (rather than diesel). There are five thermal power plants using diesel. The two largest plants are Jabana (phase 1 and 2) and SO-Energy, which are both situated in the district of Kigali.[41] They have an installed capacity of 27.8 and 30 MW respectively. No new projects will be developed in the future. The Rwandan government is focusing on renewable energy and moving away from diesel-generated power.

METHANE GAS

Rwanda has a unique source of energy: Lake Kivu where methane gas is extracted to generate energy. Lake Kivu is situated between Rwanda and the Democratic Republic of Congo (DRC) and considered a shared energy source. There is no other lake in the world that contains methane gas in the same proportions. The high levels of methane are caused by the surrounding active volcanic region. The total lake contains 60 billion m^3 of methane and it is estimated that a total of 700 MW of electricity can be generated over a period of 55 years.[42] The total potential for Rwanda is 350 MW.

At the moment, there is one power plant on Lake Kivu located in the Rwandan part of the lake. Kivuwatt is owned by a British company called Contour Global and has been operational since 2015. The plant produces 26 MW over a period of 25 years, supplying the national grid of Rwanda. The plant is running at full capacity. The construction of two additional plants is planned raising total capacity of Kivuwatt to 75 MW.[43] This project is still in the pipeline. A second project is under construction at Lake Kivu. Symbion, an American-based energy company, is constructing a plant with a generation capacity of 56 MW over a period of 25 years.[44]

[37] REG, 2019.
[38] Two large plants, Rusumo and Ruzizi III, are regional projects and the number of MW in brackets is the capacity assigned to Rwanda.
[39] REG, 2019.
[40] REG, 2019.
[41] REG, 2019.
[42] DLA Piper Africa, n.d.
[43] ContourGlobal, n.d.
[44] Symbion, n.d.

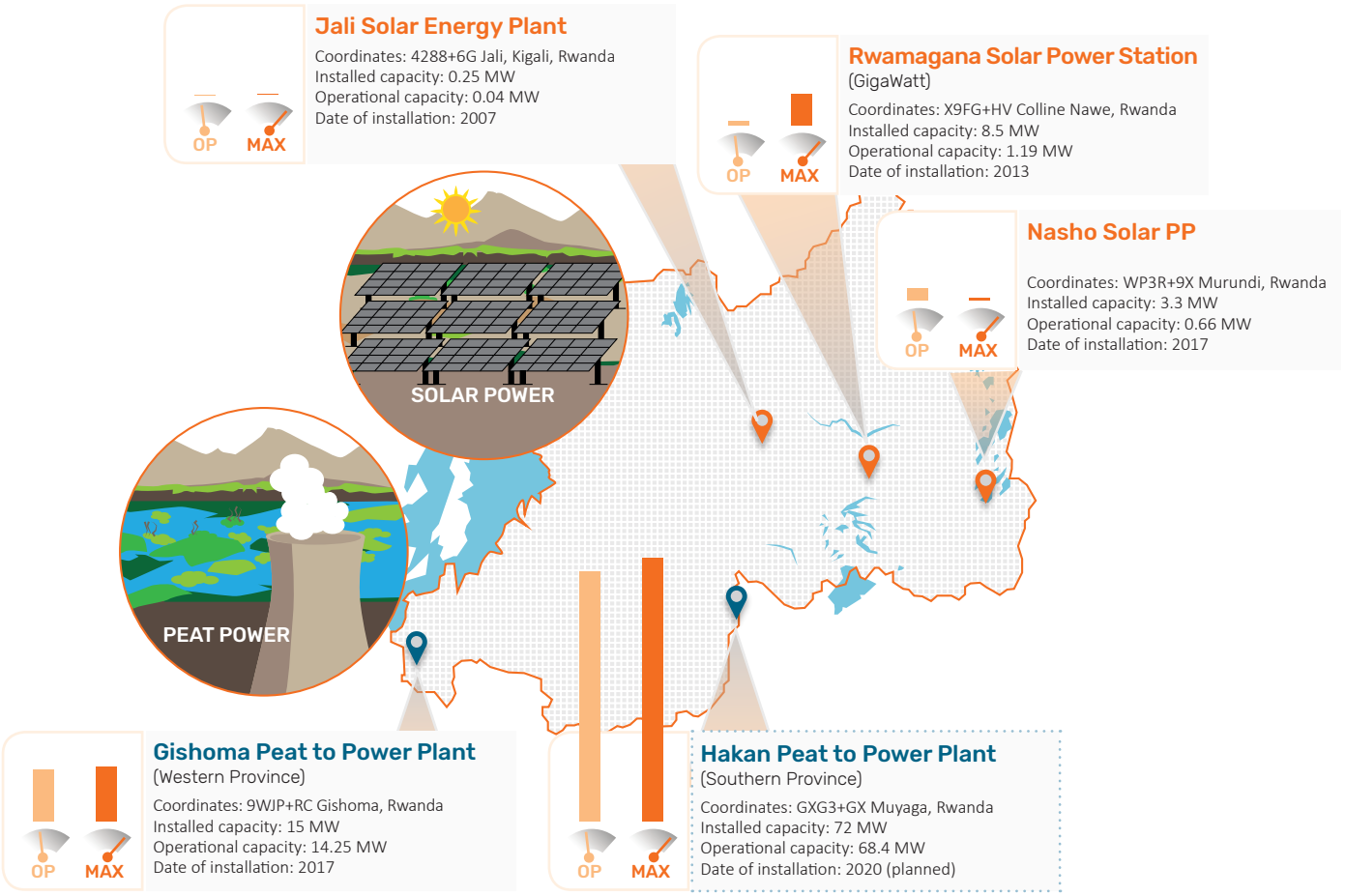
PEAT

Seven percent of energy is generated using peat. The first peat power plant in Rwanda was completed in 2017; it was a pilot project and the first of its kind in Africa. The plant is located in Gishoma, South-West Rwanda and generates 15 MW electricity supplying the national grid. A second, larger plant with a capacity of 72 MW is currently under construction. The new power plant is located in Gisagara, Southern Province and owned by Turkish Mining and Electricity company Hakan.

SOLAR

Only 5.5 percent of on-grid electricity in Rwanda is generated by solar power. The installed capacity for the generation of solar power is low. There are three power plants: Jali (0.25 MW), GigaWatt (8.5 MW) and Nasho Solar PP (3.3 MW). The total installed capacity is around 12 MW. However, capacity only reaches twenty percent on average, since there are no energy storage facilities. Most energy is needed during evening peak hours when there is no sunlight. However, due to the lack of storage surplus energy collected during the day is lost. The government-owned Nasho plant is a solar-powered irrigation project. The largest plant, GigaWatt is running at the lowest capacity of 14 percent.

REG has announced the development of a new solar plant including a storage facility, generating 30 MW of electricity. At the moment, feasibility studies are being conducted. Moreover, REG acknowledges the high potential of solar PV in Rwanda. Nonetheless, the focus areas of the Rwandan government are hydro, methane and peat, which can be explained by the short lifespan of solar infrastructure.



ENERGY IMPORTS

Energy imports are very small with 1.6 percent of the on-grid electricity being imported from Uganda and DRC.[45] 2 MW of electricity is imported via the Kawanda-Birembo High Voltage Power Transmission Line. This project is part of the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) of East-African countries. The power line starts in Kawanda, Uganda and ends in Gasabo district in Kigali.[46] This project is financed by AfDB and Japan International Cooperation Agency (JICA). 3.5 MW electricity is imported from the Ruzizi I power plant in DRC. This plant can generate 30 MW of electricity and has been operational since 1957. The aim of the Rwandan government is to phase out imports from DRC. Rwanda does not seek to increase energy imports in the future with the exception of the regional projects of the NELSAP.

