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Smart Energy Solutions for Africa

D 5.2. BARRIER ANALYSIS

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Summary Sheet

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Abstract	The barrier analysis document summarizes the main barriers at the policy level that hinder the uptake of each of the nine technologies identified in demonstration and validation countries.

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List of abbreviations

Acronym	*Description*
CC	Cubic Centimeters
DC	Direct current
EPRA	Energy Petroleum and Regulatory Authority
EV	Electric Vehicles
GHG	Greenhouse Gas
IRR	Internal Rate of Return
MoTIHUDaPW	Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works
MoE	Ministry of Energy
NEECS	Kenya National Energy Efficiency and Conservation Strategy
NGO	Non-Governmental Organization
PESTELA	Political Economic Social Technical Environmental Legal and Awareness
PUE	Productive Use of Energy
SESA	Sustainable Energy Solutions for Africa; European Union's Horizon 2020 research and innovation programme under grant agreement No. 101037141.
SHS	Solar Home System
VAT	Value Added Tax
WP	Work Package. A major sub-division of the (Horizon 2020) project includes several vital tasks and may have specific Milestones and/or Deliverables as output results.

Executive Summary

The barrier analysis covered in this report falls within Work Package 5- Task 5.2- Policy development, institutionalisation and integration in local and national plans. Technologies for implementation have been identified by partners in demonstration and validation countries. The technology matrix for demonstration and validation sites can be referred to in Table 1.1 (Chapter 1). This report covers barriers and policy gaps identified through a literature survey and stakeholder consultations for nine technologies in demonstration and validation countries (referred to as case studies); Productive Use of Solar Energy (PUE), and Electric Mobility (E-mobility) in Kenya, Clean Cooking in Malawi, Second-Life Use of EV Batteries in South Africa, PVs for Household use, and E-mobility in Morocco, Second-life Battery Use as Energy Storage for Solar Photo-voltaic Systems, and Bio-ethanol Technology for Cooking in Ghana, and Solar Irrigation in Rwanda. Task 5.2 has linkages with other work packages of the project, as well as with other tasks within the same work package (WP 5). Though there are overlaps, inputs from packages WP1 to WP4 on the barriers and needs for policies in their domains (where they dive deep), can strengthen the findings in this area. Policies identified in this work package provide inputs for policy dialogue (WP6).

The methodological framework used for the identification of barriers to the selected technologies is depicted in Figure 2.1 **(Chapter 2).** Barriers were identified from the literature as well through key stakeholders' consultation, which included policymakers, technology providers, financiers, users, experts and others in the technology value chain. The barriers framework included the following barriers categories; political and institutional, economic and financial, social and cultural, technology and infrastructure, environmental, legal and regulatory, and awareness and information (referred to as PESTELA). Stakeholder consultations/surveys were carried out to identify barriers to the technology, and responses were analysed for the two case studies.

The barriers framework was further broken into three levels, with level 3 describing relatively small elements of a barrier. The questionnaires for stakeholders were prepared at level 3 as it brings clarity to the barrier.

Stakeholders were identified in six categories: (1) policymakers (relevant government authorities), (2) end users of the technology, (3) suppliers of the technology, (4) experts from academia and other institutions, (5) NGOs, and (6) funding agencies. Questionnaires were prepared and interviews were organised in the countries by country teams. The responses were analysed qualitatively and results for the case studies have been summarised in the next section. Potential enabling measures to address various barriers were also identified (and included in the methodology) that may need to be used during the development of policy roadmaps.

Case Study 1: Barrier Analysis for Productive Uses of Energy (PUE) in Kenya

Kenya has an estimated solar power potential of 15,000 MW and grid-connected solar power had reached 172MW by 2021. Productive uses of solar energy are one promising area of off-grid application and 40 types of PUE technologies had been identified in Kenya for use in various applications. Solar home systems and solar TV are the most used off-grid applications followed by solar water pumps and refrigeration units. Solar pumps are important since 40% of Kenyans lack access to drinking water as well as water for irrigation. Off-grid solar cooling is used for vaccine storage and has the potential for use in dairy production, agricultural post-harvest, small commerce, and restaurant. Solar-charged E-mobility is another area of interest in Kenya.

Stakeholders' consultation and barrier analysis: The barriers to PUE development in Kenya are systematically analyzed using the PESTELA framework. The barrier analysis was conducted based on a literature review and eight structured interviews with different types of stakeholders (government

officers, service providers, NGOs, funding agencies, and researchers). The following barriers were identified.

Policy and institutional barriers: Though the government has initiated concrete activities in the PUE area, an overall strategy for promoting PUE in Kenya is lacking, including clear targets and timelines. The need for more technical capacity and skills to formulate adequate renewable energy legislation, facilitate related financing and licensing, and monitor and evaluate was also identified. The institutional capacity gap at the local level was particularly impeding the adoption of national renewable-related regulations and policies. Ministries mostly work in silos in PUE- coordination across them is lacking. Collaboration between the private sector and the government is only project-driven and therefore needs to be strengthened. Some efforts Kenya Renewable Energy Association (KEREA) have been made on this front by forming a working group with government and private sector agencies.

Economic and Financial barriers: High upfront costs of solar equipment and its installation were considered a key barrier to scaling up PUE by all respondents. They suggested a reduction in import duty and value-added tax (VAT). Recently, solar panels have been exempted from both import duty and VAT, but it does not apply to solar water pumps and DC appliances. Also, tax exemptions are uncertain; can be abolished at any time making it difficult for stakeholders to plan their usage. End-user financing by banks is very limited due to their risk aversion and lending criteria disfavoring users. PUE companies, therefore, must provide in-house consumer financing, which is challenging for SMEs, particularly for expensive systems.

Social and Cultural barriers: High upfront costs of solar equipment and its installation were considered a major barrier by all respondents, particularly for low-income households with elastic demand of PUE. Affordability is therefore an issue.

Technical and Infrastructure barriers: The supply chain of the solar-powered appliance for PUE is fairly well developed in Kenya but there has been an increase in substandard and counterfeit solar products in the market according to some respondents. Quality, therefore, was also an issue. Though there is skilled labour available for installation and maintenance, after-sales service needed to be improved, primarily because suppliers are not based locally.

Environmental barriers: Most respondents perceive the disposal of solar panels, solar-power appliances, and end-of-life batteries as an environmental threat. Other environmental risks result from the insulation and refrigerants used in refrigeration units and the over-exploitation of groundwater using solar water pumps.

Legal and regulatory barriers: The government drafted solar PV regulation in 2019, which is undergoing a parliamentary approval process. However, there are no national performance standards for PUE and DC appliances, which need to be established. National regulation on e-waste management, including solar panels and solar-powered appliances, is yet to be finalized and adopted.

Awareness and information barriers: Most respondents pointed out low consumer awareness of PUE, in terms of various applications of solar energy.

Case Study 2: Barrier Analysis for Electric Mobility in Kenya

The Kenya National Climate Change Action Plan has prioritized electric mobility as one of the key measures to mitigate climate change. The Action Plan includes raising awareness, developing technology for electric mobility, piloting and using electric modes of transport, and building charging infrastructure. Kenya has substantial power generation capacity with a reserve margin of over 30 per cent, which can meet electricity demand for E-mobility in the near future. Kenya has set the target of increasing the share of electric vehicles to reach 5% of cars registered every year by 2025 and has outlined some regulatory and financial measures to achieve the targets. Kenya is also at the forefront of the E-mobility space in Africa with the launch of electric vehicles including buses by Opibus and BasiGo, motorbikes and electric boda-boda (e-bike taxis).

Stakeholders' consultation and barrier analysis: The barriers to E-mobility in Kenya are systematically analyzed using the PESTELA framework. The barrier analysis was conducted based on the literature review and ten structured interviews with different types of stakeholders that included policymakers, solution providers, academia and other experts, NGOs and funding agencies. The following barriers were identified.

Political and institutional barriers: Political commitment to E-mobility should be reflected in targets, timelines, resource allocation, and allocation of responsibilities to achieve the targets. There is a target set by the Kenya government to increase the uptake of EVs in the country to 5% EVs by 2025. Also, there is a government strategy that all new public buildings are required to have charging stations. The government strategy to raise funds, a crucial requirement for scaling up E-mobility, is however primarily private-sector driven. Further, there is a lack of institutional capacity in terms of engagement with the private sector and end users. The coordination among various agencies is also inadequate according to policymakers and NGOs, which is currently driven by international partners.

Economic and Financial barriers: Economic barriers include the high price of E-mobility, making it uncompetitive with the existing solution, high payback period for end users or low internal rate of return (IRR) for solution providers. The high cost of EVs, particularly the high upfront cost was considered a major barrier by several stakeholders, including policymakers, experts and solution providers. The need for incentives to reduce costs was indicated by respondents. There has been some reduction in taxes such as excise duties but there is no consistency in policies as it changes with change in government. Access to finance for E-mobility also came out as a major barrier, as banks and financial institutions were not willing to lend due to their risk perception about technology. All this makes E-mobility difficult to compete with current technology (petrol and diesel vehicles).

