ENERGIZING RWANDA'S DEVELOPMENT

OPPORTUNITIES AND STRATEGIES FOR CATALYZING PRODUCTIVE USE OF ENERGY

ESMAP Energy Sector Management Assistance Program

THE WORLD BANK IBRD • IDA

SUSTAINABLE ENERGY FOR ALL

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UBUMWE - UMURIMO - GUKUNDA IGIHUGU

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Acknowledgments

This report aims to assess the potential of productive use of energy (PUE) in Rwanda by bridging knowledge gaps on market actors, products, and the market environment and providing recommendations for scaling up PUE technologies to enhance economic and social welfare. The project is led by the World Bank in close collaboration with Sustainable Energy for ALL (SEforALL), which financed and managed the pilot implementation of selected high-potential PUE technologies.

The report was prepared under the overall guidance of Sahr Kpundeh (Country Manager for Rwanda) and Erik Fernstrom (Practice Manager for East Africa Energy). The project team was led by Yabei Zhang (Senior Energy Specialist) and comprised Clementine Umugwaneza (Energy Specialist), Bryan Koo (Energy Specialist), Arun Singh (Energy Specialist), and Unurtsetseg Ulaankhuu (Energy Specialist Consultant). The SEforALL team included Tom Rwahama, Alice Uwamaliya, and Grace Busingye. EED Advisory, in partnership with CLASP, acted as the consultants for the report. The consultant team was led by Murefu Barasa and comprised Martin Kitetu, Martha Wakoli, Michael Maina, Alois Mbutura, Ann Kahihia, Ruth Anyango, and Alisa Reiner.

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ACRONYMS AND ABBREVIATIONS

AC	alternating current
ACES	Africa Centre of Excellence for Sustainable Cooling and Cold Chain
ASCENT	Accelerating Sustainable and Clean Energy Transformation Program
BRD	*Banque Rwandaise de Développement* (Development Bank of Rwanda)
CAGR	compound annual growth rate
CKD	complete knock-down (kit)
DC	direct current
EAQIP	Energy Access and Quality Improvement Project
EARP	Energy Access Roll-out Program
EDCL	Energy Development Corporation Limited
E4I	Energy 4 Impact
EPD	Energy Private Developers Association
ERA	Uganda Energy Regulatory Authority
ESMAP	Energy Sector Management Assistance Program
ESSP	Energy Sector Strategic Plan
EUCL	Energy Utility Corporation Limited
EUEI	European Union Energy Initiative
GDP	gross domestic product
GEF	Global Environment Facility
GIZ	German Agency for International Cooperation
GOGLA	Global Off-Grid Lighting Association
ICE	internal combustion engine
IDP	internally displaced person
IEC	International Electrotechnical Commission
IRR	internal rate of return
LPG	liquefied petroleum gas
MEPS	minimum energy performance standard
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and Economic Planning
MINICOM	Ministry of Trade and Industry
MININFRA	Ministry of Infrastructure
MSME	micro-, small-, and medium-sized enterprise
NISR	National Institute of Statistics Rwanda
PUE	productive use of energy
RBF	results-based financing
RDB	Rwanda Development Board
REF	Rwanda Renewable Energy Fund
REG	Rwanda Energy Group
RSB	Rwanda Standards Board
RRA	Rwanda Revenue Authority
RURA	Rwanda Utilities Regulatory Authority
RWF	Rwandan franc
SACCO	savings and credit cooperative
SKD	semi-complete knocked down (kit)
SNV	Netherlands Development Organisation
TAM	total addressable market
TSM	total serviceable market
TVET	technical and vocational education and training

Executive Summary

Rwanda is among the fastest growing economies in Africa. Over the past two years, annual growth in its gross domestic product (GDP) exceeded 8 percent, nearly twice the average for Sub-Saharan Africa. This growth aligns with the Rwandan government's goal of transitioning the country from an agricultural-based economy to one driven more by industry and services. Over the past eight years, Rwanda, along with six other countries in the region, achieved or surpassed required progress levels on electricity access. By 2022, the country's electrification rate stood at approximately 61 percent through grid-based (47 percent) and off-grid (14 percent) connections. In its progress toward achieving universal access, the government regularly reviews electrification targets and activities.

With the support of development partners, the government is increasingly shifting its focus toward leveraging electricity services to spur economic development and job creation. Over the past 15 years, the World Bank has consistently partnered with the Government of Rwanda to improve energy sector indicators through such initiatives as the Electricity Access Scale-up and Sector Wide Approach Development Project (EASSDP); the Rwanda Electricity Sector Strengthening Project (RESSP); the Rwanda Renewable Energy Fund (REF); the Rwanda Energy Access and Quality Improvement Project (EAQIP); and the Accelerating Sustainable and Clean Energy Transformation (ASCENT) Program, approved in 2023. The government's current Energy Sector Strategic Plan (ESSP), which is being updated for 2024/25–2029/30, aims to achieve universal coverage for productive energy users through 52 percent on-grid and 48 percent off-grid solutions.

The World Bank, in collaboration with Sustainable Energy for All (SEforALL), conducted this study to assess Rwanda's potential in the productive use of energy (PUE). The aim was to bridge knowledge gaps on market actors, products, and the market environment and provide recommendations for scaling up PUE technologies. Key objectives were to assess the potential electricity demand of Rwanda's productive energy users (grid-based, off-grid, and non-electrified), examine barriers that hinder their uptake of high-potential PUE technologies, and propose financial and technical interventions to overcome them.

Study Design and Methods

Conducted in four phases, the study achieved its objectives utilizing extensive primary and secondary data collected from a wide variety of actors across the PUE ecosystem. These included government agencies; development partners; PUE technology manufacturers, distributors, and retailers; and end users. Data collected in the early phases of the study included face-to-face surveys with a sample of 315 out of 9,446 productive users listed by the Rwanda Energy Group (REG); 8 focus group discussions (FGDs) with users of high-potential PUE technologies; and 26 key informant interviews (KIIs) with PUE technology suppliers, relevant government and development agencies, and the Development Bank of Rwanda (*Banque Rwandaise de Développement*, BRD). The third phase of the study, funded by SEforALL, piloted high-potential PUE technologies selected by this study with 12 entrepreneurs across 4 districts. Key findings gleaned from the field-testing, presented as case studies in chapter 5, are summarized in box ES.1.

Review of Policies and Initiatives

Rwanda's policy framework has made significant strides toward achieving universal energy access for productive users. Vision 2050 and the National Strategy for Transformation (NST1), which aim for the country to achieve middle-income status by 2035 and high-income status by 2050, identify priority sectors to benefit from improved electricity services (e.g., agriculture, mining, manufacturing, information and communication technology [ICT], and commercial premises). To ensure coordination among sector stakeholders, the NST1 includes specific targets and a robust monitoring and evaluation (M&E) framework, with oversight provided by the Ministry of Infrastructure (MININFRA). While not unique in the region, these documents signal clear intentions to encourage the private sector's active involvement in national initiatives. Sector-specific plans, including the Irrigation Master Plan (IMP 2020), National Cooling Strategy (NCS 2019), and Strategic Paper on Electric Mobility Adaptation (2021), offer detailed goals and timelines that support national strategies.

Recently completed and ongoing pilot initiatives have provided valuable insights on scaling the adoption of existing PUE technologies. Energy 4 Impact (E4I), for example, has worked to develop Rwanda's solar irrigation market by supporting new financing and farmer training, and the InspiraFarms cold room pilot has addressed post-harvest losses. Other pilots of new and emerging technologies include the African Development Bank's Green Mobility Facility for Africa (GMFA). Key takeaways from these and other pilots include the need to support cash-constrained PUE suppliers with technical and financial support and reduce end users' up-front costs through such financing models as pay-as-you-go (PAYG).

Analysis of Current Users

To select the high-potential PUE technologies, the study team first surveyed a representative sample of productive energy users listed in the Rwanda Energy Group (REG) database. These were distributed across 23 productive use categories in the agriculture, industry, and services sectors. More than 86 percent of users are connected to the main grid; over 8 percent use a rooftop solar system or solar home system (SHS) kit, 1 percent use a generator or battery, and 4 percent have no grid connection. Over 96 percent are connected through grid-based or off-grid solutions; however, more efforts are needed to electrify schools (e.g., preschools and primary and secondary schools), cell offices, and health posts. Aside from lights, the most commonly owned appliances reported across sectors are computers, printers, and mobile chargers. Respondents in the agriculture sector expressed a desire for water pumps, coffee processing equipment; those in the industry sector mentioned the need for woodworking and welding machines, while those in the services sector identified the need for refrigerators and electric ovens.

The study team found that unit price is the most significant factor influencing users' consumption of electricity. Based on the 23-category classification of the REG, the study team analyzed PUE enterprises' current electricity consumption and modeled how it would change under three scenarios: (1) universal access to electricity, (2) quality and reliability of supply, and (3) unit price of electricity. The results indicate that consumption would rise by 15 percent with universal, grid-tier access; by 20 percent with improved reliability; and by 62 percent if electricity tariffs were reduced by 15 percent. This suggests that tackling Rwanda's affordability issue through tariff reductions would unlock a significant amount of latent electricity demand.

For productive thermal energy—mainly cooking and water heating—more than half of the survey respondents reported reliance on firewood. Electricity is used by 20 percent of respondents, followed by liquefied petroleum gas (LPG) (5 percent), charcoal (3 percent), and kerosene (2 percent). These findings highlight the need for increased efforts to transition users from traditional to modern fuels, in accordance with ESSP targets. The study suggests that promoting electric cooking within institutions, possibly through a tariff intervention similar to the ones successfully implemented in neighboring Uganda, could boost adoption.

Ranking High-Potential Technologies

To select high-potential PUE technologies, the study evaluated the identified productive use categories using a rigorous ranking process. An equally weighted, multidimensional scoring criterion assessed each technology against three metrics: (1) economic potential, (2) sectoral reach, and (3) scalability. Economic potential refers to the role of the appliance in direct income generation, measured by a favorable return on investment (IRR); the study prioritized appliances with IRRs above 20 percent. Sectoral reach refers to the size and importance of the sector to the economy in which the PUE technology is used. Scalability considers the extent to which the appliance can be used across markets and contexts, including both grid-based and off-grid solutions.

Four high-potential PUE technologies were selected: (1) solar water pumps (SWPs) (AC- and DC- powered), (2) refrigerators (AC- and DC powered), (3) electric motorcycles (electric two-wheelers [E2Ws]), and (4) electric pressure cookers (EPCs). The markets for SWPs, refrigerators, and EPCs are largely underserved. At present, only 8.1 percent of small-scale farmers practice irrigation. About 2 percent use diesel-powered machines, indicating the potential for transitioning to solar-powered irrigation to reduce operating costs. The National Cooling Strategy estimates the current number of refrigerators at fewer than 100,000, indicating a large underserved market. Electric motorcycles can allow for quick electrification of the transport sector, potentially replacing internal combustion engines (ICEs); compared to four-wheeled electric vehicles (EVs), they cost less, have simpler charging processes, and do not require elaborate infrastructure. Electric cooking, which has been adopted by only about 0.19 percent of households and commercial institutions in Rwanda, also presents a significant growth opportunity. The indicative IRRs for the four technologies are presented in table BES.1.1 (box ES.1).

Box ES.1 Pilot Study Findings

The pilot testing conducted under this study reported a growth in income across all four selected high-potential PUE technologies despite the constrained monitoring period. Their potential impact was thus supported across the dimensions of economic development, sectoral reach, and scalability.

Table BES.1.1 Internal rate of return, by technology

High potential PUE category	Indicative IRR
Solar water pumps (SWPs)	17
Solar-powered refrigerators	34
Electric motorcycles	36
Electric pressure cookers (EPCs)	45

The pilot testing demonstrated the presence of a nascent PUE market that requires support for scaling up. Once adopted, all of the PUE technologies demonstrated significant improvements for end users in terms of time savings, increased incomes, and improved quality of life.

Solar Water Pumps (SWPs). Prior to adopting SWPs, farmers who used engine-powered pumps spent an average of about RWF 17,000 per week on fuel. After switching to SWPs, these farmers indicated a higher mean monthly income of approximately RWF 128,000 against a median of RWF 72,000 for all other farmers who cited increased incomes; 64 percent indicated that having a SWP enabled them to grow new crops owing to increased water availability and employ additional laborers.

Refrigerators. Most users power off their refrigerators at night due electricity cost concerns. Further research is required to understand how scaling up AC refrigerator adoption would impact demand on the grid. Since acquiring the refrigerators, all users reported a reduction in food waste and an increase in weekly incomes.

Electric Motorcycles. Users reported that battery swaps were cheaper than fueling bikes powered by internal combustion engines (ICEs). Eliminating the cost of changing engine oil reduced their operating expenses, and they covered longer distances with electric motorcycles. As a result, their daily income increased by a minimum of RWF 8,000.

Electric Pressure Cookers (EPCs). Three out of four users recorded an average increase in income of 60 percent per week. They also reported less kitchen smoke, reduced cooking times, and less reliance on other fuels (e.g., charcoal and LPG).

Addressable and Serviceable Markets

For each high-potential technology, a top-down sizing model was used to estimate the total addressable market (TAM) and total serviceable market (TSM) over the next decade. The TAM represents the potential number of units of each PUE appliance that could be sold over the next decade, while the TSM reflects the reachable portion of the TAM, taking affordability into consideration. The TAM was determined by evaluating the population suitable for each appliance's use cases—namely water pumping for irrigation, refrigerators for small retail outlets, electric motorcycles for transport, and electric cooking in small restaurants.

To gauge the impact of appliance prices on market reach, the TSM was evaluated under conditions simulating affordability across target groups. For SWPs, household income was compared to appliance costs. For refrigerators and electric motorcycles, enterprise income distribution was considered. In the case of electric cooking, restaurant income distribution was analyzed. The sizing model incorporated a hire-purchase acquisition approach with end-user credit terms of 18 percent interest and a 24-month repayment period, with a 10 percent initial down-payment. To prevent over-indebtedness, the model assumed that only 30 percent of the user's available monthly income would be allocated to appliance installment payments. Table ES.1 presents the detailed results of the modeling exercise.

Table ES.1 Total addressable and serviceable markets for high-potential PUE technologies, 2024

PUE technology	TAM (units)	TSM (units)	TSM/ TAM (%)	TAM (US$)	TSM (US$)	2022 import data (US$)[a]
Irrigation pumps (surface/submersible)						
Solar	104,421	2,511	2.40	121,604,771	1,499,465	6,225,345
AC[b]	291,018	7,097	2.44	231,731,692	5,650,797	
Refrigerators						
Solar	50,933	22,573	44.32	61,780,117	27,379,825	3,607,038
AC[b]	141,949	70,974	50.00	102,533,061	51,266,531	
Electric motorcycles	101,397	32,263	31.82	190,244,463	60,532,329	17,895,726[c]
Electric pressure cookers (EPCs)	11,701	10,304	88.07	7,195,827	6,337,234	1,989,488[d]
Total	701,420	145,722	20.80	715,089,931	152,666,180	

Note: TAM = total addressable market; TSM = total serviceable market.

a. Import data provides a market reference, but may not refer to the same appliance in TSM.
b. AC-powered irrigation pumps and refrigerators target Rwanda's larger on-grid population, resulting in a higher TAM compared to those that are DC-powered.
c. Includes internal combustion engine (ICE) motorcycles.
d. Includes other electric cookstoves.

The findings suggest the key role that affordability plays in the uptake of PUE technologies. Table ES.1 shows a significant gap between the TAM and TSM for 2024. Comparing the 2022 import data with the modeling results reveals that imports cover just 87 percent (irrigation), 4 percent (refrigerators), 21 percent (ICE motorcycles), and 31 percent (electric stoves) of the respective technologies' TSMs. The strong demand for ICE motorcycles suggests an opportunity for electric motorcycles, particularly in regions served by current suppliers.

Market Barriers

Manufacturing of the top four high-potential PUE technologies is limited in Rwanda. Only electric motorcycles are assembled in-country using predominantly imported component parts. The pilot study findings show that few suppliers in the capital city of Kigali maintain quality, verified products in stock. Relying on PUE technology imports exposes prices to external shocks from country-of-origin pricing, exchange-rate fluctuations, and long supply chains. Furthermore, suppliers typically import products on demand, particularly for off-grid items, which increases costs and delivery times. Other challenges impacting PUE technology investments include market access limitations, cultivation of low-value crops, perceived unreliability of electricity affecting appliance use, and low consumer awareness.

Commercial banks do not readily offer supply chain financing to PUE sector actors, which is especially challenging for start-ups and early-stage businesses. As a result, suppliers maintain limited stock, have a weak network of retail locations, and provide inadequate after-sales support. The Development Bank of Rwanda (BRD) is the primary source of local-currency credit and direct company funding, supporting some supply-side actors through the Rwanda Renewable Energy Fund (REF).

The limited purchasing power of end users significantly restricts sales of PUE technologies, especially in rural areas where high costs are prohibitive. Affordability remains a challenge despite financial incentives like zero-rated import duties and value-added tax (VAT) exemptions for certain solar appliances (e.g., SWP and solar refrigerators), as well as subsidies. For example, Energy 4 Impact (E4I) and the government's irrigation subsidy scheme provided subsidies ranging from 70 percent to 95 percent on solar irrigation pumps to encourage end-user adoption. Despite these efforts, only 1,450 farmers in the Eastern and Southern provinces adopted the pumps, falling short of the 3,000-farmer target and underscoring the ongoing need for subsidies to address affordability challenges.

Low consumer awareness of the PUE technologies' income-generating potential has led to a limited willingness to pay. This study's pilot testing showed that survey respondents perceived most of the high-potential PUE technologies as expensive. Electric motorcycles were an exception since users could immediately notice fuel-cost savings, which prompted interest in future investment.

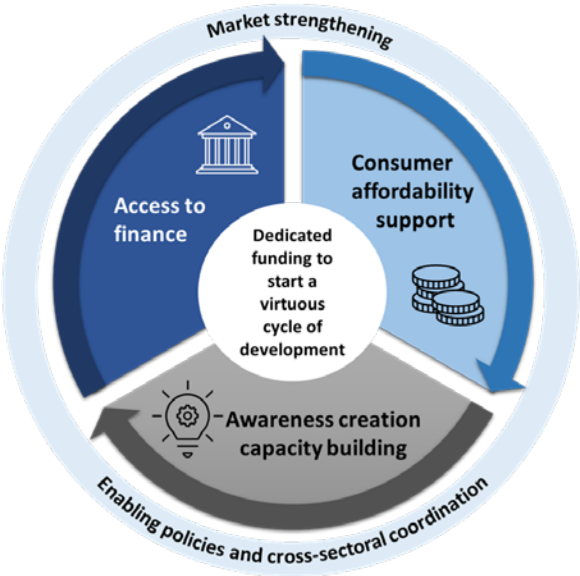
Consumer preferences can also limit the uptake of certain PUE devices. For example, the study's FGDs and pilot surveys found that restaurants preferred cooking with traditional fuels for taste, as well as reliability, especially in areas with unreliable grid access.

The study identified concerns over high electricity tariffs among PUE technology users. Electricity costs were cited as a significant operating expense for AC appliances, particularly among small businesses, who face higher tariffs compared to larger counterparts. Currently, the non-residential tariff for consumption above 100 kWh per month is set at RWF 255, the highest among user categories. Suggested interventions include government support or subsidies to promote electrical appliance use in small businesses.

Recommendations

This study recommended financial and technical interventions to address the market, policy, and sector-related challenges to accelerating the uptake of PUE technologies in Rwanda (figure ES.1).

Figure ES.1 Overarching interventions to catalyze productive use opportunities



Market strengthening

Suppliers require working capital credit support. The study suggests providing PUE technology suppliers working capital credit below commercial rates. Such support would help suppliers maintain adequate stock levels and potentially expand their retail networks to include rural and hard-to-reach areas.

In addition, they require training and capacity building in business development services to ensure sustainability and prepare them for commercial financing. These services include training in business skills, budgeting, corporate structures, technology usage, records management, marketing, savings, financial modeling, and applying for capital support.

To enhance consumer affordability, the up-front cost of appliances should be lowered using results-based financing (RBF) and concessional finance for targeted groups. This financing should feature below-market interest rates and flexible repayment terms for PUE technology purchases.

Cross-cutting market support is needed for awareness creation, after-sales service, and quality assurance. The study proposes targeted campaigns for end users nationwide, especially in rural areas with limited access to information. These campaigns could include pilot projects for institutional electric cooking, refrigeration for the fish value chain, and electric mobility. Potential consumers' widespread lack of information on EPCs suggests the need for a national campaign focused on grid-connected regions. Retailers need to provide purchasers quality assurance warranties and after-sales repair and technical support. In addition, a quality assurance framework, including relevant testing and standards, is needed to ensure the quality of imported PUE technologies.

