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ENERGY EFFICIENT
LIGHTING AND APPLIANCES
in East and Southern Africa

Consolidated Report for EAC and SADC Regions on Assessment of the Market for Productive Use of Energy Appliances

Acknowledgments

This document was developed by the Energy Efficient Lighting and Appliances (EELA) Project in East and Southern Africa. The project is funded by the Swedish Government through the Swedish International Development Cooperation Agency (Sida) and implemented by the United Nations Industrial Development Organisation (UNIDO), with the Southern Africa Development Community (SADC) Centre for Renewable Energy and Energy Efficiency (SACREEE) and the East African Centre of Excellence for Renewable Energy and Energy Efficiency (EACREEE) serving as the execution centres. The document was prepared by CLASP, a technical partner on the EELA project, in cooperation with the EELA Project Coordination Unit (PCU) team.

Executive Summary

The Southern African Development Community (SADC) and the East African Community (EAC) are regional intergovernmental organizations covering Southern Africa and East Africa, respectively. The two trade blocks seek to widen and develop their member states' economic, political, social, and cultural integration. Essential building blocks focus on streamlining governance and advancing economic growth across key energy, agriculture, and trade sectors.

Overall, we found that the key productive use of energy (PUE) appliances serves the agricultural sector due to the sector's significant contribution to the member state's economies. The PUE products identified identified as having the highest potential for impact, based on in-depth research and country analysis across the two regions, include solar milling machines, solar water pumps, cold storage, electric 2- and 3-wheelers, egg incubators, solar milking machines and oil pressing. In further sections of the report, we provide information on the technologies that are most suited to member countries of EAC and SADC based on the agricultural value chains available.

Despite the opportunities available for PUE appliances in EAC and SADC regions, barriers exist, and interventions are required to realise their potential. In fact, while there is a massive addressable market of $8,457M across the six countries studied, the addressable market is significantly reduced to USD $547M. Barriers include lack of affordability, water scarcity (in relation to solar irrigation), need for demand aggregation for shared PUE viability, low levels of awareness (across stakeholders along the value chain) on the benefits of PUE alternatives and a general need to further develop the policy environment to accelerate the PUE ecosystem's growth which is still nascent in the studied markets.

The report includes targeted recommendations for addressing the identified barriers and driving the uptake of PUE appliances, aligning with three broad intervention categories: policy and regulation, financing, and capacity building and awareness raising. Additionally, we propose integrating PUE elements into energy, agriculture, trade, and development policies as a first key step for the development of the PUE market in these countries.

Gender mainstreaming is a priority in the two regions, and member countries are making progress to empower women in the public and private sectors. While the progress is encouraging, women are still disadvantaged in nearly all economic sectors, including energy. The focus areas for PUE initiatives include enhancing women's entrepreneurial and technical skills and improving their access to financing.

Project Background

The United Nations Industrial Development Organization (UNIDO), in partnership with the East African Centre of Excellence for Renewable Energy and Efficiency (EACREEE) and the SADC Centre for Renewable Energy and Energy Efficiency (SACREEE), is implementing the Energy Efficient Lighting and Appliances (EELA) project in East and Southern Africa. This project is funded by the Government of Sweden through the Swedish International Development Cooperation Agency (Sida).

The EELA project commenced in 2019 and the first phase will run until 2024. Its goal is to create the necessary market and institutional conditions to facilitate a transformation of the sector, stimulating increased diffusion of energy-efficient lighting products, appliances, and services across all sectors in the Southern Africa Development Community (SADC) and the East African Community (EAC) regions.

UNIDO contracted CLASP to conduct a market assessment and supply chain analysis of the productive use ecosystem in EAC and SADC regions. This consolidated report presents data and in-depth knowledge on the status of productive-use appliances in the EAC and SADC regions to support the design and implementation of high-impact activities that will increase the uptake of productive-use appliances in the two regions and strengthen their supply chains The study was officially completed in January 2022 and the findings in the report represent data available up to that time.

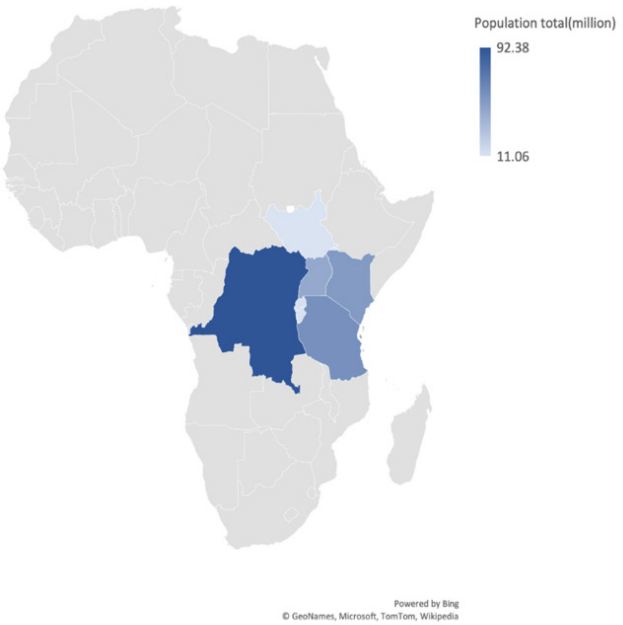
1. EAC AND SADC REGIONAL CONTEXT

1.1 Socio-economic and Energy Access Situation

1.1.1 EAC

The EAC member countries are similar in geography, climatic conditions, natural resources, and economic activities. Researchers and policymakers can leverage these similarities to develop a cohesive, productive use of energy strategy. However, it is important to note the wide demographic[1] variations between the countries[2].

	Indicator	EAC
Population	Population Total (2019) (million)[22]	177
	Growth Rate -Average (annual %)	2.54
	Population density (people per sq. km of land area) Average	200.84
Economy	GDP -Total (Current US$) (Billions)[3]	193.70
	GDP Growth- Average (Annual %)	1.21
	GDP per capita - Average (current US$)	976.42
Electrification	Electrification Rate (access to electricity (%) Average (2019)1	34.05
	Electrification, Urban (% of population) Average (2019)	67.29
	Electrification, Rural (% of population) Average (2019)	24.47



Population. While the share of urban population (24%) versus rural population (76%) is similar across the regions, total population size and density vary widely and range from 17 people per square kilometre in South Sudan (SS) to 525 in Rwanda. Average population growth rate is 2.6 %, with smaller deviations (3.27% in Uganda and 1.18% South Sudan). However, there are smaller deviations in the average population growth rate at 1.18% in South Sudan and 3.27% in Uganda.

1 The data points presented in this report were sourced from World Bank Indicator.

2 At the time of the study, the Democratic Republic of Congo had not joined EAC. The country is therefore covered in the SADC sections.

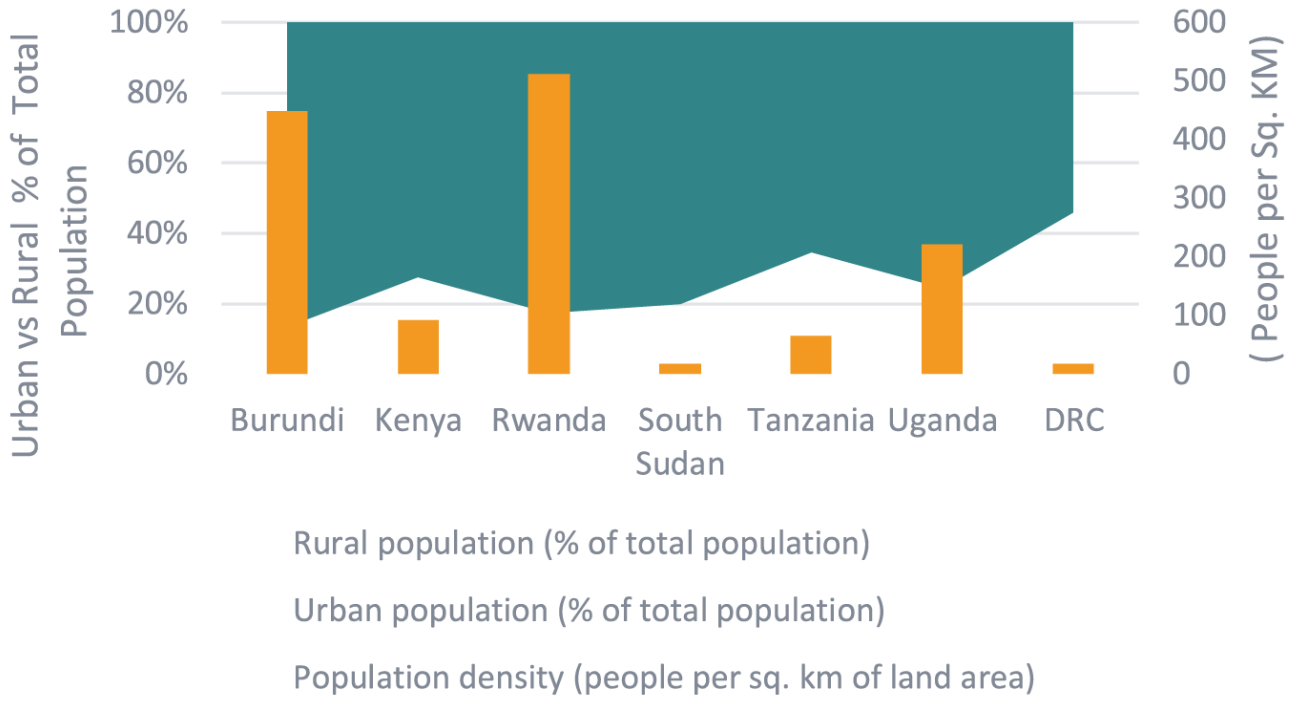


FIGURE 2: EAC POPULATION DYNAMICS

Economy. There are economic imbalances across the region, with some countries exceeding by almost 30 times the gross domestic product (GDP) of other countries and by five times their GDP per capita. Though the growth rates are not drastically different, COVID 19 inflicted high human costs across all the countries and to date, most countries are yet to reach their pre-covid growth levels Thus, an average economic description of the EAC is challenging to establish.