TRANSMISSION OF ENERGY

The transmission network transports generated electricity from the main source to sub-stations, after which electricity is distributed to end-users. Existing transmission lines in Rwanda are mainly 110 kilovolt (kV) and 220 kV and new transmission lines will support the same voltage. Between 2010 and 2017, the length of transmission lines in Rwanda increased from 462 km to 744 km. Moreover, there are sixteen planned projects to further expand the transmission network, for which funding has already been secured. Additionally, there are twenty projects in the pipeline, for which funding has not been secured. These projects support expansion of transmission lines throughout the entire country but the Kigali ring has been prioritised since 2016.

Transmission and distribution lines are not fully efficient: in 2018, capacity losses were estimated to be around 22 percent. Goal is to reduce this to fifteen percent by 2024. To compare: capacity losses in transmission lines in the Netherlands were 4.8 percent in 2014, and global average is 8.5 percent.[47]

Annually, approximately 22 percent of transmissions are lost. The financial costs are currently estimated at 28 million USD and can increase to 102 million USD considering rapidly growing energy production and consumption rates.[48] Losses are mainly caused by technical problems. Many transmission lines consist of long medium voltage (MV) feeders, low voltage (LV) lines and inefficient single-phase lines.[49] Moreover, deficient planning results in the incompatibility of lines or inefficient connections. Finally, poor workmanship and old equipment are considered as major cause of technical losses. Furthermore, there are also commercial losses resulting from faulty accounting and record-keeping, theft and non-payment by customers. Especially, non-payment by large customers causes major financial losses.

DISTRIBUTION OF ENERGY

The wiring of the energy distribution network in Rwanda is 16,000 km long, of which 35 percent is covered by MV lines and 65 percent by LV lines.[50] Currently, the distribution network has a suboptimal performance demonstrated by the number of power outages each year. In 2016–2017, REG customers faced power outages for 36 hours on average. The aim is to reduce this number to fourteen hours by 2024.[51] 91.7 percent of grid-connected households experience more than four interruptions in electricity supply each week.[52] This number includes both urban and rural areas, but outages seem to occur more often in urban areas because of the grid-connection density.

The government has launched various projects to reduce power outages. Several rehabilitation and expansion projects of the LV and MV networks have started. 350 km of wiring will be added to the distribution network. The government is also upgrading substations linking transmission and distribution networks. Electricity connections for non-residential and industrial users (public, commercial centres, factories, hotels and offices) are prioritised because the marginal costs are relatively low in comparison to households in scattered, remote areas. Moreover, residential users consume a low amount of electricity, which reduces the incentive to target this group. The government aims to connect all productive users by 2022. Also, the districts of Huye and Gisagara have a high priority since access to electricity is very low in these areas.

FUNDING MECHANISMS

The government mostly uses mixed funding mechanisms blending government, development partners and private investors resources to finance transmission and distribution projects. The projects require large capital investments, for which the government wants to involve development partners and the private sector as well. Transmission projects are mainly funded by the Rwandan government, AfDB and African Development Fund (ADF). The biggest challenge is to mobilise funds for new transmission projects. No funding has been secured for the 2020 projects and this can result in severe delays; especially considering the impact of the COVID-19 pandemic on economic growth around the world.

[45] REG, 2019.
[46] UETCL, 2019.
[47] World Bank, 2018.
[48] MinInfra, 2018.
[49] MinInfra, 2018.
[50] REG, 2019.
[51] This number only concerns officially registered long-lasting outages. Additionally, many Rwandans experience (short) outages in rainy periods.
[52] Rwanda Beyond Connections, World Bank, 2018.

GRID CONNECTION FEES

Consumption rates of both urban and rural households are insufficient to publicly fund the cost of a grid connection. An average monthly electricity consumption between 130–140 kWh is needed to break-even.[53] However, these high connection fees are also a major obstacle for consumers. At the moment, the willingness to pay (WTP) of unconnected households is low, especially in rural areas (see figure below). In 2017, connection fees were roughly 56,000 RWF (nearly 59 USD). 48 percent of customers were not willing to pay because the costs are simply too high; connections fees are higher for consumers located further away from the grid. The Rwandan government acknowledges that the fees are a barrier to the target to quickly expand grid-access.

Figure 10. WILLINGNESS TO PAY FOR A GRID CONNECTION INCREASES WHEN PAYMENT IS SPREAD OVER TIME (SOURCE: RWANDA BEYOND CONNECTIONS, 2018)

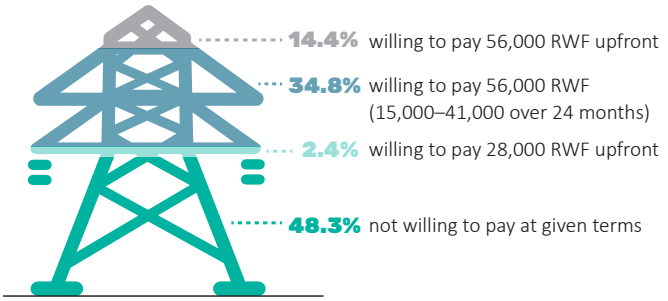
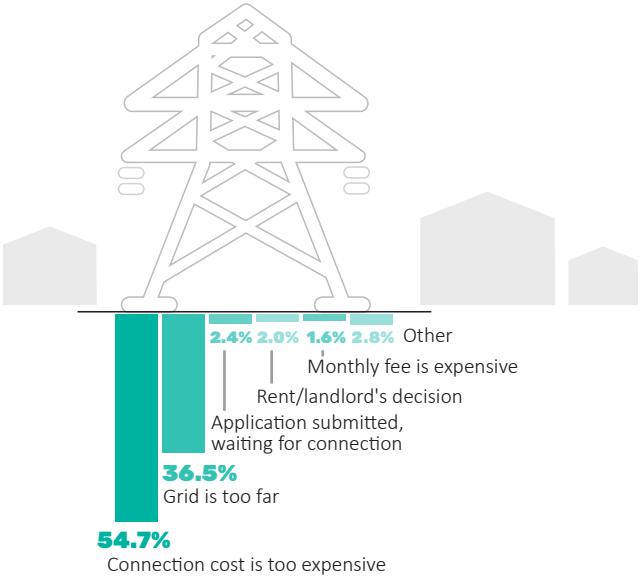
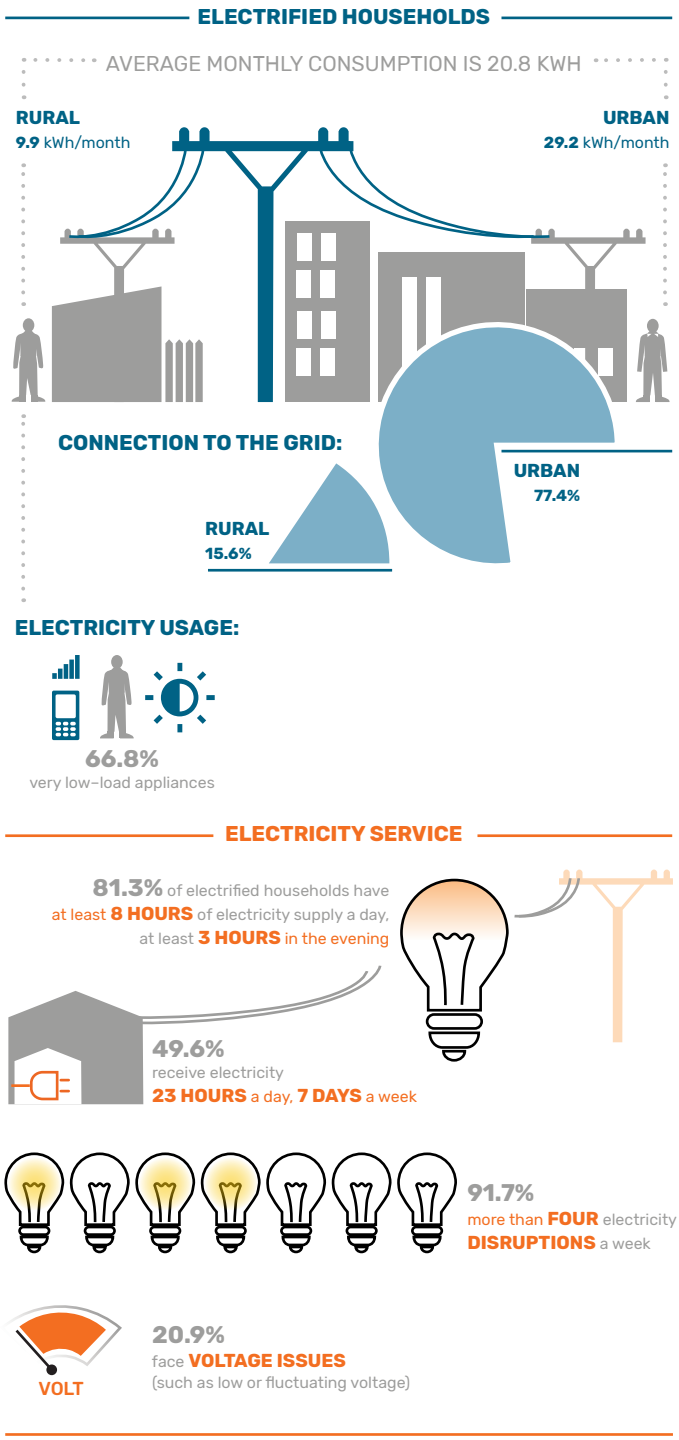