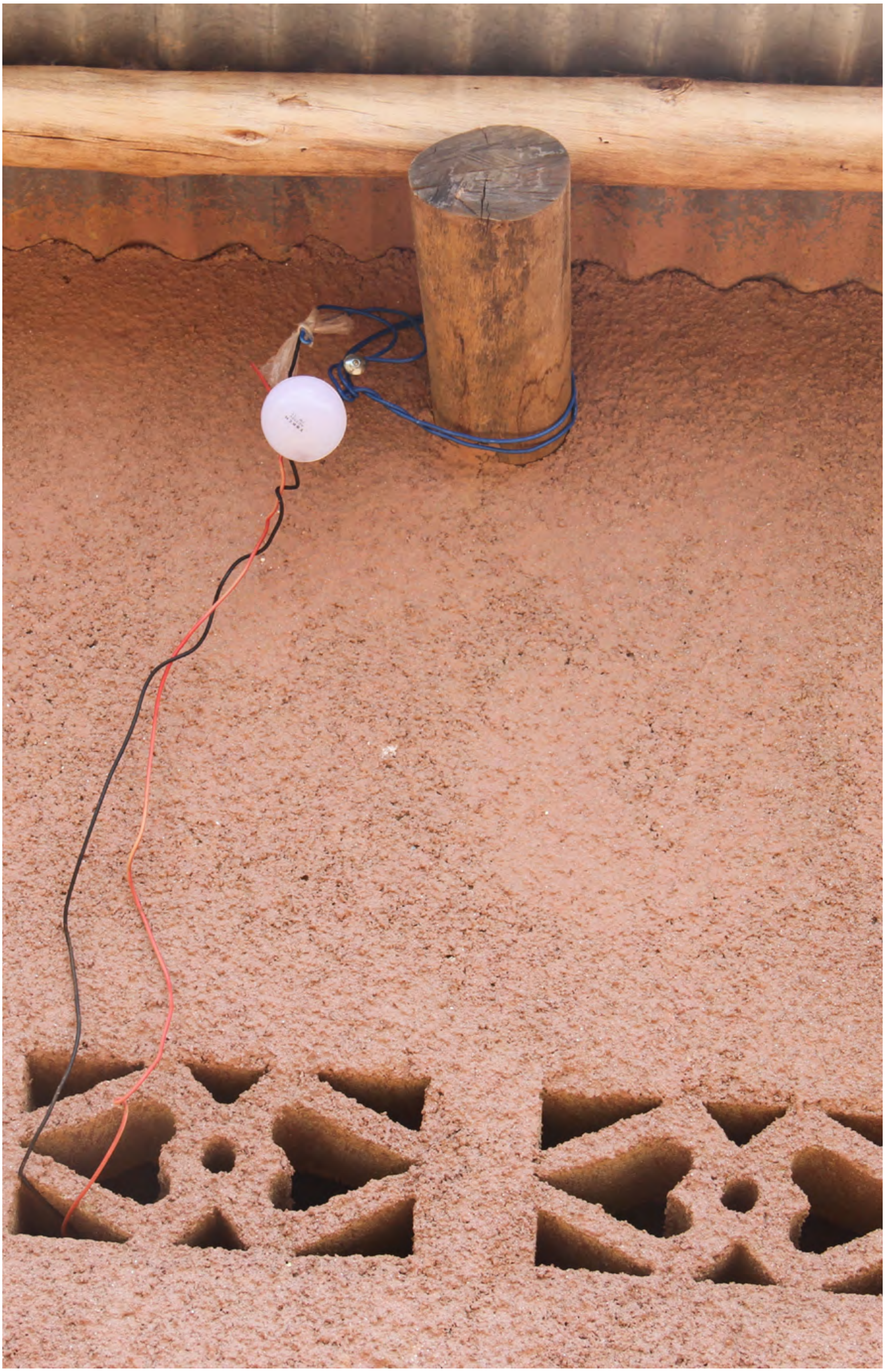
Enabling polices and cross-sector coordination

To improve the policy environment, the study suggests reducing or eliminating import taxes on high-potential PUE technologies. Aligning the tax regime for these technologies with that of solar appliances could offset lost tax revenue from AC appliances through increased electricity consumption. The study recommends a tariff review to establish PUE-specific tariffs (e.g., for electric cooking) and explore potential overall tariff reductions. Given the success of the e-mobility tariff, a comprehensive electricity tariff study could encourage wider adoption of PUE technologies by ensuring responsive pricing.

Finally, cross-sector coordination is required since catalyzing productive energy uses extends well beyond the energy sector alone. The study recommends expanding the PUE working group, which is co-chaired by the Energy Private Developers Association (EPD) and the MININFRA to include representatives from the Ministry of Agriculture and Animal Resources (MINAGRI) and the Ministry of Trade and Industry (MINICOM).

Dedicated funding to start a virtuous cycle of development

The intervention design should be structured as an exploratory venture that can quickly adapt to market changes and feedback from actors while providing valuable lessons in scaling. The study recommends limiting the initial focus to the four high-potential PUE technologies identified in this report. The multi-criteria process utilized in this study can be employed to identify additional high-potential PUE technologies to ensure the scalability of the interventions and expand their reach as the PUE market continues to evolve. Initial capital support and technical assistance funding can be provided by the World Bank's multi-year Accelerating Sustainable and Clean Energy Access Transformation (ASCENT) Program.



CHAPTER 1

INTRODUCTION

1.1 Overview of the Study Context

Rwanda is one of Africa's fastest growing economies. Between 2014 and 2022, its gross domestic product (GDP) per capita grew from US$749 to US$1,004, reflecting the government's goal of shifting the agricultural-based economy to one focused more on industry and services (UN DESA 2020). The country is densely populated, with 503 people per km^2; it is expected that some 35 percent of its population of 13.2 million will reside in urban areas by the end of 2024 (Gubic and Baloi 2019; NISR 2023a). Rwanda is also one of the main countries that hosts individuals escaping conflict and instability in the African continent (box 1.1).[1]

As of June 2022, Rwanda's household electrification rate stood at approximately 61 percent, consisting of 47 percent grid connections and 13.9 percent off-grid (mainly solar) (NISR 2022). The Energy Access Roll-out Program (EARP), a rural electrification initiative, has effectively extended electricity lines and increased the national electrification rate. Notably, the government is working to improve electricity reliability by reducing network losses and has mobilized funds for a results-based financing (RBF) project to subsidize vulnerable households' access to clean cooking solutions.

Rwanda's power system remains small, as indicated in the Least Cost Power Development Plan for 2023–50. Annual energy demand (including transmission and distribution losses) is 1,241.6 GWh, which translates to an annual per capita electricity consumption of approximately 94 kWh (NISR 2023b); this is low compared to the per capita consumption levels for Kenya (226 kWh) and Zambia (670 kWh) (IGC 2021). The transition to cleaner cooking solutions in both rural and urban households is progressing slowly.[2] In refugee camps, access to affordable and reliable energy sources is quite limited (MINEMA 2021).

As electricity access improves, the Rwandan government is shifting its focus toward ensuring the productive use of energy (PUE) to enhance productivity and economic output. The current Energy Sector Strategic Plan (ESSP) (2018/19–2023/24) (MININFRA 2022a), which is being updated for 2024/25–2029/30, aims to achieve 100 percent coverage for productive users (52 percent on-grid and 48 percent off-grid). Annual updating of the productive users database mapped by the Rwanda Energy Group (REG) is crucial to meeting the ESSP's objectives. Also critical is information on the use of grid-based and off-grid electricity for productive purposes, especially since off-grid accounts for nearly 20 percent of the national electricity access rate.

Box 1.1 Productive Use of Energy in Refugee Settings

The energy dynamics in Rwanda's refugee camps reveal significant challenges and opportunities. Access to affordable and reliable energy sources is limited owing to inadequate financial services and infrastructure to support alternative solutions; the COVID-19 pandemic has exacerbated these challenges by increasing poverty and dependence on external assistance, making it difficult for refugees to meet their energy

1 As of 2023, Rwanda sheltered 135,000 refugees and asylum seekers (IOM 2023). The country has six refugee camps (Gihembe, Karongi, Kiziba, Mahama, Mugombwa, and Nyabiheke) and four major refugee transit centers (Bugesera, Gatore, Nkamira, and Nyanza) (Integral Human Development 2021).

2 Eighty-three percent of rural households depend on firewood and more than 40 percent of urban households use charcoal.

needs (MINEMA 2021). Beyond visible objects like solar lanterns and cookstoves, many other forms of energy infrastructure go unrecognized. Refugees frequently secure their energy access independent of humanitarian providers—a practice that is seldom recorded—contributing to the "invisibility" and undervaluing of these systems. Also, inequalities in energy provision within and between camps mean that some communities receive more energy support than others.

However, recent projects integrating renewable energy solutions are successfully promoting the productive use of energy (PUE) in Rwanda's refugee camps. The Renewable Energy for Refugees (RE4R) Project, for example, reports that, across three camps, 59 percent of those who have adopted solar home systems (SHSs) are engaged in businesses or productive activities after dark (UNHCR 2021). Streetlights have made the communities feel safer after nightfall, which has enhanced their mental health and productivity. Since 2021, the Joint Strategy on Economic Inclusion of Refugees and Host Communities has sought to leverage renewable energy to promote self-employment in agriculture and business among these target groups. An updated strategy is expected to carry over the importance of energy in improving these communities' socioeconomic outcomes.

1.2 Study Purpose and Objectives

The World Bank, in collaboration with Sustainable Energy for All (SEforALL), conducted this study to assess the potential of PUE in Rwanda by bridging knowledge gaps on market actors, products, and the market environment and providing recommendations for scaling up productive use technologies (box 1.2).

Box 1.2 Clarification of Key Terms

- *Productive use of energy* refers to "the use of electricity and thermal energy for activities that enhance economic and social welfare," as defined in the Energy Sector Strategic Plan (ESSP), covering the following sectors:
  - Public infrastructure: Airport and aerodrome, IDP model villages, and water pumping stations
  - Schools: Pre-primary, primary, secondary, technical, and university
  - Health facilities: Hospitals, health centers, and health posts
  - Markets
  - Administrative offices: Province, district, sector, and cell
  - Mining and quarry areas
  - Industries: Beverages, cement, chemical/rubber/plastics, furniture and printing, tea factory, textiles/clothing, and industrial parks
  - Small industries: Food processing, coffee washing stations, milk collection centers, and integrated craft production centers
- *Small enterprise* refers to an enterprise featuring at least two of the following three parameters (as defined by the Rwanda Development Board [RDB]):

- Net capital investment of RWF 0.5–15 million
- Annual turnover of RWF 0.3–12 million
- Employees numbering 4–30 persons

• *Demand stimulation* encompasses all electrical loads, including consumptive uses of energy (e.g., social welfare uses of electricity). This is in contrast to productive use of energy (PUE), which, in large part, is specific to uses that promote income generation. It should be noted that the ESSP definition of PUE differs from that of the Energy Sector Management Assistance Program (ESMAP) with regard to including thermal energy, social welfare uses, and the exclusion of individual users (e.g., smallholder farmers) from the user categories.

• *Productive use technologies* refer to various technologies that use electrical and thermal energy, which can be grouped under the following activities: (1) agricultural loads, (2) primary processing, (3) secondary processing, (4) commercial loads, (5) advanced processing/manufacturing, and (6) transportation. The ESSP definition of PUE technologies was used to estimate electricity demand from the categories of productive users. The ESMAP definition of PUE technologies and its categorization of users was taken as the boundary for the remaining aspects of the study; thus, the definition excludes social users and includes individual productive energy users (e.g., smallholder farmers and micro-, small-, and medium-sized enterprises [MSMEs]).

Key objectives were to assess the potential electricity demand of Rwanda's productive energy users (grid-based, off-grid, and non-electrified), examine barriers that hinder the uptake of high-potential PUE technologies, and propose an intervention strategy to overcome them. The study's findings can be used to inform electrification planning by the Ministry of Infrastructure (MININFRA) and the REG to ensure sufficient power supply to meet potential demand.

1.3 Methodology and Data Collection

The study was conducted in four phases (figure 1.1), utilizing extensive primary and secondary data collection employing various data analysis methods (figure 1.2). Data collected through 26 key informant interviews (KIIs) encompassed the wide range of stakeholders that shape the PUE ecosystem, including government agencies, development partners, and the Development Bank of Rwanda (BRD); as well as productive energy users; and PUE technology manufacturers, importers, distributors, and retailers. To characterize the demand side of the PUE ecosystem, study team conducted face-to-face surveys with a representative sample of current productive energy users listed in the REG database (351 out of 9,445). The REG provided electricity usage data for the sampled grid-connected respondents from 2019 to 2022. These trends were extrapolated to the broader population of productive energy users. Further analysis tested the sensitivity of electricity consumption against three variables: (1) access to electricity, (2) quality and reliability of supply, and (3) unit price of electricity.

Figure 1.1 Study phases

1. Inception

- Inception meeting
- Inception meeting with WB and GOR
- Meetings with key stakeholders in Rwanda
- Document review of previous WB studies and GOR reports
- Mapping of existing and potential PUE using electricity and thermal energy
- Categorization of PUE applicable market segments
- Rwanda Energy Group data review
- Design KII and FGD guides, and appliance use surveys and demand assessment questionnaires
- Inception report

2. Survey

- Deploying the appliance user surveys and demand assessment questionnaires and remote monitors
- Conduct FGD's with the PUE end users and KII's with the key stakeholders
- Demand Supply assessment of high potential PUE
- Market size modelling to project TSM and TAM
- Detailed policy and regulatory review including key institutions and their roles.
- Review of programs that support PUE technologies
- Preliminary findings Report

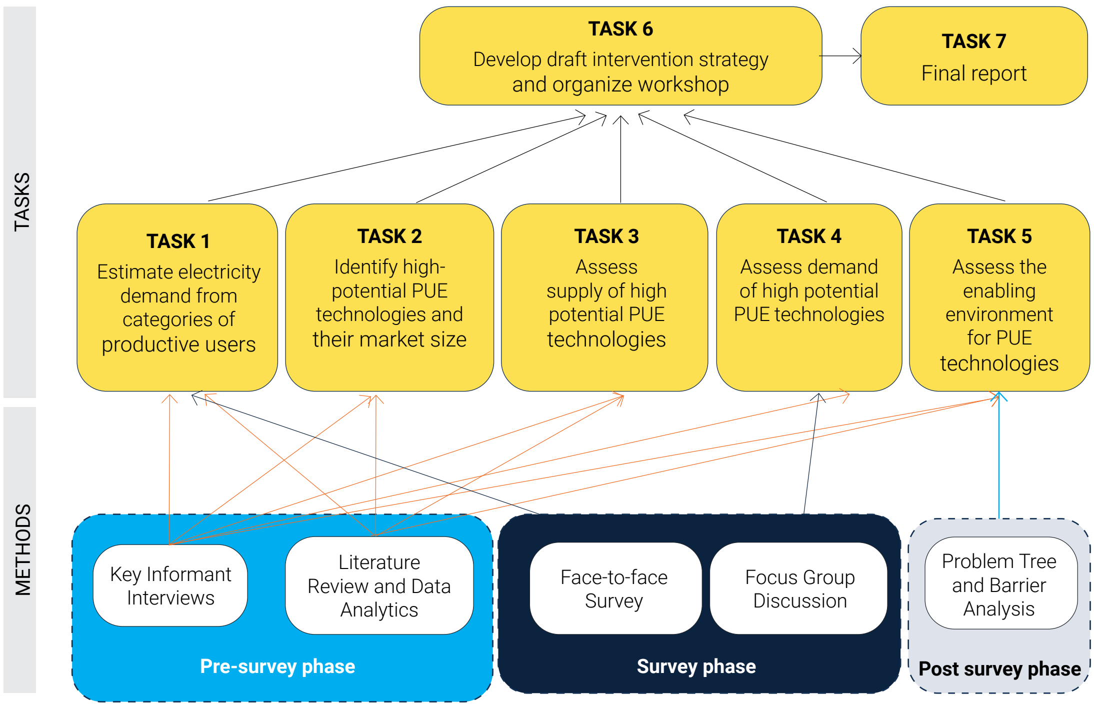
3. Pilot

- PUE product procurement
- Beta testing and installation of remote monitors
- Partner and end-user identification
- Installation of remote monitors to end-user site
- Data collection (baseline and endline surveys)

4. Synthesis

- Financial modelling to compute IRR and payback period
- Analysis of demand data collected from remote monitors
- Deman and supply assessments of key PUE technologies with case studies
- Assessment of PUE enabling environment
- Developing draft intervention strategy
- Intervention strategy and action plan
- Consultation Workshop
- Final report

Figure 1.2 Summary of study tasks by survey phase, highlighting data-collection methods



Four high-potential PUE technologies (solar water pumps [SWPs], solar-powered refrigerators, electric motorcycles, and electric pressure cookers [EPCs]) were selected through a rigorous ranking process based on the following three criteria: (1) economic potential, (2) sectoral reach, and (3) scalability. Eight focus group discussions (FGDs) were held nationwide with potential users of these high-potential PUE technologies (two per technology) to better understand their consumer profile and willingness to pay (figure 1.2). A pilot phase field-tested the four technologies to demonstrate their financial and economic benefits (chapter 5), following guidance outlined by Efficiency for Access (2022) (figure 1.1).

1.4 Structure of This Report

This report is organized into six chapters. Chapter 2 describes Rwanda's enabling environment for PUE, including institutional arrangements for planning, the policy and regulatory framework, and lessons from recent investments. Chapter 3 identifies the key categories of current productive users by sector and analyzes changes in electricity consumption under scenarios of universal access, improved supply reliability, and reduced electricity prices. Chapter 4 identifies high-potential PUE technologies and their addressable and serviceable markets, while chapter 5 summarizes the key supply- and demand-side barriers to the uptake and use of these technologies. Finally, Chapter 6 recommends an intervention strategy to overcome the barriers.

CHAPTER 2

PLANNING, POLICIES, AND INVESTMENTS

2.1 Institutional Arrangements

Rwanda's energy sector is governed by various state agencies supervised by the Ministry of Infrastructure (MININFRA) and, in the case of the Rwanda Utilities and Regulatory Authority (RURA), the Office of the Prime Minister. Figure 2.1 illustrates the administrative structure of the PUE-related government institutions, while table 2.1 briefly describes their functions.

Figure 2.1 Overview of Rwanda's PUE-related administrative structure

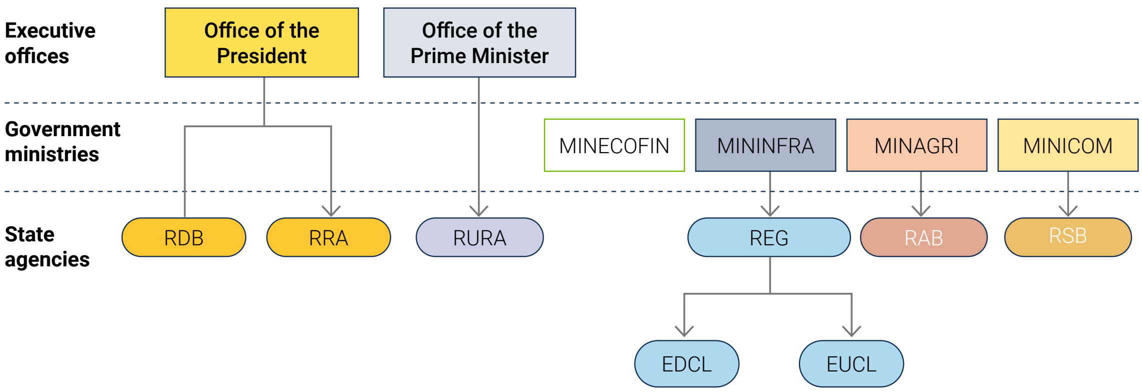


Table 2.1 PUE-related government institutions

Institution	Description
Ministry of Infrastructure (MININFRA)	MININFRA is the primary body responsible for establishing energy policy, supervising project execution, and assessing results (MININFRA 2021a). It creates supportive policies and legal frameworks for the energy sector and optimizes the use of state subsidies (MININFRA 2018). In collaboration with the Ministry of Finance and Economic Planning (MINECOFIN), MININFRA organizes resources and creates budgets. It also oversees government actions to increase access to and use of energy services. A Prime Minister's Order from February 2015 mandates MININFRA to develop policies, improve institutional and human resources, support energy programs at decentralized entities, monitor and assess national energy policies and projects, and mobilize resources for the energy sector (MININFRA 2018).
Ministry of Agriculture (MINAGRI)	MINAGRI promotes sustainable development in agriculture and livestock through modern, efficient, and competitive methods to ensure food security and empower farmers (MINAGRI 2023). Its objectives are outlined in the National Agricultural Policy (2018) and align with the Malabo Declaration (2014). The policy focuses on productivity and sustainability, inclusive markets and off-farm opportunities, technological upgrading and skills development, and creation of a supportive environment with responsive institutions (MINAGRI 2023).
Ministry of Trade and Industry (MINICOM)	MINICOM drives trade and private sector engagement. Under Rwanda's digital agricultural policy, it oversees agro-processing management systems. MINICOM also coordinates the East African Community (EAC) and Rwandan priorities within EAC protocols, treaties, and strategies.
Ministry of Finance and Economic Planning (MINECOFIN)	Established in 1999 through the merger of the Ministry of Finance and the Ministry of Planning, MINECOFIN aims to reduce poverty in Rwanda by fostering economic opportunities, promoting sustainable growth, and enhancing living standards (MINECOFIN 2023). Its key goals include boosting economic productivity, creating job opportunities, improving public investments, and enhancing the investment environment.

Institution	Description
Rwanda Utilities Regulatory Authority (RURA)	Established in 2013, RURA oversees various public utilities in both renewable and non-renewable energy sectors, including electricity, industrial gases, pipelines, storage facilities, and conventional gas production and distribution (Republic of Rwanda 2013). Its main responsibilities include protecting customers from unfair business practices; ensuring the efficient and sustainable operation of utilities; updating the electric grid code; setting quality of service standards; reviewing energy tariffs, and licensing power generation, transmission, and distribution companies, along with retail gas stations and related storage facilities (MININFRA 2018).
Rwanda Energy Group (REG)	REG was established in 2014 following the division of the Energy Water and Sanitation Authority (EWSA) (REG n.d.). It oversees and evaluates the performance of EDCL and EUCL, providing senior leadership in the energy sector. As the utility's top corporate body, REG reports to its shareholders, MININFRA, and MINECOFIN. Its goal is to deliver reliable and affordable energy while creating value for all stakeholders.
Electricity Development Corporation Limited (EDCL)	EDCL is responsible for developing transmission and generation projects, exploring new energy sources, and implementing cost-effective power strategies (REG n.d.). Its primary goal is to promote the development and utilization of domestic energy resources and investments (MININFRA 2018). While operating independently, EDCL regularly updates MININFRA on its progress and collaborates to assess the nation's indigenous resource base. EDCL also undertakes generation, transmission, and distribution projects to expand the electricity system into new areas; but ownership is transferred to EUCL on completion.
Electricity Utility Corporation Limited (EUCL)	EUCL is responsible for power generation, transmission, distribution, and end-user sales (MININFRA 2018). In grid-connected areas, it manages the transmission and distribution infrastructure. It also leads demand-side management programs and energy efficiency initiatives. Its core objectives are to reduce costs, minimize technical and non-technical losses, enhance customer satisfaction, and allocate generation resources efficiently to meet electricity demand.
Rwanda Development Board (RDB)	RDB leads investment mobilization and promotion for the energy sector, acting as a gateway and facilitator. It actively encourages private and local financial institutions to invest in energy, supports foreign direct investment (FDI) in strategic energy generation projects, and promotes cleaner, more energy-efficient technologies. RDB also issues Environmental Impact Assessments (EIAs) for all relevant energy projects.
Rwanda Revenue Authority (RRA)	Established in 1997 under Law No. 15/97, RRA is responsible for assessing, collecting, and accounting for tax, customs, and related revenues (RRA 2022). It advises the government on tax policy and handles non-tax revenue collection. It also manages the collection of taxes (e.g., value-added tax [VAT], duty, and excise) on imported PUE technologies.
Rwanda Agriculture and Animal Resources Development Board (RAB)	RAB was independently established in November 2010 under Law No. 38/2010 (RAB 2023) to supports MINAGRI goals. It enhances agriculture and animal resources through research and extension services aimed at improving the quality and productivity of agricultural and animal resources and their by-products.
Rwanda Standards Board (RSB)	RSB develops national technical standards, including performance and technological benchmarks. Its electrical metrology laboratories maintain and disseminate national measurement standards for power, energy, time, frequency, magnetism, and alternating current/direct current (AC/DC). This includes standards for appliances and energy technologies (e.g., refrigeration systems, irrigation systems, and grain mills).