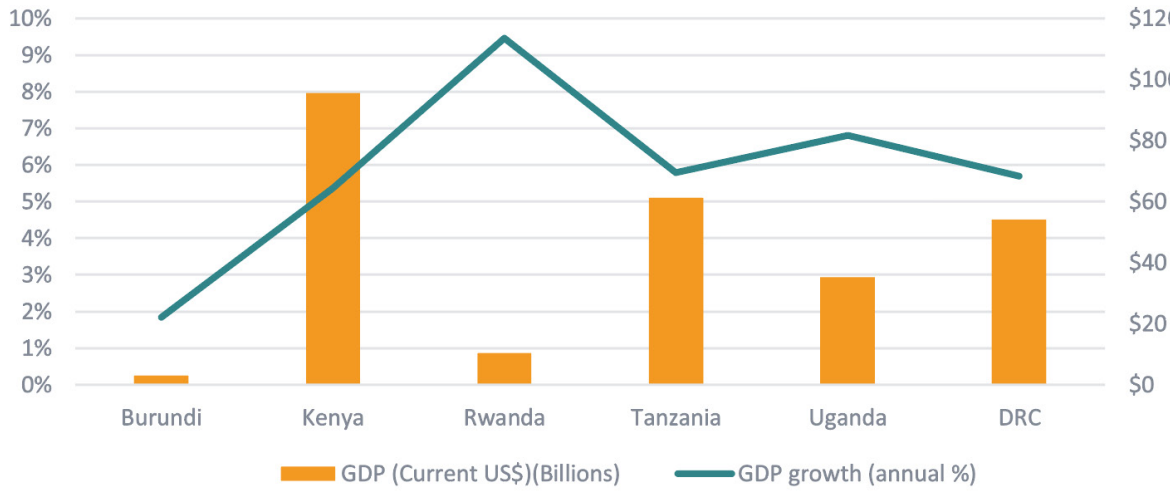


FIGURE 3: EAC ECONOMIC INDICATORS

Electrification. Electrification is not consistent in the region. On average, 34% of the EAC population has access to electricity, of which 67% are urban residents, and only 24% are rural. Electricity access varies by country, with Kenya having the highest population with total access (69.7%) and South Sudan having the lowest (6.7%). Overall, the region has higher urban than rural access to electricity, but country-specific numbers vary tremendously. Countries have greater than 70% urban electricity access with the exception of South Sudan (13%) and Burundi (62%). Electricity generation across EAC is dominated by hydropower,

with gas and oil, respectively, making up the remainder of the generational capacity. Geothermal electricity generation is only significant in Kenya (IEA, 2019a). Solar PV, wind and other renewable sources make up a smaller proportion of the electricity generation in the region. There has been heavy investment in grid expansion, and energy surplus is already a reality in most EAC countries. The EAC has initiatives to strengthen the power market regionally and jointly address power sector issues.

Off-grid electrification has grown significantly with the adoption of solar systems for productive and consumptive use. In the half year before the COVID -19 pandemic, 2.43 million solar products had been sold in East Africa. Further, East African countries have set national electrification targets and developed strategies for universal energy access through renewable energy policies that recognise off-grid electrification's vital role.

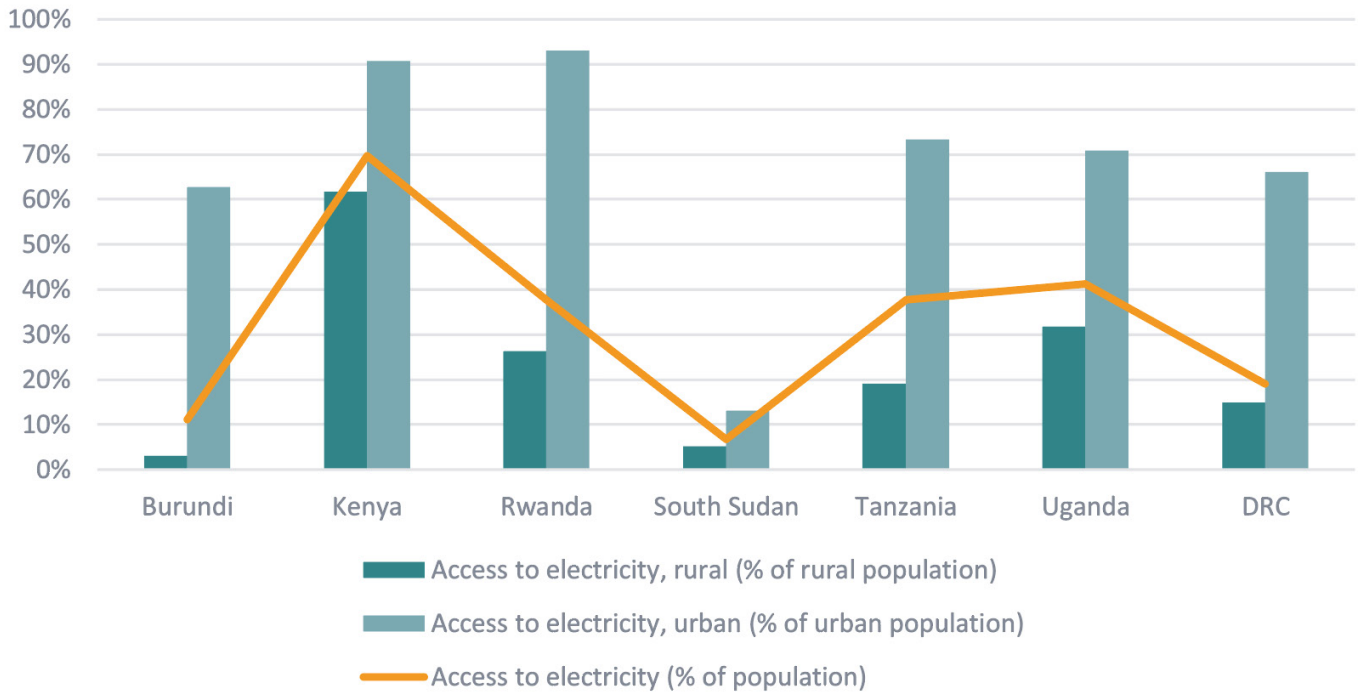


FIGURE 4: ELECTRICITY ACCESS RATE WITHIN THE EAC

The variations in demography, economics, and energy access present a challenge for addressing PUE needs uniformly across the region. Countries like Kenya, Tanzania, Uganda, and Rwanda are primed for PUE because of higher-than-average electricity access and higher GDP per capita. South Sudan and Burundi, however, are still grappling with low energy access and economic growth that may slow the development of their PUE markets.

1.1.2 SADC

Though the countries of the SADC have significantly more integration than other regional blocs, there are major differences in SADC member countries' demographics, economies and energy profiles.

	Indicator	SADC
Population	Population Total (2018) (Million)[1]	345
	Urban population (% of total population)[2]	46
	Rural population (% of total population)	56
	Population density (people per sq. km of land area)- Average	121.0
	Population growth rate (annual %)- Average	2.0
Economy	GDP- Total (2018) (Billions, US$)[3]	721.3
	GDP growth (2018) (annual %)[4]	1.8
	GDP per capita-Average (current US$)	3,938.3
Electrification	Access to electricity - Average (% of population)[5]	48
	Access to electricity, Urban – Average (% of population)[6]	75
	Access to electricity, Rural - Average (% of population)[7]	32

TABLE 2: SADC REGION DEMOGRAPHICS

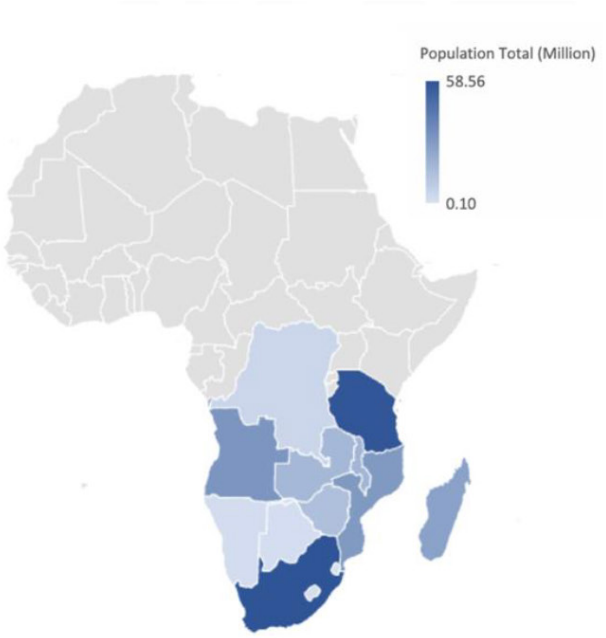


FIGURE 5: SADC POPULATION

Population. In 2018, the total population was estimated at 345 million[1], accounting for 33% of the Sub-Saharan African population and 4.5% of the world population. However, population dynamics or metrics are not homogenous across the region. For example, DRC (Democratic Republic of Congo) is the most populous member country at 89 million, while Seychelles has a significantly smaller population of 98,000 inhabitants. There are also large differences in population density. Namibia hosts 2.5 inhabitants per square kilometre despite being only 15% smaller than Tanzania, which hosts 67 inhabitants per square kilometre due to Namib's large unpopulated desert areas, while Mauritius is the most densely populated country with over 600 people per square kilometre.