Figure 11. OVER HALF OF UNCONNECTED HOUSEHOLDS ARE NOT CONNECTED TO THE GRID BECAUSE OF HIGH CONNECTION COST (SOURCE: RWANDA BEYOND CONNECTIONS, 2018)





[53] Rural Electrification Strategy, MinInfra, 2016.

4. Opportunities in on-grid electrification

In the past years, on-grid electrification has been the main focus in Rwanda whereas the off-grid and clean cooking sector are still in the early stages of development. Consequently, the on-grid sector has matured, energy supply is plentiful and investment opportunities are limited: many projects are planned or ongoing. The installed capacity of MW will provide an energy surplus following the completion of multiple large-scale national and regional projects. Rwanda follows the regional trend of oversupply. At this point, the government is not approving new projects nor signing new contracts. The main challenge is the financing of the planned (and ongoing) hydro and peat projects, which are at risk of being delayed.

There are opportunities in terms of improving and laying out transmission lines. REG is working on the improvement of transmission lines but is in need of investors and/or international donors to expand its operations. Therefore, opportunities exist related to infrastructure development and equipment. Also, opportunities exist with regard to technical support, projects design and training of technicians. The Rwandan government has currently sixteen transmission projects ongoing, which are partly funded by AfDB, EU and the German National Development Bank KfW.[54] Transmission projects with an approximate value of 50 million are in the pipeline and require funding.

Large-scale grid projects

- At the moment, there are no open tenders. Suppliers might be able to provide services or inputs for projects such as equipment, consultancies and training. Rwandan government has awarded nine large-scale (>5 MW) projects and twelve small-scale (<5 MW) projects to increase the MW generation capacity in Rwanda. Two large-scale projects are regional projects collaborating with other East-African countries.

Transmission lines

- There are over seventeen projects ongoing aiming to upgrade and expand the transmission line network. Several of these projects still require funding. Opportunities exist in realizing the infrastructure development, providing equipment, technical support, projects design and training of technicians.
- Transmission network requires general improvement. MV and LV lines need to be shortened to reduce inefficiency and losses.

Substations

- Most operational substations are outdated and cause bad connections. The number of outages (which currently run at 36 hours a year) can be reduced through the upgrading of substations and improving linkages with the transmission network.
- In remote areas with poor grid connections, productive users and or public institutions could serve as substations. This would allow for connecting currently off-grid households and improve the connectedness of already on-grid households.

Smart Meters

- Non-payment rates of customers are rather high. An opportunity lies in the distribution of smart meters to avoid non-payment by large(r) customers.
- Accounting and record-keeping are a burdensome task and the processes are prone to mistakes. Smart meters can reduce financial errors resulting from miscalculations.

Awareness

- 6.5 percent of electricity generation is lost due to commercial losses. A large share of these losses is caused by illegally tapping electricity from the national net. Companies can collaborate with the government to raise awareness on the risks of energy theft. Illegally tapping energy can be extremely dangerous, especially when electricity is drained from MV or HV lines.

[54] For the distribution projects, 1,5 milion USD is provided by MinEcoFin (Rwanda), 73 million USD by AfDB, 3.4 million by the World Bank, 11 million by Enabel. About 46.4 million USD still needs to be raised.

5. Major trends in off-grid electrification

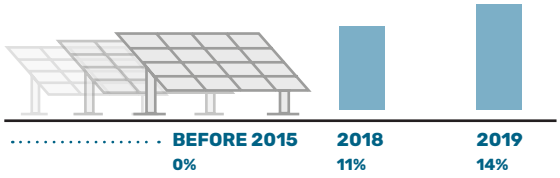
The off-grid sector in Rwanda is developing but progress has not been made as fast as in the on-grid sector. The off-grid sector should target rural areas because of the low connection rates and high connection fees. Moreover, off-grid electrification is supposed to target households rather than productive users. Only productive users located 800 meters or further from a grid infrastructure can be connected to an off-grid source. The assigned areas for off-grid expansion are visible in the NEP, which defines the target areas for off-grid sources.

Moreover, the Rural Electrification Strategy (RES) and NEP have delegated the responsibility for off-grid development to IPPs. The RES extensively describes the role of the private sector as a key player and the possibilities to obtain financial support from the government. The RES is divided into four programmes:

- Establishment of a mechanism to allow low-income households to access modern energy services through basic solar systems;
- Establishment of a risk-mitigation facility for the private sector to make sure solar products are available on an affordable tariff for the target group;
- Development of mini-grids by the private sector with a strict overview of the government, who identifies sites for the grids, and development of financial frameworks;
- Government continues to focus on EARP.

After the launch of the RES and NEP, there was an impressive increase in households, mainly rural, being connected to off-grid sources. This rapid increase was mostly realised through SHS and to a lesser extent by the more recent development of mini-grids. The government recognises the high costs of off-grid electrification remain problem since most target groups are low-income households with low consumption rates. Looking at the existing policies and future plans, main focus is on the development of SHS and more specifically, stand-alone solar systems.

CONNECTION TO AN OFF-GRID SOURCE[55]



SOLAR HOME SYSTEMS

The climate in Rwanda is suitable for SHS with slight seasonal variation: daily solar irradiation ranges from 4 kWh/m² in the north to 5.4 kWh/m² in the south of the country.[56] The Eastern and Southern Province have the highest potential for solar power. There are different types of SHS ranging from Solar Lighting System (SLS) powering two or more light bulbs and have a phone charging capability, to SHS powering two or more light bulbs and appliances such as a television, iron, microwave, or refrigerator.[57] Most Rwandans with an off-grid electricity connection use a stand-alone SHS; there is no connection to the grid whatsoever.