In addition to the institutions described in table 2.1, the Energy Private Developers Association (EPD) co-chairs a working group with MININFRA that coordinates private-sector initiatives in the PUE space. The Africa Centre of Excellence for Sustainable Cooling and Cold Chain (ACES) manages a Steering Committee and a National Technical Advisory Committee to guide the National Cooling Strategy's implementation.

The Government of Rwanda coordinates its energy sector efforts with development partners, civil society, and the private sector through biannual Sector Working Group (SWG) meetings. Chaired by MININFRA and co-chaired by a development partner representative, the SWG includes four technical working groups focused on energy access, generation and transmission, biomass, and energy efficiency. These groups harmonize efforts and interventions, ensuring that planned and ongoing activities in the PUE sector are discussed and coordinated effectively.

2.2 Policy and Legislative Framework

2.2.1 Sector policies

Rwanda's policy framework has spurred progress toward achieving universal energy access for productive users (World Bank 2023a), and the focus is shifting toward leveraging energy for economic benefits. Vision 2050 and NST-1 highlight key sectors for improved electricity services, while sector-specific plans detail goals and timelines that align with national objectives, signaling the government's intention to encourage private-sector involvement. Given the cross-sectoral nature of PUE, it is critical that the PUE working group, co-chaired by EPD and MININFRA, include MINAGRI and MINICOM representatives to support effective monitoring and evaluation (M&E) of sector-specific plans. The relevant sector-specific policies and development plans are described below.

- ***Rwanda Energy Policy (REP 2015).*** This high-level policy document outlines measures to promote energy efficiency through various approaches, including regulations, new codes, and standards. It introduces economic incentives (e.g., subsidies for solar water heaters), encourages industrial end-users to conduct energy efficiency audits, and addresses such barriers as systemic disincentives and split incentives for energy-efficient technologies in buildings. In addition, it supports bulk procurement strategies, including importing light-emitting diode (LED) lamps. The document establishes governing laws, strategic directions, and guiding principles for Rwandan institutions and partners.

- ***Energy Sector Strategic Plan (ESSP).*** Complementing REP 2015, the current ESSP (2018/19–2023/24) outlines the status and plans for the electricity, biomass, and petroleum sectors. Building on progress from the second Economic Development and Poverty Reduction Strategy (EDPRS II), it sets new targets and approaches for enhanced performance. Currently under review, the updated ESSP for 2024/25–2029/30 will ensure universal access to electricity, aiming for 100 percent coverage for productive users achieved through 52 percent on-grid and 48 percent off-grid electrification.

- ***National Electrification Plan (NEP 2022).*** This document guides and regulates the extraction, development, and use of Rwanda's energy resources in a transparent and sustainable manner. NEP 2022, and the current ESSP are complementary. NEP provides a long-term vision and high-level goals, while ESSP specifies targets and an implementation framework for measuring progress. As of July 2024, NEP 2022's goals for electrifying unconnected villages and productive users had not been met (REG 2022). Funding discussions with stakeholders are ongoing, and the document is under review to set new targets.

- ***National Strategy for Transformations (NST-1).*** This strategy, which replaces EDPRS II, aims for Rwanda to achieve middle-income status by 2035 and high-income status by 2050. A key objective is providing universal electricity access for productive energy users. NST-1 focuses on scaling up electricity generation and enhancing its quality, affordability, and reliability. It prioritizes such sectors as mining, manufacturing, ICT, and commercial premises to boost demand and emphasizes PUE connections, including industrial zones, market centers, schools, and health facilities. NST-1 is currently being revised to update targets.

- ***Least Cost Power Development Plan (LCPDP 2020–40).*** This plan aims to systematically develop Rwanda's generation resources by prioritizing the most cost-effective options to ensure affordable tariffs. Its key objectives are to maximize the use of renewable energy, optimize electricity supply to meet peak demand without creating excess capacity, and adhere to REP 2015 and ESSP, emphasizing a least-cost approach to power generation capacity and investment.

- ***Vision 2050.*** Vision 2050 outlines a pathway for Rwanda to reach upper-middle-income status by 2035 and high-income status by 2050. Its main objectives are to promote economic growth, prosperity, and a high standard of living. Vision 2050 is based on five pillars: (1) human development, (2) competitiveness and integration, (3) agriculture for wealth creation, (4) urbanization and agglomeration, and (5) accountable and effective state institutions. Energy will play a crucial role in achieving Vision 2050 by expanding affordable and reliable electricity access, ensuring sustainable biomass supply, and securing petroleum supplies (MININFRA 2017).

- ***National Cooling Strategy (NCS 2019).*** This strategy forecasts increased demand for space conditioning and refrigeration, projecting its impact on the power system. It highlights the need to scale up cold chain and off-grid cooling infrastructure as a key intervention. This includes reducing post-harvest losses in agriculture, preserving perishables in trade and export, and maintaining vaccines and medicines in the health sector. NCS 2019 aimed to establish 60 cold room sites and secure funding for cooling in productive sectors by 2023 (MoE 2019).

- ***Irrigation Master Plan (IMP 2020).*** This plan aims to maximize the potential of modern irrigation through the sustainable and efficient use of surface and groundwater. Recognized as a key strategic activity, irrigation is a significant use case for PUE. IMP 2020 targets irrigating some 220,000 ha of the country's estimated 500,000-ha potential by 2050 (RAB 2020). The government's Small Scale Irrigation Technology (SSIT) program (including ready-to-use kits with portable pumps, pipes, and sprinklers capable of irrigating 1, 5, or 10 ha) is expected to cover 28,000 ha of the target.

- ***Strategic Paper on Electric Mobility Adaptation (2021).*** This strategic paper aims to boost the adoption of electric transportation by addressing current barriers and proposing incentives to accelerate e-mobility (MININFRA 2021b). Based on a 2019 feasibility study, it targets 30 percent of electric motorcycles, 8 percent of electric cars, 20 percent of electric buses, and 25 percent of electric taxis by 2030 (Twagirimana 2022). The paper outlines both fiscal and non-fiscal incentives to support this growth.

→ ***Various standards.*** Rwanda has adopted various appliance standards and minimum energy performance standards (MEPS), including several standards of the International Electrotechnical Commission (IEC). Pro-solar policies adhere to IEC standards for quality control; however, no product-specific MEPS have been established for PUE appliances and equipment (Wambui, SACREEE, and EACREEE 2022), although ministerial guidelines set minimum performance requirements for solar home systems (SHSs) and refrigerators (table 2.2).

Table 2.2 Appliance-related standards

Standard	Description
RS IEC 60335 -1	Household and similar electrical appliances: General requirements
RS IEC 60335 -2 -14	Household and similar electrical appliances: Particular requirements for kitchen machines
RS IEC 60335 -2 -29	Household and similar electrical appliances: Particular requirements for battery chargers
RS IEC 61960	Secondary cells and batteries
RS IEC 60364 -7-712	Low voltage electrical installations: Solar photovoltaic power supply systems
RS IEC 60086 -1/2	Primary batteries: general, physical, and electrical specifications
2021 MEPS for Refrigerators	Minimum energy performance standards for refrigerators
2023 Draft MEPS for Electric Motors	Draft minimum energy performance standards for electric motors (relevant for electric vehicles, industrial machinery, and household appliances)

Source: RSB.

In addition, the 2016 National E-waste Management Policy was established to prevent electrical and electronic equipment (EEE) from being discarded with general waste, thus averting an e-waste crisis. This policy is integrated into the National Sanitation Policy. Notably, Rwanda is the second country in Africa to have an e-waste dismantling and recycling facility (ACE TAF 2021a).

2.2.2 Laws and tax regime

Rwanda' existing energy-sector policies, strategies, and laws are listed in table 2.3 (MININFRA 2017).

Table 2.3 Energy-sector laws and regulations in Rwanda

Law	Year	Description
Electricity Law of Rwanda	2018	Governs activities of electricity production, transmission, distribution, and trading
Guidelines Promoting Energy Efficiency Measures	2013	Guides electricity consumers on the promotion of efficient energy use; applicable for business/industry, residential, and institutional consumers
Ministerial Guidelines for Clean Cooking Technologies	2022	Enforces the adoption of modern clean cooking practices in households and institutions for the transition to energy-efficient and clean technology
Public-Private Partnership (PPP) Law	2016	Establishes processes and requirements for entering into PPPs (including procurement)
Radiation Protection Law	2017	Establishes rules and requirements for the use of radiation

Law	Year	Description
Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems (SHSs)	2022	Outlines the standards that should be considered in the design and installation of SHSs and accessories (e.g., lamps, batteries, solar photovoltaic [PV] panels, and charge controllers)

Table 2.4 Examples of tax-exempt, off-grid PUE appliances

Product	Exemption		
	Value-added tax (VAT)	Import duty	Other taxes and fees[a]
Solar water pump (SWP)	✓	✓	×
Solar refrigerator	✓	✓	×
Solar home system (SHS)	✓	✓	×
Solar TV and radio	✓	✓	×
Electric vehicle	✓	✓	×
Clean cookstove	✓	×	×

a. Other taxes and fees include withholding tax (5%), infrastructure development levy (1.5%), strategic reserves levy, quality inspection fee (0.2%), and African Union levy (0.2%).

Conventional PUE appliances, whether powered by alternating current (AC), direct current (DC), or engines, are taxed like other machinery or equipment. The average import duty on finished goods is 25 percent. Excise duty on appliances and machinery is in a range of 5–15 percent, with a value-added tax (VAT) of 18 percent and a 5 percent withholding tax also applied. However, as illustrated in table 2.4, various off-grid PUE products benefit from tax exemptions.

2.3 Investments in PUE

2.3.1 Overview

Energy access is a priority economic sector under the 2021 Investment Code (RDB 2021a), prompting support for the energy sector, particularly PUE, from various development partners, nongovernmental organizations (NGOs), and financial institutions. Owing to the high cost of PUE, investments must be patient capital. Research by the Powering Renewable Energy Opportunities program estimates that about US$864 billion will be needed over the next decade to invest in PUE appliances and equipment in rural Sub-Saharan Africa, equivalent to US$86.4 billion annually. Of this amount, US$598.4 billion is specifically required for acquiring PUE equipment and appliances.

Philanthropy plays a significant role in the emerging off-grid energy sector due to its ability to respond swiftly and adapt as needed. In 2021, the leading sectors for philanthropic climate funding in Africa were clean electricity, forests, food, and agriculture; philanthropic funding for clean electricity averaged US$25 million (Desanlis et al. 2022). This funding supports such initiatives as the development and deployment of renewable energy, utility reforms, grid efficiency, energy access, and renewable sources integration. While PUE generally falls under the energy access category, specific data on funding directly aimed at stimulating PUE is not readily available. Key development actors in the PUE sector include major development partners, financial institutions, NGOs, philanthropies, and organizations (e.g., World Bank Group, United States Agency for

International Development [USAID], Development Bank of Rwanda [BRD], Practical Action, Ikea Foundation, and Global Off-Grid Lighting Association [GOGLA]).

2.3.2 PUE programs

A variety of initiatives promoting PUE in Rwanda have recently completed, are ongoing, or are yet-to-be-launched. Nascent markets and small companies generally require up-front grants and technical assistance to enable the sector to grow and continue attracting private investment. Results-based financing (RBF) is an appropriate tool to incentivize companies to enter underserved geographical areas (table 2.5).

Table 2.5 Summary of PUE investment programs

Funding mechanism	Program name	PUE technologies	Funding amount	Supporting organization	Implementation period
Results Based Financing (RBF) + Lines of credit	Rwanda Renewable Energy Fund Project (REF)	Not applicable	US$50 million	World Bank	2017–24
	Rwanda Pro-Poor Program	Solar home system (SHS)		USAID	2020–21
	Energizing Development Initiative	Energy for lighting, cooking, and electrical appliances	US$19.4 million	GIZ, SNV, and UKaid	2006–09 (Phase 1); 2009–10 (Phase 2)
	E-Moto Credit Enhancement Facility (Mitigation Action Facility 2024)	Electric motorcycles	EUR 16.8 million	Rwanda Green Fund and BRD	2024–29
	Energy Access and Quality Improvement Project	Clean cookstoves	US$288 million	World Bank	2021–26
	Energising Change	Hydro, stoves, grid, solar	EUR 31.1 million	GIZ, SNV, and AVSI	2009–24
Pilot	BRD E-Mobility	Electric motorcycles	US$200,000	Government of Rwanda	2022–24
	EPC	Electric pressure cookers	EUR 700,000	EEP and Empowering Villages	2021
	Retrofit Electric Motorcycles Project	Electric motorcycles	US$68,000	UNDP	2021
	Solar Cold Storage and Processing in Rwanda	Solar refrigerated storage	n.a.	InspiraFarms	2018
Grant	Nasho Solar-powered Irrigation System	Large-scale solar irrigation system	US$54 million	Howard G. Buffett Foundation	2020
	Feed the Future Hinga Weze Activity	Various agrotechnologies	US$32.6 million	USAID	2017

Note: n.a. = not available.

Projects promoting solar water pumps (SWPs) and solar refrigeration offer key lessons for accelerating consumer uptake of these technologies (boxes 2.1 and 2.2).

Box 2.1 Solar Irrigation in Rwanda

Overview

Energy 4 Impact (E4I), through the Solar Irrigation in Rwanda (SIR) project, worked to develop the solar irrigation market in Rwanda by supporting new financing and building farmer awareness through training. The SIR project was implemented between February 2018 and November 2020 and was funded by a US$1 million grant from the OPEC Fund for International Development. It supported solar irrigation projects fed by mobile and stationary solar water pumping systems. The project offered beneficiaries a mix of subsidies and loans; 100 percent grants were given for the demonstration sites, and 70–95 percent grants were offered in conjunction with the then ongoing government subsidy program, of which SIR offered 20 percent. It was noted that surface pumps perform better in rivers, while submersible pumps are better adapted to lakes. However, the river water was found to be silted, which would wear out the pumps at a faster rate. The submersible pump was found to have the best performance though it had a high retail price of about US$4,000. The project enabled 1,450 farmers in the Eastern and Southern provinces to adopt the irrigation systems—less than half of the original target of 3,000 farmers. Farmers that adopted the solar water pumps (SWPs) improved their yields by about a third, indicating the huge productivity benefits that solar irrigation brings.

Lessons

The project report highlighted a lack of awareness of solar irrigation and its benefits, consumer affordability issues, and supply chain problems, which may have impacted the outcomes. For future solar irrigation interventions, the project recommended the following actions:

- Demonstration or pilot sites should be created to educate the stakeholders, especially farmers, on adopting the technology as a method of creating awareness.
- Subsidies should be used to activate the early-stage market. Donor-funded programs should complement and work in tandem with government financial support to ensure efficiency and effectiveness. The level of subsidization should ensure affordability is met. Asset financing at commercially high interest rates is unattractive to most farmers; therefore, loan products should be customized for smallholder farmers, including low collateral requirements and interest rates. Pay-as-you-go (PAYG) business models could be considered to address capital affordability constraints.
- Although contract farming and fixed offtake of smallholder farmer produce is not widespread in Rwanda, they could potentially help in unlocking the pre-harvest funding of inputs, including irrigation pumps.

Key takeaways

- The cost of the most preferred SWPs far exceeds the annual wage of a typical smallholder farmer, necessitating subsidies to encourage uptake. The need for subsidies would be expected to fall as farmers gain awareness of the benefits of solar irrigation and product prices decline.

- SWP distributors require both technical support (e.g., training in after-sales service) and financial support to eliminate cash-flow constraints.

Source: E4I 2021.

Box 2.2 Solar Refrigeration Pilot in the Rwandan Dairy Sector

Overview

The International Fund for Agricultural Development (IFAD) extended a US$2.2 million grant to SunDanzer to strengthen smallholder farmers' capacity to reduce post-harvest losses. In Rwanda, the program targeted the dairy value chain through nearly 30 50-liter and 165-liter pay-as-you-go (PAYG)-enabled solar refrigerators. These ranged from US$800 to US$1,200 (subsidized cost) and were offered with 18-month financing and no interest. SunDanzer worked with Clean Energy Technologies (CET) as an in-country partner and last-mile distributor. CET set up the PAYG system to be able to sell and market the refrigerators across the country. By the closing date of the five-year program (March 2023), approximately 100 of the targeted 300 systems had been deployed. The project fell short of its target largely because of low uptake of the refrigerators in the dairy sector and therefore diversified to other use cases, including retail shops and fish cold chain.

Lessons

- Solar-powered refrigeration for milk in Rwanda did not do well because of the affordability constraints faced by medium-scale dairy farmers. Also, farmers lacked the business orientation and milk volumes to make the use case viable. Project visits to more than 12 milk cooperatives and milk collection centers (MCCs) revealed that, though significant work had been done to set up and electrify the MCCs, the electricity tariff, at US$0.257 per kWh, was too high to operate the equipment. A revised tariff could potentially unlock more use of the MCCs and therefore latent electricity demand.
- Retail shops and fisheries have a higher ability to pay and a greater perceived need for solar refrigerators than the dairy sector and would benefit from the technology.
- Demand for solar refrigerators encountered in areas supplied with grid electricity was driven by the availability of financing, high cost of electricity, and reliability of the grid.

Key takeaways

- The fishing subsector and retail shops present an opportunity for solar refrigeration.
- The PAYG model is useful for offering financing and lowering up-front costs.

Sources: Efficiency for Access 2021; IFAD 2021.

In addition to these financial initiatives, GOGLA is finalizing a Productive Use of Renewable Energy (PURE) market assessment and roadmap. This project aims to guide the governments of Rwanda, Ethiopia, Kenya and Uganda in scaling up PURE opportunities. In Rwanda, the market assessment, which examined barriers on both the demand and supply sides, was carried out by EPD and a working group chaired by MININFRA.

CHAPTER 3

UNLOCKING ELECTRICITY DEMAND FOR PRODUCTIVE USES

3.1 Introduction

Rwanda is considered the second most favorable country in Africa for electricity access after Mauritius (World Bank 2020). Its electricity access rating is well above the regional average for Sub-Saharan Africa and high-income countries of the Organisation for Economic Co-operation and Development (OECD), indicating a supportive environment for electricity-dependent businesses. To better understand how Rwanda's energy sector performance impacts the productivity of enterprises, the study surveyed a representative sample of productive energy users listed in the Rwanda Energy Group (REG) database and then used the consumption data from grid-connected respondents to examine changes in electricity consumption that would occur under scenarios of universal access, improved reliability, and lower unit prices for electricity.

3.2 Profile of Productive Energy Users

To estimate the electricity demand of productive energy users, the study team conducted face-to-face surveys with a representative sample of current users listed in the REG database (351 out of 9,445). Sample selection was based on the Cochran formula. Stratified random sampling was used, distributing the sample across a total of 23 productive use categories (table 3.1).

Table 3.1 Survey sample, by sector

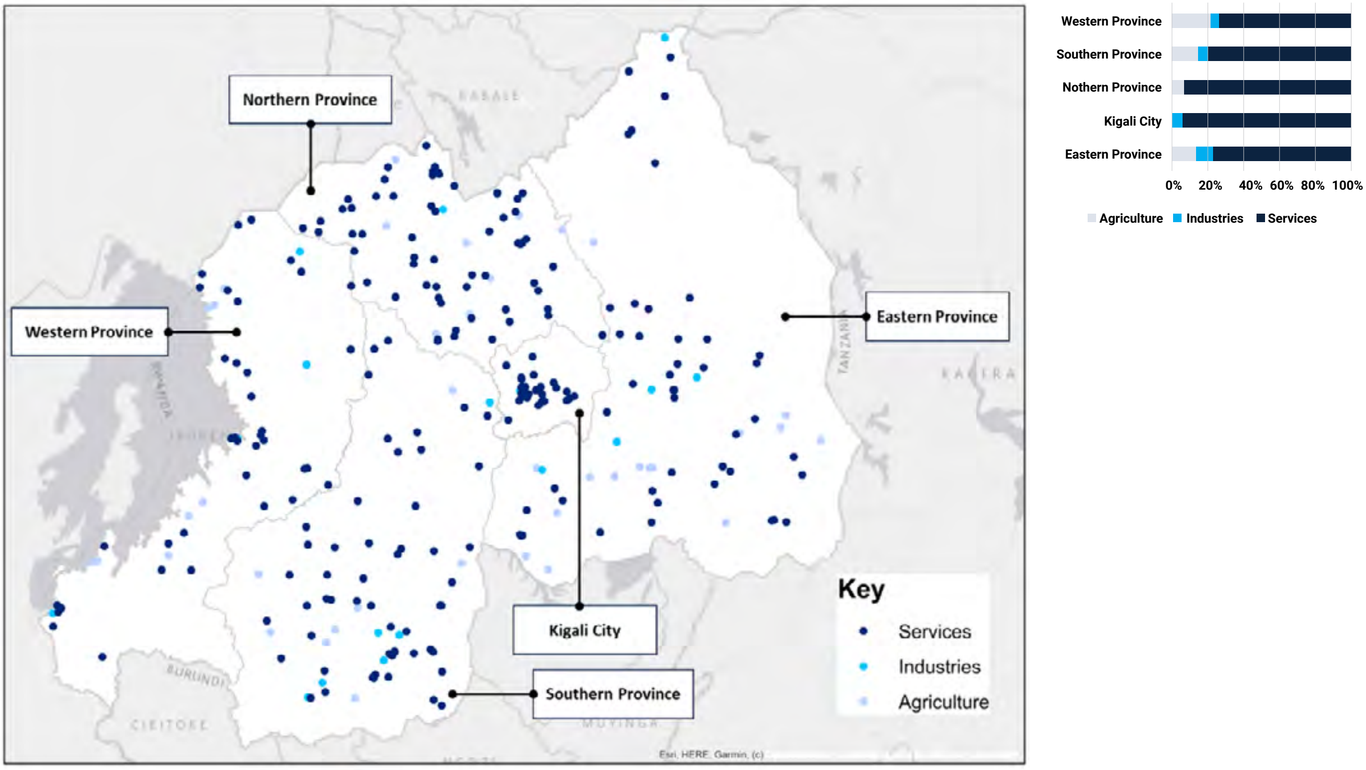
Productive use category	Sector	Total productive users in country	Sample size estimation	Completed surveys
Tea factory	A	15	7	6
Irrigation pumping	A	42	11	10
Milk collection centers	A	127	8	8
Coffee washing stations	A	295	20	20
Integrated craft-production centers	I	9	7	6
Industry parks	I	10	10	6
Water pumping/ treatments	I	108	9	7
Province offices	S	4	2	2
Airports and aerodromes	S	8	3	0
Polytechnic schools	S	18	7	6
District offices	S	30	12	12
Trade centers	S	13	8	9
Hospitals	S	48	9	11
IDP model villages	S	49	14	14
Universities and institutions	S	76	21	16
TVET schools	S	328	20	20
Sector offices	S	417	23	23

Productive use category	Sector	Total productive users in country	Sample size estimation	Completed surveys
Markets	S	417	31	28
Health posts	S	491	10	10
Health centers	S	503	12	10
Secondary schools	S	1,573	33	46
Cell offices	S	2,040	39	38
Pre-school and primary schools	S	2,825	54	43
Total		9,446	370	351

Note: All sampled airports and aerodromes, as well as various individuals from the other 22 categories, declined to participate in the survey. MINECOFIN color-coding is used to distinguish the sectors; A = agriculture, I = industry, and S = services.