1 SADC Summary Facts & Figures: https://www.sadc.int/about-sadc/overview/sadc-facts-figures/

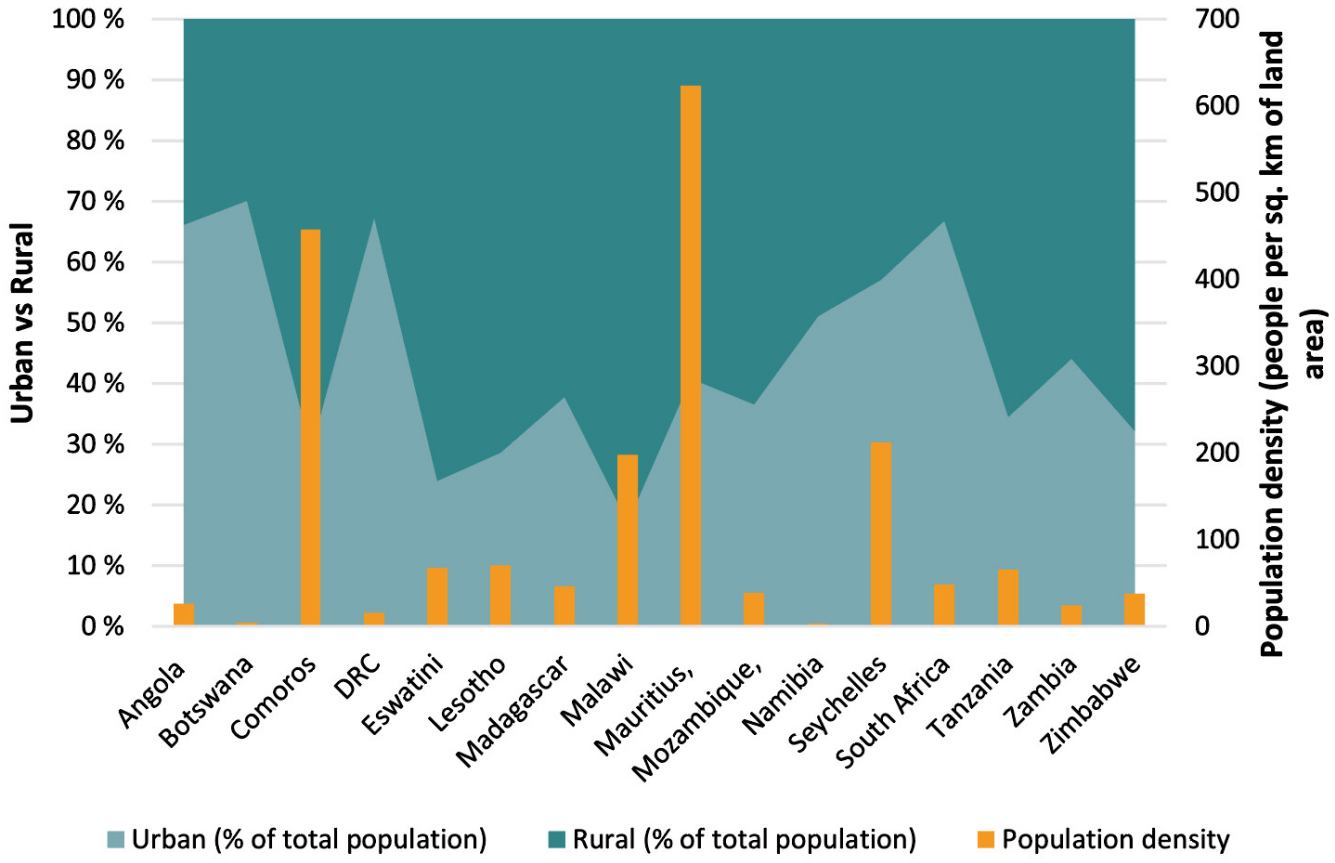


FIGURE 6: SADC POPULATION DYNAMICS

Economy. The size and performance of SADC member countries' economies also differs largely as indicated by measures of GDP. For example, the 2020 GDP ranges from USD $302 Billion in South Africa to USD $1.1 Billion in Seychelles, while GDP per capita rises from USD $625 in Malawi to USD $11,425 in Seychelles. See Figure 7.

Recently, due to a pandemic-induced contraction in GDP coupled with increased inflation and increasing public debt, the regional economy has suffered. Luckily, it is forecasted that economic growth and recovery post-pandemic will be achieved with the diversification of economic activities. Other drivers for recovery will be the enhancement of national and regional capacities in producing medicines, medical supplies, developing vaccines, and harnessing digital technology across sectors.

The social profile across the region is also complicated and varied, with the Human Development Index between 0.418 (Mozambique) and 0.782 (Seychelles) and nine member states below 0.50, pointing to high inequality in the region and significant poverty levels.

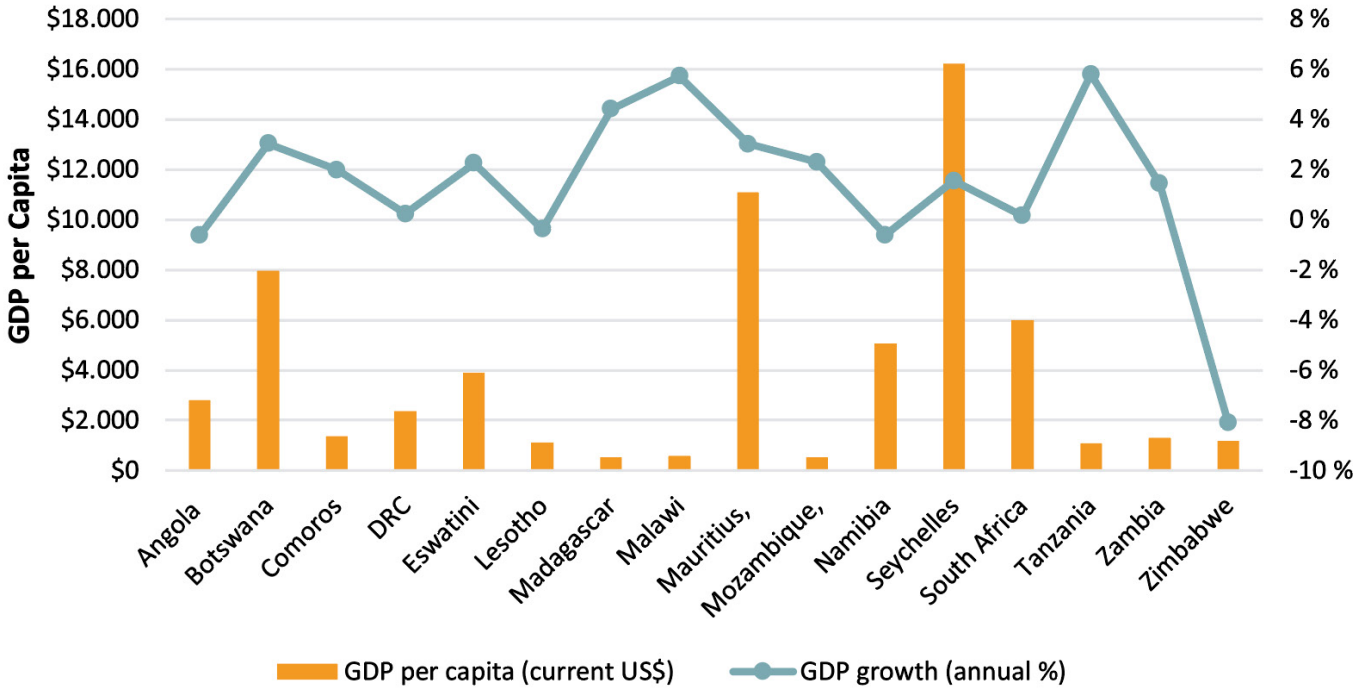


FIGURE 7: SADC ECONOMIC INDICATORS (GDP PER CAPITA AND GROWTH RATE)

Electrification. Since 2007, the region has experienced electricity shortage. Further, some member countries have the lowest access globally, for example, Mozambique and Madagascar at approximately 25% each and Malawi at 11%. In 2019, on average only 32% of rural areas in the region had access to electricity. However, this varies by country, with Malawi, DRC, and Madagascar all having under 10% access for rural populations. Access to grid-based electricity has improved since 2015 through grid extension programs and two member states, Mauritius, and Seychelles, are at 100% access.

The region's installed capacity is still dominated by coal-fired power plants, mainly in South Africa. In the rest of Southern Africa, there has been a rapid growth of private companies selling micro-scale clean energy products such as pico-solar lanterns, street lighting, and power for irrigation pumps, with many using pay-as-you-go (PAYG) systems to generate revenue and provide support services. Some member states such as Zambia and Zimbabwe offer subsidies and assistance for installing off grid systems. . Such subsidies accelerate the uptake of clean energy products in poorer economies.

The SADC region is also becoming a key player in the international trend towards developing renewable energy resources and energy efficiency, where renewable energy sources accounted for 23.5% of power generation in 2016. Power capacity and improvements in electricity interconnections through Southern African Power Pool (SAPP) is a major factor in strengthening regional energy security. In comparison to the EAC, SADC Member States have significantly more integrations with 27 legally binding protocols to guide and standardise the work of SADC Member States. The SADC protocols enshrine the aims of the Community by providing codes of procedure and practice on various issues, as agreed by the Member States. For example, as pre-empted in the SADC Protocol on Trade, SADC Member States established the Free Trade Area in 2008, which is yet to include Angola and DRC.

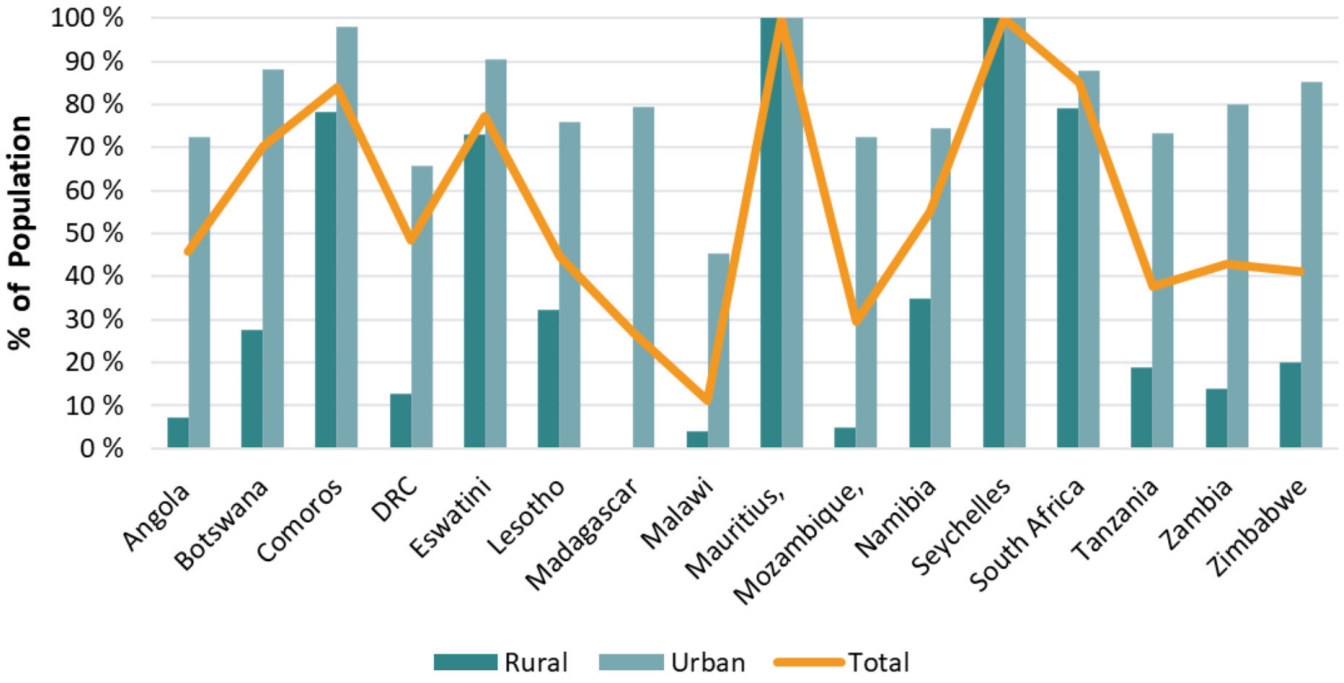


FIGURE 8: ELECTRICITY ACCESS RATE IN SADC REGION

1.2 KEY ECONOMIC ACTIVITIES AND VALUE CHAINS

1.2.1 EAC

Though the EAC countries have begun diversifying into the service and industry sectors, agriculture remains the single largest economic sector in the region, with manufacturing and mining making a significant share of the remainder[1].