Social and cultural barriers: Social barriers refer to social biases affecting acceptance of the technological solution. Affordability for a large part of society can also be a barrier in many cases. According to respondents, the affordability of EVs is an issue due to widespread poverty in Kenya and ordinary citizens cannot afford EVs.

Technology and infrastructure barriers: Technical barriers include a lack of access to technology, a lack of skills required to operate and maintain the technology, and technology not suitable due to geographical, environmental or other reasons. According to respondents, though the technology is not very complex, some capacity building will be needed. Spare parts are not that readily available and that can be an issue. A lack of charging infrastructure was categorised as a major barrier by most stakeholders. The need for improved grid reliability was also pointed out so that the right voltage and frequency are available for charging. E-mobility is also seen as a solution to support rural areas meet their mobility requirements. However, a lack of charging infrastructure, and a lack of connectivity to the grid (by households) are major challenges.

Environmental barriers: Disposal and handling of batteries is a concern for service providers. Scaling up E-mobility will generate significant waste and therefore handling hazardous waste is seen as a barrier if proper plans are not made in parallel.

Legal and regulatory barriers: These include existing policies and laws, which may be unfriendly for E-mobility. The regulatory framework needs strengthening and enforcement according to a respondent. Building codes facilitating charging and lower EVs tax are other measures needed to promote E-mobility. An enabling environment needs to be created for the adoption of the technology through reduced taxes on importation, reduced excise duty, and attractive tariffs for charging vehicles.

Awareness and information barriers: A lack of awareness about E-mobility and its benefits and governmental incentives was observed by some respondents. Therefore, there is a need for measures to raise awareness about electric mobility and to educate the public about the benefits of electric vehicles. According to some respondents, demonstration pilots may also be needed to create awareness. Social media and radio/TV adverts can also be used to enhance awareness about E-mobility among the general public.

Case Study 3: Barrier Analysis for Clean Cooking in Malawi

Malawi is one of the poorest countries in Africa with more than 80% population living in rural areas where only about 4% are connected to the electricity grid. Over 50% of the population lives in poverty, and about 95% of households use the three-stone fire cooking stove, which is harmful to human health, forests, and the climate. Improved cook stoves have been developed to address these issues, but they face several obstacles in reaching rural communities due to limited resources and low electrification rates. These barriers must be addressed to promote sustainable cooking practices and reduce the negative impact on the environment and public health. Following the PESTELA Framework, the following barriers have been identified:

Political and institutional barriers: Despite strong efforts, limited resources and capacity constraints represent the main political and institutional challenges for the Malawian government to transition towards universal clean cooking in the country. More predominantly, limited cross-level coordination can exacerbate already constrained governmental efforts. While there is institutional recognition and support for clean cooking efforts amongst the energy and natural resources sectors, clean cooking efforts in Malawi could be further enhanced by integrating clean cooking into other departments and their policies especially those concerned with gender and private commerce to improve coordination and resource sharing.

Economic and Financial barriers: The Malawian national budget is severely constrained thus limiting the extent to which national plans and upscale schemes can be implemented, which is one of the main economic and financial barriers to the wide deployment of the technology in the county. In many African countries accessing finance can be challenging, particularly for small-scale producers and artisans, who are often considered informal, lacking accounting records, and without sufficient collateral. Access to finance to meet upfront costs affects both producers and artisans alike who are widely unable to access finance for capital outlay. In addition, obtaining buy-in with poor users for ICS and sustainable fuels is a challenge, as this involves high costs related to buying and maintaining ICS, which may be unaffordable, compared with three stone fire stoves using wood, which can be collected for free. Additionally, import duties on the requisite materials for clean cooking technology are still a significant barrier. Moreover, end-user finance for cookstoves is not widely available in sub-Saharan Africa, mostly because loan sizes for cookstoves are too low for banks and microfinance institutions, but too high for cash purchases. Government support to access loan finance for ICS in Malawi is extremely limited. Lastly, another barrier is the cost of producing sustainable fuels in the form of briquettes and/or pellets. The production, transport and retail costs associated with supplying sustainably harvested biomass products mean the companies would incur costs that simply do not exist with free illegally collected biomass, which makes it extremely challenging to compete.

Social and cultural barriers: Access and affordability are major social obstacles to the uptake of ICS across Malawi. Related to this is the matter of access to affordable sustainably harvested fuels. In the case of cultural barriers, social norms play an important role. In rural Malawi, most of the cooking is done by women, whereas men tend to oversee household finances. Thus, there is a limited influence of those who cook to make financial decisions about cooking technology. When clean cooking is introduced, a full transition to ICS tends to happen slowly with households continuing to use traditional methods alongside the new ICS to maximize cooking outputs. This is known as 'fuel stacking' and may occur due to uncertainty about the new technology, long-standing behavioural preference, and/ or cultural obstacles.

Technology and infrastructure barriers: The main technology and infrastructure barriers relate to safety and quality related to the performance of the new technology and there isn't a lab for testing cookstoves efficiency in Malawi. Moreover, a lack of maintenance facilities for ICS can be a major barrier to the long-term sustainability of cleaner cooking, especially in rural areas, where hesitation and lack of know-how require training.

Legal and regulatory barriers: There are several legal and regulatory points to consider in Malawi. Policy measures for increasing cooking efficiency are important but not sufficient to overcome the growing demands that will accompany the increasing population of Malawi. Thus, policy measures for supply-side measures are necessary to increase sustainable supply through, for example, agroforestry for biomass energy. In addition, the alignment between national and local policies around clean cooking practices remains ad-hoc and not structured, which poses a barrier. Lastly, the biomass fuel market is dominated by illegal charcoal with limited regulation. Illegal and over-harvesting of fuel wood and charcoal created the need to transition away from heavy reliance on biomass and towards sustainable and efficient technologies.

Awareness and Information barriers: The technology is new to most citizens, particularly in rural areas. Awareness around outlay, maintenance costs of the cookstove, quality assurance standards, distributor location, and distributor criteria are significant barriers. On the user end, guidance on how to use the cookstove, common issues and ways to fix the stoves, safety, and fire responses, and opportunities to access credit/loans remain prominent barriers.

Case Study 4: Barrier Analysis for Second-Life Use of EV Batteries in South Africa

Batteries are a key component in the mobility landscape as the transition slowly leads to electric mobility. Managing batteries when they reach the end of their life is a challenge that most countries including South Africa face. EV batteries can still be used for electricity storage purposes as they retain significant capacity after they reach the end of life for EV use. Battery storage, at the utility or even smaller scales, is one of the key technologies that can enable the uptake of renewable energy in the short term and provide this flexibility. This is due to the fact that it is relatively easier to scale up and deploy compared to other storage technologies. Second-life batteries have a significant cost advantage over new batteries and can reduce overall costs for stationary storage to be used in combination with decentralized electricity generation technologies, such as solar photovoltaics. There are several other potential uses of second-life batteries that include industrial-scale operations, to provide ancillary grid services, in smaller vehicles, such as two- or three-wheelers, as well as for solar-powered devices and backup power home systems. However, there are several barriers to the use of second-life batteries; the barriers framework in Chapter 2 was used and stakeholders from research/ academia (2), an NGO, technology companies (2) and a funding agency were interviewed. The findings indicate the following barriers.

Political and institutional barriers: Political push for EVs is limited in South Africa as low carbon fuel (biofuels) are also a part of their sustainable mobility agenda. Therefore second-life batteries are also not the government's priority. Once EVs pick up, the enabling environment can be expected for second-life batteries as well.

Economic and Financial barriers: Low penetration of EVs means the battery recycling chain does not exist. Second-life batteries though cheaper may also face competition from new batteries due to their falling prices.

Social barriers: There are barriers related to health hazards from e-waste from batteries, affecting its acceptability.

Technology and infrastructure barriers: There is little standardization leading to complications in dismantling and multiplicity of softwares to check battery health and other parameters. There is also a lack of skilled manpower to handle battery waste.

Environmental barriers: These include the risk associated with batteries and their recycling as well as repair for second life uses, and ultimate disposal, from the leaching of toxic materials into the environment.

Legal and regulatory barriers: E-waste is not a top priority sector for the government at present and there is a need for regulation related to safety and risk from second-life batteries.

Awareness and capacity barriers: There is a general lack of awareness of good practices and standards. The notion of second life uses for batteries is relatively new in general, and even less well-known among consumers.

Case Study 5: Barrier Analysis for PVs for Household use in Morocco

Morocco is among the leading countries that plan to transition to renewable energy with an NDC target to reduce GHG emissions by 45.5% by 2030. Decentralised PVs are now gaining importance with the promotion of the self-production of solar power. Morocco has several large-scale solar power projects and an initiative to promote small-scale solar projects was taken in 2016 with access to low voltage grid and provision for the sale of surplus power. In 2002 a new law was brought to promote the self-production of power. The potential has remained unrealized. Six stakeholders; three experts, one NGO, and two solution providers were interviewed to identify the barriers to PVs for household use in Morocco. to producer and this has not been through solar PVs. Following barriers were identified by them:

Political and institutional barriers: Government support has been mainly for mid-scale or large-scale PV installations, and this changed only recently changed. However, political barriers and day-to-day problems persist. The electricity prices continue to be regulated due to shortages of energy supply, making it difficult for PV power to compete. Also, energy operators have no incentive to support decentralized solutions as self-produced energy may be seen as competitive to their offer.