[55] MinInfra, 2018; REG, 2019.
[56] Get.Invest, n.d.
[57] Rwanda Beyond Connections, 2018.

Businesses looking to enter the Rwandan market for SHS, should follow strict governmental guidelines. All SHS on the Rwandan market are required to meet certain minimum standards. Businesses need to make sure their SHS product meets these criteria, which define 'basic access to energy.' Otherwise, their product does not enable Rwanda to achieve SDG 7. Systems which do not meet these standards cannot be imported. A few examples of requirements are specified below:

- Quality of the system: systems need a proof of conformity recognized under the International Electrotechnical Commission (IEC) Conformity Assessment and/or Lighting Global;
- Technical specification of lamps[58], solar PV panels[59], and batteries[60];
- Warranty: products below tier 1 (basic SLS) require at least one-year warranty, tier 1 has a minimum of two-year warranty (basic SHS), and tier 2 and above has a minimum of three-year warranty (more advanced SHS);
- Agreement between purchaser and supplier: it needs to cover responsibilities of both parties, resolution/complaint handling, after sales services and a timeline.

The private sector has introduced innovative business models to improve financial access of households to SHS. Service models seek to remove high upfront costs for customers. In 2016, 55.5 percent of the Rwandan population was living below the poverty rate earning 57–59 USD per month. Meanwhile, the price range for a medium-size SHS was 50–100 USD. The main business model is Pay As You Go (PAYG): this modality is used for 96 percent of off-grid SHS sales.[61] PAYG requires customers to make daily or weekly instalment payments (usually) through Mobile Money (MoMo). The SHS company has the ability to disable the system if the required amount has not been paid.[62] The PAYG system is designed to mitigate risks associated with giving loans to customers with no credit history; the prepaid system takes away the risk of non-payment of high costs.[63] Nonetheless, it seems difficult to keep default rates and non-payment low when households with lower and irregular incomes are reached.[64]

At the moment, SHS are distributed by both local and foreign private sector investors.[65] Many SHS companies are from Europe and North America. Most SHS kits are produced in China. A Dutch company, NOTS, is planning on moving assembly activities and subsequently, production of SHS to Rwanda.[66] Often these companies have received grants or lenient loans from development organisations, larger private companies or universities. Furthermore, the Rwandan government is developing two financial schemes to raise household access to SHS: a subsidy scheme targeting consumers and a support scheme targeting producers.

The SHS subsidy scheme for consumers is based on the Ubudehe categories. It targets households in tier 1, 2 and 3; no subsidies are provided to households in tier 4 and 5. Most support will be available for the most affordable SHS products developed for households in the lowest tier. The support plans were announced in 2019 but have not been implemented yet.

Figure 12. SOLAR LIGHTING PRODUCT SALES BY PAYMENT MODALITY (SOURCE: ENDEV, 2018)

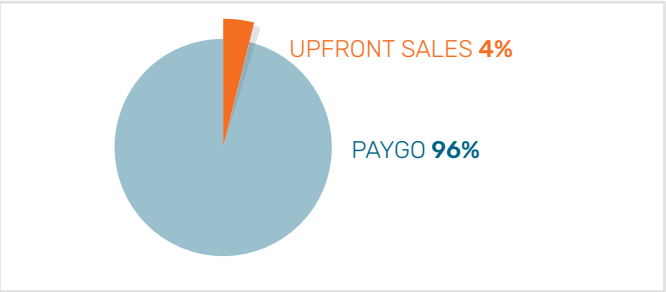
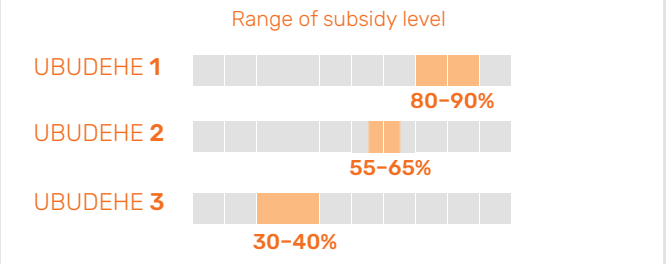


Figure 13. PLANNED TARGETED SUBSIDIES TO INCREASE THE AFFORDABILITY OF SOLAR HOME SYSTEMS (SOURCE: MININFRA, 2019)



In addition to the subsidy scheme for consumers, the government has developed financial support system for investors (IPPs) called the Scaling up Renewable Energy Program (SREP) fund. This programme has not yet been launched. It will offer the following ways of support[67]:

- Companies have access to risk mitigation facilities for SHS bought by households and productive users in Ubudehe tiers 2, 3 and 4.[68]
- Companies investing in SHS can acquire loans to invest in their SHS business.
- Households in Ubudehe tiers 2, 3 and 4 can get a loan from the Savings and Credit Cooperatives (SACCO) to buy a SHS. Loans are already being provided.[69]

[58] LED, >120 lumens, 2 W power consumption and >20,000 lifetime hours.
[59] Crystalline or Poly Si, 12/24/48 V and minimum 12-Watt Peak.
[60] Deep cycle, maintenance free, storage capacity of 60 Wh and depth of discharge of 80 percent.
[61] EnDev, 2018.
[62] Power Africa, 2019.
[63] Power Africa, 2019.
[64] EnDev, 2018.
[65] The following SHS companies are active in Rwanda: Aptech Africa (UG), Ared (IT/RW), Azuri (UK), BBOXX (UK), DASSY Enterprise (RW), Davis and Shirtliff (RW), Great Lakes Energy (RW), Ignite (UK/US), Mobisol (DE), Munyax (BE), NOTS solar lamps (NL), RENERG (DE), Serve and Smile LTD (RW) and Zola (US).
[66] NOTS, 2020.
[67] MinInfra, 2019.
[68] Facilities will be (partly) funded by the SREP. SREP has a total budget of 50 million USD fund assigned to rural electricity access expansion.
[69] It is expected households in Ubudehe tier 2 and 3 will no longer need loans once the subsidy scheme is introduced. Households in Ubudehe tier 4 cannot make use of the subsidy scheme and can continue to access loans.

An upcoming way by companies to finance off-grid electrification projects is international crowdfunding. In this way, companies raise the initial funds required to produce a high number of SHS systems, which can be donated to low income households. This trend has been visible throughout East Africa. In 2018, 19 USD million of funding for SHS in East Africa was supplied through crowdfunding, compared to 2.5 USD million in 2017.[70]

The main issues that arise with SHS are the limited purchasing power, customers' lack of understanding of the credit system, remaining uncertainty among the population with regard to the potential construction of grid connections, and increasing competition enabling customers to switch to cheaper alternatives.[71] These issues make it difficult for companies in SHS to become profitable. The first SHS companies entered the Rwandan market in 2014 and only recently in 2019–2020, some managed to break even.

MINI-GRIDS

There are three types of mini-grids: solar power, hydropower and diesel. The latter is the least popular because of the limited supply of diesel in remote areas, high operational costs and fossil fuel emissions. Therefore, the Rwandan government encourages private sector investors to develop hydro and solar mini-grids. Mini-grids are considered a potential source of energy for households and businesses located in the most remote areas. These consumers are highly unlikely to get a grid connection. Companies needed to wait for the finalisation of the NEP, in which the zones for mini-grid development were determined. Nowadays, mini-grid permits are still limited and expensive.[72] It is obligatory for companies to do extensive market research to assess potential customers' electricity demand prior to the installment of a mini-grid.

The market of mini-grid supply in Rwanda is still in the early stages of development. There are currently six companies operating in Rwanda (Table 2).