Despite an abundance of arable land in the region, food production rarely meets demand, with some countries like Rwanda and Burundi making up for the shortfall with significant food imports. Although food crops like staple grains (maize, millet, sorghum) and root tubers (potatoes, cassava) make up a substantial portion of agricultural produce in the region, a variety of cash crops are also grown for export and account for a sizeable portion of export earnings. Production of tea and coffee is ubiquitous across the countries, with crops like cotton, tobacco, sisal, and pyrethrum being a major focus in one or two countries. Horticulture is pervasive and straddles the food/cash crop divide, with most being grown for export, e.g., cut flowers, fruits, and specialised vegetables for Western markets. Livestock is similarly pervasive, although there are differences in the animals kept and products generated. Appendix A shows the mapping of specific value chains in EAC countries.

he industrial sector revolves primarily around agricultural processing, including dairy, leather, and meat. Further, all the countries participate in producing small-scale consumer goods such as furniture, textiles, flour, and beverages. Cement production, sugar production, and brewing are also present in Kenya and Uganda, and oil refining in Kenya and Tanzania. Mining is significant in all countries but Kenya. The

1 See Appendix A for a mapping of these value chains.

most developed services in the region are travel services[2] related to the tourism market. Other significant services for economic growth include port facilities (with cold chain infrastructure), trade, business and finance.

Industries' contribution to the regional GDP is currently an average of 9.7%, with the region aiming to reach 25% by 2032[3]. Overarching building blocks to industrial development in the region include the harmonisation of policies to support regional production systems, enhancing institutional and technical capacities and new financial mechanisms to support development and upgrades.

Mobility is an enabler for all other economic activities. In EAC, poor infrastructure development limits mobility, particularly in rural areas. The lack of high-grade rural roads makes last-mile distribution a specific challenge in the region. Inadvertently, the poor infrastructure reduces the market for goods and increases the delivery costs, thus making them uncompetitive with other more accessible markets. For example, in agriculture, the movement of produce for smallholder farms is limited to farm gates or aggregation points, sometimes developed by intermediaries who exploit farmers. Where possible, travel to markets is typically on foot, bicycles, petrol motorbikes, and petrol three-wheelers (tuk-tuks). These modes are inefficient and can be expensive, given fluctuating fuel prices. The efficiency of movement and reduced emissions could be supported by electrifying transport. Electric 2 and 3-wheelers can also support the emergence of new income streams through hire transport.

1.2.2 SADC

As in the EAC, agriculture is the mainstay of the SADC economy, contributing about 20% of its GDP. It contributes to about 13% of the total export earnings and about 66% to the value of intra-regional trade. About 70% of the SADC population depends on agriculture for food, income, and employment. Between 2010 and 2018, the SADC member states with the highest levels of agricultural employment included Malawi (85%), Mozambique (75%), and Madagascar (73%).

Small-scale farming is the most dominant mode of agriculture, encompassing 80% of the region's cultivated land and contributing 90% of its produce[4]. It is primarily rain-fed and, therefore, highly vulnerable to climate change experienced through unpredictable rainfall events, heat waves, and fierce winds. The most common climatic hazards in the region are drought and extreme rainfall. The Regional Indicative Strategic Development Plan identifies key areas of production that can be enhanced, including agricultural intensification through expansion of the area under cultivation, irrigation, mechanisation, sustainable use of fertilisers, and better seed quality and distribution. Crop production in the region is diverse, with staple foods and cash crops. The key staple crops in the region include maize, wheat, pulses, other cereals, cassava, and other root tubers.

2 Travel services include hotels, restaurants, catering, travel agencies, tour operator services, and tourist guides.

3 https://www.eac.int/industry/eac-and-industrialisation

4 Gosling, A. et al., 2020, *Agriculture in the SADC Region Under Climate Change*

Cash crops include tobacco, tea, coffee, cotton, sugarcane, spices, and oilseed. Nut production as a food and cash crop is also significant in SADC. Beef is the most significant livestock output from the region, with other major outputs being milk, eggs, poultry meat, pork, lamb, and goat.

The fisheries and aquaculture sector in the SADC region employs around 2.6 million people and accounts for 11% of the region's agriculture GDP. Coastal fisheries are present in Tanzania, Mozambique, Madagascar, and the Islands. Inland fishing is primarily on the region's major lakes, including Lake Victoria and Malawi. Despite its potential, fishing yields are constrained by pollution and overfishing. In addition, efficient fisheries resource utilisation and marketing are limited by inadequate infrastructures such as roads, fish markets, landing sites, cold chain and storage facilities, fish handling and processing facilities.

Mining has strategic importance in SADC given the concentration of rare minerals and gems: 36% of the world's gold and nearly half the global vanadium, platinum, and diamond are found in the region's member countries, contributing significantly to those economies. Mining employs just 5% of the population but contributes 60% to the foreign exchange earnings and 10% of GDP for the SADC region[5].

Tourism and the service sector is also a rapidly growing industry that SADC recognises could greatly benefit the region. Island nations, rely heavily on tourism as a GDP contributor, given the land use limitation for large-scale agriculture. Traditionally, governments have not prioritised tourism as it has fallen in the gap of other sectors it engages in, e.g., transport, and trade. Further, monitoring systems have not captured the economic value generated by tourism in the region, leading to its de-prioritisation. However, the Protocol on Tourism[6] aims to stimulate investment and encourage government cooperation with the private sector. Other services of significance in the region include financial services (Seychelles and Mauritius), business services (South Africa), and ICT (Information and Communication Technologies).

The generation of goods and services has increased economic productivity, led to more robust regional integration, and reduced poverty for people in the region. However, the state of industry varies widely throughout SADC as member states are in different stages of economic development. In all SADC member states, the manufacturing sector's contribution to GDP is less than 20% and, in some cases, lower than 5%. Moreover, industrialisation intensity is low, with industrial output heavily concentrated on low-technology products such as food, beverages, textiles, clothing, and footwear[7]. The SADC industrial development policy framework identifies challenges to the growth of industry and manufacturing, linked to limited domestic and regional markets, insufficient productive capacity and diversification, technical skills gaps and low levels of investment. Additionally, there's a need to improve standards, quality, and conformity infrastructure within the region.

5 SADC, 2021, Mining.

6 SADC, 2021, Protocol on the Development of Tourism-1998.

7 SADC, 2018, SADC Industrial Development Policy Framework.

1.2.3 GENDER IN EAC AND SADC

The EAC and SADC regions are making progress in efforts to empower women. Gender mainstreaming initiatives are being implemented by policymakers and private sector actors. For example, in Kenya, the Constitution mandates that elected and appointed officials to public offices comprise at least 30% of either gender, a trend being adopted by the private sector. In Tanzania, the country's Rural Energy Agency and the National Energy Policy of 2015 include specific provisions for women. Non-profit initiatives, such as the Tanzania Gender and Sustainable Energy Network (TANGSEN) and the Gender and Energy Network in Zimbabwe (GENEZ)[1], formed under Zimbabwe Women's Resource Centre and Network (ZWRCN), also focus on gender mainstreaming in the energy sector.

However, studies demonstrate that women are still disadvantaged in nearly all economic sectors, including energy. They are overrepresented in part-time, informal, low paid or unpaid work. For example, in Rwanda, women aged 15-60 years spend 33% of their time in agriculture, while men only spend 19% of their time[2]. Furthermore, many women employed in agriculture face disadvantages, e.g., low pay, long hours and balancing family commitments. Women also often face obstacles when they seek non-traditional employment, and very few make it to senior management for those in formal employment. For example, in Mozambique, only 16% of firms in Mozambique have female top managers..

Access to electricity can unlock more significant economic opportunities for women. It can free up time and labour and promote better health and education within communities. It is important to note that men and women have differentiated priorities in energy services. Consequently, there is a need to develop contextualised policies, involve women in decision-making, and create opportunities for them in the energy sector. Focused interventions such as education and financial literacy support mechanisms; affordable and accommodative credit facilities will boost the productivity and competitiveness of women-owned micro-, small-, and medium- enterprises (MSMEs).

1 GENEZ is a network with a membership of 15 organizations. It seeks to empower children, youth, and women through skill development workshops, training programs, awareness campaigns, increasing local participation in energy projects and campaigns.

2 Mindje, Mapendo & Ngirinshuti, Leonce & Funmilola, Agbebi & Kibogo, Andrew, 2020, Contribution of women to aquaculture development in Rwanda.

2. GLOBAL PUE PRODUCTS MARKET

PUE is very varied, and its successful application depends on appliance and context-dependent factors. A key consideration is the global market maturity of the appliance. The categorisation in Figure 9 is broadly based on the best available quantitative data (e.g., number of companies in the marketplace, global sales volumes, product performance data, and investment capital) and qualitative data (e.g., stakeholder interviews and on-the-ground learnings). It should be noted that such a grouping in different stages, though subjective, can help in understanding relative maturity, better characterise the market for similar product classes, and identify common next steps. See Annex B for factors that should be considered for specific groupings of PUE applications.

FIGURE 9: MARKET MATURITY ASSESSMENT OF SOLAR APPLIANCE TECHNOLOGIES

2.1 PUE SUPPLY CHAINS

The PUE appliance market supply chain is similar to that of conventional appliance and small machinery. See Figure 10 for its general components.

FIGURE 10: TYPICAL PUE SUPPLY CHAIN

Several types of private sector supply chain actors are involved in delivering PUE. The most common type emerging is Original Equipment Manufacturers (OEM) coupled with vertically integrated companies or distributors. OEMs are typically involved in the first three steps of the chain; they source and custom manufacture the technology to fit their buyers' needs (i.e., distributors or vertically integrated Distributed Energy Service Companies (VI-DESCOs). They are usually located in China and throughout Asia. The main difference between distributors and VI-DESCOs is that the later are invested in product design, engineering, and testing to develop products that integrate seamlessly with their distributed energy supply. These companies also coordinate all transportation logistics from shipping to last-mile distribution and sell the appliances through in-house agents or offices. Shipment and importation of PUE appliances can be greatly eased by supportive national trade and agricultural policies such as tax exemption. Appendix C maps two key supply chains and provides case studies from Rwanda and Tanzania from companies selling solar water pumps.