Economic and Financial barriers: The high upfront investment, regulated power tariffs, and need for roof-top space and energy storage facility were considered barriers to widespread adoption. The problem of selling surplus power was also pointed out as an issue. Unfavourable tax is another barrier; the power offered via the grid is taxed at 14% (VAT) while self-produced power is taxed at 20%.

Technology and infrastructure barriers: Feeding excess electricity into the power grid, even if permitted, is considered technologically challenging for the stability of the grid. Technology is not an issue, but maintenance skills may get tested over a period of time.

Environmental barriers: Recycling PVs is currently not an issue but may become one as technology use is widespread. This indicates the need for proper recycling of PV-linked materials.

Legal and regulatory barriers: Legal and regulatory measures are currently well developed except for self-production of power, which has been misinterpreted in practice in the past and the central issue of selling the power back to the grid (by self-power producers) is not fully resolved. Only 20% of the power produced can be sold.

Awareness and information barriers: The only area of concern was a lack of awareness of the maintenance requirements of PVs, which could lead to various safety and technological hazards.

Case Study 6: Barrier Analysis for E-mobility in Morocco

In Morocco, the transport sector consumes 38 percent of energy and represents the country's second-largest CO2-emitting sector. The government has adopted a National Strategy for Sustainable Development, incorporating sustainable mobility. Morocco is now accelerating its energy transition and electrical mobility is considered an important sector for energy transition. However, the Moroccan government is not active in promoting E-mobility solutions to end users. The government aims to double electric car production by 2024 but production is mostly devoted to export to the European market.

Three stakeholders; one solution provider, one expert from academia, and one NGO were interviewed to get their perspective on barriers to E-mobility in Morocco. The findings have been summarised below.

Political and institutional barriers: All the interviewees stated that the Moroccan government is not actively promoting E-mobility across the country. However, a charging station network has been developed near some cities on account of private sector interest, which is also indicative of the governmental intention to shift to electric mobility slowly.

Economic and financial barriers: There is no incentive for electric vehicles except partial exemption in the annual basic tax of the electric car. As a result, the high price of electric cars is a barrier for most of the Moroccan car users. Price has been coming down, but the lack of charging facilities is a major barrier currently. Small-scale e-vehicles, such as scooters, are priced competitively and used widely.
Technical and infrastructure barriers: The main infrastructural barrier to the development of e-mobility in Morocco is the lack of charging infrastructure in the country. Further, the remoteness of some areas of the country, especially in the south, will make it difficult to provide a strong network of charging stations and facilities for electric mobility in those areas. At the household level, the lack of space and availability of adequate electricity, as well as connection to the grid (in the case of rural households), represents a major obstacle to the purchase of electric mobility solutions. For the production of cars, the scarcity of material to produce batteries, and the lack of end-of-life solutions for them were listed as barriers. The remoteness of some areas of the country, especially in the south, will make it difficult to provide a strong network of charging stations and facilities for electric mobility in those areas.
Environmental barriers: Currently, electricity produced in Morocco is very polluted but the shift to renewable means this will not be a barrier to shifting to E-mobility.
Legal and regulatory barriers: Interviewees pointed out that there are no regulatory barriers but policymakers in the country are debating about regulating the use of Mobility as a Service (MaaS) solutions for micro-mobility on the model of some European cities, which might affect the use of electric scooters.

Case Study 7: Barrier Analysis for Second-life Battery Use as Energy Storage for Solar Photo-voltaic Systems in Ghana

Second-life batteries are estimated to cost 60 to 75% of the price of new batteries. Their potential uses include energy storage for microgrid installations, storing energy for charging EVs, for use in low-powered electric vehicles such as forklifts, and supporting off-grid as well as grid-connected renewable energy systems. Renewable systems are noted for power fluctuations due to time variability and the intermittent nature of renewable sources. Second-life batteries could be used in these instances to store the energy and later supplied to the grid, when needed. In the case of off-grid applications, the stored energy could be directly connected to the applications.
Second-life batteries have however several barriers in their application which include difficulty in determining, safety concerns, and other technical issues. For their application as energy storage for PV systems, barriers to scaling up renewable energy in Ghana add up to the list of barriers.

Six interviews were conducted for this study to explore barriers from key stakeholders' perspectives. These included three policymakers (governmental agencies) and three solution providers. The summary of their perspective on barriers to second-life battery use as energy storage for solar photovoltaic systems in Ghana is given below.

Policy and institutional barriers: Some work on standards for electric vehicles and batteries has been initiated but currently there are no plans and regulations regarding the use of second-life batteries in Ghana. Also, there are no initiatives for local manufacturing in the near future, leading to full dependence on imports even after plans and policies are formulated. Besides a lack of policy to promote second-life batteries, barriers to renewable energy adoption also impact the adoption of second-life batteries as storage for PV systems.

Economic and Financial barriers: Though solar PV technology is now considered viable, high up-front cost, a lack of access and high cost of finance are barriers to its adoption in Ghana. It requires financial incentives to address these barriers and achieve the renewable energy target. The use of second-life batteries, which could reduce costs, is however faced with several barriers inhibiting the growth of the sector.

Social barriers: Competing demand for water for other activities such as agriculture and tourism and resulting forced migration, condition of workers in Lithium mines and safety concerns have been brought out as social issues in some studies.

Technological barriers: Despite experience with PV systems, skilled labour and access to solar technologies remain challenges for many companies in Ghana. In the case of second-life batteries, there is a lack of technical staff to test second-life batteries, and there is also uncertainty around cost reduction in the use of second-life batteries.

Environmental barriers:

According to a study, the second- life processing of batteries delays the recycling process for end-of-life batteries as in some cases, these batteries could be reused for between 6 to 10 years in second-life applications. In such instances, the materials needed for producing new batteries need to be mined, which can have environmental consequences.

Legal barriers: Importing used batteries and refurbishing them for second life may not be allowed and face legal barriers in Ghana according to a policy maker. Also, standards for testing second-life batteries have not been framed yet and there is no laboratory to test or capacity for this in the country.

Awareness and capacity building barriers: A lack of education and awareness of the existing legal regulations on e-waste handling is a major hindrance to the adoption of this technology. As a result of this, solution providers are under the impression that there is a ban on the importation of second-life EV batteries for use but according to the EPA, there are specific protocols to be followed that would allow for the importation of same. Banks also do not offer to finance this product due to a lack of awareness.

Case Study 8: Barrier Analysis for Bio-ethanol Technology for Cooking in Ghana

According to estimates, a mere 72% of the world's population will have access to clean cooking fuels and technologies by the year 2030. The situation in Ghana exhibits no significant difference from the global phenomenon. In the last ten years, there has been an increase in the population predominantly dependent on clean fuels for cooking. Indeed, it rose from 18% in 2010 to approximately 37% in 2021. The present trajectory of expansion points to a trajectory that indicates that the percentage of individuals with access to clean cooking technologies will reach approximately 49% by 2030, which falls short of the SDG 7 objective of 100%. According to the 2021 population and housing census, an estimated 4.5 million households used fuels and technologies for cooking that emit pollutants. This implies that roughly 18.4 million individuals were subjected to the harmful effects of these polluting fuels. Consequently, more than 50% of the populace in Ghana is susceptible to contracting illnesses resulting from indoor air pollution emanating from unhygienic cooking methods and fuel sources. Scaling clean cooking in Ghana via bioethanol currently faces several barriers that must be overcome. These barriers must be addressed to promote sustainable cooking practices and reduce the negative impact on the environment and public health. Following the PESTELA Framework, the following barriers have been identified:

Political and institutional barriers: Ghana has a Renewable Energy Master Plan to provide a framework for the promotion and development of renewable energy resources. However, the extent of these efforts has been insufficient in scope. The fact that it lacks specific targets and timelines for the implementation of bio-ethanol technology is a significant political and institutional barrier. Moreover, the current state of institutional capacity in both the public and private sectors regarding the integration of bio-ethanol technology into mainstream usage is still in the developmental stage, offering another prominent barrier. Lastly, while multiple stakeholders including government agencies, academia, donor agencies, NGOs and SMEs are engaged in the advocacy of bio-ethanol technology, their level of coordination is deemed insufficient, which is a significant institutional and structural barrier.

Economic and Financial barriers: The adoption of technology by households and small businesses is impeded by the high cost of the technology, limited financing options, and a dearth of financial incentives from the government. Moreover, the cost of bio-ethanol technology may increase due to the imposition of import duty and domestic taxes, including VAT, posing a significant economic and financial barrier in the country. On the consumer/user end, access to affordable finance is limited for numerous households and small businesses in Ghana, which poses a challenge in financing the initial costs of acquiring the technology. Lastly, a prominent barrier to be removed is the high initial costs and limited financing options for users and developers alike.