Mini-grid development requires a high initial investment and seems more financially challenging in comparison to SHS in Rwanda. Installment and material costs are high, whilst energy consumption rates and number of customers are low. The price of a mini-grid producing one kW range from 4,000–7,000 USD (including installment and transportation) and costs per customer range from 250–650 USD.[73] Some companies manage to reduce costs per consumer connecting more households to a mini-grid; MeshPower has connected on average 35 households to one mini-grid.

Table 2. MINI-GRID COMPANIES OPERATING IN RWANDA (SOURCE: ENDEV, 2018)

Company	Technology	Location	Size	No of households connected	Grant support	Headquarter locations
Neseltec	Solar	Kirehe district	30 kW	183	EEP	Rwanda
ECOS	Hydro	Muhanga district	11 kW	303	EnDev	Rwanda
RENERG	Solar	Nyamasheke district	30 kW	121	USADF	Germany
MeshPower	Solar	Multiple in Bugesera and Ngoma districts	1 kW each, 57 sites	2,046	EEP & EnDev	USA
MeshPower	Solar	Bugesera district	4 kW AC/DC	78	None	USA
Absolute Energy	Solar	Gatsibo district	50 kW	505	EnDev	UK
ARC Power	Solar	Nyamata, Bugesera district	20 kW	200	Renewable Energy Performance Platform (REPP)	UK/Rwanda
ARC Power	Solar	Nyamata, Bugesera district	40 kW	290	Renewable Energy Performance Platform (REPP)	UK/Rwanda

[70] Power Africa, 2019.
[71] EnDev, 2018.
[72] RURA, 2015.
[73] EnDev, 2018. This number is based on an average monthly consumption of 1 kWh per rural household in Rwanda.

Nonetheless, it seems unlikely mini-grid electricity will be affordable for low-income households in the absence of government subsidy schemes or other (donor) financing systems. The two main mechanisms used to finance mini-grid development in Rwanda are grants and debt financing. Most companies finance their operations through grants, which cover 40-70 percent of the investment costs. Grants are a type of results-based financing (RBF) creating an initial risk for mini-grid developers.

Furthermore, the Rwandan government has designed a subsidy and financial support system for mini-grids in the RES. The system would provide risk mitigation facilities for mini-grid investors, targeting low-income households and productive users.[74] Companies will have the possibility to acquire loans to invest in their mini-grid business. When a mini-grid project is unsuccessful, the government shares the risk of failure with private investors (IPPs).[75] For example, a mini-grid project might fail due to environmental reasons: the source of a mini-hydro source can run dry following changing rain patterns. This subsidy and financial support system has yet to be launched.

Solar mini-grids and nano-grids are 'standalone' energy distribution networks powered by solar panels. Standalone means they are not connected to the national grid.[76] A major advantage of solar mini-grid systems is the flexibility: they can be installed anywhere with sufficient solar potential. The greatest disadvantage is the short lifespan of solar panels, which need to be replaced approximately every ten years. Currently, there are six sites with solar mini-grids and 57 sites with nano mini-grids.[77] In total, these mini-grids connect 3,726 households. 1 kW nano-grid systems can supply an average of 35 households. Full potential of 1 kW per hour (kWh) can be reached under optimal circumstances.

Hydro mini-grids or pico-hydro[78] grids are powered by a source of water with a sufficient, constant flow of water. At the moment, there is one operational hydro mini-grid in Rwanda connecting 303 households. The advantage of hydro mini-grids is the long life-span and low maintenance. The disadvantages are the dependence on high material costs, logistics and water (rainfall). The latter disadvantage is most problematic: climate change seems to result in shorter, more intense intervals of rainfall in Rwanda.

[74] MinInfra, 2019.
[75] Facilities will be (partly) funded by the Scaling Up Renewable Energy Program in Low Income Countries (SREP). SREP has a total budget of 50 million USD fund assigned to rural electricity access expansion.
[76] Nano-grids can generate 1 kW or less, and mini-grids generate above 1 kW electricity.
[77] All 57 nano-grids were developed by Mesh Power.
[78] Pico-hydro grids are those mini-grids with a power of less than 5 kW.

6. Opportunities in off-grid electrification

There are major market opportunities in off-grid electrification in Rwanda considering the urgent need to connect a high number of remote households: so far only fourteen percent of the Rwandan population has been connected to an off-grid source, meaning another 34 percent (approximately 1.2 million households) still need to be connected by 2024. Furthermore, the government has put the private sector in the driving seat to realise quick expansion. Nonetheless, it remains a challenge to provide low-income households in remote, rural areas with access to energy. The main issues hampering the rapid distribution of SHS and mini-grids are the low purchasing power and energy consumption rates of Rwandan customers. Eventual returns on investment remain unclear. Some SHS companies have managed to break-even after 5–6 years of operations in Rwanda. All mini-grid companies are still dependent on loans and grants. However, there are planned and ongoing government and donor programmes to provide low-income households with access to energy via SHS or mini-grids. Off-grid electrification is a domain of aid and trade solutions. Innovative concepts are needed taking a multi-stakeholder approach engaging the private sector, government and development organizations.

SOLAR HOME SYSTEMS

Product development

- In 2016, 55.5 percent of the Rwandan population was living below the poverty rate earning 57-59 USD per month. Meanwhile, the price range for a medium-size SHS sold on the local market was 50–100 USD.
  - Improve the cost-efficiency of SHS products and especially, reduce operating expenses to increase affordability.
- Most households are unable to afford their own SHS, but they might be able to share one.
  - Explore opportunities to create SHS that can be shared by multiple households in terms of design and business model.
- There are productive users (such as shops and small factories) who can purchase higher electricity generating SHS kits. These users could serve as a host and provide surrounding households with electricity services.
  - Identify unconnected productive users, who could become hosts for surrounding households.

Local production

- Most SHS kits are currently being sourced from China. One company is investigating the option to set up a local assembly or production line. Preference for 'made in Rwanda' products can provide companies with access to investment incentives.
  - Explore opportunities to assemble or produce SHS kits locally.
- There are safety issues with affordable SHS kits on the market: stronger equipment and wires are needed to improve the quality of systems.
  - Develop stronger SHS products focusing on wiring.

Electricity Storage

- Most households do not have access to energy storage facilities, while energy consumption rates peak at night.
  - Explore ways to improve storage capacity and to enable the sharing of storage capacity among neighbors or productive users nearby.

Payment method

- WTP for SHS increases when households are allowed to pay in installments.
  - Use innovative business models based on a PAYG system or provide micro-loans to households.
- Customer loyalty is limited, which results in high transaction costs.
  - Improve contracts and customer relations to avoid customers from switching to competitors without notice.

Financial model

- Households are unable to pay the actual price of SHS and the government has limited options of support. Start-up and operational costs can potentially be covered by donors, private investors, universities. These actors have proved a reliable source of income for other companies.
  - Tap into alternative financial flows to support the business model.
- Crowdfunding is an upcoming financing source, which has recently gained popularity. Companies raise the initial funds required to produce a high number of SHS systems, which are subsequently donated to low income households.
  - Launch a crowdfunding initiative to scale up a business.
- SREP fund and Ubudehe subsidies will be launched soon providing funds to reach low-income households.
  - Benefit from financial support provided to SHS companies and consumers.

MINI-GRIDS

Product development

- International market prices of solar PV panels are falling. Opportunities in the mini-grid sector are growing for companies that manage to reduce their production costs.
  - Improve cost-efficiency thanks to reduced costs of inputs.
- Develop partnership strategies between companies to lower the cost of mini-grid development.