3. MARKET FOR PUE PRODUCTS IN EAC AND SADC REGIONS

3.1 Key PUE in EAC

A comprehensive exploration of each country in the EAC was not within the scope of this study. Therefore, the discussion and selection of key PUE presented for EAC are based on in-depth research in Tanzania and Rwanda. Table 3 shows the summary of prioritized key PUE in these two countries according to the scoring methodology provided in the Appendix E. Other technologies that were considered but did not score highly (less than 9) in the selection criteria, given the relevant value chains in Tanzania and Rwanda, include solar-powered pulping machines (for coffee), solar dryers, solar milking machines, fishing lights, oil pressing, and peanut shelling. Additionally, owing to robust milk value chains in Rwanda, milk refrigeration was also identified as an important PUE, that can fit under cold storage technologies.

	Grain Milling	Cold Storage	Egg Incubators	Refrigeration (Milk)	Solar Water Pumps	EVs 2/3-wheelers
Tanzania	11	10	-	-	12	9
Rwanda	10	11	10	-	13	9

Economic activities are remarkably similar across the EAC region, and the following inferences can be made on the applicability of the key PUE appliances identified:

- Grain milling is applicable region wide as grains are a considerable proportion of the economic activity across all countries. Both on-grid electric mills and solar mills should be considered depending on the energy supply context.
- Solar water pumping and cold storage equally apply across all countries, particularly for producing and storing horticultural produce. However, the choice of the specific food value chains in which to apply these technologies will be country dependent and requires further study. In highly electrified countries like Kenya and Rwanda, grid-based cold storage may be an easier entry point since the technology is available and tested.
- E-vehicles for transporting goods to market will also be suitable across the region. However, some countries will have a more conducive environment in the short term. For example, countries like Burundi with lower access to grid electricity would need significant off-grid solutions to enable e-vehicles.
- Whilst poultry farming is common in many EAC countries, egg incubators are particularly suitable in Rwanda and Uganda, where poultry farming is developed. Intensive farming is ideal, given the high population density with smaller land areas. The same inference can be made for milk production and storage technologies, i.e., solar milking machines and refrigeration for milk.

3.2 Key PUE in SADC

The choice and selection of key PUE for SADC are based on in-depth research in the selected countries, Tanzania, Zimbabwe, Zambia, Malawi, and Mozambique. Table 4 shows a summary of identified key PUE appliances according to the scoring methodology provided in Appendix E. Other technologies that were considered but did not score highly (less than 9) against the selection criteria, given relevant value chains in the five countries, include egg incubators (all countries had a score of 8), solar-powered pulping machines (for coffee), solar dryers, solar milking machines, fishing lights, oil pressing and peanut shelling. Milk (Zambia and Zimbabwe) and fish (all countries apart from Tanzania) value chains also indicate an opportunity for refrigeration PUE.

	Grain Milling	Cold Storage	Solar Water Pumps	EVs 2/3-wheelers
Tanzania	11	10	12	9
Zimbabwe	11	10	12	9
Zambia	11	10	13	9
Malawi	11	10	12	9
Mozambique	11	10	13	9

Though economic activities can be quite similar across some SADC member states, few are shared region wide. However, countries were divided into three classifications to help construct a framework to recommend successful PUE appliances in each country.

Livestock agriculture-driven states are the southernmost countries with temperate to arid climates that mainly support livestock rearing. These countries also tend to have extensive mineral deposits, which form a sizeable portion of the economic output. They include South Africa, Eswatini, Lesotho, Botswana, Namibia, and Angola. None of the countries in this grouping is covered by the country profiles making inferences on PUE difficult. However, given the prevalence of livestock farming and large-scale grain farming, grain milling, refrigeration, and cold storage are likely to be successful PUE activities. Solar water pumps are also applicable and can help mitigate frequent droughts, however, given water scarcity concerns in these countries, they should be applied with caution and submersible solar water pumps should be regulated to prevent groundwater over-extraction. Finally, e-vehicles like Electric 2- and 3-wheelers may be of particular interest if coupled with renewable energies. Many countries in this grouping rely heavily on fossil fuel power with negative climate implications. Therefore, a switch to e-vehicles would have both economic and environmental benefits.

Island nations, i.e., Comoros, Mauritius, and Seychelles, are characterised by large population density, and in the case of Mauritius and Seychelles, high GDP per capita and almost universal access to electricity.

The in-depth country profiles did not cover any of these countries. Refrigeration and cold storage, especially for fishing, are likely to be successful on the island, given the presence of aquaculture. Cold services are energy-intensive; therefore, the near-universal grid coverage on the island means that existing and assessed on-grid refrigeration technologies can be utilised efficiently and quickly instead of nascent off-grid cooling technologies. The island nations also have a significant portion of their economy focusing on services like tourism, where Electric 2- and 3-wheelers may be applied for the tourism sector. Comoros stands out in the island states as being more agrarian and food insecure. PUE technologies that increase food production, such as egg incubators and solar water pumps, may have potential as well as food processing PUE such as grain mills.

Crop farming-driven states: These are countries that form most SADC member states. They are closer to the equator with similar climatic conditions and rely primarily on crop farming as the main agricultural economic activity. They tend to be lower income with larger poverty levels and under-electrification. They include Tanzania, Malawi, Zambia, Zimbabwe, Mozambique, the Democratic Republic of Congo, and Madagascar. Separate in-depth country profiles have been developed for these nations apart from the DRC and Madagascar. For DRC and Madagascar, just like the other member nations in this group, solar water pumping could help support smallholder and subsistence farmers who rely on rainfall. In a region with abundant water, solar water pumps could increase farming efficiency by reducing labour associated with water movement. Further, there could be a knock-on effect for delivering domestic water, an essential but not universal service in these low-income nations. Although not highly ranked in the scoring criteria for the relevant value chains, oil Pressing is a unique PUE technology and could be extremely successful in nations with a large production of oil seed and nuts, such as Tanzania and Malawi and in nut-growing countries like Mozambique.

3.3 Policy Environment

Member countries in EAC and SADC have country-specific policies that affect PUE; the policy types, member examples, and PUE specificity are summarized in the following tables. Fundamentally, PUE can be a key contributor to achieving set objectives and goals in various policy and strategy documents. The summary tables propose integrating PUE elements into energy, agriculture, trade and development policies, as well as strengthening products' standards programs as a key first intervention to anchoring PUE appliances in these countries.

TABLE 5: EAC PUE POLICY SUMMARY AND INTERVENIONS

	POLICY TYPES	EAC COUNTRY EXAMPLE	PUE IN POLICY	OPPORTUNITIES FOR PUE APPLIANCES' INTEGRATION IN POLICY
ENERGY	Energy Sector Strategic plans and Energy Policies, such as Rural Energy Act (Tanzania) and Electricity Acts (multiple countries) provide the overall policy direction for the energy sector with a long-term vision for the state of the sector, including efficient use of energy. In some cases, specific policies may target rural areas and thus have more off-grid integration.	Rwanda Energy Policy	Yes	The current strategy recognises PUE and undertakes to improve electricity access among PUE users. The policy could be augmented to ensure that it covers both on and off-grid PUE appliances.
		Tanzania's Rural Energy Act of 2005	No	The act promotes the socio-economic well-being of people without access to energy. However, it does not mention the role of PUE. It establishes the Rural Energy Board, whose mission is to promote rural socio-economic development by facilitating expanded access to modern energy services for productive economic uses, health and education, clean water, civil security, and domestic applications. It could expressly talk about PUE appliances and how the agency could support the private sector to scale PUE appliance adoption.
		Tanzania's National Energy policy 2015	No	The policy aims to scale up the utilisation of renewable energy and diversify the country's energy mix by using solar, biomass, wind, small-scale hydro, and geothermal. PUE contributes to demand stimulation and express recognition in this policy would mean that investment in generation matches the demand.
	Mini-grid Regulations: Rural energy agencies typically adopt regulations related to mini-grids. They specify licensing requirements, tariff guidelines, and procedures upon grid arrival.	Rwanda Mini-grid Regulations	No	PUE contributes to demand stimulation and express recognition in this regulation would mean that investment in generation matches the demand.
AGRICULTURE	National Agricultural Policies: These would typically take account of technological advances, the increasing role devoted to the private sector in the development, regional integration, and the threat of climate change.	Rwanda National Agricultural Policy	No	The policy mentions areas of technological advances. It could expressly recognise the role of PUE technologies in meeting the overarching role of agriculture across Rwanda.
	Irrigation Master Plans: where these exist, they aim to manage water resources, promote irrigation, and improve food security.	Rwanda Irrigation Policy	Yes	The policy promotes irrigation and could be augmented to include quality, performance and efficiency requirements. This could include initiatives that support increased affordability such as subsidies and increased awareness.

STAN-DARDS	Appliance specific standards towards quality assurance of PUE	Tanzania's Standards for Solar water pumps	Yes	The policy promotes the quality of solar irrigation pumps. Tanzania Bureau of Standards adopted solar pumps standards from the International Electrotechnical Committee, and they are awaiting these to be published in the Government Gazette.
DEVE-LOPMENT	Development Policies and Programs: these are specific policies and programs (usually at the country level) that aim to accelerate one or more development goals, e.g., food security and poverty reduction. Sometimes they are depicted as pathways towards such developments, e.g., Rwanda's Vision 2050 and Kenya's Vision 2030.	Rwanda's Economic Development and Poverty Reduction Strategy and National Strategy for Transformation	No	The policy promotes the quality of solar irrigation pumps. Tanzania Bureau of Standards adopted solar pumps standards from the International Electrotechnical Committee, and they are awaiting these to be published in the Government Gazette.
		Tanzania - Second Five-Year Development Plan (2016/17–2020/21)	No	The plan supports value chains and looks to improve agricultural productivity and strengthen agricultural value chains, it expressively talks about this in urban areas and mostly in the industrial sector. The plan can be augmented to include the role of productive use in increasing the quality of life and economic growth in rural areas.