Social and cultural barriers: The perceived inconvenience associated with the use of bioethanol in comparison to conventional fuels is a key social and cultural barrier to be overcome. The perceived inconvenience was attributed to various factors, including the requirement for specialized stoves, fuel accessibility, and potential obstacles in fuel storage and transportation. Moreover, certain behavioural habits and cultural preferences may impede the adoption of bio-ethanol technology. Specifically, individuals' adherence to customary cooking techniques and culinary habits are potential obstacles. Lastly, gender norms and dynamics may be barriers to being understood and addressed, as including women in decision-making processes can catalyze the effective implementation of a given initiative. Currently, women are in charge of cooking but are often impeded to partake in decision-making regarding buying appliances.

Technology and infrastructure barriers: Currently a lack of professionals and technicians possessing specialized knowledge and expertise in bio-ethanol production, processing, and associated domains is presently a key barrier to consider. Moreover, the acquisition of bio-ethanol technology in the Ghanaian market is challenging, and the development of bio-ethanol production facilities requires infrastructure for the cultivation, transportation, and processing of feedstock, these are not fully in place, posing a challenge for the country. Another key point to consider is that the inadequate provision of infrastructure, including storage facilities and transportation networks, may impede the uptake and proliferation of bio-ethanol technology. Maintenance and QA are prominent challenges associated with the implementation of the technology in the country (i.e., include issues related to laboratory facilities, testing procedures, and compliance with global standards). There is an insufficient allocation of resources for research and development on bio-ethanol technology, which poses a constraint on the progress of technological advancements, innovation, and cost-effectiveness.

Environmental barriers: The inadequate management of bio-ethanol production poses several environmental hazards, which is an environmental barrier to be considered. Moreover, the production of bioethanol may result in amplified demands on land usage and water resources, thereby causing unfavourable effects on biodiversity and ecosystem services. The generation of bioethanol has the potential to have an impact on air quality, particularly during the stages of fermentation and distillation, which is another environmental barrier to be addressed. Lastly, the utilization of biomass feedstock in the production of bioethanol emits greenhouse gases, including methane and carbon dioxide, which are harmful to the planet and the climate and is also a barrier that must be addressed.

Legal and regulatory barriers: The establishment of supportive legislation is lacking in Ghana and represents a key legal and regulatory barrier to be overcome. The creation of enabling legislation that offers financial incentives, e.g., tax exemptions, grants, or subsidies, can effectively encourage the establishment of bio-ethanol production facilities, and this at present is not found in the country.

Awareness and Information barriers: The current level of awareness regarding bio-ethanol technology in Ghana is inadequate. A significant number of participants recognized the insufficient awareness and comprehension among the populace regarding the advantages, accessibility, and application of bioethanol as a cooking fuel, posing an information and awareness barrier to be mitigated.

Case Study 9: Barrier Analysis for Solar Irrigation in Rwanda

Solar irrigation is a relatively new technology in Rwanda, but it has been gaining popularity over the past few years due to its potential to increase agricultural productivity and income while reducing greenhouse gas emissions. Solar energy is used in the country's agriculture sector primarily via two areas of application: solar-powered irrigation, which has been promoted for the last 3 to 4 years; and solar-powered refrigeration for post-harvest storage. Though solar irrigation has been documented as having the potential to enhance growth and support poverty reduction efforts in African countries where there is still heavy dependence on subsistence farming, there are several challenges that continue to hinder the smooth adoption of the technology including uncovered risks, lack of incentives, and lack of capacity. These challenges and barriers must be addressed to promote sustainable cooking practices and reduce the negative impact on the environment and public health. Following the PESTELA Framework, the following barriers have been identified:

Political and institutional barriers: At this stage, no political and institutional barriers to solar-powered irrigation in Rwanda were identified.

Economic and Financial barriers: The initial cost of setting up solar-powered irrigation in Rwanda is high, including the purchase and installation of solar panels, pumps, and storage systems. Farmers are particularly impacted by the high costs and do not have the financial resources to invest up-front in this equipment, which is a significant barrier since farmers are the primary users of the technology. For smallholder farmers, a lack of access to inexpensive financing is a barrier that must be addressed.

Social and cultural barriers: Limited social networks and knowledge sharing on irrigation in Rwanda can be categorized as social barriers to the promotion of solar-powered irrigation in the country. In addition, gender issues and traditional patriarchal gender norms can be considered social barriers to solar-powered irrigation in Rwanda. In many Rwanda rural communities, women play a significant role in agricultural activities. However, they often have limited access to resources, information, and decision-making power.

Technology and infrastructure barriers: In Rwanda, access to solar-powered irrigation technology is not an issue. However, in some regions of the country, access to reliable water sources can be a challenge. Reliability of the solar-powered irrigation technology has been identified as a barrier in some solar-powered irrigation systems, due to solar pumps being labour-intensive and affecting the reliability of the system. In some other cases, such as in direct pumping systems, the setup is mostly undersized. Lastly, an important barrier to consider is the insufficient technical knowledge and limited availability of maintenance services, which can impede the widespread adoption of these systems in the country.

Environmental barriers: Some environmental barriers to solar-powered irrigation in Rwanda include the concern that solar-powered irrigation systems may generate electronic waste (e-waste) when components reach the end of their lifecycle, which is a barrier that should be addressed.

Legal and regulatory barriers: At present, there is an absence of regulatory frameworks that can therefore hinder progress in Rwanda. Enabling rules and regulations to adequately incentivize the sector, and establish standards, while building on the required capacities for monitoring and evaluating progress are vital components to the deployment of the technology. These items are not found in the country yet, and the overall absence of regulatory frameworks can therefore hinder the expansion of the technology and progress in consumer access to it.

Awareness and Information barriers: Many farmers in Rwanda are not aware of the benefits and technical aspects of solar-powered irrigation. They may have limited knowledge about the availability of solar-powered irrigation systems, their efficiency, and their potential impact on crop yields. Moreover, there are no demonstration projects, success stories, and peer-to-peer learning opportunities related to solar-powered irrigation, which is a significant barrier to the technology.

1. Introduction

1.1 About the SESA Project

SESA is a collaborative project between the European Union and nine African countries (Kenya, Ghana, South Africa, Malawi, Morocco, Namibia, Tanzania, Rwanda, and Nigeria) that aims at providing energy access technologies and business models that are easily replicable and generate local opportunities for economic development and social cohesion in Africa. Through several local living labs, it is expected to facilitate the co-development of scalable and replicable energy access innovations, to be tested, validated, and later replicated throughout the African continent.

The SESA project covers innovative energy access solutions for a range of applications in both urban and rural areas across the African continent. The innovations are designed to be initially co-developed by partners in Kenya as a demonstration case (also referred to as the living lab). The living lab aims at addressing three focus areas related to innovation in energy transitions, namely: (1) access, (2) productive use, and (3) a circular economy. The demonstration case is subsequently followed by the validation cases in living labs in Morocco, South Africa, Malawi, and Ghana.

The SESA solutions include decentralised renewables (i.e., solar photovoltaics), innovative energy storage systems including second-life electric vehicle batteries, smart microgrids, waste-to-energy systems (i.e., biomass to biogas), climate-proofing, resilience and adaptation, and rural internet access.

The project's overall objective is to provide innovative energy access technologies and business models that are easily replicable and generate local opportunities for economic development and social cohesion.

To achieve its objectives, activities to be carried out in SESA have been divided into nine work packages (WP) with specific objectives, and sub-divided into various tasks with work packages, leading to various project deliverables. The tasks are carryout d by project partners in collaboration with each other.

1.2 About this report

This report entitled "**Barrier Analysis**" is one of the deliverables (D5.2) under the **package WP5- Task 5.2.** The report includes methodology developed for the barrier analysis and its application to nine technologies in demonstration and validation countries (referred to as case studies); Productive Use of Solar Energy (PUE), and Electric Mobility (E-mobility) in Kenya, Clean Cooking in Malawi, Second-Life Use of EV Batteries in South Africa, PVs for Household use, and E-mobility in Morocco, Second-life Battery Use as Energy Storage for Solar Photo-voltaic Systems, and Bio-ethanol Technology for Cooking in Ghana, and Solar Irrigation in Rwanda. Each partner in the task is responsible for the analysis of barriers for one technology (two in the case of TUB) at demonstration or validation sites. The partners will also be preparing policy roadmaps and policy briefs to address these identified barriers as a part of Deliverable 5.3 An overview of the roles and responsibilities of partners regarding Deliverables 5.2 and 5.3 can be found in Appendix 1.

The technologies for some of the validation countries were finalised in early 2023. The data collection, stakeholder interviews and barrier analysis for these countries were carried out by partners and finished in May 2023.