Production and installation

- Production costs for mini-grids are currently very high.
  - Explore opportunities for producing kits and mini-grids locally to reduce costs.
- Installation and maintenance costs can be reduced following the increasing availability of skilled technicians in Rwanda.
  - Provide training to increase the number of qualified technicians.

Payment method

- The most suitable payment methods for households connected to a mini-grid are PAYG and payments in installments.
  - Introduce flexible tariffs that allow customers to switch to higher or lower tariffs whenever necessary to reduce non-payment rates.

Financial model

- Financing of mini-grids will likely require blended public, donor and private funds. Close collaboration with government institutions and donors is needed to design suitable blended finance mechanisms and mitigate investment risks. The Rwandan government is willing to guarantee for around 50 percent of the investment in case of failure.
  - Tap into blended finance to fund mini-grid development engaging donors, public and private actors.
- Today's competitive market makes it difficult to generate investments. Hence, it is necessary to look into alternative financing mechanisms.
  - Use crowdfunding to raise the finance for the mini-grid.
- Most households cannot afford the high energy prices. Financial support for SHS companies will become available via the SREP fund (expected in 2021) and can reduce costs for households. SREP will fund a maximum of 37 percent of total financing costs.
  - Benefit from public financial support provided to SHS companies and consumers.

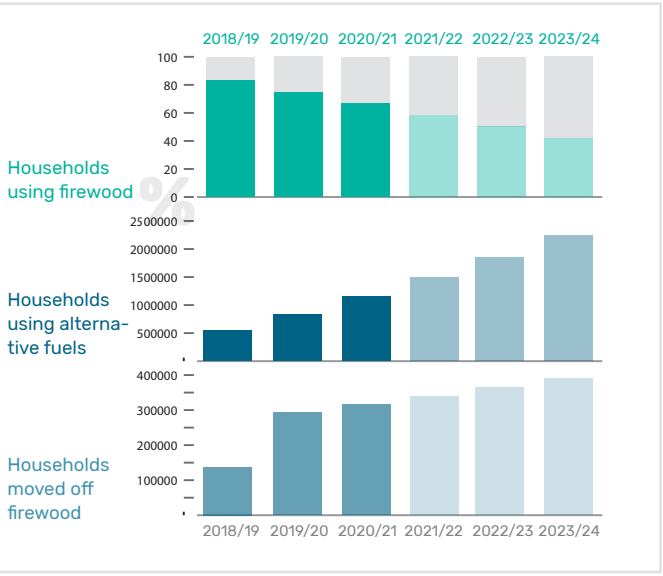
7. Major trends in clean cooking

SDG 7 *'access to affordable, reliable, sustainable and modern energy'* also includes access to clean cooking facilities. The transition to clean cooking is important because traditional cooking has a severe negative impact on the natural environment and public health. Traditional cooking requires the use of biomass, mostly firewood and charcoal, of which the sourcing is a major cause of deforestation.[79] Also, biomass is a highly polluting and inefficient energy source causing up to 25 percent of black carbon emissions. Moreover, traditional stoves cause household air pollution and pose security risks; especially for women who prepare the family meals. Cooking facilities are qualified as 'clean' on the basis of World Health Organization (WHO) standards for household air pollution levels based on the emission levels of particulate matter and carbon monoxide. Available options for clean cooking include electricity, gas, ethanol, solar and high performing biomass stoves.

Traditionally, Rwandans only used wood as their cooking fuel. Between 1990 and 2005, the use of wood was 60 percent.[80] Moreover, Rwandans consume a high amount of beans, which have a long cooking time. There is still little awareness with regard to the health problems caused by traditional cooking practices. Nowadays, even though alternatives like Liquefied Petroleum Gas (LPG) are available on the market, people still prefer to use wood because of tradition. This is especially the case in rural areas.

At this moment, 98 percent of the Rwandan population still uses biomass for cooking: wood, charcoal and dung.[81] 91 percent of households still rely on the most inefficient type of biomass: firewood, which households collect every day for 40-80 minutes. On average, households consume around 1.8 tons of firewood per year.[82] The total value of wood used for cooking is difficult to measure because it is gathered rather than bought. 80 percent of the Rwandan population uses charcoal as cooking fuel. The market of charcoal (about 150.000 tons) accounts for two percent of GDP, with a total value of 50 million USD.[83] The Rwandan government aims to reduce number of households dependent on traditional cooking technologies by fifty percent by 2024.[84] Furthermore, MinInfra has developed the Biomass Energy Strategy to reduce the amount of biomass used in Rwanda. The strategy focuses on the improved management of wood biomass resources, promotion of alternative fuels and efficiency of biomass usage.

Figure 14. CHANGES IN BIOMASS USE AND ALTERNATIVE FUEL ACCESS 2018–2024 (ESSP, 2017)



[79] In Rwanda, deforestation causes erosion, landslides and floods.
[80] National Tree Foundation, n.d.
[81] FAO, 2019.
[82] FAO, 2019.
[83] Global Alliance for Clean Cookstoves Rwanda Market Assessment Sector Mapping, 2012.
[84] MinInfra, 2018.

There are many types of Improved Cookstoves (ICS) of varying quality in terms of health and safety standards. The Global Alliance for Clean Cookstoves (GACC) has defined tiers (0-5) to rank the quality of stoves based on the WHO guidelines. Tier 0 stoves are of the lowest quality including firewood stoves. Tier 5 stoves are the highest quality including LPG, solar and electric stoves. Improved biomass cooking stoves belong in tier 4: only tier 5 stoves are considered clean on the basis of WHO guidelines. Nonetheless, tier 4 stoves can be used as transitional solutions being much safer than traditional stoves.[85] The replacement of biomass with alternative clean cooking fuels (LPG and electricity) is usually too expensive for the low-income groups. Only 6.5 percent of the Rwandan population currently uses different types of stoves mixing biomass and clean fuels.

In Kenya, the uptake of ICS has been much faster (Figure 16). This increase can be explained by the fact that Kenya is a LPG-producing country, which makes LPG distribution cheaper and widely available. Moreover, the usage of Pay-As-You-Go and smart meters for LPG is widespread, which makes this fuel more affordable for low-income groups. Kenya also has multiple factories where ICS are being produced. Also, there is an ICS testing centre in Kenya where official certificates are obtained for produced cookstoves. Rwandan producers have to send stoves to Kenya for testing to obtain certification.

Above: Firewood-based ICS from BURN Kuniokoa (Kenya, USA) on the left; Charcoal-based ICS from Ecozoom (Kenya, USA) on the right.
Below: Charcoal-based ICS from GGS (Geni Green Solutions, Rwanda)

[85] GACC, 2019.