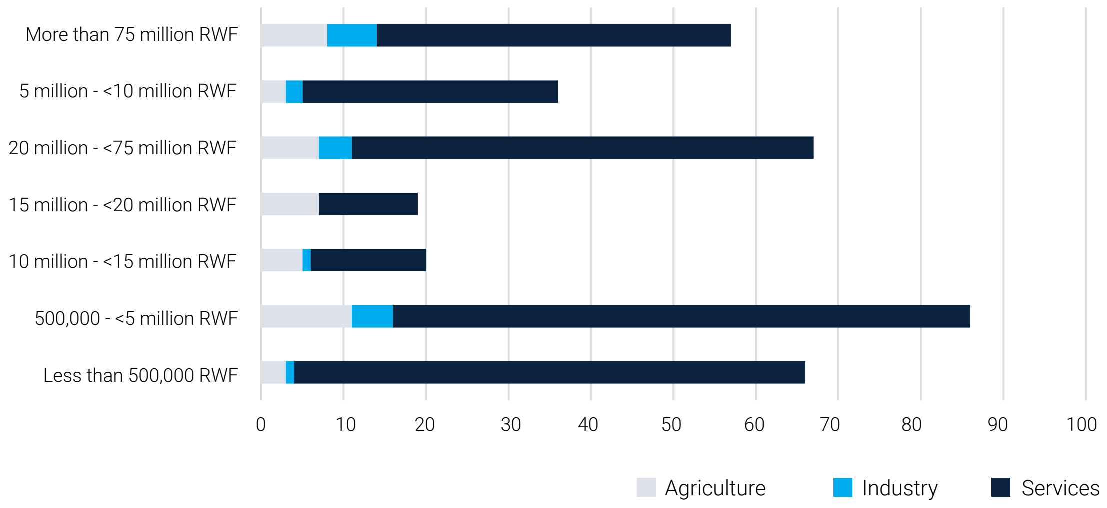
Productive energy users in the agriculture sector are highly concentrated in the Western, Southern, and Eastern provinces. By contrast, Kigali City is limited exclusively to the industry and services sectors (figure 3.1).

Figure 3.1 Map showing geographic distribution of survey respondents, by sector



The average annual income of the survey respondents varied greatly (figure 3.2). Most indicated an income that ranged between RWF 500,000 and RWF 5 million. The second largest income bracket was RWF 20–75 million.

Figure 3.2 Average annual income of survey respondents, by sector



The study found that 86.4 percent of productive energy users are connected to the main grid, while 8.5 percent use a rooftop solar system or solar home system (SHS) kit, 1.1 percent use a generator or a battery, and 4.0 percent have no grid connection (figure 3.3a). This indicates that more than 96 percent of the surveyed users have access to electricity through grid and off-grid solutions, suggesting that Rwanda is progressing toward electrifying all PUE categories, as outlined in its Energy Sector Strategic Plan (ESSP).

Figure 3.3 Power sources for productive energy users and access type

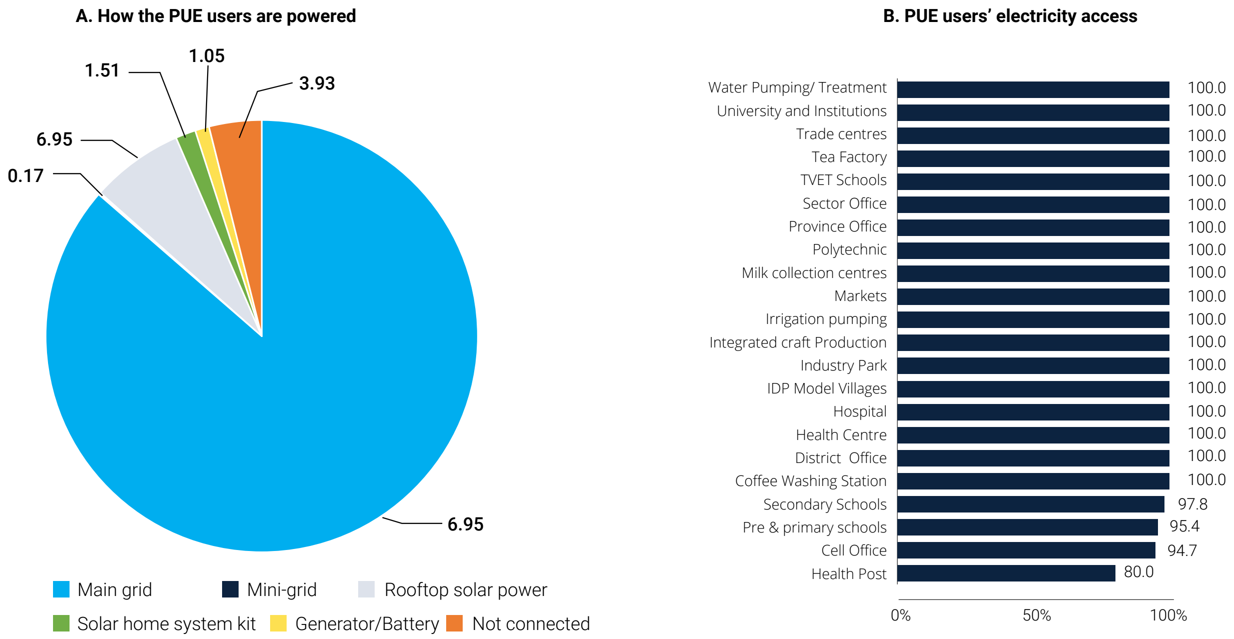
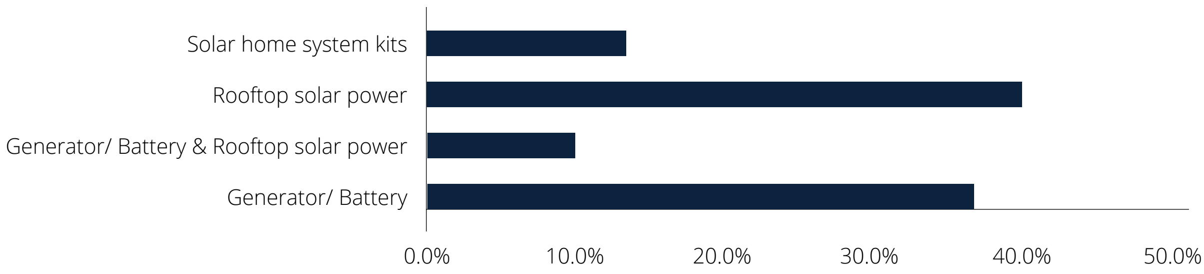


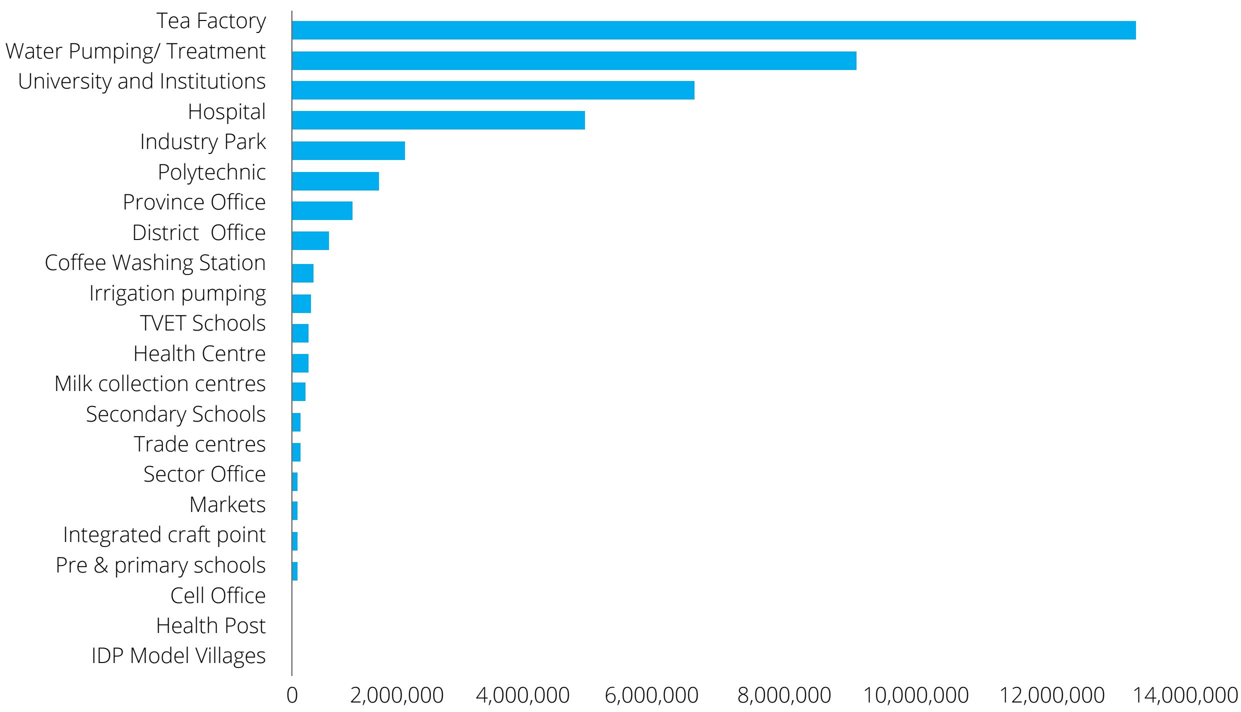
Figure 3.3b shows that most categories (e.g., health centers, sector offices, and markets) have achieved 100 percent electricity access. It also highlights the need for greater effort to electrify schools, as well as cell offices and health posts.

Figure 3.4 Grid backup sources and monthly energy expenditure by use category

A. Main grid backup

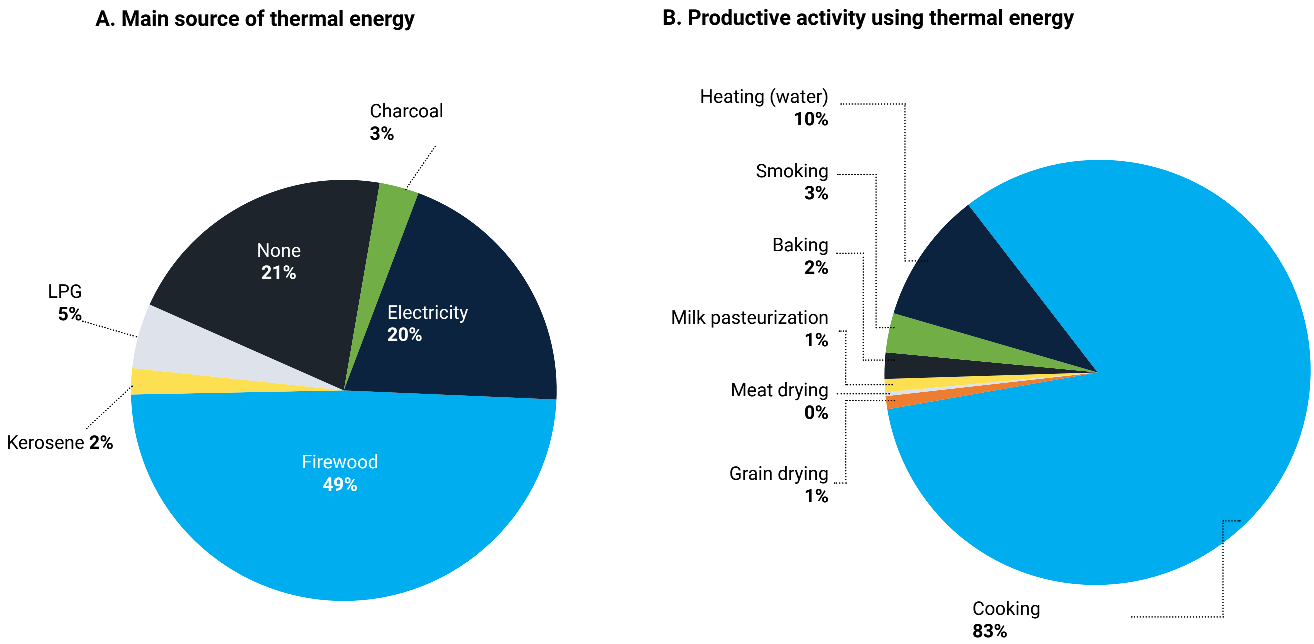


B. Average monthly expenditure on electricity and generator fuel



Some 10 percent of survey respondents that are connected to the main grid reported having a backup power source, the most common being captive rooftop solar PV, followed by a generator or battery (figure 3.4a). Monthly expenditure on electricity and generator fuel varied greatly by respondent categories. The surveyed tea factories and water pumping/treatment stations, all of which have universal main-grid access, have an average monthly expenditure of RWF 13.3 million and RWF 8.9 million, respectively (figure 3.4b). They utilize both grid and backup generators to maintain productivity uptime of equipment.

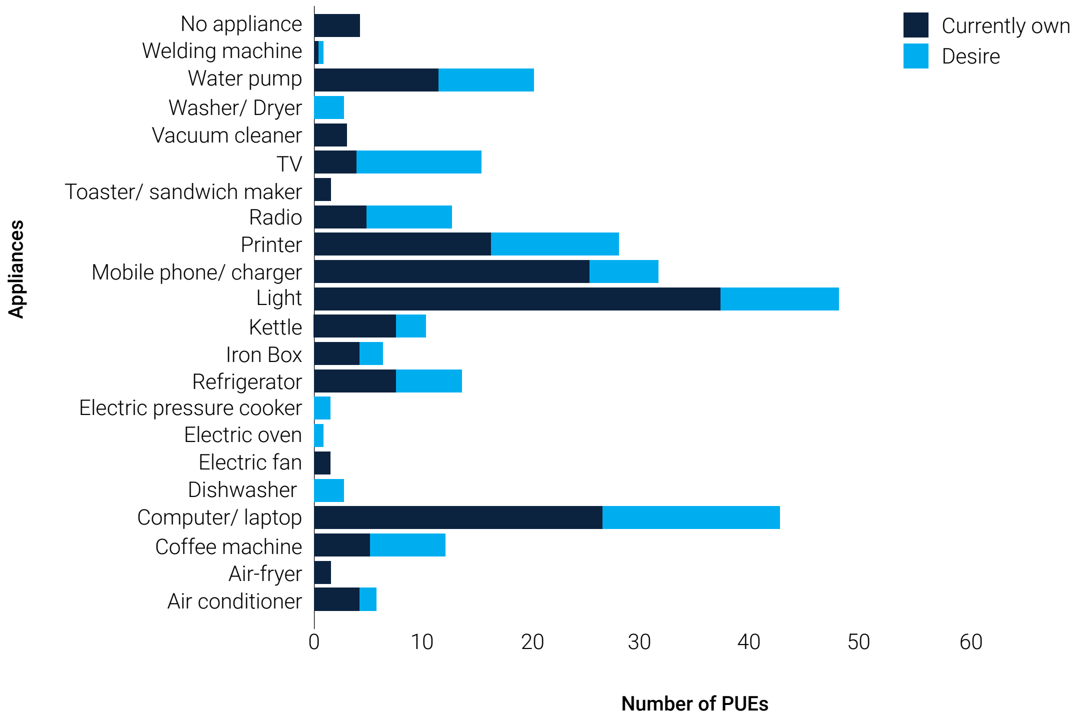
Figure 3.5 Thermal energy sources and productive activities



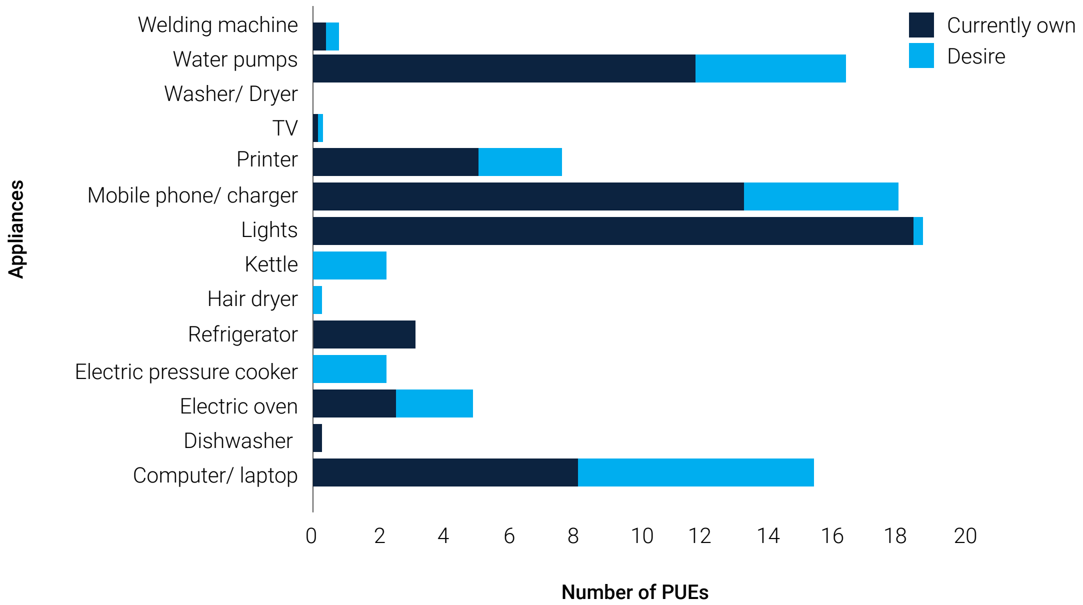
The study also examined respondents' main sources of thermal energy (figure 3.5a), as well as the productive activities that utilize them (figure 3.5b). As shown, the main source of thermal energy firewood, which is used by nearly half of the respondents (49 percent); this is followed by electricity (20 percent), liquefied petroleum gas (LPG) (5 percent), charcoal (3 percent), and kerosene (2 percent). Approximately 21 percent of the respondents reported not using any form of thermal energy. Cooking was reported by 83 percent as the main productive activity using thermal energy, followed by heating water (10 percent), smoking fish or meat (3 percent), and baking (2 percent); milk pasteurization and grain drying accounted for 1 percent each.

Figure 3.6 PUE appliances currently owned and desired, by sector

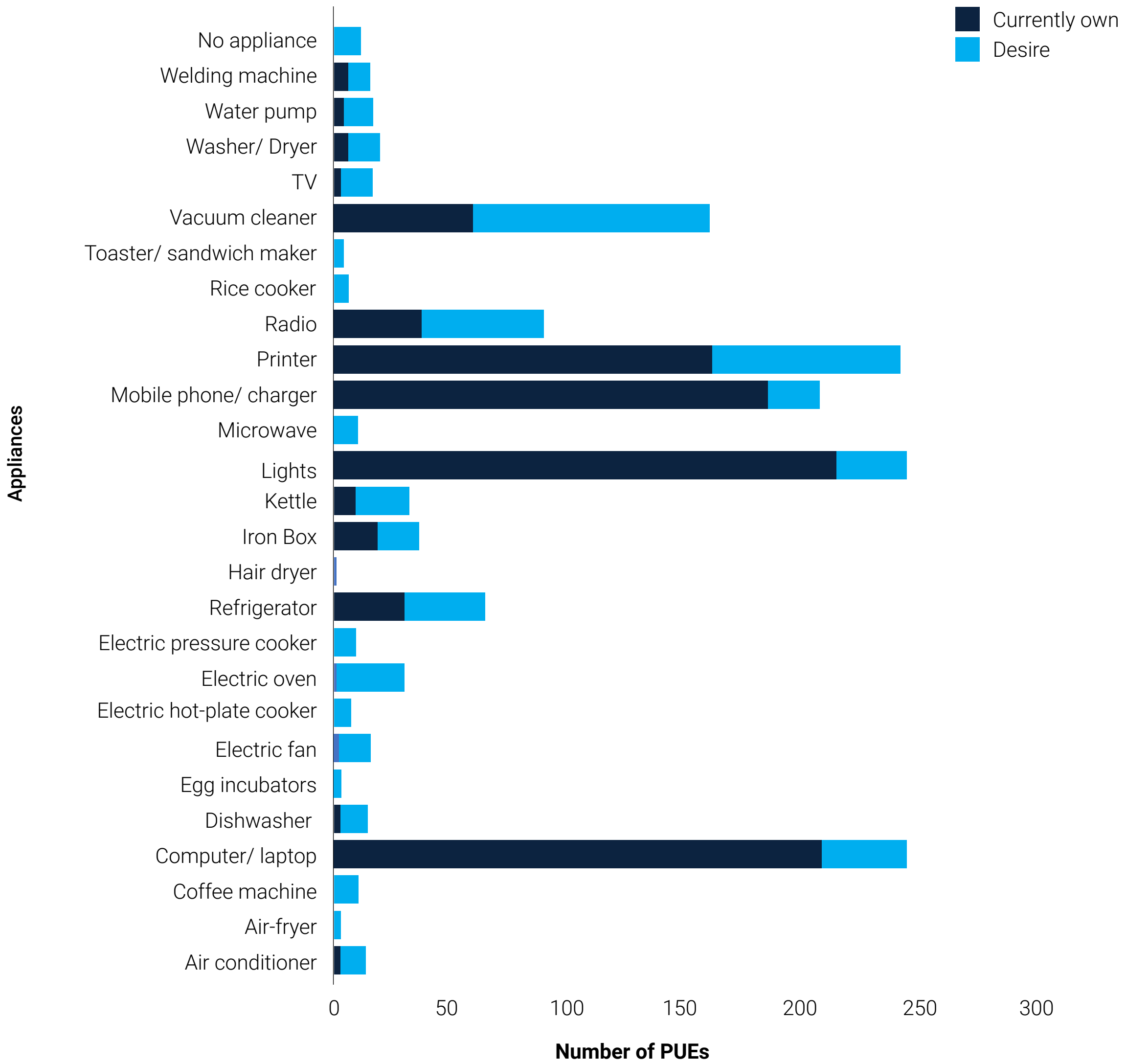
Agriculture



Industry



Services



The study investigated PUE appliance ownership by asking respondents to list the appliances they currently own and would like to own (figure 3.6). Aside from lights, the most commonly owned appliances across sectors were computers, printers, and mobile chargers (indicating mobile phone ownership). This trend was found to continue when reporting their most desired appliances (i.e., computers, laptops, and TVs). The highest ownership of computers and printers was found in the services sector, led by educational institutions (pre-primary and primary schools, secondary schools, and universities), followed by cell offices. Among the 20 coffee washing stations surveyed, 14 were using coffee processing machines; while 5 of the 8 milk collection centers surveyed, were using milk-cooling equipment. Among the 31 health-services facilities surveyed, 11 reported that they utilize a variety of medical appliances (e.g., oxygen plants and laboratory equipment).