The methodology covered in Chapter 2 (enabling policy framework methodology) helps prepare the barrier analysis reports. The reports bring out the main barriers at the policy level that hinder the uptake of the identified technologies in demonstration and validation countries. For this exercise, nine technologies have been identified in the demonstration and validation countries to deliver nine barrier analyses (also referred to as case studies) (Deliverable 5.2). The barrier analyses will act as the primary input for the development of policy roadmaps for each of the identified technologies (Deliverable 5.3).

As part of the methodology, key stakeholders were be identified for each energy solution / technology, that includes policymakers, technology providers, financiers, technology users, academia and experts, and NGOs. Stakeholders' consultations / surveys were carried out to identify specific barriers to each of the selected technologies. From the consultations, the findings on barriers at the policy level were summarized and compiled into the barrier analysis of each case study document.
Similarly, with inputs from the barrier analysis, policy roadmaps and policy briefs to remove barriers for the identified technologies will be developed. A minimum number of nine policy roadmaps and policy briefs will be developed to provide policy guidance to the partner countries indicating the enabling framework needed both at national and local levels to support scaling up the project's activities (Deliverable 5.3).

The methodology feeds directly into Deliverable 5.2 (Barrier Analyses), which in turn provides a basis for the preparation of Deliverable 5.3 (Policy Roadmaps).

1.3 Linkages with other work packages

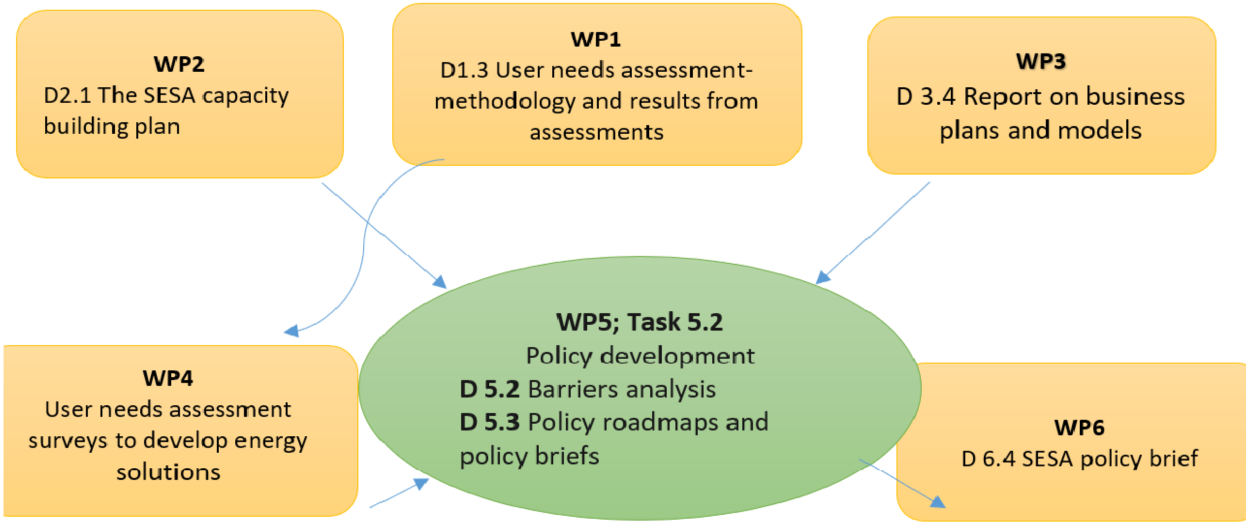
The Task has clear linkages with other work packages of the project, as well as with other tasks within the same work package (WP 5), as shown in Figure 1.1. The linkages are briefly described below.

Work Package 1 and 4 (WP1 and WP4): The framework for user needs assessment developed in WP1 is also used in WP4 to carry out a user needs survey. User surveys provide inputs for innovative energy solutions for WP4 and provide inputs on barriers and policies needed to address the barriers to the technologies uptake from the users' perspective. As such, the user needs assessment reports are the responsibility of WP1 (Deliverable 1.3), which can also provide inputs on barriers as well as policies needed to remove barriers from users' perspectives.

Work Package 2 (WP2): One of the deliverables of WP2 is the SESA capacity building plan for various demonstration and validation sites. Capacity-building needs have been brought out in the plans based on the barriers identified and policy actions have been recommended to implement the plans. This provides inputs on capacity-building policies for Deliverable 5.3 on policy roadmaps.

Work Package 3 (WP3): Various business models for solution providers for technologies to be employed at various sites are explored in WP3. Deliverable D 3.4 brings out various models and policy requirements to address various issues (barriers) in implementing the models. It thus provides inputs for policy roadmap from solution providers' perspective for the models they plan to employ for penetration and dissemination of selected technologies at various sites.

Figure 1.1: Linkages between Task 5.2 and other work packages



Work Package 6 (WP6): The policy roadmaps and policy briefs produced in WP5 will serve as starting points for the policy dialogues (Task 6.4). The policy dialogues are to be organized in the framework of Regional Events in Task 6.2. The results of the discussion will be summarised in a final SESA policy brief (Deliverable 6.4) to amplify the outcomes and widen the impact of the SESA project. The policy briefs will be disseminated among local governments to enable them to scale up their climate action.

2. Barrier Analysis and Enabling Policy Framework Methodology

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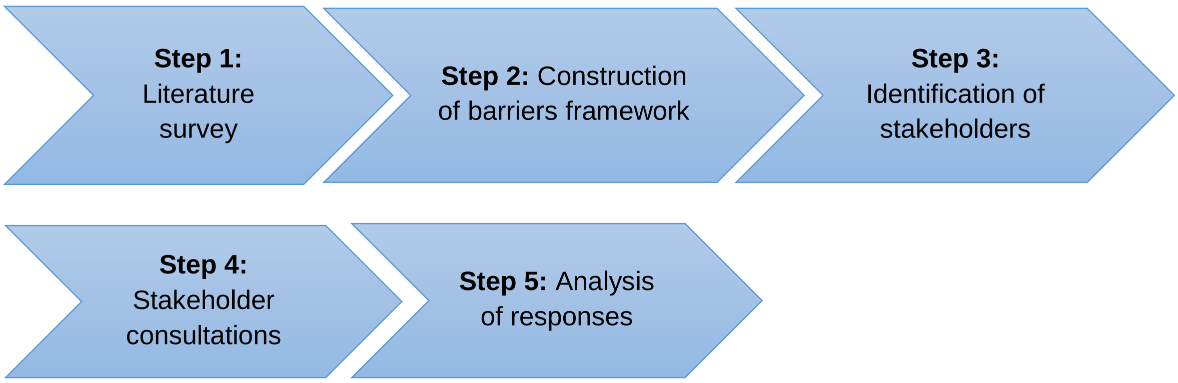
2.1 Methodology

The introduction of new technology in any country always faces a variety of barriers. In this document, the methodology for identifying barriers includes constructing a barriers framework consisting of the identification of key barriers to the selected technology, and the identification of key stakeholders for the technology that includes policymakers, technology providers, financiers, users, experts and others in the technology value chain. An enabling policy framework to promote technology can be devised after barriers have been identified. Stakeholder consultations/surveys are carried out to identify barriers to the technology, and policies needed to address the barriers. A stepwise approach for the identification of barriers is illustrated in Figure 2.1 and explained in this section.

Figure 2.1: Identification of barriers to the technology



2.2 Literature survey

Desk research was conducted to bring out barriers to the technology from existing studies that can help the construction of the barrier framework as well as validate the findings from primary data collection on barriers through stakeholder surveys.