Figure 15. SEGMENTATION OF ANNUAL CHARCOAL MARKET VALUE IN 2008 (MILLION USD)

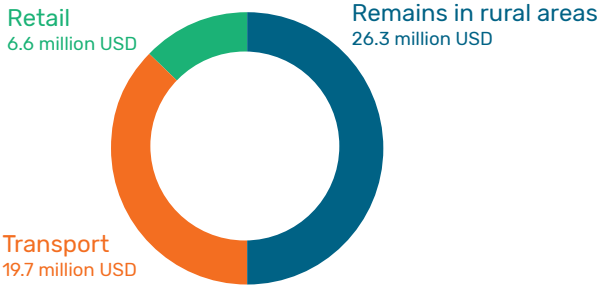


Figure 16. ACCESS TO CLEAN FUELS AND TECHNOLOGIES FOR COOKING (% OF POPULATION) (SOURCE: WORLD BANK, 2019)

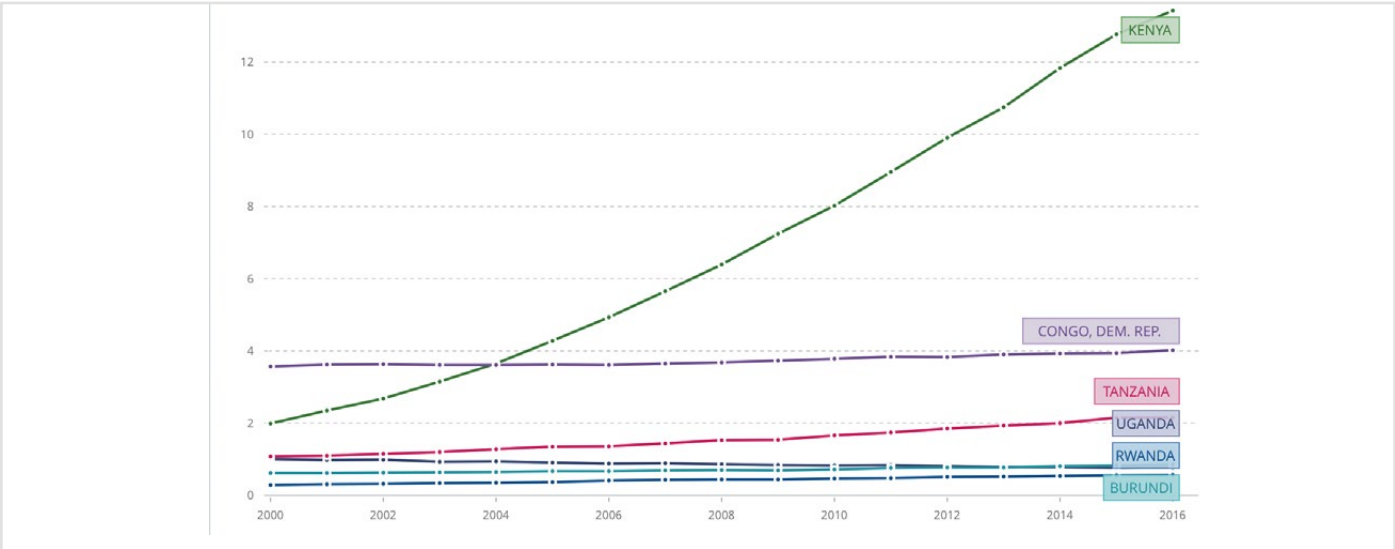


Figure 17. MULTI-TIER FRAMEWORK FOR ICS AND CLEAN COOKING ALTERNATIVES (SOURCE: RWANDA BEYOND CONNECTIONS, 2018)

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
COOKING EXPOSURE	**Emission: Fuel**	Firewood, dung, twigs, leaves, rice husks, processed biomass pellets or briquette, charcoal, kerosene				Biogas, ethanol, high quality processed bio-mass pellets or briquettes	Electricity, solar, LPG
	Emission: Stove design	Three-stone fire, tripod, flat mud ring, traditional charcoal stove	Conventional or old generation ICS	ICS + chimney, rocket stove or ICS + insulation	Rocket stove with high insulation or with chimney, advanced insulation charcoal stoves	Rocket stove with chimney (well sealed), rocket stove gasifier, advanced secondary air charcoal stove, forced air	
	Ventilation: Volume of kitchen	Less than 5 m³	More than 5 m³	More than 10 m³	More than 20 m³	More than 40 m³	Open air
	Ventilation: Structure	No opening except for the door	1 window	More than 1 window	Significant openings (large openings below or above height of the door)	Veranda or a hood is used to extract the smoke	Open air
	Ventilation level		Bad		Average	Good	
	Contact time	More than 7.5 hours	Less than 7.5 hours	Less than 6 hours	Less than 4.5 hours	Less than 3 hours	Less than 1.5 hours
			Bad		Average	Good	
COOKSTOVE EFFICIENCY	**ISO's voluntary performance targets (TBC)**	Less than 10%	More than 10%	More than 20%	More than 30%	More than 40%	More than 50%
CONVENIENCE	**Fuel acquisition (through collection or purchase) and preparation time (hours per week)**	More than 7 hours		Less than 7 hours	Less than 3 hours	Less than 1.5 hours	Less than 0.5 hour
	Stove preparation time (minutes per meal)	More than 15 minutes		Less than 15 minutes	Less than 10 minutes	Less than 5 minutes	Less than 2 minutes
SAFETY OF PRIMARY COOKSTOVE		Serious accidents over the past 12 months				No serious accidents over the past year	
AFFORDABILITY		Levelized cost of cooking solution (fuel) more than 5% of household income				Levelized cost of cooking solution (fuel) less than 5% of household income	
FUEL AVAILABILITY		Primary fuel available less than 80% of the year				Primary fuel is readily available 80% of the year	Primary fuel is readily available throughout the year

Table 3. TIER PERFORMANCE TARGETS FOR COOKSTOVES (SOURCE: GACC, N.D.)

Tier	Thermal Efficiency (%)	Carbon Monoxide Emissions (gram/ megajoule delivered)	Fine Particulate Matter Emissions (milligram/ megajoule delivered)	Safety (score)	Durability (score)
5	≥50	≤3.0	≤5	≥95	<10
4	≥40	≤4.4	≤62	≥86	<15
3	≥30	≤7.2	≤218	≥77	<20
2	≥20	≤11.5	≤481	≥68	<25
1	≥10	≤18.3	≤1031	≥60	<35
0	<10	>18.3	>1031	<60	>35

Rwanda already has a group of ICS suppliers.[86] The government works with several suppliers whose product quality ranges from tier 1 to 5.[87] Businesses are required to present a certificate stating the quality of the stoves.[88] The main target of the government is to reduce the number of households using traditional cooking stoves whilst raising the number of households using an improved biomass cookstove. Improved biomass cookstoves are more energy efficient and producing less emissions. The government appeals to the private sector for the distribution of ICS recognising the major role of businesses to reach biomass reduction targets. The objective of Rwanda is to distribute 300,000 ICS per year.

The main issue for the distribution is the affordability of the stoves. Businesses should carefully consider the affordability of their product (stove) and cooking fuel. Households spending the most time collecting cooking fuels a week (around 130 minutes) are most willing to pay for a biomass-based improved cook stove.[89] However, households are only able to spend approximately 3,000 RWF (3.20 USD).[90] Moreover, companies need to develop alternative business models or acquire external financial support because most households are unable/ unwilling to pay upfront. There are several options: installment payments are the most common. Companies have also experimented with fixed purchasing agreements of inputs; pellets or briquettes. Companies selling ICS using pellets or briquettes will likely need to set up a factory to produce these themselves.

Considering these challenges, the distribution of ICS will require close collaboration between the government, development partners and private sector. The objective of the Rwandan government is to distribute 300,000 ICS per year. It appeals to the private sector for the distribution of ICS recognising the major role of businesses to reach its biomass reduction targets. Hence, the government is looking into options to provide (financial) support to customers and/or suppliers. Future support will likely be provided on the basis of the target group and associated Ubudehe categories. Also, the government designs incentives for those companies willing to produce locally or that are willing to move its headquarters to Rwanda.

Table 4. NUMBER OF INCREASE IN ICS EACH YEAR (2017/18 IS BASE YEAR) (SOURCE: MININFRA, 2018)

Year	ICS
2017/18	1,839,684 ICS disseminated
2018/19	137,219 ICS disseminated
2019/20	293,191 ICS disseminated
2020/21	315,490 ICS disseminated
2021/22	339,127 ICS disseminated
2022/23	364,112 ICS disseminated
2023/24	390,544 ICS disseminated

[86] Two companies, Ignite and Geni Green Solutions, are operating in Rwanda (and until recently Inyenyeri). There are several other companies, which are still in their 'initiation' phase.