Respondents in the agriculture sector expressed a desire for water pumps, coffee processing equipment, and general-use appliances like computers and printers. Those in the industry sector mentioned needing woodworking and welding machines, while respondents in the services sector expressed a need for refrigerators and electric ovens (Figure 3.6).

To gauge the prevalence of the hire-purchase business model, the study asked respondents if they had previously used it to buy appliances. The vast majority of respondents (95.2 percent) indicated they had not used the model, suggesting it had not been widely adopted in the country.

3.3 Electricity Consumption for Enterprise Productivity

To better understand the correlation between energy sector performance and users' electricity consumption, the study analyzed the current electricity consumption of productive users and modeled how their electricity consumption would change with (1) universal access, (2) improved reliability, and (3) lower electricity prices.

3.3.1 Consumption scenarios

To estimate the consumption baseline, the study obtained four years of electricity usage data provided by the REG (2019–22) for the sampled grid-connected respondents. To estimate consumption for each PUE category, the study matched the meter names and numbers from the survey with those in the REG database. Owing to mismatches and incomplete meter numbers, the final dataset was limited to 276. This included each PUE name and meter number, the REG consumption data for the four-year period, the PUE category (*i*), the 2023 grid access rate per PUE category (*R*), and the number of enterprises in each category (*N*). The study calculated the 2019–22 consumption compounded annual growth rate (*CAGR*) per PUE category, which was used to estimate the average consumption of a PUE in 2023 and 2024, as expressed in the following two equations:

2023 AVG consumption for PUE in category i=2022 Avg for category $i \times (1+CAGRi)$

2024 AVG consumption for PUE in category i=2022 Avg for category $i \times (1+CAGRi)$

The study calculated the estimated consumption in 2023 for current grid users, as follows:

Base Scenario=2023 AVG consumption for PUE in category $i \times N \times R$.

The universal access calculation was based on the Rwandan government's original aim of achieving universal (grid-tier) access by the end of 2024, expressed as follows:

Universal Access=2024 AVG consumption for PUE in category $i \times N$.

The respective scenarios for improved reliability and lower electricity price equal the estimated base scenario multiplied by the percent change in the consumption of more reliable or cheaper electricity. Table 3.2 presents the consumption modeling results.

Table 3.2 Baseline and modeled electricity consumption, by PUE category

PUE category	Electricity consumption (kWh)					
	Baseline scenario (kWh)	Universal access (kWh)	Improved reliability (kWh)	Improved reliability (% increase)	Reduced price (kWh)	Reduced price (% increase)
Province offices	66,285	58,474	66,285	0.00	69,999	6
Industry parks	8,951	9,152	8,952	0.01	11,927	33

PUE category	Electricity consumption (kWh)					
	Baseline scenario (kWh)	Universal access (kWh)	Improved reliability (kWh)	Improved reliability (% increase)	Reduced price (kWh)	Reduced price (% increase)
Tea factories	12,184	9,690	12,249	1	18,535	52
Polytechnic schools	273,002	313,334	275,790	1	293,172	7
District offices	568,236	607,325	589,498	4	576,721	1
IDP model villages	3,664	4,889	3,802	4	4,641	27
Markets	1,045,114	1,707,547	1,107,219	6	1,186,052	13
Integrated craft production centers	24,020	34,560	25,694	7	25,278	5
Coffee washing stations	914,359	2,354,166	982,184	7	1,021,570	12
Sector offices	502,645	536,717	548,970	9	219,699	-56
Hospitals	4,529,263	4,379,046	4,955,882	9	5,164,152	14
Health posts	39,668	134,134	43,675	10	31,184	-21
Secondary schools	3,685,829	3,902,976	4,171,891	13	4,060,795	10
Pre-schools and primary schools	1,137,074	1,485,846	1,359,473	20	1,411,114	24
Cell offices	229,747	259,703	276,001	20	264,968	15
Health centers	3,378,634	3,969,062	4,156,996	23	4,212,719	25
Universities and institutions	10,510,484	11,253,732	13,311,295	27	10,840,449	3
Milk collection centers	901,451	1,052,577	1,191,746	32	1,149,455	28
TVET schools	1,267,189	1,329,487	1,830,775	44	1,737,062	37
Trade centers	17,221	20,866	17,777	3	18,511	7
Total	29,115,021	33,423,283	34,936,154		32,318,003	

The combined annual electricity consumption for PUE users in 2023 was 29.1 GWh (table 3.2),[3] with hospitals and universities representing the largest consumers. According to the REG, nationwide energy consumption in 2022/23 totaled 993,643,572 kWh. Table 3.3 estimates electricity consumption by customer segment.

Table 3.3 Rwanda's electricity consumption in 2022/23

Customer segment	Consumption (kWh)	Consumption (%)
Domestic/Residential	193,599,740	19
Export	7,364,392	1
Industries		
Large	246,528,191	25
Medium	50,084,009	5
Small	20,580,637	2

3 Excludes airports, irrigation, and water pumping stations since no energy consumption data for these categories was received for analysis.

Customer segment	Consumption (kWh)	Consumption (%)
Non-residential		
Others[a]	228,321,950	23
Water treatment plants	51,301,146	5
Telecommunication towers	53,239,965	5
Hotels	49,310,219	5
Water pumping stations	40,898,264	4
Health facilities	21,847,137	2
Streetlights	23,605,027	2
Broadcasters	4,846,362	0
Data centers	2,116,534	0
Total consumption	**993,643,572**	**100**

Sources: RURA 2023; REG data.
a. REG classification.

The survey covered 20 PUE categories classified as non-residential customers or industries,[4] whose estimated consumption is 29,115,021 kWh. Including secondary data from the REG for water treatment plants and water pumping stations (indicated in table 3.3), the total PUE consumption for 21 categories is 121 GWh or 12.2 percent of national consumption. However, this data may be underestimated as such large industries as airports were not included.

3.3.2 Key findings

According to the surveyed users, the unit price of electricity is the most significant factor influencing electricity consumption, surpassing the perceived lack of reliability by a factor of 3. The modeling findings indicate that users' electricity consumption would rise by 15 percent with universal grid-tier access, by 20 percent with improved reliability, and by 62 percent if electricity tariffs were reduced by 15 percent. These findings are in line with those of the Ease of Doing Business and Enterprise Survey reports (World Bank 2020; World Bank Group 2020), which show that Rwanda's electricity access and reliability parameters are leading the Sub-Saharan Africa region, with more than 84 percent of firms reporting that electricity presents little to no obstacle to business operations.

Although 39 percent of enterprises do experience electrical outages, this figure compares favorably with the 77 percent experienced by the region overall (World Bank Group 2020). Power outages cause median losses estimated at 2 percent of total annual sales, with the highest loss being 30 percent. This equates to a median monetary loss of RWF 150,000 (US$150). The amount of time spent using backup generators averages 7.3–10.1 percent. The annual electricity expenditure of PUE enterprises, averaging US$1,382 for retailers and US$20,403 for manufacturers, aligns with the high power consumption typical of productive electricity use. To sum up, the findings suggest that tackling Rwanda's affordability issue through tariff reductions would unlock a significant amount of latent electricity demand.

4 The 20 PUE categories are cell offices, coffee washing stations, district offices, health centers, health posts, hospitals, IDP model villages, industry parks, integrated craft-production centers, markets, milk collection centers, polytechnic schools, Pre-schools and primary schools, secondary schools, province offices, sector offices, tea factories, trade centers, TVET schools, and universities and institutions.

CHAPTER 4

ANALYSIS OF PUE TECHNOLOGIES

4.1 Market Overview

Manufacturing of appliances and consumer electronics is not widespread in Rwanda. For example, the country does not manufacture modern cooking appliances (Ntivunwa 2022), and the East Africa region generally has hardly any manufacturing of refrigerators and TVs (UKaid 2021). Therefore, to ascertain the level of supply for various productive use of energy (PUE) technologies, the study analyzed the import and sale of appliances.

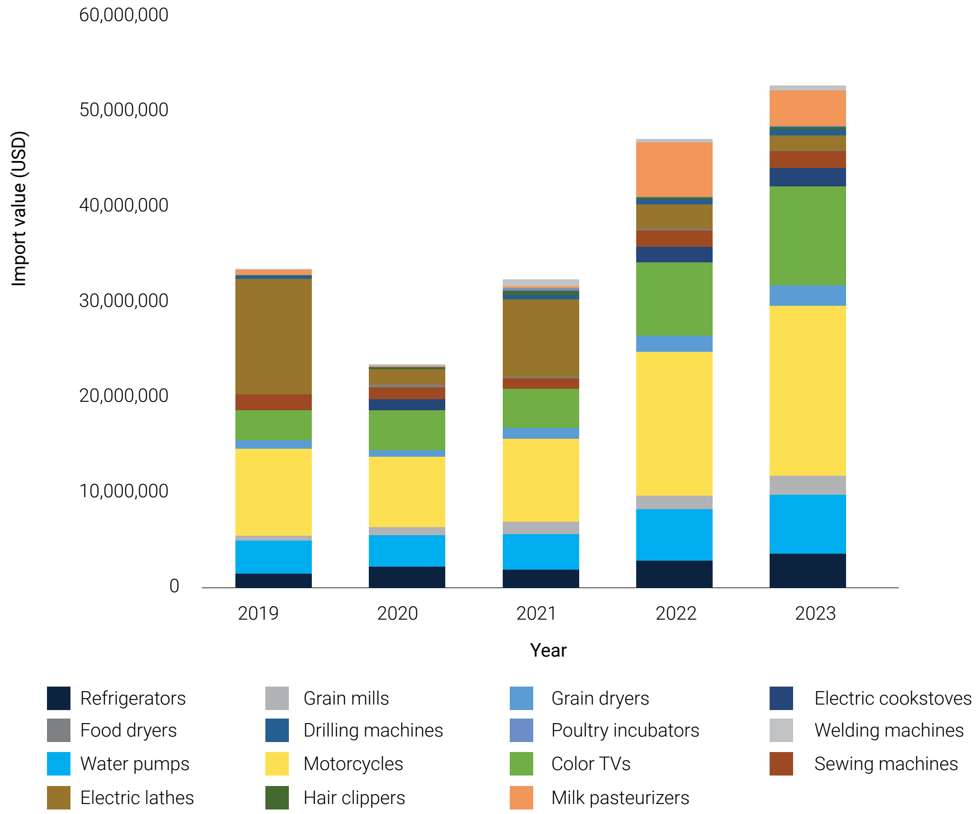
Electrical machinery (both on- and off-grid), electronics, and mechanical appliances are the largest group of imports in Rwanda.[5] In 2021, this group, worth nearly US$650 million (OEC 2023), accounted for more than 18 percent of imports. Analysis of import data from the Rwanda Revenue Authority (RRA) suggests that imports of common PUE appliances totaled over US$47 million in 2022,[6] up from US$32 million in 2019 (figure 4.1). Based on the RRA data, the most consistently significant imports over the past four years with the highest U.S. dollar value are motorcycles, color TVs, water pumps, and refrigerators. Over the same period, imports of electric lathes, grain dryers, and milk pasteurizing equipment experienced an uptick for a year or two, but then fell back, possibly because of these appliances' specific uses.

The PUE technologies market for off-grid appliances in Rwanda is still nascent, especially for such ones as solar egg incubators; off-grid cold storage; and solar irrigation, which is undergoing early-stage testing (ACE TAF 2021b). This market, which covers agro-processing, has a large potential compared to more developed markets in the manufacturing, mining, and, to some extent, services and information technology (IT) sectors. For example, in the first half of 2022, 5,400 off-grid appliances were sold, consisting mostly of TVs, as well as fans, refrigeration units, and solar water pumps (SWPs) (GOGLA 2023); these sales represented a 26 percent increase from the previous half year, indicating a present and growing demand for these service appliances (figure 4.2). Because these four appliances are considered to have reached mainstream levels of production, GOGLA includes them in its semi-annual sales and impact reports (GOGLA 2023). Other appliances, which participating off-grid companies generally do not report on owing to their lower volumes, include hair clippers, solar electric cookstoves, and stereo systems.

5 Refined petroleum is the largest import.

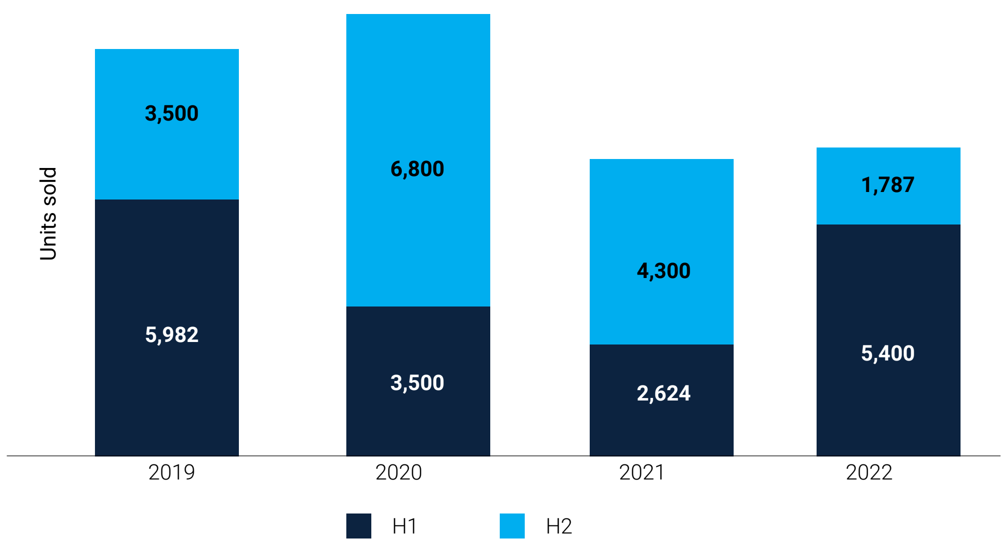
6 Exchange rate of US$1 to RWF 1,000.

Figure 4.1 Appliance import data



Source: RRA.
Note: The 2023 import values are estimates based on the CAGR of the previous years.

Figure 4.2 Off-grid appliances sold, 2019–22



Source: GOGLA reports.
Note: H1 and H2 refer to the first and second halves of the year, respectively.

Based on interviews with appliance retailers, table 4.1 lists many of the PUE technologies currently on the market.

Table 4.1 Non-exhaustive list of PUE technologies on the market, by sector

PUE product	Model	Supplier	Price (RWF)	Power rating (W)	Power type	Warranty (no. of years)
Agriculture[a]						
Solar irrigation pump	SUNFLO-S 1000C	Dayliff	1,500,000	1,000	Solar	1
	SUNFLO-S 300		620,000	300	Solar	1
	DSD 3/13		2,500,000	750	Solar	1
Grain mill	5TY-60G	Bleu Gear Machinery	700,000	1,600	AC	0
	FFC45		1,800,000	11,000	AC	0
	9FC2021R		1,000,000	7,500	AC	0
	9R50-60F		4,000,000	30,000	AC	0
	-	GIT Ltd	1,500,000	3,000	AC	1
Industry[b]						
Welding machine	Makita GA9020	SOFARU	145,000	2,200	AC	1
	Makita GA9063		250,000	2,200	AC	1
	Stanley AC-ST-183	Akagera Business Group	178,000	1,300	AC	1
	Bosch HWS24-230		180,000	1,300	AC	1
	Edon ARC630	Set Tools Hardware	300,000	630	AC	1
	Kingmax TIG-400		400,000	400	AC	1
	Werder BX6-500B AC		500,000	500	AC	1
	Edon NBC-500		1,500,000	24,000	AC	1
Sewing machine	Dragonfly DF954	Sonniac Electronic	350,000	90	AC	0
	JH307		280,000	220	AC	0
	Citizen 81K6		200,000	300	AC	0
Soldering machine	Suder SE-830	M. N. Uwimana	8,000	30	AC	0
	Terminator TE950		7,000	30	AC	0
Services[c]						
Electric cooker	Bluefame S6031ER-I	CIDU Electrical	370,000	3,000	AC	3
	Nobel NBH6040SH	Akagera Electronics	230,000	5,000	AC	1
Refrigerator	RISH KRF-138-WF	CIDU Electrical	300,000	100	AC	2
	ROCH RFR-230DT-B		350,000	120	AC	2
	ICONA London ILRF-455GB		700,000	20	AC	3
Freezer	SAYONA SAY-2013		300,000	120	AC	3
	FLORSA HS338Y		280,000	300	AC	5
Hair clipper	WAHL 8487	Birori Electronic Shop	65,000	11	AC	0
	WAHL 8187		85,000	11	AC	0
	Philips S1223		60,000	20	AC	0
Hair dryer	Leriotti 101GK011	Kazi ni Kazi	40,000	1,700	AC	0
	Mengyashi MYS-998	CIDU Electrical	30,000	2,000	AC	1

a. Food crops, export crops, livestock and livestock products, forestry, and fishing

b. Manufacturing, mining, and quarrying

c. Wholesale and retail trade, transport, hotels and restaurants, telecommunications, health, and professional services

4.2 Selection of High-Potential Technologies

To identify high-potential PUE technologies, the study began by examining (1) the key economic sectors linked to GDP growth in the country, as provided by the Ministry of Finance and Economic Planning (MINECOFIN); (2) common technologies or processes that currently power these sectors; and (3) potential replacement by PUE technologies (table 4.2).

Table 4.2 GDP growth sectors and technologies

Sector	Current technologies or processes	Potential PUE technologies
Agriculture[a]		
Production	Manual and engine-powered irrigation pumps, hatcheries, manual milking	Electric and solar-powered pumps, egg incubators, milking machines
Processing	Engine-powered mills, sunning, grinding, manual threshing, fermentation	Food dryers, electric mills and grinders, pasteurization
Post-processing	Open-air storage and transportation, milk cans, natural cooling	Freezers, milk coolers, electric vehicles
Industry[b]		
Production	Hand tools, diesel-powered welding, manual sewing machines, hand saws	Electric sewing machines; electric welding, drilling machines, and lathes; electric saws
Services[c]		
Barber shops and hair salons	Mechanical hair clippers, hot irons	Hair clippers and dryers
Hotels and restaurants	Fuel-based cooking, natural cooling	Electric cooking, refrigerators
Wholesale and retail trade	Candles and torches, natural cooling	Electric lighting, refrigerators
Telecommunications	n.a.	Mobile phones, computers and scanners, TVs and radios
Transportation	Fossil fuel–powered vehicles	Electric vehicles

Note: n.a. = not available.

a. Food crops, export crops, livestock and livestock products, forestry, and fishing.

b. Manufacturing, mining, and quarrying

c. Wholesale and retail trade, transport, hotels and restaurants, telecommunications, health, and professional services

The next step was to evaluate the identified technologies based on an equally weighted, multi-dimensional scoring criterion that assessed the technologies against three metrics: (1) economic potential, (2) sectoral reach, and (3) scalability (table 4.3).

Table 4.3 Selection criteria

Metric	Description	Scoring method		
		1	2	3
Economic potential	Role of the appliance in direct income generation demonstrated through a favorable return on investment	Low internal rate of return (IRR) or net present value (NPV) of the appliance	Moderate IRR or NPV of the appliance	High IRR or NPV of the appliance
Sectoral reach	Size and importance of the sector to the economy in which the PUE technology is used	Appliance used in an economic sector with a low contribution to GDP and contributes minimally to employment	Appliance used in an economic sector with a moderate contribution to GDP or employs a significant percentage of the population	Appliance used in an economic sector with a high contribution to GDP and employs a significant percentage of the population

Metric	Description	Scoring method		
		1	2	3
Scalability	Extent to which the appliance can be used across markets and contexts as opposed to specific areas or functions: 3 = universally applicable; 2 = more than one application; 1 = specific to one application	Appliance can be used in only one productive use application	Appliance can be used in up to two productive use applications	Appliance can be used in multiple productive use applications

This analysis uses a scale of 1–3 to allocate a score against each of the three metrics, classifying the outcome on a red, amber, and green (RAG) rating (table 4.3). The final score is the sum of the three metrics (table 4.4). The RAG screening score is also color-coded. The score allocation is based on an evaluation of information and data using various data collection approaches (Annex A).

Table 4.4 PUE technology ranking

PUE Technology	Economic potential	Sectoral reach	Scalability	Score
Electric water pumps	3	3	2	8
Solar water pumps	3	3	3	9
Egg incubators	3	2	1	6
Milking machines	2	3	1	6
Food dryers	2	3	1	6
Electric mills	2	3	1	6
Cold storage and refrigeration	3	3	2	8
Milk coolers	3	2	1	6
Electric sewing machines	2	2	1	5
Electric welding machines	3	2	1	6
Electric drilling machines	3	2	1	6
Electric lathes	3	2	1	6
Electric saws	3	2	1	6
Hair clippers and dryers	2	2	1	5
Electric cookstoves	2	2	3	7
Electric motorcycles	3	3	3	9
TVs and radios	1	2	2	5
Computers and scanners	1	2	2	5

4.2.1 Water pumps

The Rwandan government has proposed reducing reliance on rainfed agriculture through marshland, hillside, and small-scale irrigation. The original target was to have increased the hectares under irrigation from 68,126 in June 2022 to 102,284 in 2024 (MINAGRI 2022). Water pumps, both grid-based and solar-powered, can help achieve this goal. Water pumps can facilitate a wide range of agricultural production (e.g., food crops, export crops, livestock production, pond fishing, and washing stations used in coffee processing). Solar water pumps (SWPs) score higher than grid-powered electric pumps because of their ability to reach both grid-based and off-grid markets; however, both types of pumps benefit from a similarly high internal rate of return (IRR).

Currently, only 8.1 percent of small-scale farmers practice irrigation (MINAGRI 2022), while only 2 percent practice machine-powered irrigation (mostly using diesel fuel) (E4I 2021). It has been shown that the net present cost (NPC) for SWPs is over 28 percent (Uwamahoro 2020); this figure is lower than the NPC for diesel-powered pumps, indicating that, despite their initial expense, SWPs are cost-effective over the long term. SWPs do not have variable operating costs, but they do have fixed maintenance expenses, which might include replacing the pump every 8–15 years, depending on siltation and quality of the water supply (Guno and Agaton 2022); however, diesel pumps are also impacted by water quality. Depending on the type of crop and number of seasons cultivated, a SWP would pay for itself within six months to three years (E4I 2021).