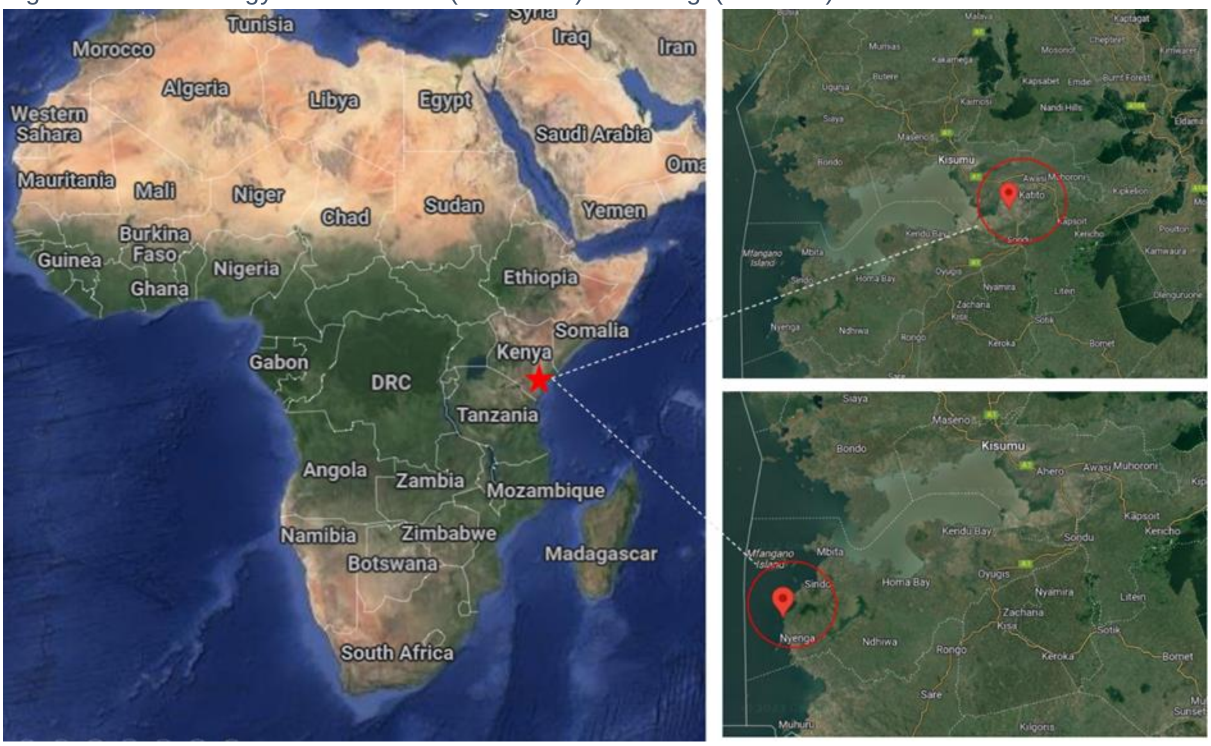
2.2.1 Introduction to technologies- examples from Kenya

Introduction to the use cases: Demonstration implementation activities are being carried out at two project sites, Kisegi, a rural village in Homabay County, and Katito a peri-urban community in Kisumu County.

Energy use cases: These include generating sustainable off-grid electricity, with sector linkages such as fishing, water pumping, water purification, e-mobility, and e-waste, and combining energy solutions with local Info Spots for access to information, on energy, climate and digital skills.

Mobility use cases: There are just a few companies working with E-mobility solutions in the region. Power Hive has an E-mobility project in Kisii County with electric motorbikes and a few electric three-wheelers as well. Kisumu County and Kenya Power and Lighting Co. have introduced electric motorbikes for some county officers and meter readers in Kisumu. Other than these two initiatives, there is essentially no company promoting the use of electric vehicles in the region. Nearly all vehicles are driven by petrol or diesel engines and even the level of awareness of the development of electric vehicles is very low.

Figure 2.2: The energy hubs in Katito (urban site) and Kisigi (rural site)



2.3 Constructing a Barriers Framework

The barrier framework has been constructed at three levels, namely:

2.3.1 Level 1 barriers

It contains barriers at the highest level, which are divided into various categories including economic and financial barriers, technical barriers, policy barriers, legal and regulatory barriers, and awareness and information. A variety of classifications of barriers and techniques to identify them can be found in the literature on barriers. In this report, we build up on the PESTEL framework, which is normally used by organisations in a variety of situations; for example in their strategic planning processes, to analyse and monitor the macro-environmental factors that may have an impact on their performance, developing new products and services, and entering new markets. PESTEL refers to Political, Economic, Social, Technological, Environmental and Legal barriers, and it has been used here in the context of introducing a new technology in the country and extended to include awareness and information as a factor (barrier) in the framework and therefore referred as PESTELA.

2.3.2 Level 2 barriers

A level 2 barrier is made up of several barriers within the category, which can be referred to as "sub-categories" of a Level 1 barrier. The sub-categorisation of barriers helps in a better understanding of the barriers. Economic and financial barriers, for example, can kick in due to a variety of issues including e.g., the economic viability issues for the technology, access to finance (loan from final institutions) or cost of finance issues, and market development issues. These have been termed as sub-categories of the economic and financial barriers. One or more sub-categories of the barrier can be present, which may have implications for the enabling framework needed to address the barrier.

2.3.3 Level 3 barriers

A Level 2 barrier can be further broken down to the next lower level (level 3), termed as "components" of the Level 2 barrier**.** The lowest level in the hierarchy, this (level 3) is important for identifying specific policies and measures to address the identified barriers at the sub-category level (Level 2), and eventually at Level 1 since there is a cause-effect relationship from lower levels to upper levels. For example, in case of "economic and viability issues" (a sub-category of the economic barrier level 2), the product can be uncompetitive due to a variety of "reasons" such as high production price of the end product, high taxes, and duties, high import tariffs, high payback period, low rate of return for the business etc. These "reasons" are termed level 3 barriers and the presence of one or more of them can cause a Level 2 barrier (economic viability) to exist. However, often, it is not necessary to address all these Level 3 barriers; addressing one or more of these may be sufficient to address its parent barrier at Level 2. The same is true for level 2 barriers, as it may not be necessary to address all Level 2 barriers for removing the barrier at the highest level (i.e., Level 1), though often this may not be the case.

The questions for stakeholders are usually developed at level 3 since it is easiest to identify as well as address a barrier at that level. A generic barrier framework developed for the introduction of new technology in a country for the SESA is included in Table 2.1.

Table 2.1: Barriers Framework: various levels of barriers for a technology (E-mobility for illustration)

Level 1	Level 2	Level 3
1. Political	**1.1 Ambitions, strategies and plans**	(A lack of) Governmental commitment to the E-mobility through targets and timelines to achieve targets
		(A lack of) Governmental commitment to the E-mobility through the allocation of resources to implement E-mobility targets.
		(A lack of) Governmental commitment to the E-mobility through institutional responsibilities defined.
2. Economic and financial	**2.1 Economic viability issues**	High Price of E-mobility products (not competitive with existing solutions) High taxes and duties: Taxes and duties can be of various types, levied both on imported and domestically produced items (e.g., Sales tax, VAT etc.) or only on domestically produced items (e.g., Excise duties).
		High import tariffs: As the title suggests, these are levied only on imported items.
		A lack of incentive for EVs to neutralize high costs. The long payback period for end users (if applicable; for example, in shifting from the existing mobility solutions (based on IC engines to E-mobility) Low internal rate of return (IRR) for businesses: IRR is an important parameter for a company to decide whether to include a product in its portfolio or not.
	2.2 Access to finance and cost issues	Up-front cost: High upfront cost can be an important barrier, particularly when access to financing is also an issue. Access to finance: often, new technologies have problems accessing finance due to risk perception. Cost of capital (interest rate): cost of capital, usually reflected in the interest costs, is an important parameter in the adoption of new technologies.
	2.3 Market development issues	Supply chain: It refers to various entities, resources and technologies etc. involved from the production of an item to delivery to the final customer. The Development of the supply chain is essential for the success of any new product / technology.

		Business models: green technologies may require innovative and unique business models for adoption and dissemination.
3. Social and Cultural	**3.1 Affordability issues**	Affordability: Affordability (due to high prices) can be an important issue for many users.
		Policies / programmes for low-income households: Often, special policies (extra subsidies for example are needed for low-income households to adopt a technology).
	3.2 Social biases	Consumer preferences: Consumers can have biased views about a new technology due to misinformation or other reasons.
	3.3 Health and well-being issues	Health and well-being: A new technology could be perceived as bad for health and well-being.
4. Technical and infrastructure	**4.1 Technology challenges**	Access to E-mobility technology: non-availability of new technology due to patents or other concerns can also be a barrier.
		Skill requirements: new technologies may require special skills for their operation as well as maintenance.
		Quality and appropriateness of the technology / product: The quality of the product can be an issue with the new technology, or it may need to be modified for local use considering the local environment such as weather, terrain, lifestyles and preferences of users etc.
		Safety issues: Safety can be an issue with new technology.
	4.2 Infrastructure and other issues	Infrastructural issues: A lack of infrastructure can be a barrier to the use of a technology.
		A lack of maintenance facilities
		Research & development: Local R&D may be required to address local issues in technology adoption.
5. Environmental	**5.1 GHG emission reduction potential**	GHG emissions reduction potential: A technology with high GHG emissions reduction potential may be supported by policymakers as well as donors.
	5.2 Local pollution reduction potential	Air pollution reduction: A technology offering a reduction in air pollution may be supported by policymakers and local stakeholders.

		Potential negative environmental impacts from the E-mobility: There may be potential for negative environmental impacts from the introduction of technology, requiring extra efforts and resources to address the impacts. For example, groundwater level decline due to pumping, wastes batteries from the use of EVs etc.
6. Legal	**6.1 A lack of enabling policies and regulations**	Existing policies, laws and regulations: These can be unfriendly for E-mobility.
		Enabling environment: t refers to friendly policies and regulations for the technology.
	6.2 A lack of technical standards and user-friendly procedures	Technical standards for the technology and competitive products: A lack of technical standards for E-mobility as well as for competing products (existing mobility solutions based on IC engines) can also be barriers. For example, a lack of emissions or fuel standards may benefit IC technology.
7. Awareness and Information	**7.1 Awareness and information about technology**	Awareness and information about E-mobility: Often, a lack of awareness is a barrier to new technology.
		Communication strategy: It is needed to communicate policies and create awareness about technology and its benefits.
	7.2 Promotional measures	Promotional measures: Promotional measures are normally needed in the initial stage of new technology.
		Pilots for the technology demonstration: Pilot projects can help a technology disseminate faster.