TABLE 6: SADC PUE POLICY SUMMARY

	POLICY TYPES	SADC COUNTRY EXAMPLE	PUE IN POLICY	OPPORTUNITIES FOR PUE APPLIANCES' INTEGRATION IN POLICY
ENERGY	Energy Sector Strategic plans and Energy Policies, such as the Rural Energy Act (Tanzania) and Electricity Acts (multiple countries) provide the overall policy direction for the energy sector with a long-term vision for the state of the sector, including efficient use of energy. In some cases, specific policies may target rural areas and, thus, have more off-grid integration	Zimbabwe's Electricity Act of 2002 (amended in 2007) and National Energy Policy (NEP) of 2012	No	The policy seeks expansion of electricity access across various energy sources – a key enabler for the uptake and growth of PUE.
		Zambia's Rural Electrification Act	Yes	The Act promotes the utilisation of available rural electrification technological options to enhance the contribution of energy to the development of agriculture, industry, mining, and other economic activities in rural areas. This can be further expounded to expressly recognise applicable PUE and interventions to support actual adoption.
		Zambia's National Energy Policy	No	The Act establishes the Rural Energy Board, which aims to promote rural socio-economic development by facilitating expanded access to modern energy services for productive economic uses, health and education, clean water, civil security, and domestic applications. It could expressly talk about the productive use of appliances and how the agency could 25 support the private sector to scale PUE appliance adoption.
		Tanzania's Rural Energy Act of 2005	No	The Act promotes the utilisation of available rural electrification technological options to enhance the contribution of energy to the development of agriculture, industry, mining, and other economic activities in rural areas. This can be further expounded to expressly recognise applicable PUE and interventions to support actual adoption.
		Mozambique- The New and Renewable Energy Development strategy for the 2011-2025 period (EDNR)	No	The policy aims to improve access to energy services through renewable energy sources, develop the technologies to further promote the use of renewable sources and promote investments from the public and private sectors in renewable energy. PUE contributes to demand stimulation and express recognition in this regulation would mean that investment in generation matches the demand.
		National Energy Policy (NEP) 2018 & Malawi Renewable EnergyStrategy (MRES), 2017	No	The policy seeks expansion to electricity access across various energy sources – a key enabler for the uptake and growth of PUE.
AGRICULTURE	National Agricultural Policies: These would typically take account of technological advances, the increasing role devoted to the private sector in the development, regional integration, the threat of climate change as well as the required investment as identified in Malawi's NAIP.	Zimbabwe Draft national agriculture policy framework (2018-2030)	No	The policy can specify PUE as a pathway toward realising full productivity potential, particularly in agriculture.
		Zambia's National Agricultural Policy	No	The policy can explicitly include PUE in the relevant sections highlighting the opportunities for increased productivity in crops and livestock
		National Energy Policy (NEP) 2018 & Malawi Renewable EnergyStrategy (MRES), 2017	No	The plan can specify PUE as a pathway toward realising full productivity potential, particularly in agriculture.

STANDARDS	Appliance-specific standards towards quality assurance of PUE	Tanzania's Standards for Solar water pumps	Yes	The policy promotes the quality of solar irrigation pumps. Tanzania Bureau of Standards adopted solar pump standards from the International Electrotechnical Committee, and they are awaiting these to be published in the Government Gazette.
TRADE	Trade policies: these are specific policies that look to advance trade and could include specifications around subsidies	Zimbabwe's Indigenization and Economic Empowerment Act	No	The act can include a direct mention and inclusion of PUE appliances business as a pathway towards increasing investments and participation in the country's economy.
		Malawi National Trade Policy and National Export Strategy (NES) 2013-2018	No	The policy can include a direct mention and inclusion of PUE as a catalyst and enabler for improved and increased productivity to meet demand and take full advantage of the expanded market access to increase exports.
DEVELOPMENT	Development Policies and Programs: these are specific policies and programs (usually at the country level) that aim to accelerate one or more development goals, e.g., food security and poverty reduction.	Zambia-National Development Plan	No	This plan looks to increase economic diversity and alleviate poverty amongst other goals. It also recognises agriculture as a key sector of the Zambian economy. The plan could be augmented to expressly recognise the intersection between energy and agriculture and integrate relevant PUE interventions
		Mozambique - The National Development Strategy (ENDE) for 2015-2035	No	The strategy identifies the agricultural and industrial sectors as key areas to be promoted. The strategy could be augmented to expressly recognise the role of PUE in meeting the overarching role of agriculture across Mozambique.
		Malawi Growth and Development Strategy (MGDS) (2005)	No	The strategy can directly mention and include PUE in the intervention/roadmap plan towards the achievement of the policy focus areas particularly agriculture and food security; irrigation and water development; transport infrastructure development; energy generation and supply; and integrated rural development.
		Malawi Second Five-Year Development Plan (2016/17–2020/21	No	Whereas the plan supports value chains and looks to improve agricultural productivity and strengthen agricultural value chains, it expressively talks about this in urban areas andmostly in the industrial sector. The plan can beaugmented to include the role of productive use in increasing the quality of life and economic growth in rural areas.

3.4 On-going Initiatives

In both regions, most PUE appliances programs focus on grant-making for R&D, pilots and market research. They cover a variety of technologies, but solar irrigation and cooling appear to be a high priority. Below are ongoing initiatives that are helping increase productivity and household incomes and will be worth engaging with for any activities intended to increase uptake of productive use appliances in the two regions:

- Efficiency for Access Coalition: a multi-stakeholder coalition focusing on harnessing energy efficiency to accelerate access to modern energy services. PUE projects include the Global LEAP Award, an international competition to identify and promote the world's best off-grid appliances, accelerating market development and innovation; and the Low-Energy Inclusive-Appliances (LEIA) program, a research and innovation programme to double the efficiency and halve the costs of these off-grid and weak-grid technologies.
- The Powering Renewable Energy Opportunities (PREO) Program: a demand-led, PUE program stimulating partnerships, innovation and learning to address the needs and improve the livelihoods of sub-Saharan African communities including Rwanda, Kenya, Uganda and Burkina Faso.
- Climate Resilient Agribusiness for Tomorrow (CRAFT): an SNV project in Kenya, Uganda, and Tanzania to increase the income for smallholder farmers and SMEs (Small Medium Enterprises), increase business performance for agribusiness SMEs and cooperatives through facilitating climate-smart investments in selected agricultural value chains and improve the enabling environment.
- The Energy and Environment Partnership Trust Fund (EEP Africa14): a clean energy financing facility hosted and managed by the Nordic Development Fund (NDF) that provides early-stage grant and catalytic financing to innovative clean energy projects, technologies, and business models in 15 countries across Southern and East Africa.
- Water and Energy for Food (WE4F): a new program that builds on the learnings from Powering Agriculture and focuses on scaling water-energy-food innovations.
- Productive Use Leveraging Solar Energy (PULSE): a research report by ESMAP exploring opportunities to catalyse growth in the market for PULSE micro-applications powered by small standalone solar systems.
- PRODUSE: a joint initiative from ESMAP, AEI, and GIZ aiming to gain insights into the interaction of energy access and productive activities. PRODUSE has developed a manual, study, and methodology. The manual provides practical guidance for energy projects focusing on promoting PUE and is also used in this report.
- The Beyond the Grid Fund for Africa: focuses on providing financial incentives for private firms providing energy solutions for off-grid populations. Funded by Sweden, managed by NEFCO and imple-

mented by REEEP, it aims to replicate the results of the Beyond the Grid Fund for Zambia and bring clean, affordable off-grid energy access to millions of people in Burkina Faso, Liberia, Mozambique, Zambia, and Uganda.

- REACT SSA: The AECF's engagement in the energy sector under REACT SSA is designed to catalyse the private sector to increase the supply of cleaner fuels, raise awareness of the dangers from indoor air pollution, demonstrate how new knowledge in renewable energy technologies can be put into practice in ways that benefit the underserved, especially women, and provide evidence on challenges in policy formulation and implementation. Target SADC countries are Mozambique and Zimbabwe.

3.5 Scoring of PUE products for EAC and SADC Countries

Several key criteria were used to identify the PUE technologies with the highest promise. They included technology maturity, user income potential, private sector stimulation, energy efficiency gains, GHG emission reduction, inclusivity, and scalability. Appendix D provides more information on these criteria.

Each potential PUE appliance was evaluated against the above criteria in a quantified scoring methodology See Appendix A. Sources used to make scoring judgments include available data, literature review, and stakeholder survey findings. All criteria are weighted equally, and the justification is given in the references. Table 7 provides a summary of the scoring of key technologies across the countries. In EAC, irrigation, milling and cold storage came out strongly.

TABLE 7: PUE SCORING

	Rwanda	Tanzania	Malawi	Mozambique	Zambia	Zimbabwe
Solar Water Pumps	13	13	13	13	13	12
Grain Milling	10	10	11	11	11	11
Cold Storage	11	11	11	10	10	10
Electric 2-3 Wheelers	9	9	9	9	9	9
Egg Incubators	10	8	8	8	8	8
Oil Pressing		8	8	8	4	8
Coffee Pulping	2	6	7	7		7
Fish Lighting		6	6	6		6

Peanut Shelling		6	6	5		6
Solar dryer	6			8		
Solar Milking Machines	6				4	
Cell phones				10		

3.6 Market Sizing

The total and serviceable market size for the PUE appliances that ranked high across countries was evaluated in the different countries. The market sizing methodology used can be found in Appendix E.

TABLE 8: TOTAL ADDRESSABLE MARKET IN FOCUS COUNTRIES , 2033 (UNITS)

	Grain Milling	Cold Storage	Egg Incubators	Solar Water Pumps	EVs 2/3 wheelers
Tanzania	38.318	24.660	228.922	2.273.700	334.872
Zimbabwe	5.164	162.505	33.116	583.270	77.743
Zambia	13.456	171.289	57.299	574.515	101.411
Rwanda	2.651	98.635	410.124	591.637	76.160
Malawi	20.341	740.600	57.299	1.051.935	113.078
Mozambique	13.325	565.581	140.617	1.283.863	182.029

TABLE 9: TOTAL SERVICEABLE MARKET IN FOCUS COUNTRIES, 2033 (UNITS)

	Grain Milling	Cold Storage	Egg Incubators	Solar Water Pumps	EVs 2/3 wheelers
Tanzania	-	-	224.773	409.266	50.231
Zimbabwe	-	-	26.493	-	-
Zambia	-	-	34.370	17.235 (surface)	-
Rwanda	-	4.891	369.112	53.247 (surface)	-
Malawi	-	-	48.704	63.166 (surface)	-
Mozambique	-	-	84.370	-	-

The model illustrates that there is a massive addressable market with a total value estimated at $8,451M across the six countries that is significantly reduced to USD $547M by these recurrent themes:

- Affordability is the first and most significant barrier to PUE appliances' adoption when compared to less costly incumbent technologies. This is further compounded by limited access to flexible, longer-term, and affordable credit to finance PUE assets.
- In all countries, irrigation presents a large market, but limited water access is a key constraint.
- For small-scale operations, a high degree of aggregation is required for the viability of shared PUE appliances, like cold storage and grain milling. Currently, these PUE are designed for and better suited for larger farmers or co-operatives.
- Refrigeration for milk and aquaculture is becoming increasingly viable, but the cooling for horticulture is still out of reach for many rural communities. The units could work in the context of Cooling as a Service, as the smallest units still target larger aggregated produce.
- In the case of EVs as a solution to rural mobility, target users may not have much information on the PUE asset and how it works. Diesel-powered motorcycles and other vehicles are better understood; therefore, more consumer awareness would be required to increase the acceptance of EVs and grow their market size.
- Commercial players in the PUE appliances sector are only beginning to enter the studied markets for some product types. As a result, the availability of spare parts and maintenance services is likely to be limited as well as the landing price of the PUE within those markets may be higher than what has been modelled due to logistical bottlenecks in the initial phases.
- The penetration of PUE appliances requires an ecosystem approach that addresses other barriers such as tax, policies around importation, access to water, quality of roads and other transportation infrastructure, access to markets to sell the increased yields and better data on customers to allow asset finance solutions to evolve as quickly as the technology. This requires collaboration across multiple sectors, private and public organizations.