An estimated IRR as high as 36 percent has been recorded for both AC-powered pumps and SWPs (World Bank 2018). This study's pilot findings show that the estimated IRR for a farmer earning RWF 120,000 per month is 17 percent, with a 24-month payback period for the appliance, assuming pay-as-you-go (PAYG) terms of 18 percent annual interest over the loan repayment period. The difference in IRR can be attributed to the type of crop chosen by the farmers. High-value cash crops and those that are cultivated multiple times a year offer a higher IRR.

4.2.2 Cold storage and refrigeration

To mitigate post-harvest losses, currently estimated at 40 percent, the National Cooling Strategy is promoting cold storage (MoE 2019). The strategy also envisions cooling infrastructure to support such productive sectors as trade and exports and health. The number of refrigerators in Rwanda is expected to increase sharply owing to growth in GDP, population, and electricity access.[7] At present, residential customers represent 85 percent of refrigerator sales, while commercial users account for the remaining 15 percent (e.g., hotels, restaurants, agribusiness, and food and beverage production) (MoE 2019). Packhouses, cold rooms,[8] and charcoal coolers are mainly used to preserve flowers, fruits, and vegetables (NAEB 2019). Most of these are open to the public for rent using pay-as-you-store operating models. Cold rooms run by individual companies for their own use are fewer in number, but represent the bulk of storage capacity volume. Currently, the rental charge to the public per 70 kg sack is in a range of RWF 31–200. Aside from high energy costs, frequent power interruptions, and low levels of cold-room maintenance, the location of cold rooms must be paired with other strategic services (e.g., airports or major roads) in order for users to benefit from the enhanced supply chain logistics.

It has been found that off-grid refrigerators with a payback period of six or more years are viable for productive uses when the net income for capital recovery is approximately US$10 per week and taxes are exempt (Efficiency for Access Coalition 2020). Compared to off-grid and solar refrigerators, on-grid refrigerators cost significantly less—about half the price in some cases (E4I 2017), but their operating cost is higher; they consume 0.8–1.5 kWh per day (BASE 2020), which translates to about US$10 per month. However, the payback period (three-to-four years) is less than that of a similarly sized off-grid or solar refrigerator. During the study's pilot-testing phase, a respondent with a net income of RWF 180,000 purchasing a 208 liter refrigerator with a 24-month loan repayment period (at 18 percent annual interest) had an estimated IRR of 34 percent.

7 Current estimates on the number of refrigerators in Rwanda are 75,000 (MoE 2019) and 97,500 (BASE 2020).

8 As of 2019, the country had 52 cold rooms across 15 districts.

4.2.3 Electric motorcycles

Fossil fuels are Rwanda's largest import. In 2021, more than US$302 million worth of refined petroleum was imported into the country. (OEC 2023). High reliance on imported oil hampers Rwanda's energy security, leaving it vulnerable to external shocks. Also, the transport sector is among the country's main emitters of greenhouse gases (GHGs). The national fleet of approximately 265,000 vehicles (2020 figure), excluding government and security agency vehicles, has an annual growth rate of 12 percent (MININFRA 2021b).

Electric motorcycles can potentially replace internal combustion engines (ICEs) for delivery and taxi use. Moreover, in off-grid regions utilizing solar PV, they can aid smallholder farmers and micro-, small-, and medium-sized enterprises (MSMEs) to transport raw products and finished goods. At present, Rwanda has at least three electric motorcycle companies in operation (MININFRA 2021b). It has been found that electric motorcycle taxis are less than 8 percent more expensive than petrol-driven ICE motorcycles to buy and operate for the first year (MININFRA 2021b), with 30 percent lower annual operating expenses thereafter. During the study's pilot-testing phase, a respondent generating RWF 250,000 per month purchasing an e-motorbike with a 24-month loan repayment period (at 18 percent annual interest) had an estimated IRR in a range of 36–94 percent. Electric motorcycles can allow for quick electrification of the transport sector; compared to four-wheeled electric vehicles (EVs), they cost less, have simpler charging processes, and do not require elaborate infrastructure.

4.2.4 Electric cookstoves

Biomass is used to meet up to 85 percent of Rwanda's current energy needs.[9] Households account for the bulk of this use (91 percent), with the remainder represented by industry (4 percent), non-energy usage (2 percent), and commercial and public sectors (1 percent). At present, the prevalence of electric cooking (eCooking) in Rwanda is quite low, at just 0.19 percent (Čukić et al. 2021). However, ongoing improvements in energy access and reliability have created the potential for widespread adoption.

9 Details are available from the Ministry of Infrastructure (https://www.mininfra.gov.rw/).

The Biomass Energy Strategy (BEST), developed by Rwanda's Ministry of Infrastructure (MININFRA), aims to reduce the use of wood energy resources through the promotion and adoption of alternative clean and efficient cooking solutions. In 2022, the Rwandan government set a 2024 target for reducing dependency on biomass cooking energy from 77.7 percent to 42.0 percent. The policy target for liquefied petroleum gas (LPG) was set at 40 percent of the population (across residential, institutional, and industrial sectors); and targets for electricity, biogas, and improved high-efficiency biomass cookstoves were set at 2 percent. No specific target was set for eCooking; however, the government included electricity as an alternative source of cooking energy, particularly for the hospitality sector and high-income segments of the population.

In accordance with the Ministerial Guidelines for Clean Cooking Technologies (MININFRA 2022b), the local government should regularly carry out awareness campaigns through its existing platforms on the adoption and use of clean cooking technologies. Also, the Development Bank of Rwanda (BRD) should implement measures to promote investment in clean cooking technologies to attract private investors in the production of clean cooking fuels and appliances.

The positive outcomes for e-Cooking are many, including lower cooking costs, shorter cooking times, less deforestation, reduced GHG emissions, and cleaner air (Byrne et al. 2020). During the study's pilot-testing phase, it was found that a business making RWF 250,000 per month purchasing electric pressure cookers (EPCs) with a 12-month loan repayment period (at 18 percent annual interest) had an estimated IRR 45 percent higher than that of all other appliances tested.

4.3 Market Sizing

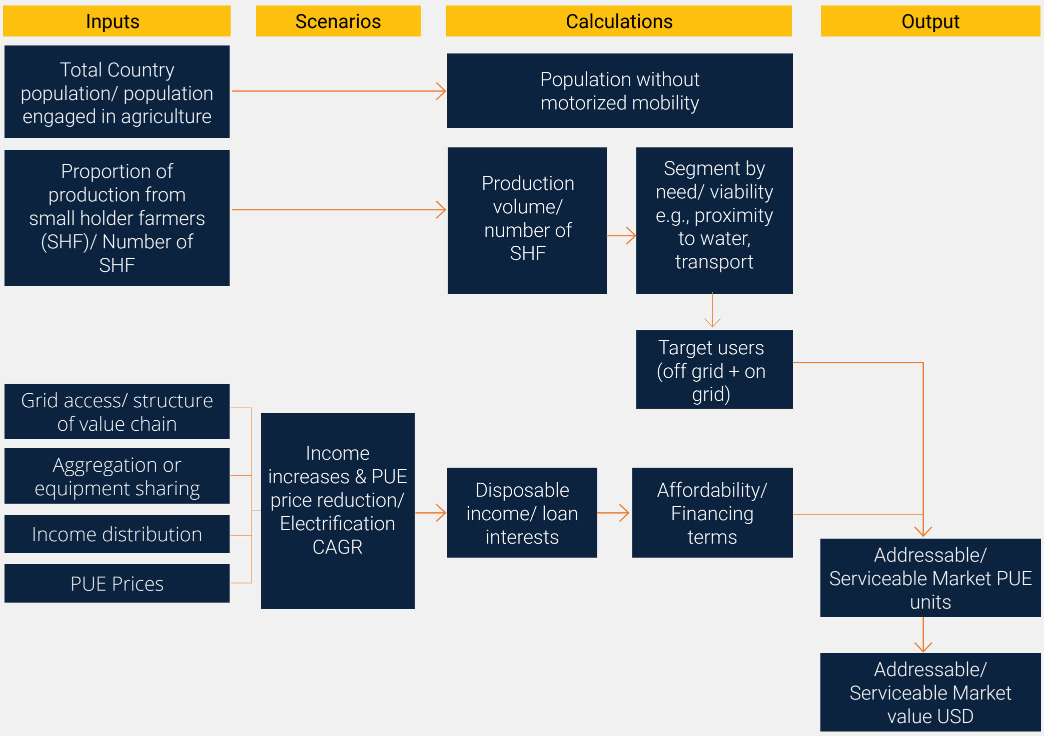
4.3.1 Overview of the analysis

Estimating the addressable and serviceable markets for the four identified, high-potential PUE technologies was based on Rwanda's economic activities and the potential growth of the appliance market projected over the next decade. The market sizing model employed a top-down approach using the latest available data and updated the assumptions with appropriate available data, and where missing, applied a region-specific assumption (box 4.1). The model heavily referenced the latest Rwanda census data to obtain relevant demographic information and other survey reports from the National Institute of Statistics of Rwanda (NISR) (NISR 2023 a–d). Data from stakeholder consultations was used to validate secondary data sources. Table B.1 lists the model's data sources and explains key variables and data definitions (Annex B).

Box 4.1 Value Chain Analysis

The study's market-sizing modeling exercise involved a detailed value chain analysis, as well as a sector-specific evaluation to quantify production volumes (figure B4.1.1). When sizing the market for irrigation pumps and refrigerators, the number of smallholder farmers was key to determining the total addressable market (TAM). For electric motorcycles, the study adopted an alternative method that examined the existing vehicle penetration rate and the percentage of the population reliant on electric motorcycles for transport. This helped to estimate the number of households that will require motorized mobility. The modeling exercise also considered other constraints (e.g., grid access, affordability, and financing terms) that are essential for determining the total serviceable market (TSM). The TAM and TSM were multiplied by the unit price of the appliance to calculate the market value in dollars.

Figure B4.1.1 Logical flow of the PUE market-sizing model



4.3.2 Addressing affordability assumptions

Multiple key informant interviews (KIIs) conducted by the study indicate that the up-front cost of PUE appliances is out of reach for most of the population, suggesting the need for demand-side interventions. On the supply side, the equipment companies do not always provide a hire-purchase model for the appliances.[10] One reason given by those interviewed is that the distribution companies do not have access to affordable credit lines and thus maintain low inventories and are unable to offer end users long-term credit.

10 Under the hire-purchase model, appliances are bought by placing a down-payment and making installment payments over the course of a contracted period.

For the purposes of this estimation, a lease-to-own model was considered to enable acquisition of the PUE assets. Research carried out by Efficiency for Access indicates that productive energy users require an average of one-to-two years to see positive returns and increase their revenue enough to pay off the loan within the product's warranty period (Ireri et al. 2023). Considering the interest rate on loans in Rwanda's commercial sector, the study applied an average of 18 percent interest with a 36-month repayment period after deducting a 10 percent down-payment. This was validated by checking with the Development Bank of Rwanda (BRD) on the typical commercial terms for credit. The customers' ability to pay was computed based on the assumption they would commit a maximum of 15 percent of their monthly income toward repayment of the appliance. This conservative figure was chosen to minimize the risk of default due to over-indebtedness, given that disposable income levels are already quite low. Adjusting this figure upward could potentially increase affordability but would be less representative as incomes are typically seasonal (Efficiency for Access 2023). It is also important to note that pricing in this version of the model did not consider the cost of auxiliaries (e.g., water infrastructure in the case of water pumps or insurance and other related costs in the case of electric motorcycles). Ideally, such costs would be covered at the time the initial deposit is made.

4.3.3 Estimating addressable and serviceable markets

For each of the high-potential PUE technologies studied, the model used the following tools to estimate Rwanda's current and potential market size over the next decade:

- **Total Addressable Market (TAM).** This is the estimated value of the entire revenue opportunity for a product or service that exists in a market. It is expressed as the total number of potential customers multiplied by the U.S. dollar value of the product or service per customer.

- **Total Serviceable Market (TSM).** This is the part of the market that can be immediately and realistically served. It is expressed as the total number of potential customers multiplied by the U.S. dollar value of the product or service per customer, which is then multiplied by the percentage of ready and reachable customers (CFI 2022). The figure for ready and reachable customers is derived from the willingness-to-pay and income matrix, which analyzes the potential customers that are the easiest to reach. The TSM introduces the affordability constraint, informed by population income levels and credit terms.

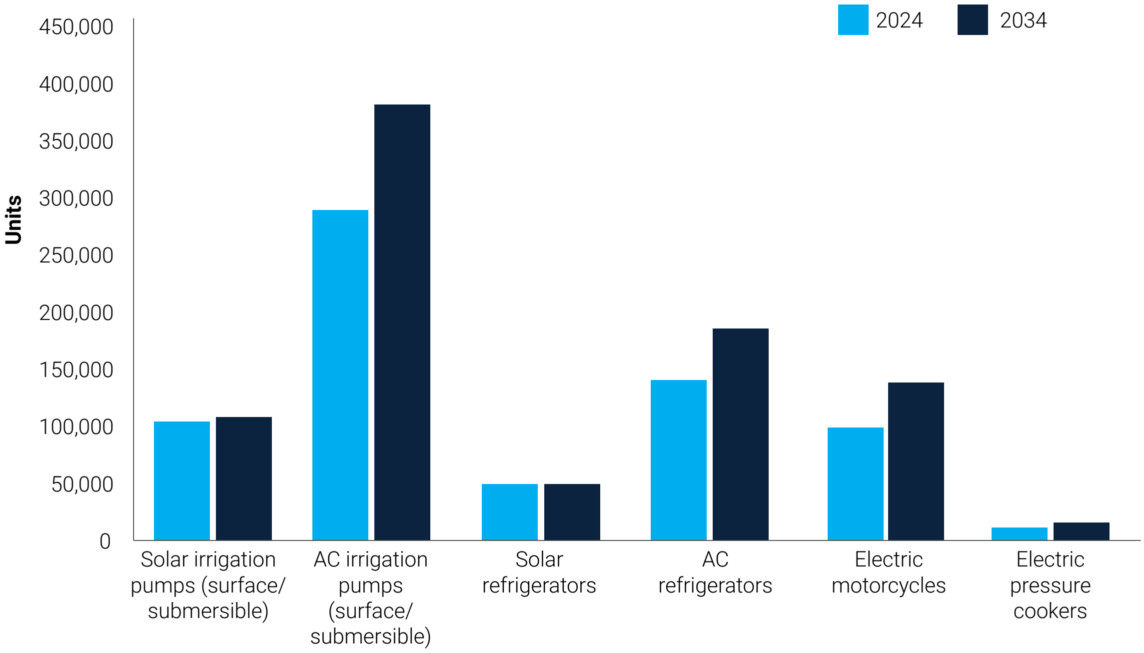
A forecast of the productivity gains and increased income derived from owning a PUE technology was used to compute the estimated internal rate of return (IRR) and appliance payback period. The economic analysis was enhanced by considering how the future costs of both the existing and upcoming technologies will evolve. For example, solar-powered PUE alternatives have seen a price reduction due to improved technology efficiency and declining prices for batteries and panels. The study employed the use of experience curves to model the relationship between the technologies' cost decrease and cumulative production experience.

The modeling results show that today's TAM for the high-potential PUE technologies is approximately US$715 million, which is projected to rise to over US$856 million by 2034 (table 4.5 and figure 4.3).

Table 4.5 TAM per technology, 2024 and 2034

PUE technology	TAM (units)		CAGR (%)	TAM (US$)	
	2024	2034		2024	2034
Irrigation pumps (surface/submersible)					
Solar	104,421	109,368	0.5	172,928,221	172,867,401
AC	291,018	383,720	2.8	231,731,692	291,627,372
Refrigerators					
Solar	50,933	53,705	0.5	61,780,117	53,181,417
AC	141,949	188,425	2.9	102,533,061	129,903,085
Electric motorcycles	101,397	139,946	3.3	190,244,463	250,608,173
Electric pressure cookers (EPCs)	11,701	16,149	3.3	7,195,827	9,479,030
Total	701,420	891,312		715,089,931	856,361,080

Figure 4.3 Current and projected TAMs

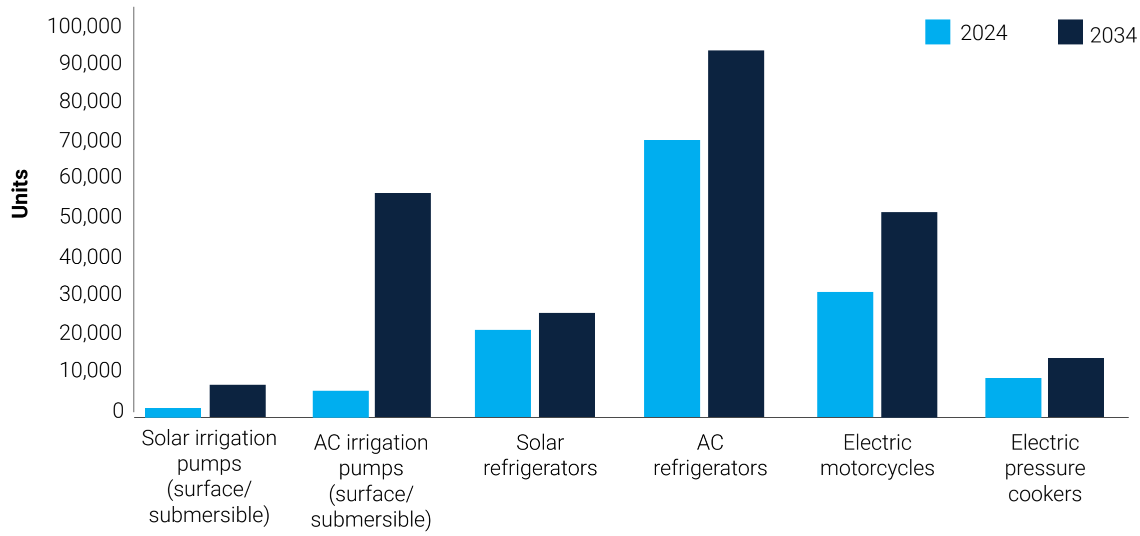


To ascertain the corresponding TSMs, the affordability parameters were added. The results indicate that the TSM is a significantly small subset of the TAM (table 4.6 and figure 4.4).

Table 4.6 TSM per technology, highlighting the latest import market data

PUE technology	TSM (units)		CAGR (%)	TSM (US$)		Imports in 2022 (US$)
	2024	2034		2024	2034	
Irrigation pumps (surface/submersible)						
Solar	2,511	8,643	13.2	1,499,465	4,926,741	6,225,345
AC	7,097	57,790	23.3	5,650,797	43,920,755	
Refrigerators						
Solar	22,573	26,852	1.8	27,379,825	26,590,708	3,607,038
AC	70,974	94,213	2.9	51,266,531	64,951,542	
Electric motorcycles	32,263	52,480	5.0	60,532,329	93,978,065	17,895,726
Electric pressure cookers (EPCs)	10,304	15,139	3.9	6,337,234	8,886,590	1,989,488
Total	145,722	255,118		152,666,180	243,254,402	

Figure 4.4 Current and projected TSMs



4.4 Summing Up

Comparing the modeled 2024 TSM with the 2022 import data reveals that, in 2022, the technologies accounted for 87 percent (irrigation pumps),[11] 4 percent (refrigerators), 21 percent (ICE-powered motorcycles), and 31 percent (electric cookers) of the modeled results for 2024. The serviceable market was lowest for refrigerators, even though the TSM was more than 40 percent of the TAM. This suggests a large untapped market for both solar and AC-powered refrigerators, for which user affordability is not the only constraining factor. The TSM for electric cookers was over two-thirds of the TAM. This indicates that EPC affordability is not a major constraint, suggesting that other challenges (e.g., lack of consumer awareness and high electricity tariffs) may be hindering the accelerated uptake and use of the technology. The import data for ICE-powered motorcycles suggests that electric motorcycles could meet the current demand, especially in regions where the suppliers operate.

One should also note the model's limitations. Servicing asset loans is capped at 15 percent of the consumer's total monthly income. However, this percentage might vary, given the observed income disparities between urban and rural households and individual producers' willingness to contribute toward repayment. Also, the model applies a uniform interest rate (18 percent) and repayment period (36 months) across appliances. In reality, these factors will likely vary since warranty periods differ among appliances and each financial institution has its own method for evaluating borrower risk. In addition, the model does not adequately capture the real cost of appliance acquisition as neither accessories nor maintenance and operating costs, which impact long-term affordability, are embedded. Finally, the model assumes price reductions for mature and immature technologies using arbitrary numbers based on technology and market readiness; however, these may not accurately represent the real market owing to inflation, government policies, and other influences.

11 One should note that the import data for water pumps is not specific to the irrigation case and also includes such uses as domestic water supply.

CHAPTER 5

MARKET LANDSCAPE

5.1 Introduction

The productive use of energy (PUE) is increasingly viewed as the major catalyst for improving enterprises' income generation potential through diversifying economic activities, mechanizing processes, and forestalling inventory losses.[12] However, financial outcomes will vary, depending on the presence of other foundational economic and business variables (e.g., access to raw materials, consumer purchasing power, access to markets and capital, sufficient business and technical capacity, and symmetric information). This chapter analyzes supply- and demand-side factors that can affect the productivity of enterprises considering the adoption of the top four high-potential PUE technologies, and then summarizes the main market barriers. Case study examples gleaned from the study's pilot-testing phase highlight key challenges and lessons learned (Annex C).

5.2 Supply-Side Analysis

5.2.1 Technology suppliers

Rwanda's supply chain for high-potential PUE technologies is dominated by distributors and retailers who import their stock of appliances in partnership with manufacturers from abroad. Among the four high-potential technologies examined in this study, only electric motorcycles are assembled in-country; however, they use predominantly imported components (case study 1). Distributors in Rwanda function mainly as a manufacturer's country office and market only those products, while retailers act as wholesale partners of several manufacturers.[13]

Case Study 1. Ampersand

Ampersand road-tested its first motorcycle in 2019, followed by the commercial phase launched in 2022. The company imports motorcycle frames from abroad and assembles the complete knock-down (CKD) kits in Rwanda. The frames are assembled with the drivetrain, battery, and motor. The company owns the batteries in perpetuity, and bears the cost of battery maintenance and replacement, offering its clients a battery as a service (BaaS) business model.

The company's main target market is moto taxi riders. Most cannot afford to purchase the bikes up front and so obtain asset financing from financial institutions. This forms the bulk of sales as financing companies and individuals act as market enablers. However, Ampersand provides direct financing for some 100 customers that are part of its test pool, enabling the company to monitor market needs. Financing terms are usually 24 months at commercial interest rates. The company is currently focused on Kigali and the surrounding area due to the large size of the untapped market. It has placed swap stations in Kigali, Nyabugogo, and Ruwenzi. Expansion is market driven, based on the movements and needs of the riders. As of February 2023, 1,754 bikes were on the road.

12 The case for modern PUE appliances is especially strong in irrigation applications by smallholder farmers (i.e., switching from manual or engine-powered pumps to grid-powered or solar pumps, respectively, to improve water output or reduce operating and maintenance costs.