2.4 Identification of stakeholders

Stakeholders' consultations play an important role in identifying barriers and enabling policy actions to remove them. Generally, in the case of the introduction of a new technology, six categories of stakeholders can be consulted. These include: (1) policymakers (relevant government authorities), (2) end users of the technology, (3) suppliers of the technology, (4) experts from academia and other institutions, (5) NGOs, and (6) funding agencies. Stakeholders were identified from all these categories for consultation.

2.5 Stakeholders' consultations

Stakeholders' consultations can be carried out from a variety of methods including surveys through questionnaires, interviews, facilitated workshops, focus groups etc. In most cases, the consultations can be in person, through digital survey methods (e.g., email surveys), online, or a combination of these depending on the availability of resources. In the case of facilitated workshops, adequate background can be provided to participants, and break-out/focus groups can be used for input.

2.6 Preparation and administration of the questionnaire

An E-mobility questionnaire (used in Chapter 4) was provided as a template to the partners to customize it for their technologies selected for the barrier analyses. Questionnares used by partners for their technologies and countries are included chapter-wise in the Appendices section of this report.

Desk research was carried out to include additional barriers relevant to the selected technology in the selected country by each partner. Once ready, the questionnaire was administered to the identified stakeholders. Precaution was takern to ensure that only relevant questions are administered to each category of stakeholder.

2.7 Analysis of responses

The data analyse part of the barrier analysis consists of two steps, namely the tabulation of responses and the response analyses. Both are further explained below.

2.7.1 Tabulation of responses

The first step in the analysis is the tabulation of responses for each stakeholder category as well as combined responses where relevant.

2.7.2 Analysis of responses

The questionnaires were is a mix of qualitative and quantitative responses. The questionnaire contained two types of questions: (i) Questions that require qualitative opinion/information from the responder about their knowledge of technology, its attributes, and its use, and (ii) A few objective-type questions requiring responders to indicate the importance of selected features and barriers to technology on a ten-point scale. The questionnaire also includes an open-ended question on policy measures that respondent thinks should be taken to address a barrier. The responses were analyzed qualitatively andthis was done without identifying personal details.

2.7.3 Importance of barriers and measures to remove barriers

The importance of barriers was brought out, wherever feasible, from the responses given by interviewwes. Measures to address the barriers (policies) to create an enabling environment were also included based on inputs from stakeholders, obtained during the survey. This goes as an input to the enabling policies framework, which contains a list of potential policies to address barriers as indicated by stakeholders.

2.8 Enabling Policy Framework for E-mobility

The methodological framework for the subsequent deliverable (D 5.3) has also been included here in line with the scope of work under Task 5.2.

Enabling measures refer to the development of strategies and policies that help create an enabling environment to address the barriers. The enabling environment consists of institutional, regulatory, and political frameworks that are conducive to the promotion and diffusion of technologies. The country-specific circumstances that include existing market and technological conditions, institutions, resources, and practices are considered, which can be subject to changes in response to government actions. The policy measures may target both; supply-side and demand-side aspects of the transfer and diffusion of technologies. It is important that various barriers and enabling measures/policies are brought out through stakeholder engagement. A list of potential enabling measures/policies based on the stakeholders' responses can then be generated. For illustration, potential enabling measures/policies for up-scaling E-mobility are given in Table 2.2

It is to be noted that a table like this is a list of compressive measures, and not all measures will be needed/selected by the stakeholders responsible for the action. Selection and finalization of policies are done at the stage of roadmap preparation when targets, timelines, resources, and institutional responsibilities are also defined.

Table 2.2: Potential enabling measures/policies to support large-scale deployment of E-mobility.

Enabling measure /policy category	**Potential enabling measures/policies**	**Stakeholders responsible for the action**
Political	• Targets for E-mobility • Resource allocation for E-mobility • Institutional responsibilities defined	○ Ministry of Finance ○ Ministry of Energy ○ Ministry of Transport
Economic and financial measures/policies	End-user purchase subsidy: The end-users can be encouraged to adopt EVs through subsidies linked to quality, performance, and safety standards.	○ Ministry of Finance ○ Banks and financiers ○ Regulatory agencies
	End-user interest subsidy: Mechanisms can be devised to enable end users to access loans at low-interest rates.	○ Ministry of Finance ○ Banks and financiers
	Exemption of Import duties: Import duties on EV can be that meet defined quality and safety standards can be slashed.	○ Ministry of Finance ○ Relevant industry associations ○ Regulatory agencies
	Reduction in VAT/sales tax: The taxes can be reduced or eliminated until the market has developed and price parity is reached between EV and ICE vehicles.	○ Ministry of Finance and Economic Development ○ Regulatory agencies
	Incentives for local assembly/ manufacture of EVs and their components: These are alternate/ complementary measures that can be considered from the supply side. These include fiscal incentives (capital/ interest/ tax subsidies) for local assembly and manufacturing of EVs and components.	○ Ministry of Finance ○ Industry associations
Policy, regulatory, technical and infrastructural measures	EV Safety standards: These may be needed to ensure quality and world-class safety standards to generate confidence among users.	○ Ministry of Transport ○ Standard institutions ○ Other stakeholders

	Battery recycling and re-use guidelines: Includes Lithium Battery recycling, and re-use guidelines covering collection, storage, transportation, and recycling of waste batteries (for suppliers, manufacturers, and consumers).	○ Ministry of Transport ○ Ministry of Energy ○ Ministry of Mines and Mining Development ○ Ministry of Industry ○ Regulatory authority etc.
	Charging Infrastructure subsidies and incentives for EVs: to encourage industry and distribution company participation through fiscal incentives (capital/ interest/ tax/ electricity subsidies) for setting up EV charging stations and services.	○ Ministry of Finance ○ Other relevant stakeholders
	Public Charging Infrastructure Guidelines for EV: Guidelines for public charging infrastructure to ensure the right selection of charging options (slow or fast) and interoperability.	○ Ministry of Transport ○ Ministry of Energy ○ Local Authorities ○ Others
	Home and Office Charging Infrastructure Guidelines for EV: Building codes and guidelines for setting up appropriate charging infrastructure (especially for multi-storied residential and offices).	○ Ministry of Transport ○ Ministry of Energy ○ Local Authorities ○ Others
	EV technology training and skill development: Guidelines for OEMs and dealers to partner with local institutions and build strong training and certification skill programs to build local expertise to assemble EVs, set up maintenance services etc.	○ Ministry of Transport ○ Ministry of Energy ○ Academia and Research Institutions ○ Others
Information, awareness and promotional measures	EV Adoption mandate and bulk procurement of EVs for Government Departments: Mandating government departments to purchase EVs for their new fleet procurement and/or leasing.	○ Relevant stakeholders in the country
	EV Awareness program for users: Designing and conducting public awareness programs on EV.	○ Ministry of Transport ○ Ministry of Education ○ Others
	Supporting EV pilots: Encouraging EV pilots through funding, and incubation support for purchase, research and implementation.	○ Ministry of Transport ○ Ministry of Finance ○ Ministry of Education ○ Others
	EV Awareness program for OEMs and dealers: Awareness programs to assist ICE manufacturers to gradually shift to EVs, and for dealers to take up EV selling	○ Relevant stakeholders

Gender-sensitive measures	Institutional measures: Strengthening institutional capacity to advocate for rights, needs and priorities of women, youth, children, elderly and the most vulnerable within transport and infrastructure development.	○ Relevant stakeholders

3. Barrier Analysis for Productive Uses of Solar Energy (PUE) in Kenya

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Reviewers: Jyoti Painuly and Julia Rocha Romero (UNEP Copenhagen Climate Centre)

3.1 Productive Uses of Energy in Kenya

Kenya has an estimated solar power potential of 15,000 MW due to its high solar irradiation throughout the year (KIPPRA, 2022). In 2021, grid-connected solar power reached 172MW. However, demand for off-grid solar has largely been untapped. Productive uses of solar energy are one promising area of off-grid application to power appliances that help users operate an income-generating activity. ENDEV/SNV (2021) found 40 types of PUE technologies in Kenya used in agricultural production, agricultural post-harvest processing and storage, dairy, poultry and livestock, fisheries, light industry, small commerce, and restaurants and hospitality.