[87] No further information on these suppliers is available when writing this report. However, two investors, GGS and SNV were interviewed. SNV is a Dutch NGO exploring opportunities in the ICS sector. Geni Green Solutions is a Kigali-based company selling tier 1–2 ICS especially in Gasabo district in Kigali, with around 6000 customers at the moment.

[88] Locally produced stoves need to be transported to Kenya since this is the nearest place for testing the quality of stoves and acquiring a certificate.

[89] Survey included 45 households living in Kigali.

[90] Rwanda Beyond Connections, World Bank, 2017.

8. Opportunities in clean cooking

"The private sector will play a prominent role in delivering access to clean cooking technologies. Government will engage with the private sector and promote investments through establishing an appropriate enabling environment. Barriers to entry and bottlenecks will be identified and reduced or removed, resulting in competition and innovation in both technologies and business models." (ESSP)

Product development

- Many ICS companies target the upper market segment, whilst, low-income households are unable to afford tier 4 and 5 stoves. A market entry with an alternative, improved tier 0–3 cooking stove provides a larger consumer base. These stoves can offer a transitional solution.
  - Develop new affordable products for low-income households.
  - Upgrade existing products with insulation to increase heat efficiency.
  - Sell second-hand products.
- Existing ICS are still produced at high cost per unit. The most cost-efficient products can count on the highest subsidies from the Rwandan government.
  - Attempt to reduce production costs using second-hand materials and focusing on high volumes producing in bulk.
- Companies can focus on selling less efficient stoves (WHO tier 1–3).

Alternative cooking fuels

- Availability of pellets and briquettes is limited, and these fuels are sometimes imported. Companies should consider setting up their own production facility. The government is willing to facilitate access to raw materials for factories (e.g. providing forest concessions to pellets makers).
  - Investigate the possibility to produce fuels locally to reduce usage costs of tier 4–5 stoves.
  - Investment in the controlled and sustainable production of biomass and clean fuels.
- Most Rwandans still use wood or charcoal which harms our natural environment because the costs of clean cooking fuels are still too high. Business might enable customers to exchange raw biomass for pellets or briquettes. Alternatively, they can obtain discounts when providing raw biomass.
  - Develop an inclusive business model with solutions for low-income households.

Financial model

- Low-income households are unable to pay the full price of an ICS at once. The introduction of innovative and alternative payment methods such as PAYG could provide a viable business model.
- Government support is provided to achieve other goals related to SDG 7 'access to energy' improving the financial access of low-income households. Initiatives will be launched to support SHS and mini-grid companies and consumers.
  - Advocate for a subsidy system based on Ubudehe categories to make payment of ICS feasible focusing on rural areas and female-headed households.
- Producers of cooking stoves are confronted with high start-up costs and working capital needs.
  - Provide financial support (grants or subsidies) to manufacturers and distributors (e.g. by establishing working capital facilities).

Awareness

- Cooking practices are linked to strong cultural and behavioral values in Rwanda. Consequently, it is difficult to convince people to change their ways introducing new technologies in both urban and rural areas.
  - Contextualise sales strategies and awareness campaigns to local values.

TRAIDE

Annexe 1 | Overview of categorized donors for off-grid electrification, on-grid electrification and clean cooking

These companies/organisations are currently providing (financial) support to programs in Rwanda or used to support projects in the past.

ON-GRID ELECTRIFICATION

AfDB
Arab Bank for Economic Development in Africa (BADEA)
China Exim Bank
Development Bank of Rwanda (BRD)
Emerging Africa Infrastructure Fund
Enabel
Energy and Environment Partnerships Trust Fund (EEP Africa)
European Union (EU External Action)
Finnfund
FMO
JICA
KFW Entwicklungsbank
Norfund
STEG International
USAID/Power Africa
World Bank

OFF-GRID ELECTRIFICATION

Acumen Capital Partners
Africa Enterprise Challenge Fund
Development Bank of Rwanda (BRD)
DFID
Energise Africa
Energising Development (EnDev)
Energy Access Ventures
Energy and Environment Partnerships Trust Fund (EEP Africa)
Fonerwa
GIZ
KawiSafi
Shell Foundation
Stichting DOEN
UNIDO
USAID/Power Africa
World Bank

CLEAN COOKING

Acumen Capital Partners
Africa Enterprise Challenge Fund
Energising Development (EnDev)
Energy and Environment Partnerships Trust Fund (EEP Africa)
EU External Action
Fonerwa
Osprey Foundation
World Bank (Carbon Initiative for Development)

TRAIDE

Annexe 2 | Development organisations supporting ongoing energy projects in Rwanda

ENERGISING DEVELOPMENT PARTNERSHIP (EnDev) OF I.A., GIZ, DUTCH MINISTRY OF FOREIGN AFFAIRS AND UKaid

The EnDev partnership has two phases: the first phase was operational between May 2006 and September 2009. The current second phase is from October 2009 to December 2020. The total budget of this project is 19.4 million USD. The objective of this project is to supply 1,021,430 people with energy for lighting and electrical appliances and 20,544 people with cooking energy. This project was funded by organisations including GIZ, the Ministry of Foreign Affairs of the Netherlands and UKaid.

EUROPEAN UNION (EU)

In 2014 the government of Rwanda and European Union signed a financial agreement of 23 million euros to upgrade Rwanda's electricity network systems to reduce losses of already scarce power produced. An example of a project done in cooperation with the EU, is the Jabana Power Substation at Gasabo. EU granted 6 million euros to Mobisol for prepaid Energy 'Rent to own' solar Home systems (off grid) project. The goal of the project is to provide solar power systems to more than 70,000 households, and 100 schools in rural areas.

AFRICAN DEVELOPMENT BANK (AFDB)

In 2018 AfDB signed a loan contract of 229.2 million euros to support electricity supply and access to electricity. This loan included 181 million USD of loans from AfDB and 70 million USD from the African Development Fund. This is a special fund within the AfDB Bank Group focused on economic and social development in least developed African countries. The program will enable connections to 193,000 households on-grid and 124,000 off-grid.

In 2015 Rwanda signed a loan contract with AfDB of 138 million USD for the regional Ruzizi III hydropower plant project. This project is part of the Program for Infrastructure Development in Africa (PIDA) and involves other EAC countries like Burundi and DRC.

In 2011 AfDB provided a loan worth 25 million USD for the development of the methane gas on-grid power plant KivuWatt phase one.

FMO

In 2011 FMO provided a loan worth 31.5 million USD for the development of the methane gas on-grid power plant KivuWatt phase one.

In 2014 FMO funded roughly 10.6 million USD for the development of the on-grid solar plant Agahozo-Shalom owned by Gigawatt Global Rwanda Ltd.

RWANDA RENEWABLE ENERGY FUND OF THE WORLD BANK

The REF plans to help 1.8 million people to access electricity off grid through its support to government projects within the RES. The projects started in 2017 after the government of Rwanda and the World Bank signed the 48.9 million USD SREP fund.

POWER AFRICA OF USAID

Power Africa mainly provides the development of on-grid projects done by its partners. The organisation supports interested private investors linked to Power Africa and development banks willing to provide loans or grants. Examples of developed projects are the Hakan peat to power (on-grid power plant, 80MW), SoEnergy diesel generation plant and the Agahozo-Shalom on-grid solar plant.

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TRAIDE