13 The study team interviewed the following distributors and retailers: Ampersand, Clean Energy Technologies Ltd (CET), Ignite Solar, Spironet, Electrocook, Solektra, CIDU Electrical Ltd, Akagera Electronics, and Davis and Shirtliff. Agsol and Sundanzer, which supply their products to the respective distributors and retailers for sale to end-user consumers, were also interviewed.

5.2.2 Market prices

The importation of PUE technologies as the main source of supply leaves PUE prices vulnerable to external shock from the country of origin and import logistics pricing (table 5.1).

Table 5.1 Non-exhaustive list of current prices for high-potential technologies

PUE product category	Model name	Supplier	Price (RWF)	Power rating (W)	Power type	Warranty (no. of years)
Irrigation pump	SUNFLO-S 1000C	Davis & Shirtliff	1,500,000	1,000	Solar	1
	SUNFLO-S 300		620,000	300	Solar	1
	DSD 3/13		2, 500,000	750	Solar	1
	SUNFLO-B500C		2, 200,000	500	Solar	1
	SUNFLO-A- 600H		1, 640,000	600	Solar	1
	SUNFLO-B-120H		1, 230,000	1,200	Solar	1
	SUNFLEX750		1, 990,000	1,200	Solar	1
	SUNFLEX 1100C3		1, 600,000	1,600	Solar	1
	SUNFLEX 1500C5		2, 127,000	2,000	Solar	1
	SUNFLEX 2200C9		2, 180,000	3,200	Solar	1
	5TY-60G	Bleu Gear Machinery	700,000	1,600	AC	0
	FFC45		1,800,000	11,000	AC	0
	9FC2021R		1,000,000	7,500	AC	0
	9R50-60F		4,000,000	30,000	AC	0
	n.a.	GIT Ltd	1,500,000	3,000	AC	1
Electric pressure cooker (EPC)	Instant Pot 140-0050-01	Best Shop	250,000	1, 000	Electric	0.5
	COMFEE		125, 000	1,000	Electric	0.5
	SOYANA SPS -4414	Dubai Market	110, 000	1000	Electric	1
	RAF N.988		100, 000	900	Electric	1
	NUTRICOOK NC-SP204K	Hot Point	225, 000	1,000	Electric	1
Refrigerator	RISH KRF-138-WF	CIDU Electrical	300, 000	100	AC	2
	ROCH RFR-230DT-B		350, 000	120	AC	2
	ICONA London ILRF-455GB		700, 000	20	AC	3
	SAYONA SAY-2013		300, 000	120	AC	3
	FLORSA HS338Y		280, 000	300	AC	5
	FLORISA TF-220	Dubai Market	350, 000	70	Electric	1
	MIKA MRDCD261XDM		520, 000	70	Electric	1
	ROCH RFR -370DBD-L		650, 000	80	Electric	1
	ICONA ILRF-200VDB		560, 000	70	Electric	1
	GLAMSTAR GSCF-200-L		400, 000	80	Electric	1
	HISENSE RB341D4WGU		600, 000	120	Electric	1
	SKYHOOD SHF-320	Magasin Faruki Trading	648, 000	100	Electric	0.5
	LG top mount freezer GN-B202SQBB	Hot Point	720, 500	100	Electric	2
	Samsung RT26HAR2DSA		799, 000	100		
	VON VART - 25NVY		643, 500	200		

PUE product category	Model name	Supplier	Price (RWF)	Power rating (W)	Power type	Warranty (no. of years)
	DAEWOO FKM295FWT1AZ	Sachi Electronics Ltd	610, 000	86	Electric	1
Electric motorcycle	Ampersand	Ampersand Rwanda Ltd	2, 100, 000	5,000	Electric	1
	Revoo	Rwanda Electrical Motorcycle Ltd	1, 850, 000	2,000	Electric	1
	Spiro	Africa Green Mobility Solution	2, 000, 000	3,400	Electric	1

Note: n.a. = not available.

5.2.3 Business financing and advocacy

Currently, Rwanda has 10 commercial banks, 3 microfinance banks, 1 cooperative bank, 1 development bank (BNR 2022), 416 Umurenge savings and credit cooperatives (SACCOs), and 22 non-Umurenge SACCOs (AFR 2020). Umurenge SACCOs—a government initiative to enhance financial inclusion, especially for the rural population—was launched in 2008, a time when only 21 percent of the population was using the formal financial system (RCA 2012). Owing to the initiative's success, 77 percent of the population is now covered (ITA 2022).

Commercial banks seldom offer financing to PUE supply-chain actors. When offered, the financing is not PUE-specific and the prevailing lending rate applies (approximately 16 percent). During this study's key informant interviews (KIIs), it was reported that most local institutions do not have a specific PUE finance facility and often require borrowers to have collateral to which they may not have immediate access. That said, in 2019, Ignite Power secured a financing agreement with I&M Bank (one of Rwanda's largest banks) to support its growth drive (Karie 2019).[14] The Development Bank of Rwanda (BRD), through its Renewable Energy Fund (REF) and various other funds, is the leading source of local-currency credit and direct company funding in the country (ACE TAF 2021b).

The Energy Private Developers Association (EPD) is the main professional association of private companies in the energy sector registered in the country. EPD works closely with the government, development partners, and other stakeholders to advocate for its members. It has more than 117 members operating in the various energy subsectors, ranging from renewables (e.g., solar and hydropower) to conventional energy (e.g., LPG, methane gas, and transmission lines). EPD carries out its mandate through subsector-level engagements. In 2021, it participated in the policy and market review for modern cooking energy in Rwanda, carried out by Energy 4 Impact (E4I), and facilitated changes within the REF window 5 subsidy financing program, including the removal of the RWF 1 billion subsidy cap for participating off-grid solar companies and promotion of flexible verification procedures. In 2022–23, EPD partnered with the Global Off-Grid Lighting Association (GOGLA) to conduct the market assessment and roadmap development for the Productive Use of Renewable Energy (PURE) initiative. Currently, EPD co-chairs a PUE working group with the Ministry of Infrastructure (MININFRA).

14 This financing was the latest in a series of commercial loans afforded Ignite Power from I&M Bank.

5.3 Demand-Side Analysis

The demand side of the market for the four high-potential PUE technologies—comprising smallholder farmers and micro-, small-, and medium-sized enterprises (MSMEs)—is characterized by low consumer affordability. Discussions with supply-side actors showed that end-user subsidies would substantially improve the technologies' affordability. To illustrate their effect on the total serviceable market (TSM), a sensitivity analysis was conducted for each technology. Two scenarios were modeled, one applying a 25 percent subsidy to the unit price and the other a 50 percent subsidy. The results show that the TSM would rise by 12 percent and 45 percent, respectively (table 5.2).

Table 5.2 Sensitivity analysis results

PUE technology	TSM (units)		
	Baseline	25% subsidy	50% subsidy
Irrigation pumps (surface/submersible)			
Solar	2,511	4,596	9,971
AC	7,097	13,056	28,472
Refrigerators			
Solar	22,065	22,065	25,460
AC	69,379	70,956	88,300
Electric motorcycles	32,263	38,600	44,937
Electric pressure cookers (EPCs)	10,304	10,969	11,036
Total units	143,618	160,241	208,177

Productive users who already own PUE technologies indicated that electricity is expensive. This perception, obtained through focus group discussions (FGDs) and in-person surveys, corresponds with high electricity tariffs. The 2020 review of the tariff structure, carried out by the Rwanda Utilities Regulatory Authority (RURA) board of directors (decision N001/BD/ER-EWS/RURA/2020), includes tariffs for industrial and non-industrial customer categories (table 5.3). MININFRA extended the large-industry category, which has the lowest tariff level, to electric vehicle charging stations (MININFRA 2021b). This tariff also allows for time-of-use (TOU) pricing benefits. Introduction of the e-mobility tariff has successfully led to an increase in the number of electric vehicles in the country while reducing electricity wastage (Giki, Associate, and Ondanje 2023).

Table 5.3 Electricity tariff structure

Consumer type	Category	Consumption (kWh/month)	Energy charge (RWF/kWh)
Non-Industrial	Residential	0–15	89
		> 15–50	212
		> 50	249
	Non-residential	0–100	227
		> 100	255
	Telecom towers	All	201
	Water treatment plants and water pumping stations	All	126
	Hotels	All	157
	Health facilities	All	186
	Broadcasters	All	192
	Commercial data centers	All	179
Industrial (flat-rate)	Small		151
	Medium		123
	Large		106

Industrial (time of use)					
Category	Energy charge (RWF/kWh)	Maximum demand charge (RWF/kVA/month)			Customer service charge (RWF/month)
		Peak (6:00 p.m.–10:59 p.m.)	Shoulder (8:00 a.m.–5:59 p.m.)	Off-peak (11:00 p.m.–7:59 a.m.)	
Small	134	11,017	4,008	1,691	10,000
Medium	103	10,514	3,588	1,292	10,000
Large	94	7,184	2,004	886	10,000

Source: REG.

As shown in table 5.3, non-residential consumers with a monthly consumption over 100 kWh—where most SMEs fall—are currently charged the highest tariff, at 255 RWF per kWh.

5.4 Consumer Profile

The study developed the profile of consumer types for the four high-potential PUE technologies based on nationwide FGDs and pilot testing with 12 entrepreneurs across 4 districts (Annex C).

5.4.1 Smallholder farmers

Subsistence farming is the primary source of income for more than three-quarters of Rwanda's population (NISR 2020a). Currently, however, the Rwandan government is striving to shift the agricultural industry from subsistence farming to a value-creating, market-oriented food sector with substantial contributions to national output and household food security (MINAGRI 2019). A recent study shows that in 2021–22, maize was the most extensively farmed crop, with 57 percent of all smallholder farmers growing it. Other crops regularly planted by smallholders include bush and climbing beans, at 52 percent and 42 percent, respectively. These are followed by cassava, planted by 34 percent; various types of bananas for cooking (29 percent), making desserts (23 percent), and brewing (13 percent); sweet potato (27 percent); sorghum (24 percent); Irish potato (21 percent); avocado (20 percent); and soybean (12 percent) (Warner et al. 2023).

More than 70 percent of the country's smallholder irrigated farms in low-lying marshland utilize with gravity irrigation canals. Approximately 17 percent of hillside irrigated farms have pressurized innovations (e.g., drip, sprinkler, and pivot systems) that employ electrical power as the energy source (World Bank 2021). According to the Rwanda Water Board, assessments show that the country has a national irrigation potential of over 600,000 ha, taking into account the following domains: runoff for minor reservoirs (125,627 ha), dam runoff (31,204 ha), direct river and flood water (80,974 acres), lake water resources (100.153 ha), groundwater resources (36.434 ha), and marshlands (222,418 ha).

Case Study 2. Irrigation Pumps in Bugesera and Ngoma

Key facts*
Pump size: 2–3 inch
Pump price: RWF 900,000
Monthly income: below RWF 240,000
Seasonal maintenance cost: RWF 20,000–50,000
Daily fuel cost for 3-inch pump: RWF 30,000
Calculated IRR for SWP: 17%
** Averages*

Appliance ownership
Farmers in Bugesera and Ngoma primarily own diesel-powered Koshen water pumps, with most respondents owning 1–5 units. The prices of these pumps vary, with some significantly lower due to government subsidies provided in 2019. Besides water pumps, farmers also own motorbikes, pick-up trucks, cooling chambers, scooters, bicycles, and torches. Reliance on diesel fuel was consistent among all pilot survey respondents, indicating a preference for this energy source for irrigation purposes.

Willingness to pay
Farmers expressed a preference for flexible payment plans, such as pay-as-you-go (PAYG), installments, and seasonal plans. Some farmers indicated their willingness to take out loans for making significant purchases (e.g., a three-wheeled motorcycle worth RWF 3.2 million), showcasing a readiness to invest in their farming operations if suitable financing options were to become available.

Ability to pay
The average monthly income of respondents is about RWF 240,000, though some earn over RWF 600,000 per month. Farmers' ability to pay is affected by high operating costs, particularly for diesel fuel. One farmer reported spending about RWF 1.5 million on diesel fuel in one season. Farmers expressed a preference for seasonal payment plans so that they can manage expenses in line with agricultural income.

Appliance accessibility
Challenges include limited access to electricity, difficulty in obtaining reasonably priced petrol owing to limited fuel trader and transportation issues, and lack of marketing agents for new technologies like solar water pumps (SWPs). Financial constraints are significant, making it challenging to invest in sophisticated appliances without external support.

All 12 farmers who participated in FGDs in Bugesera and Ngoma reported that they currently use diesel-powered water pumps to irrigate their farms and cultivate a variety of crops for commercial, rather than subsistence, purposes. Among the pilot study participants who utilized SWPs, maize and beans were the most commonly grown crops; 60 percent earned less than RWF 240,000 per month from farming activities, while the other 40 percent reported monthly farming earnings in a range of RWF 240,000–607,000 (case study 2). The SWP price averages RWF 1.6 million. All of those surveyed had received their SWPs through a government-supported project, with each having contributed RWF 200,000 to the purchase cost. Sixty-seven percent of those surveyed reported using their savings to finance their contribution toward purchasing the pumps, while 33 percent indicated they had received contributions from family members. Since owning their SWPs, 87 percent of the farmers reported an increase in their monthly income, while 64 percent said they had hired additional laborers and added new crops. The main challenge cited was the accurate sizing of the pump since, owing to steep slopes, farmers struggle to pump to higher ground.

5.4.2 Butcher, milk, and retail shops

The study held FGDs on refrigerators with 13 respondents in Kayonza, Gatsibo, and Nyagatare. In Kayonza, the FGD was held with representatives of fisher cooperatives and butcher-shop entrepreneurs, while those in Gatisbo and Nyagatare included entrepreneurs who own milk and retail shops (case study 3). Fish farming in Rwanda allows for employment and an increasing supply of high-value animal protein (Niyibizi et al. 2022). Most activities are concentrated in 3 of 17 inland lakes: Kivu, Cyohoha, and Mugesera (Niyonshuti 2021). In Kivu Lake, fishing provides more than 20,000 tons of fish annually, supporting some 500,000 people in Rwanda and the Democratic Republic of Congo (DRC) (Chimatiro et al. 2021). In 2021–22, production rose from 41,664 tonnes to 43,560 tonnes, as reported by the Ministry of Agriculture and Animal Resources (Nkurunziza 2023). Annual production has increased since the introduction of fish farming; by 2024, the country aims to produce 112,000 tons per year (MINAGRI n.d.).

Case Study 3. Refrigerator Use in Kayonza, Gatsibo, and Nyagatare

Key facts*
Daily income: RWF 27,000
Monthly expenses for AC electricity: RWF 20,000−55,000
Appliance cost: RWF 180,000 (used refrigerator); RWF 350,000 (new refrigerator); RWF 2.25 million (milk cooler)
Calculated IRR for solar refrigerator: 34%
** Averages*

Appliance ownership

Respondents own a range of appliances, including refrigerators, freezers, gas burners, and milk coolers. Most appliances are grid-powered, with a few solar cool boxes donated. Such brands as Samsung, Phillips, and LG are preferred for their quality and efficiency.

Willingness to pay

All refrigerator users reported an increase in weekly income; and reduced meat and fish wastage was cited as a major benefit. Most said they prefer installment payments over a 3–6 month period. Savings groups, business loans, and cooperative savings are used to facilitate purchases. Electricity cost is perceived as high, particularly among meat product vendors, for whom it constitutes about 25 percent of monthly operational costs. Before the pilot, some respondents were not aware of the availability of solar coolers. All users said they would recommend the appliance to others with similar businesses.

Ability to pay

The ability to pay for new appliances among the respondents is influenced by their monthly business sales, operational costs, and preferred payment methods. An average monthly sales figure of about RWF 788,461 and a preference for installment payments indicates a cautious approach to managing financial resources. The respondents' reliance on savings groups and business loans suggests that they are willing to invest in the appliance, but high electricity and operational costs pose a significant burden. The respondents' ability to pay is further challenged by the added costs associated with transportation and the need for reliable power sources to ensure business continuity.

Appliance accessibility

Transporting appliances from Kigali to the Eastern Province is a challenge owing to the size of some appliances. High electricity tariffs and the need for government support were highlighted. Knowledge about some appliances and demand for more efficient business practices are lacking. The main challenges include power cuts, which can cause milk losses and disrupt business operations. A reliable solar backup system is needed to mitigate losses during power outages. The high cost of electricity and lack of up-front information about power cuts are also concerns.

5.4.3 Motorcycle users

Rwanda's road transport sector comprises public vehicles and motorcycles. Public motorcycles, known as "moto," have experienced rapid expansion in both urban and rural areas. According to RURA, authorized motorcycle transport increased by 17,099 (from 11,488 to 28,587) between the third quarter of 2021 and the fourth quarter of 2022 (RURA 2022). Rwanda has over 100,000 commercial motos, about 25,000 of which operate in the capital city of Kigali (USAID 2022). An increasing population and rapid urbanization have created a high potential for growth in motorcycle transport.

Case Study 4. Kigali's Transition to Electric Motorcycles

Key facts
Average years of operation: 8
Most popular engine capacity: 125 cc
Price of most popular bike (TVS): RWF 2.15 million
Average daily income: RWF 4,000–6,000
Fuel consumption: 1 liter of petrol per 50–60 km
Engine oil change: RWF 10,000–11,500 per 5,000 km
Calculated IRR for electric motorcycle: 36%

Ownership and financing

Out of 16 riders, 14 owned their bikes. Financing options varied, with one rider taking out a loan of RWF 3.6 million to be paid over 2.5 years and another entering into a RWF 3.95 million contract with weekly payments. These financial arrangements typically span 14–16 months, indicating a commitment to long-term investment in their means of livelihood.

Willingness to pay
Many riders are considering the switch from traditional internal combustion engine (ICE) bikes to electric ones owing to rising fuel costs and the growing preference for electric bikes among tourists. However, they are cautious about the increasing cost of battery swaps and the limitations of electric bikes in terms of range and hill-climbing capabilities. The riders obtain information about bikes and appliances from company sales teams, local dealers, and promotional advertisements on social media, radio, and TV. They have a clear preference for such brands as TVS, Tecno, MTN, and Airtel, which are trusted for their reliability and warranty offerings.

Ability to pay
The ability to pay for new appliances and the transition to electric bikes is a critical factor for the riders. With a typical daily income of RWF 4,000–6,000 after expenses, the riders rely on financing options and savings groups to afford new investments. The preference for weekly payment plans indicates a need for manageable and flexible payment schedules. However, the rising costs of maintenance and battery swaps pose challenges to their financial capacity and willingness to switch from ICE motorbikes.

Appliance accessibility
High electricity tariffs and the prevalence of counterfeit appliances pose significant challenges for the riders. They also face the challenge of poor electrical installations in low-cost housing, which can damage their appliances.

All pilot study participants indicated they had attained at least a primary education and were earning approximately RWF 250,000 per month. Two participants (both users of electric motorcycles), reported covering an average distance of more than 150 km per day and daily earnings of at least RWF 8,000 after deducting the cost of battery swaps. Both made two or three swaps per day at a cost of RWF 1,600 per swap, which they reported as being less than the daily fuel cost. Both appreciated the speed and power of their electric motorcycles, which allowed them to carry heavy loads over hilly terrain (case study 4).

5.4.4 Restaurants

The tourism and hospitality sector, one of Rwanda's largest drivers of economic growth, accounts for up to 13 percent of total GDP, which is higher than the global average of 10.4 percent (RDB 2021b). Growth of the hospitality sector is expected to contribute significantly to the country's economic development. Visa requirements have been lifted for all Africans (Rwigema and Celestin 2024), who currently account for more than 60 percent of international arrivals (RDB 2023). The sector employs approximately 4 percent of the country's total labor force; accommodations and food services account for 2.1 percent, while the majority of employment is informal (NISR 2023c). The envisioned growth in international and domestic tourism establishes a noteworthy foundation for the growth of restaurants and food services.

Case Study 5. Electric Pressure Cookers in Kigali Restaurants

Key facts
Average weekly income: RWF 15,000
Monthly fuel cost: approximately RWF 25,000 for electricity; RWF 90,000 for LPG
Appliance cost: RWF 550,000 (electric oven); RWF 150,000–250,000 (microwave oven)
Calculated IRR for EPC: 45%

Appliance ownership

Business owners in Kigali have a diverse range of mainly grid-powered appliances, including refrigerators, freezers, microwave ovens, fryers, and electric kettles. However, the high cost of operating electric appliances has led some owners to adopt more traditional methods (e.g., firewood for ovens). Notably, none of the businesses surveyed own an electric pressure cooker (EPC), indicating a potential market gap or a lack of suitability for commercial use.

Willingness to pay

Business owners expressed interest in acquiring various new appliances, including electric fryers, solar-powered refrigerators, commercial blenders, and gas ovens. Their willingness to pay is influenced by the perceived benefits of the appliances (e.g., reducing electricity or gas usage, enhancing business operations, or meeting specific customer demands). Their preferences for payment vary, with many favoring installment plans to spread out the cost of repayment.

Ability to pay

The average monthly income of respondents is RWF 60,000. Their ability to pay for new appliances is constrained by several factors. Owners rarely use their business revenue for such purchases, relying instead on personal savings or savings groups. This cautious approach is partly due to uncertainties in the business environment, such as regulatory pressures and fluctuating costs. Some business owners set aside a portion of their daily or monthly earnings specifically for savings or appliance purchases.

Appliance accessibility

The high cost of electricity is a significant challenge, with some businesses spending up to 15 percent of their monthly operating costs on electricity. Rising LPG prices further complicates the situation. Business owners are also mindful of their appliances' electricity consumption rate, often turning them off overnight to conserve energy. The unavailability of installment payment options, questionable quality and durability of appliances, and lack of information about new product lines are additional hurdles.

The study held two FGDs with 16 restaurant owners in Kigali, all of whom own and operate businesses (e.g., bars, restaurants, and eateries) within the city and already own and use various types of electric cooking appliances (e.g., microwaves, electric ovens, and fryers). During the pilot testing, none of the respondents found it difficult to start cooking with electric pressure cookers (EPCs) even though all were first-time users. The meals most often prepared on the EPCs were rice, green bananas, and meat. After adopting the EPCs, three out of four business owners mentioned reduced time spent cooking food, improved kitchen air quality, and reduced usage of other fuels; they also recorded an average weekly revenue increase of 150 percent. The pilot-testing participants' main reported concern was the size of the EPC; each business was testing with two 6-liter EPCs, and indicated the need for larger ones (case study 5).