3.7 Policy and Regulatory Interventions for PUE

Apart from Tanzania, none of the other countries had specific regulations that focused on PUE. It is vital that a quality assurance program for key off-grid technologies is developed. PUE program designers and implementors should focus on the development of testing methodologies and quality standards. Test methods define a standard set of processes to test and measure product performance, quality, and safety. They enable test labs, manufacturers, and others to assess product performance and produce test results that are consistent, comparable, and repeatable. Quality standards define a baseline level of quality, including energy efficiency, to protect and better serve consumers, buyers, and sellers. Stakeholders such as national governments, procurement programs, and others recognise standards' role in keeping sub-standard products out of the market while promoting the market for high-quality products.

3.8 Capacity Building and Awarness Raising

PUE interventions and understanding remain nascent. A capacity-building program that focuses on key stakeholder groups - governments/policymakers, private sector supply chain actors, financial institutions, academia and end consumers - will raise the profile of PUE and help remove barriers where continued dialogue and collaboration among multiple stakeholders are required. Capacity-building efforts should:

- Increase testing capacity in the different member states to support the implementation of the quality assurance program.
- Increase government awareness about PUE and elevate it as both a method to bolster energy access and a potential activator of rural economies, contributing to a country's GDP.
- Train off-grid PUE private sector supply chain actors to successfully deploy PUE products in the rural off-grid sector. Training will introduce appropriate business models to help overcome affordability barriers, irregular incomes, supply chain challenges in the targeted communities, as well as product performance over the lifecycle.

PUE program designers and implementers should support awareness-raising on the benefits of PUE amongst market players, policymakers, and consumers across all relevant countries. Armed with the specific knowledge of the more viable PUE in the region, implementers could carry out public information campaigns using TV, radio, social channels, and outreach events to promote the potential of PUE.

3.9 Finance and Financing for PUE

Regardless of the PUE choice in each country, modelling results indicate that a lack of financing is a significant barrier to adoption. This applies across all technologies and countries to the extent that some PUE is entirely unserviceable. The design of these innovative appliance finance programs targeting PUE technologies should be specific to the needs of each country and categorized to help bring down the initial cost of PUE appliances.

- Private sector Incentives: Financial incentives increase the penetration of appliances by lowering the risk for private sector participation. PUE program designers should work with PUE private sector players within the appliance supply chain to explore financial incentives to stimulate PUE uptake. This can include investigating the potential of bulk procurement mechanisms and policy interventions such as tax and interest reductions for PUE products and investments. Similarly, such incentives should be geared towards local companies where possible.

- Innovative end user financing can lower the initial costs of PUE asset acquisitions. Low and seasonal incomes is a big constraint on affordability. End user financing is difficult to structure, and few programs offer this service to the private sector. PUE program designers and implementers could launch a specific facility to support the development of affordable end user financing models for key PUE such as end user-focused results-based financing (RBF) programs to lower the cost of PUE appliances. Additional considerations can include mechanisms to create and support community-owned assets, thus reducing the cost of assets for an individual.

3.10 Gender

PUE programs can focus on developing the entrepreneurial and technical skills of women. Working with women's cooperatives and sending programme officers to support women during harvesting will build relationships among peers with the aims of scalability and education. PUE Program implementers could investigate opportunities for partnerships with private sector stakeholders and work together to bridge the capacity gap for women.

PUE programs could also collaborate with the private sector to implement payment plans with a grace period to cover cash flow strains common amongst women. Conversations with stakeholders indicated that women tend to farm crops consumed at home while men tend to farm cash crops. Women also do not have assets to acquire loans since most of the collateral assets, like land, are predominantly owned by men. To increase the purchase of PUE appliances amongst women, PUE programs could grant or lend money to private stakeholders to offer these appliances under a grace period.

Existing credit enhancement and micro-finance programs targeting women could be further improved to drive investments, including in PUE technologies, such as solar water pumps, and promote women as energy entrepreneurs. Additionally, women should be better informed about the existence of such opportunities.

3.11 Country Level Deep Dives

This report suggests that PUE activity is applicable in the EAC and SADC regions based on in-depth research in six countries: Rwanda, Tanzania, Malawi, Mozambique, Zambia, and Zimbabwe . However, as determined in the report, each PUE category has specific barriers and opportunities. These must be explored in depth within the context of each country to form firm recommendations on the choice of PUE. The nations of the EAC have much in common but also have huge disparities, for example, in energy access. Unique country-level factors must be considered. Country-specific PUE plans should account for the potential of the EAC and SADC to implement regional programs and policies.

4. Appendice

4.1 Appendix A: Mapping the Presence of Specific Value Chains in EAC

	Kenya	Rwanda	Tanzania	Uganda	Burundi
Agriculture	-	-	-	-	-
Crop Farming	X	X	X	X	X
Grains (Maize sorghum, millet...)	-	X	X	X	X
Root tubers (potatoes, cassava...)	X	-	X	X	-
Horticulture	X	X	X	X	X
Tea	X	X	X	X	X
Coffee	X	-	-	X	-
Sugarcane	-	X	X	-	-
Pyrethrum	-	-	X	-	-
Sisal	-	-	X	X	-
Cotton	-	-	X	X	-
Tobacco	-	-	X	X	-
Nuts	-	-	X	X	X
Bananas	X	-	X	-	-
Livestock	-	X	-	X	-
Poultry	-	X	-	X	X
Meat	-	X	-	X	X
Dairy	X	-	X	-	-
Aquaculture / Fishing	X	X	X	X	X
Manufacturing and Industry	X	-	X	-	-
Small-scale consumer goods	X	X	-	X	-
Agricultural products processing	X	-	-	X	-
Oil Refining	X	-	-	X	-
Cement	-	X	X	X	X

Brewing	-	-	-	-	-
Sugar	X	-	X	-	-
Mining	-	-	-	-	-
Services	-	-	-	-	-
Tourism	-	X	-	X	-

4.2 Appendix B: Key Considerations for various PUE Groupings

1. Motor-driven Agro-processing, e.g., milling, hulling, and threshing (excluding drying): This PUE is ideally at the community level (rather than individual user) with a multitude of users/ customers in a relatively small catchment area. It is energy-intensive, and the energy used is typically proportional to the throughput achieved. Therefore, the following should be considered;

- Presence of sufficient catchment to utilise the service effectively. Population density is a good indicator.
- Use of efficient technologies to reduce investment cost (especially solar system size) and operation cost (specifically cost of energy) by integrating permanent magnet motors.
- If stand-alone solar PV is utilised, consider the following;
  - » Provision of ancillary services, such as hair cutting or selling cold drinks, as a way of leveraging idle energy.
  - » Demand-side management to ensure maximum operation at peak sun hours through aggregation.
  - » The value proposition for solar applications is highest in remote areas where the distance to travel to existing services is a greater challenge.

2. Water Pumping - This can either be community-based or individually owned. Solar water pumps are most appropriate for individual use, while grid and mini-grids power pumps that require substantial amounts of power are more suitable for community use. However, water pumps are highly customisable depending on crop-specific water needs, climate, weather patterns, and water resources.

The available water source is a major determinant of the choice of water pumping technology and capacity; thus, water resource mapping is key.

- Poor water quality (high levels of sediments) is a major cause of pump performance decline.
- Pump add-ons such as water storage and irrigation systems are crucial. They give the end-user more flexibility in when and how they can access water and promote water conservation.

- Quality, durability, and thus warranties vary significantly across technologies and markets.
- For solar water pumps:
    - » Pump efficiency is key to achieving maximum water yield.
    - » Portability may be desired and expected by end-users.
- Be cautious of over-abstraction and attendant lowering of the water table.

3. Cooling, e.g., refrigeration, walk-in cold stores, milk chillers. This can be deployed at various scales, from individual and community to large-scale warehousing solutions.

- Different technologies are appropriate for different use cases; a mapping exercise is vital. For example, phase change material may be the most appropriate for applications that require high autonomy technologies.
- Performance is heavily affected by ambient temperature and relative humidity.
- Skilled and specialised labour is often required for most cooling technologies.
- The choice of refrigerant is crucial and regulated, including by international protocols to eliminate climate-harming refrigerants.
- In community-based solutions, issues of catchment areas are similar to agro-processing issues.
- Cooling technologies should rarely be viewed in isolation, as most value chains require a cold chain to be established
- If stand-alone solar PV is utilised, consider energy storage can be prohibitively expensive. Innovations like solar direct-drive (SDD) technology, which eliminates the need for batteries, should be considered.

4.4 Appendix C: Exsisting Supply Chain

FIGURE 11: PRODUCER SUPPLY CHAIN ROLES OVERLAID WITH OEM SUPPLY CHAIN ROL (ORANGE)

FIGURE 12: VERTICALLY INTEGRATED DESCOS. SUPPLY CHAIN ROLES

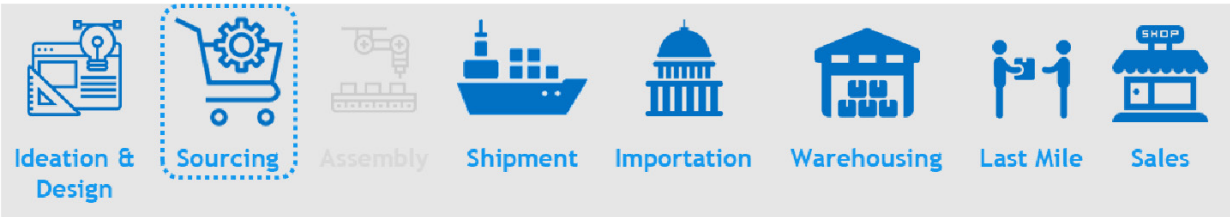
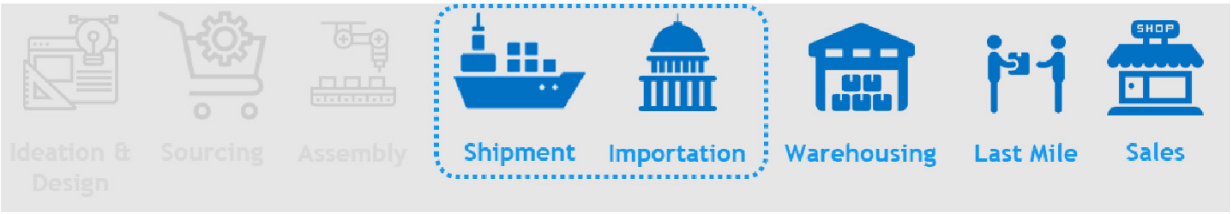


FIGURE 13: DISTRIBUTOR'S SUPPLY CHAIN ROLES



4.6 Appendix E: Miscellaneous

Case Study One

Company A

Location: Tanzania and Uganda

Business Description and products:

The company's key technologies are solar water pumps (SWPs) and solar fishing lights. Within their business, they source individual components and assemble products. They also design customized systems, distribute, service and maintain products in the field. They have their own PayGo technology.

Manufacturing, shipment, and importation:

the company sources components for SWPs from China, India, and the US. The sourcing country selection is dependent on the kind of components/ systems being sourced and the quality. Some of the components shipped include pump controllers, solar panels, and control panels. The company works directly with manufacturers of the components and not traders. Compared to Solar Home Systems (SHS) it is more complicated to ship SWP parts/components as the former are usually already assembled before importation. They typically do not import accessories such as drip irrigation kits, such accessories are not only expensive but also require additional installation skills.

Shipment and customs:

The cost of shipment from the three regions is quite similar. The customs and clearance processes are one of the biggest challenges. The company carries out Pre-Verification of Conformity (PVoC) before shipment and reported to not have any issues with the associated standards bodies. They have however had immense delays (as long as two months) when shipping in various SWP components such as connectors. A possible cause of this delay is lack of awareness across the customs officers on PU technologies and therefore the inability to identify related components that are required in a SWP. A proposed solution was training customs officials on PU technologies to ease the identification process and clearance. SWPs are not tax exempt in either of the countries of operation.

Distribution and sales:

The company's SWP solutions are customized to fit the different use cases. They do not have specific product lines, but rather import components which allow them to design systems on a need-by-need basis.

Maintenance and End of life

Sediments is the biggest cause of failure in the company's SWPs. A possible cause is that the wells are not lined and therefore collapse introducing soil into the water source. Sediments cause the motor to fail. The motors are not reparable and are usually replaced to resume operation to the end user. The company uses water filled motors in their SWPs as oil filled ones can leak into the water source and cause pollution. They only ship motors back to manufacturers when they are recalled. Otherwise, they store the faulty pumps.

Case Study Two,

Company B

Location: Rwanda

Business description and products:

The company deals with Solar Home Systems (SHS) and Solar Irrigation Systems (SIS). SHS had been their mainstay since their establishment and added SIS to their product offerings in 2019.Their focus on SIS is informed by the role played by agriculture across the Rwandan economy; 70% of the population are farmers. Their SIS is a solar surface pump. They are cheaper/ more affordable for the farmers. The company also offers battery backup options to farmers.

Manufacturing, shipment, and importation:

The company imports motors from Ennos in India. They purchase solar panels from Kenya. They design their own trolleys and purchase flexible pipes within Rwanda. The pipes and batteries are imported from China. The Government of Rwanda (GoR) exempts pumps from taxation through the Ministry of Agriculture since 2018. Additionally, from 2020, importers no longer pay import duty.

Importation is seamless. The only cause of delay during importation would be the physical verification process. The GoR has put out a list of tax-exempt products and assigned codes to each. This simplifies the importation process substantially for the company. They only pay import duty on accessories. The accessories are used as spare parts.

The Rwandan government is interested in mechanizing agriculture and has as a result implemented multiple supporting policies.

Tax exemption allows the company to sell the pumps at the lowest price possible

Distribution and sales:

The company distributes its solar water pumps through public projects implemented by the Rwanda Agricultural Board in collaboration with the World Bank. This program subsidizes the price of the SIS by nearly 75% alongside a support package (maintenance and business plan development) for farmers to access small-scale irrigation equipment. Whereas this program initially focused on farmers with all land sizes, it now focuses on those with more than 5hectares as they seem to have realized the full benefits in terms of increasing productivity.

As Rwanda is a small country size geographically, distribution is not challenging.

Maintenance and servicing:

The company provides training on maintenance and as well as awareness raising. Whereas they have seen a substantial shift in acceptance in the past two years, the biggest challenge continues to be low awareness and affordability across consumers. The pumps are generally maintenance free with very few electronics.

Waste:

As customers shift from using diesel pumps to solar powered pumps, the company has found that some farmers still retain the diesel pumps for use on cloudy days. In other cases, farmers sell their diesel pumps to other farmers. The company has an agreement with Enviroserve Rwanda to manage irreparable pumps.

4.7 Appendix F: Scoring Criteria and Technology

The criteria for prioritising PUE interventions are listed below,

A. Technological maturity: assessed against these indicators:

1. Availability of the technology at scale,
2. Affordability of technology,
2. Presence and ease of repair and maintenance.

B. Income Potential for users: assessed against these indicators:

1. Presence of suitable business models,
2. Local capacity (skills to successfully exploit the PUE asset),
3. Sufficient catchment areas,
4. Off-takers for generated outputs.

C. Private sector stimulation: the presence of an active private sector that could capitalise on the opportunity.

D. Energy Efficiency gains: the potential for increased efficiency of the appliance/ machinery or replacement of inefficient machinery.

E. GHG emission reduction: the potential to displace diesel-powered machinery.

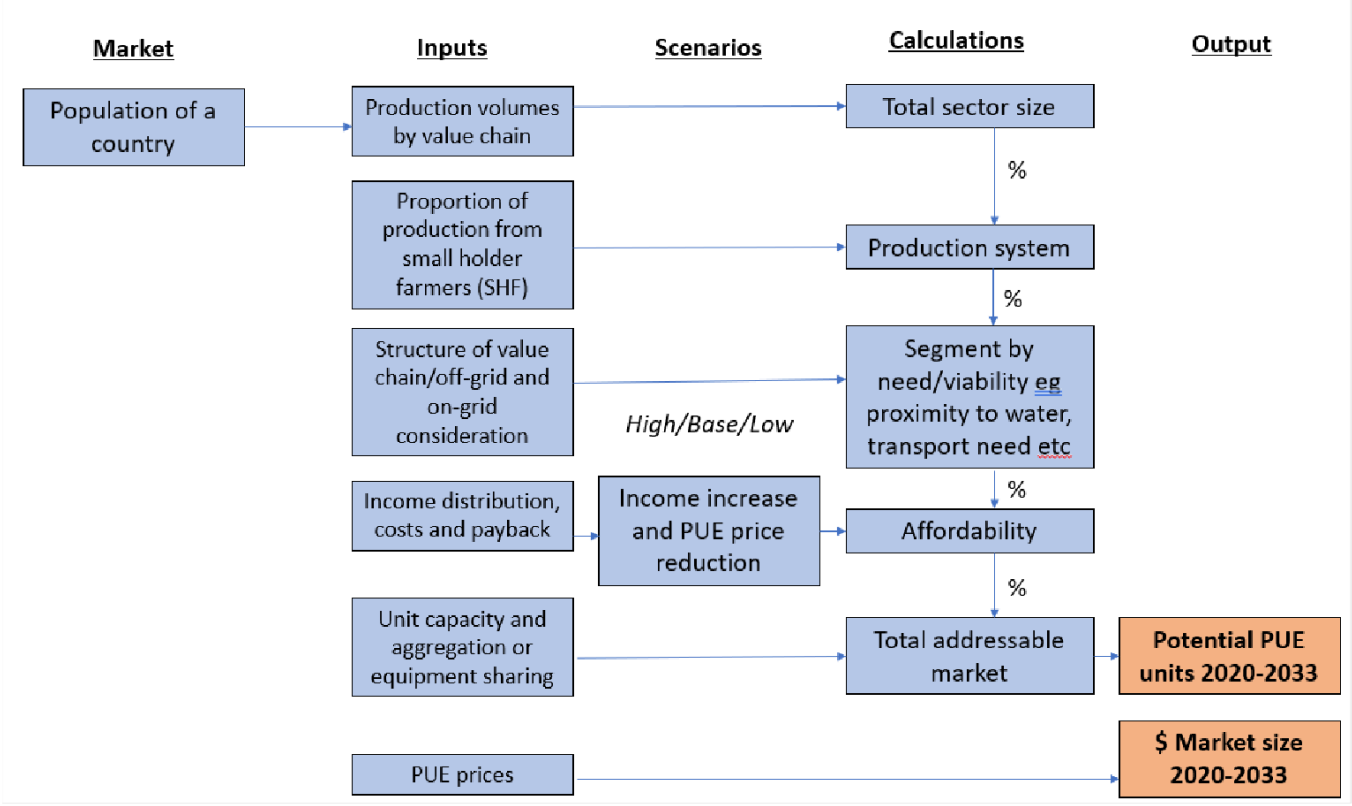
F. Inclusivity: the potential to improve gender dynamics for equity and empowerment, especially of women and girls.

G. Scalability: the potential to scale and replicate across multiple geographies/ value chains.

The scoring methodology: Each potential PUE was evaluated against the above criteria in a quantified red, amber, and green scoring. See Table 8. The sources used to make scoring judgements include available data, literature review and stakeholder survey findings. All criteria are weighted equally, and justification is given in the references.

CRITERIA	2	1	0
Tech Maturity	Has all maturity indicators	Has at least two maturity indicators	Has less than two of the maturity indicators
Income potential	Has all the income potential indicators	Has a least two of the income potential indicators	Has less than two of the income potential indicators
Private Sector stimulation	Numerous and varied actors	Few private sector actors	No real private sector actors, government or donor-driven economies
Efficiency gains	Likely and potentially significant	Likely Some	None / Unlikely
Emissions reduction	Likely and potentially significant	Likely Some	None / Unlikely
Inclusivity	Yes-specifical for women and girls	-	No
Scalability	Very Likely	Likely	Unlikely - too niche

4.8 Appendix G: PUE Market Sizing Logic



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