5.5 Summary of Market Barriers

This chapter's analysis reveals several types of market challenges. The supply chain for the high-potential PUE technologies in Rwanda is weak or nascent. As discussed, most distributors and retailers do not maintain bulk stock and so are unable to handle large-scale demand. They operate on an order basis: Customers make a down-payment when they place an order, which triggers the importation and sale of the technology. This importation process, in turn, makes PUE appliances in Rwanda expensive.[15] The cost of business financing is also high. Supply-side actors find it challenging to access loans from commercial banks to finance their operations. The high collateral requirements placed by banks on suppliers are tough to meet, especially for start-up companies. Furthermore, commercial financing is charged at approximately 18 percent. On the demand side, few consumers can afford to purchase the PUE appliances without financial assistance. Existing incentives (e.g., zero-rated tax or subsidies), though beneficial, have not significantly catalyzed uptake. [16]

Other issues cut across both sides of the market. Knowledge of appropriate technologies that can enhance productive activities is not widespread among end users, especially in rural areas. The reason is that most PUE distributors and retailers are located only in major towns, without expansive network coverage in rural areas. Limited networks create a gap in consumer training, which should occur before and after appliance purchase, as well as after-sales support for parts and repairs.

15 For example, a water pump costing US$700 in India, where it is manufactured, retails for up to US$2,000 in Rwanda because of logistics, taxes, and supplier markup. One possible solution is increased in-country manufacturing and/or assembly of complete knock-down (CKD) or semi-knocked down (SKD) kits.

16 For example, when Practical Action offered a 70 percent subsidy on solar millers, and end users sought support from financial institutions to cover the remaining 30 percent.

CHAPTER 6

RECOMMENDATIONS

6.1 Strategy Overview

Overcoming the identified barriers to catalyzing productive use of energy (PUE) in Rwanda requires dedicated funding, which can start a virtuous cycle of development (figure 6.1). Strengthening the market will require specific supply- and demand-side interventions that improve access to capital across the supply chain; offer end users, including marginalized market segments, appropriate financial services and incentives to increase affordability; and build capacity and awareness to promote the uptake and sustained use of PUE appliances. Enabling policies and coordination across relevant sectors are also vital to enhancing product affordability and accelerating development of the market ecosystem.

Figure 6.1 Overarching interventions to catalyze productive use opportunities

6.2 Market Strengthening

6.2.1 Access to finance

Working capital credit below commercial rates is required by PUE technology suppliers to reduce the high cost of business financing. Given that most of these technologies are imported, suppliers require working capital large enough to stock them; otherwise, they must operate on an order basis. This subsidy support will enable suppliers to maintain adequate stock levels and potentially expand their retail networks to rural and hard-to-reach areas. Also, the subsidy can assist early-stage PUE technologies in gaining market traction; this would involve setting up demonstration sites or pilots to mainstream fledgling technologies (e.g., electric cooking in schools, hospitals, and commercial organizations).

6.2.2 Consumer affordability support

6.2.2.1 Results-Based Financing

Over the past decade, results-based financing (RBF) has become a proven mechanism for accelerating energy access across Africa. Early RBF programs in Rwanda include an Energising Development (EnDev)–supported project to incentivize mini-grid developers, a Rwanda Energy Group (REG)–administered clean cooking initiative co-financed by the World Bank, and the African Development Bank (AfDB)–financed Scaling Up Electricity Access Program. Under the World Bank–supported solar home system (SHS) RBF, the Rwanda Renewable Energy Fund (REF) has had significant success, having reached approximately 500,000 households to date. However, RBF initiatives in Rwanda have not been dedicated to PUE appliances, with the notable exceptions of multi-country programs (e.g., Global Lighting and Energy Access Partnership [LEAP] and Africa Enterprise Challenge Fund [AECF] REACT).

Currently, the hire-purchase model for PUE technologies is not widespread in Rwanda, opening an opportunity to expand this business model using mobile money. As a financing tool, RBF ensures that participating recipients align their operational outcomes with program objectives. This intervention encourages flexible payment models (e.g., mobile money–enabled pay-as-you-go [PAYG]) as a sustainable pathway to the uptake of PUE technologies, and encourages participating distributors and retailers to offer it for various mature PUE technologies on the market. Development partners or the Development Bank of Rwanda (BRD) could partner with PUE retailers utilizing RBF, which guarantees this hire-purchase model.

6.2.2.2 Concessional Finance

In addition to RBF, concessional finance can also be used to improve consumer affordability. This can be set up by bringing local banks, microfinance institutions (MFIs), and savings and credit cooperatives (SACCOs) on board and developing financial products favorable to the more mature PUE technologies (e.g., electric motorcycles, solar water pumps [SWPs], and solar and electric refrigerators and freezers). To accelerate uptake among vulnerable end-user groups, such financing may be offered to interest groups (e.g., women entrepreneurs and women farmers) facilitated by development partners or the BRD offering financial institutions capital for on-lending or by offering guarantees to reduce the potential risk of end-user default. The intervention facility may also operate by working with registered end-user groups (e.g., smallholder farmers; women's groups; and small- and medium-sized enterprise [SME] associations). Participating members of such groups would be eligible for concessional finance while addressing individual credit risk through collective or group participation. Previously, Actionaid's Promoting Opportunities for Women's Empowerment and Rights (POWER) program supported women's groups in Rwanda through training in better farming practices and group savings (Actionaid 2023). Such groups can potentially participate in providing their members concessional finance for PUE technology purchases.

6.2.3 Awareness creation and capacity building

6.2.3.1 Awareness-Raising Campaigns and Technology Promotion

Throughout the study's data-collection process, the lack of consumer awareness about the existence and use of PUE technologies was striking. Distributors and retailers should conduct effective awareness-raising campaigns on the various PUE appliances. Targeted end-user campaigns should be held throughout the country, with special attention given to rural and hard-to-reach areas, where information is more limited. Interviews with Rwanda's solar irrigation stakeholders indicate that most solar water pump (SWP) sales are concentrated in the comparatively drier Eastern Province, suggesting that SWP awareness creation and technology promotion are best suited to that province. Similarly, potential consumers' widespread lack of information on electric pressure cookers (EPCs) suggests the need for a national campaign focused on grid-connected regions.

6.2.3.2 Supplier Training in Business Development Services

In addition to working capital, suppliers require training and capacity building in business development services (BDS) to ensure sustainability and prepare them for commercial financing (e.g., equity financing). These services include training in business skills, budgeting, corporate structures, technology usage, records management, marketing, savings, financial modeling, and applying for capital support.

6.2.3.3 Training in After-Sales Service and Quality Assurance

Most PUE suppliers in Rwanda lack a network of offices and staff trained in after-sales service and repair. Lack of such support contributes to a negative perception among end users, particularly those new to the market, about the quality of PUE technologies. Retailers need to provide purchasers quality assurance warranties and after-sales repair and technical support. They should also ensure that their technical staff undergo regularly scheduled training; this deepens their knowledge about the marketed PUE products, allows them to adapt their existing skills to new technologies, and promotes a customer-centered working environment. In addition, a quality assurance framework, including relevant testing and standards, is needed to ensure the quality of imported PUE technologies.

6.3 Enabling Policies and Cross-Sector Coordination

6.3.1 Advocacy for favorable tax regimes

To improve the policy environment, the study recommends advocating for import tax removal or reduction on high-potential PUE technologies (e.g., shifting to a tax regime similar to that of solar appliances). The opportunity cost of lost tax revenue from AC appliances would be regained through increased electricity consumption and productivity within the country.

6.3.2 Comprehensive electricity tariff study

The success of Rwanda's e-mobility tariff suggests that an appropriate tariff review could promote the uptake of certain PUE technologies. It is advised that a comprehensive electricity tariff study be carried out to ensure responsive pricing levels that can unlock other PUE technologies that are owned and used by SMEs. For example, Uganda's Electricity Regulatory Authority launched a review of its electricity tariff structure, which introduced an electric cooking tariff for domestic and institutional consumers (Manyire 2021); the aim of the tariff (effective in January 2022) is to increase the adoption of electric cooking from the 2022 level of 1.4 percent (Ogwok et al. 2022). Introducing a similar electric cooking tariff in Rwanda could potentially unlock the uptake of EPCs, reducing the use of non-renewable biomass energy for cooking.

6.3.3 Consultative efforts across sectors

Catalyzing productive energy uses extends well beyond the energy sector alone. It requires the consultative efforts of colleagues across the productive/activity sectors, ranging from agriculture, commerce, and transport to education and health, among others. In the case of the high-potential solar and AC-powered irrigation technologies identified in this study, this means having access to relevant market linkages and training on appropriate cropping and cultivation techniques. To enhance cross-sector coordination, as well as the M&E of sector-specific plans, the study recommends expanding the PUE working group, which is co-chaired by the Energy Private Developers Association (EPD) and the Ministry of Infrastructure (MININFRA), to include representatives from the Ministry of Agriculture and Animal Resources (MINAGRI) and the Ministry of Trade and Industry (MINICOM).

6.4 Dedicated Funding to Start a Virtuous Cycle of Development

The intervention design is structured as an exploratory venture that should quickly adapt to market changes and feedback from actors while providing valuable lessons in scaling.[17] The study recommends limiting the initial focus to the four high-potential PUE technologies identified in this report. Their uptake is expected to result in increased enterprise productivity, reduced agricultural losses, additional employment opportunities, less indoor air pollution, and abatement of greenhouse gases (GHGs).

6.4.1 Eligibility criteria

The multi-criteria process described in this study can be used to identify additional high-potential PUE technologies. This will ensure the scalability of the interventions and expand their reach as the PUE market continues to evolve. The selection criteria for supply-side actors should include well-defined requirements (e.g., compliance with quality standards and minimum, prequalification, and evaluation criteria for business operations). The selection of end-user program categories must consider gender inclusivity, income and wealth disparities, location-specific characteristics, and macroeconomic dynamics that influence the targeted end users. Selection of the demand- and supply-side participants must also ensure inclusivity and equity, addressing the needs of marginalized and vulnerable groups while reducing all eligible participants' barriers to equitable access.

17 The intervention design assumes that the foundational factors of production already exist; design features and priorities are also guided and limited by the indicative resources available to the implementing partners.

6.4.2 Funding for implementation

Initial capital support and technical assistance funding can be provided by the World Bank's multi-year Accelerating Sustainable and Clean Energy Transformation (ASCENT) Program. To ensure longer-term support, additional funding may be obtained from upcoming projects supported by the World Bank and other development partner agencies. The intervention's selection of carbon-neutral PUE technologies (e.g., SWPs, EPCs, and electric motorcycles), which displace the use of conventional GHG-emitting technologies, could attract carbon financing, which can be used to expand the technologies' reach.

6.4.3 Results tracking

To monitor the impact of the intervention program, the facility must have clear targets and indicators. Feedback data from the monitoring and evaluation (M&E) process should be used to assist in structuring implementation adjustments and improvements. Independent third-party verification is also necessary to confirm the impact indicators of participant organizations.

ANNEXES

Annex A. Technology Screening Notes

Electric and solar water pumps (SWPs) score 3 for economic potential as irrigation pumps have an internal rate of return (IRR) of up to 34–36 percent (World Bank 2018). They also score 3 for sectoral reach because the agriculture sector, in which they are used, accounts for 66 percent of employment and 29 percent of gross domestic product (GDP) (FAO 2018). Electric water pumps score 2 for scalability because they can be used for irrigation and coffee washing, among other activities; however, compared to SWPs, they are not as easily moveable for various uses.

Egg incubators score 3 for economic potential because of their high IRR (15–43 percent) (Taplah et al. 2018). They score 2 for sectoral reach because of the agriculture sector's importance to the economy though the poultry subsector employs only a portion of the agricultural workforce. They score 1 on scalability because they can only be used in one application.

Milking machines score 3 for economic potential because they have an IRR of 36 percent (USAID 2018). They score 3 for sectoral reach because of their importance in the agriculture sector. They score 1 for scalability because they have only one application.

Food dryers score 2 for economic potential because they have an IRR of 29 percent (Santana, Carvalho Lopes, and Neto 2020). They score 3 for sectoral reach because of their importance in the agriculture sector. They score 1 for scalability because they have only one use.

Electric mills score 2 for economic potential because they have an IRR of more than 50 percent (USAID 2020). They score 3 for sectoral reach because of their importance in the agriculture sector and score 1 for scalability because they have only one use.

Cold storage and refrigeration score 3 for both economic potential and sectoral reach because they have an IRR of 20 percent (Alda, Salia, and Jensson 2008) and are important in both the agriculture and services sectors. They score 2 for scalability because they can be used in both.

Milk coolers score 3 for economic potential because of their IRR of 25 percent (Lukuyu, Blanchard, and Rowley 2018). They score 2 for sectoral reach because of their importance in both the agriculture sector and dairy subsector, contributing 6 percent to overall GDP. They score 1 for scalability because they are limited to one application.

Electric sewing machines, hair clippers, and hair dryers score 2 for economic potential because of their IRR of about 27 percent (NPCS n.d.). They score 2 for sectoral reach because the services sector, in which their activities are carried out, accounts for 50 percent of GDP (UNCTAD 2014). They score 1 for scalability as they have very specific uses.

Electric welding, drilling, saws, and lathe machines score 3 for economic potential because they have payback periods of less than 12 months (AMDA 2020). They score 2 for sectoral reach because the services sector, in which their activities are carried out, accounts for 50 percent of GDP. They score 1 for scalability as they have very specific uses.

Electric cookstoves score 2 for economic potential; even though they have a payback period of less than eight months (MECS 2023), stove stacking or use of multiple cookstoves for various cooking sessions tempers this high economic potential. They score 2 for sectoral reach because the services sector, in which their activities are carried out, accounts for 50 percent of GDP. They score 3 for scalability as they can be used in a variety of settings.

Electric motorcycles score 3 on all three screening criteria because of their significantly better operating costs compared to traditional motorcycles (MININFRA 2021b). They have a wide range of uses (i.e., from deliveries to motorcycle taxis). Owing to their versatility, they can be used in various sectors.

Annex B. Market Sizing Model

Table B.1 Model variables, data sources, and definitions

Variables	Data sources	Definitions
Production volumes (maize, cassava, dairy, and horticultural crops)	FAOSTAT (UNdata 2023); Seasonal Agricultural Survey (NISR)	Maize, cassava, horticultural crops, and dairy production volumes are measured in tonnes
Smallholder production volumes	Seasonal Agricultural Survey (NISR)	Amount of maize and cassava produced by smallholder farmers
Country population and other related variables	Fifth Rwanda Census Report (NISR 2023d)	Total country population, urban versus rural share, household size, and population growth rate
Urbanization rate	Rwanda Urbanization-Demographics (Index Mundi 2021)	n.a.
Households engaged in agricultural activities	Fifth Rwanda Census Report (NISR 2023d)	Households engaged in crop production, livestock production, or both crop and livestock production
Electricity access	Fifth Rwanda Census Report (NISR 2023d)	Total population with access to electricity and urban and rural share of electricity access
Gross National Income (GNI)	World Bank (2023b)	Measurement of Rwanda's income, including all income earned by the country's residents, businesses, and earnings from foreign sources
Irrigation potential	Rwanda Irrigation Master Plan (UNEP 2023)	Area of land suitable for irrigation development, considering land and water resources (including land already under irrigation)
Percentage of household distribution by farm size	Agricultural Household Survey (NISR 2020b)	Household distribution by farm size
Smallholder farmers share of production volumes	Rwanda Development Board (RDB 2020)	Share of the total production volumes from smallholder farmers
Value-added tax (VAT) and import duty	EAC Handbook on Solar Taxation (UNREEEA, KEREA, and USEA 2022)	Taxation rates per country for solar off-grid products
Access to motorized mobility	Roadmap for e-mobility transition in Rwanda (Bajpai and Bower 2020)	Number of registered vehicles (motorcycles and passenger vehicles)

Note: n.a. = not available

Annex C. Pilot Study Summary

The pilot testing conducted under phase three of the study demonstrated the economic benefits of the selected high-potential PUE technologies. Despite the short monitoring period, the reported trend across all four appliance categories was a growth in income and a high internal rate of return (IRR) (table C.1).

Table C.1 Calculated indicative IRR, by productive use category

Category of high-potential PUE technology	Indicative IRR (%)
Solar Water Pump (SWP)	17
Electric motorcycle	36
Electric pressure cooker (EPC)	45
Solar-powered refrigerator	34

Prices and Parameters

Table C.2 lists the indicative prices and technical parameters applied during the process of selecting the high-potential PUE appliances C.2)

Table C.2 Appliance prices and technical parameters

PUE product	Size	Power type	Indicative price RWF)	Quality framework
Irrigation pumps	< 0.5 kW	Solar	1,500,000–2,500,000	IEC 62253: 2011, IEC 62257-9-5:2018, IEC 62257-9-8, IEC 60335-2-41 and 2023 Draft MEPS for electric motors
		Grid	1,000,000–2,000,000	IEC 60335-2-41, IEC 62262: 2002
Electric pressure cookers (EPCs)	40 liter (internal volume)	Grid	790,000–1,500,000	IEC 60335-1, IEC 61817 (1:2004), BS EN 12778:2002, and IEC 60335-2-15:2012
Refrigerators	< 100 liter (Internal volume)	Solar	1,500,000–3,000,000	IEC 61730, IEC 60335-1, IEC 60335-2-89, and 2021 MEPS for refrigerators
		Grid	500,000–1,500,000	
Electric motorcycles	60 km (single charge range)	Grid (battery swap and charge at home)	1,850,000–3,000,000	IEC 60335-2-29, IEC 62660-3:2022, IEC 61851-24:2014,and 2023 Draft MEPS for electric motors

Respondent Selection Process

The pilot used a mixed approach to finalize the selection of survey respondents and potential beneficiaries, including leveraging pools of potential appliance buyers from the identified PUE companies, as well as recommendations provided by Sustainable Energy for All (SEforALL) and the in-country partner. All of the potential beneficiaries were screened to gauge their willingness and suitability to participate. The premises of potential beneficiaries of electric pressure cookers (EPCs) were screened for electrical wiring suitability. For potential refrigerator beneficiaries, the premises were screened for distance between the solar panels and the refrigerator. Multi-storied premises were eliminated to mitigate voltage losses (i.e., cabling from a very high roof to a shop on the ground floor introduces electric loss due to high resistance in the long wires). The pilot testing made a deliberate effort to include women-led entrepreneurs and recommended integrating these considerations into follow-up scaling (box C.1). Table C.3 highlights the gender distribution by appliance category.

Box C.1 Focus on Gender Considerations

When it comes to utilizing and benefiting from electricity, women entrepreneurs face distinct obstacles because of gender-based differences in the types of productive activities carried out (Pueyo and Maestre 2019). Studies have shown that women's employment, especially non-farm employment, benefits greatly from electrification (Dinkelman et al. 2010).

In Rwanda, where women comprise 51 percent of the population (Nsengimana and Naicker 2024), they own just 33 percent of formal small- and medium-sized enterprises (SMEs); however, they dominate the informal business sector, where access to finance and balancing family responsibilities are significant challenges. Adopting productive use of energy (PUE) technologies can greatly benefit women's informal enterprises. Moreover, women are the primary decision-makers in clean fuel and stove purchases (Gihana and Kooijman 2020).

The findings from this pilot study showed a higher number of women entrepreneurs in the services sector, especially the hospitality subsector. Also, it was found that women entrepreneurs in other sectors, such as transport, may own the business and PUE technology, but employ a man to run the operations.

The women-run enterprises that piloted refrigerators all reported an increase in weekly income attributed to increased demand for cold drinks and reduced food loss, especially among butchers and fish vendors. Participants that piloted electric pressure cookers (EPCs) reported reduced cooking times for meals that require boiling food. Food was reported as staying warm for longer, which reduced the need for reheating and enhanced energy efficiency. Restaurant kitchens reported better indoor air quality, which was visually noticeable.

Table C.3 Distribution of appliance categories by number and gender of respondents and enterprise location

Appliance category	Appliance users (number)	Gender of users (M, F)[a]	Enterprise location
Refrigerator	5	1 M, 4 F	Ndego-2 Kigali-1 Bugesera-1 Ngoma-1
Electric motorcycle	2	1 M, 1 F	Kigali-2
Electric pressure cooker (EPC)	8 (2 per business)	2 M, 2 F	Kigali-4
Solar water pump (SWP) (new users)	1	1 M, 0 F	Mukarange
SWP (existing users)	14	12 M, 2 F	Ngoma and Kayonza

a. M = male; F = female.

Recommended Actions

Based on the challenges reported by the pilot participants and insights from the data, the following actions were recommended to address key barriers to accelerating PUE uptake and use:

- Design tailored incentives for women and marginalized communities to adopt PUE to ensure gender and social equity in economic growth.
- Collect additional information and pilot commercially-sized (40 liter and above), energy-efficient models to drive EPC awareness and innovation for enterprise and institutional use. At the time of the baseline, half of respondents indicated they had not heard of EPCs, and many did not know where to purchase them. When asked whether EPCs were affordable, all of the respondents perceived that they were expensive, indicating the need for demonstrations to increase consumer awareness and confidence in the products.
- Ensure the safe use of PUE appliances. For EPCs and solar refrigerators, the enterprise's wiring standards must be considered. EPCs have a one-time installation charge to protect the safety of consumers and avoid unregulated power spikes. For DC refrigerators, siting is crucial as solar panels must be placed on a stable surface that has access to direct sunlight (usually a roof). To ensure optimal performance, they are best suited to shops in stand-alone, single-storey buildings located in areas with minimal cloud cover and shading. To minimize dust, the panels require proper maintenance. All of these factors must be considered to map the population that would be best served by this solution and those that could potentially use an AC-powered alternative.
- Develop a skilled installation, servicing, and maintenance ecosystem to support growth of the PUE sector. The respondents expressed a willingness to pay on a hire-purchase basis since most of them generate income on a daily or weekly basis. After-sales support is crucial to ensuring that the appliance being paid for remains in good working order over its lifetime.
- Provide a wide range of PUE appliance sizes and models to meet the unique needs of various end users. At the time of the pilot, few distributors offered VeraSol quality–tested appliances and had limited stock in the country. To scale up, distributors will require operating capital to be able to stock more than a few models of a particular appliance at any given time so that end-user consumers are offered more options. For example, multiple site-specific design considerations determine a SWP's suitability; thus a variety is needed to meet the correct flow rate and head specifications for each unique use case.
- For SWPs, take a hybrid approach to solarization of irrigation, given the topography of areas inhabited primarily by farming communities. For maximum impact, larger systems with solar panels, storage tanks, and water reticulation pipes for communal use should be deployed together with smaller portable solar pumps for farmers located farther from the central water points already provided by communal projects. Investment at multiple levels is needed, with community-level infrastructure financed separately from end-user concessional credit terms for portable pumping units.
- Enhance grid stability and reliability so that grid-reliant products (e.g., EPCs and E-bikes) perform optimally; this is key to scaling up beyond the capital city of Kigali.
- Consider preferential tariffs for such PUE appliances as EPCs to incentivize adoption.

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