According to the Global Off-grid Lighting Association (GOGLA)'s Global Off-Grid Solar Market Report (GOGLA, 2022), the off-grid solar market in Kenya has been dominated by solar TVs (91%)[1], most of which have been sold together with Solar Home System (SHS). Next to the TVs are solar water pumps and refrigeration units. More than 40% of Kenyans are estimated to lack access to safe water. Solar water pumps can provide water for irrigation and purification of drinking water. Over 5500 solar water pumps were sold in the first half of 2022. The potential of solar pumps for irrigation is particularly huge due to the national target of significantly increasing irrigation use in the country (e.g., Kenya Vision 2030 aims to increase the area under irrigation from 110,000 ha to 210,0000 ha by 2030) (USAID, 2019; Kenya Vision 2030, n.d.). Off-grid solar cooling has also expanded its primary use in vaccine storage to households and MSMEs. Its vast potential for dairy production, agricultural post-harvest, small commerce, and restaurants has largely been untapped (EnDev & SNV, 2021). Solar water pumps, solar cooling, and solar-charged E-mobility have gained strong interest from investors. Kenya has more than 82 companies that are active in these sectors (EnDev & SNV, 2021).

Despite the high potential of PUE and the active network of PUE companies, the country still faces various barriers to scaling up its PUE sectors.

3.2 Stakeholder's Consultation and Barrier Analysis

This section presents the barriers to PUE development in Kenya are systematically analyzed using the PESTELA framework (Political, Economic, Social, Technological, Environmental, Legal, and Awareness). The barrier analysis was conducted based on a literature review and eight structured interviews with different types of stakeholders (government officers, service providers, NGOs, funding agencies, and researchers).

3.2.1 Barriers

Policy and institutional barriers for the Productive Use of Solar Energy (PUE) in Kenya Under this barrier category, we assess a) government plans to implement PUE, b) the institutional capacity in the

[1] They are used in small commerce and restaurants and hospitality. They are also used for private purpose and thus do not generate income, as defined in PUE.

government for formulating and enforcing regulations for PUE and c) the coordination of PUE within the government and between government and other stakeholders.
The Kenyan government generally supports PUE through overarching strategies and renewable energy policies. One respondent from the interviews highlighted the importance of Kenya National Energy Efficiency and Conservation Strategy (NEECS) published by the Ministry of Energy (MoE) in 2020. It aims to promote efficient off-grid PUE in the agriculture sector and outlines four key activities:

- Five demonstration projects of renewable energy-based solar pumping water systems, cold chains, grain millers
- Market analysis needs to report to map agricultural value chains where off-grid solutions will be utilised.
- Capacity-building programs by county governments on agriculture value chains
- Credit schemes and concessional loans, and improved results-based financing

Together with UNEP-CCC and other national stakeholders, the MoE developed the Implementation Plan (Ministry of Energy, 2021), which specifies the budget for each activity.

Despite the concrete activities, an overall strategy for promoting PUE in Kenya is lacking, including clear targets and timelines, which one respondent also pointed out.

Kenya has several national energy regulations incorporating renewable energy. However, SESA researchers identified a need for more technical capacity and skills to formulate adequate renewable energy legislation, facilitate related financing and licensing, and monitor and evaluate. Especially at the local level, the institutional capacity gap has impeded the adoption of national renewable-related regulations and policies (Schroder et al., 2021).

Besides, PUE policy formulation and implementation require strong cooperation and coordination among concerned ministries. The MoE approaches it through energy access policies. The Ministry of Agriculture (MoA) does not specify PUE in its policies, although they recognize its importance. The Ministry of Industry, Trade, and Economic Development (MoITED), which oversees the development of MSMEs (including PUE providers and users), has yet to identify PUE's benefits systematically. Finally, PUE is not explicitly mentioned in the NDC submitted by the Ministry of Environment and Forestry (MoEF), which is responsible for climate change and electronic waste management (EnDev & SNV, 2021). Currently, relevant ministries in Kenya work in a silo on PUE. One respondent also confirmed this.

All respondents agreed that the private sector in Kenya had driven the supply chain of solar appliances for PUE. Almost all respondents described the collaboration between the private sector and the government to be project-driven and thus reactive. There is no continuous coordination mechanism. Thus, the respondents suggest that government and private sector coordination needs to be strengthened. In April 2022, SNV, in partnership with Kenya Renewable Energy Association (KEREA)[2], s launched a PUE working group representing the MoE, MoA, KEREA, The Global Off-grid Lighting Association (GOGLA), GIZ, SNV, and PUE companies (SNV, 2022). Among others, the working group aims to participate in a national inter-ministerial public-private dialogue on PUE and engage with government, regulatory bodies, and other development partners to review and implement quality standards in the sector. It will thus serve as a dedicated coordination and communication platform on PUE between the government and the private sector.

Economic and Financial barriers for the Productive Use of Solar Energy (PUE) in Kenya

[2] Their members are from the renewable energy industry in Kenya.

All respondents said the upfront costs of solar equipment and its installation are high, representing a key barrier to scaling up PUE. They suggest that taxation, i.e., import duty and value-added tax (VAT), should be decreased to reduce the cost. Recently, solar panels have been exempted from both import duty and VAT. However, solar water pumps and DC appliances (e.g., DC fridges) are subjected to both (EnDev & SNV, 2021). In addition, tax exemptions appear to be unpredictable, for example, the Finance Act 2020 and the Tax Amendment Act 2020 abolished tax exemptions for off-grid solar equipment (ITA, 2022). In 2021, the same Acts re-introduced tax exemptions (KIPPRA, 2022).

In terms of financing, end-user finance provided by banks is very limited due to banks' risk aversion and lending criteria disfavoring users. PUE companies provide in-house consumer financing to address consumers' financial barriers, i.e., they finance solar panels and appliances (e.g., PAYGo). However, for expensive systems, this financing mechanism is challenging for companies, particularly for small and medium providers with limited working capital. In Kenya, the PUE companies also have limited access to financing from local banks (SNV, 2022). One respondent pointed out that most financial institutions require a track record, which small and medium start-ups often lack.

Social and Cultural barriers for the Productive Use of Solar Energy (PUE) in Kenya

All respondents claimed that the upfronts cost of solar equipment and its installation are high. It would particularly affect low-income households with elastic demand of PUE. Affordability is therefore an issue for them and there are no policies addressing this barrier.

Technical and Infrastructure barriers for the Productive Use of Solar Energy (PUE) in Kenya

All respondents indicated that the supply chain of the solar-powered appliance for PUE is fairly well developed.

However, there has been an increase in substandard and counterfeit solar products in the market (KIPPRA, 2022), which was confirmed by two respondents. Another respondent pointed out that quality varies among different PUE technologies.

Most respondents said sufficient skilled labour for installing and maintaining solar-powered appliances is available in Kenya. The energy and petroleum regulatory authority (EPRA) also issues licenses to technicians for installing and maintaining solar-powered PV systems. However, some respondents mentioned that after-sale service (e.g., repairing) needs to be improved. One reason is that many suppliers are not based locally, which makes it difficult and costly to provide timely after-sale service (Colenbrander et al., 2022).

Environmental barriers for the Productive Use of Solar Energy (PUE) in Kenya

Off-grid solar power installations comprise PV panels, one or more batteries, control devices, cables, and appliances (e.g., light bulbs). Lead-acid batteries consist of mostly lead and lead-oxide and 10 – 15% sulfuric acid. Many crystalline silicon PV panels contain lead-based solder paste. Lead is a highly poisonous heavy metal that has adverse health impacts. Sulfuric acid can cause skin burns and eye damage (GIZ, 2018). Thus, almost all respondents perceive the disposal of solar panels, solar-power appliances, and end-of-life batteries as an environmental threat.

Other environmental risks result from the insulation and refrigerants used in refrigeration units and the over-exploitation of groundwater using solar water pumps(EnDev & SNV, 2021).

Legal and Regulatory barriers for the Productive Use of Solar Energy (PUE) in Kenya

Minimum energy performance standards (MEPS) have been developed for refrigerators, air conditioners, lighting appliances, and motors (EnDev & SNV, 2021). The government drafted The Energy Act (EPRA, 2020), which is undergoing a parliamentary approval process. The regulation includes minimum performance standards for standard-alone solar systems and requires technicians to be certified. One respondent perceives this legislation would improve the quality of the solar systems and the competence of technicians and thus increase the confidence of the consumers and the uptake of solar-powered systems. However, there are no national performance standards for PUE and DC appliances (EnDev & SNV, 2021). Thus, three respondents emphasized that such standards need to be established.

Besides, national regulation on e-waste management (GOK, 2022) including solar panels and solar-powered appliances, is still a draft version. Thus, solar companies, which are yet to establish their business models, are not incentivized to integrate e-waste management into their business (Hansen et al., 2022). This was highlighted by a respondent as a legislative barrier leading to the above-mentioned environmental barrier.

Awareness and information barriers for the Productive Use of Solar Energy (PUE) in Kenya
A governmental respondent highlighted that nine out of ten Kenyans know about solar energy. However, most respondents mentioned that consumers' awareness about what it can do, including different PUE, is still low. A funding agency respondent said that social media has helped with awareness-raising of solar and PUE. Except for awareness, consumers' knowledge of PUE appliances (performance and sizing) also represents a barrier to purchasing (Colenbrander et al., 2022). Besides, technologies such as solar irrigation, also require consumer behavioural change (EnDev & SNV, 2021).

3.3 Conclusion

The policy environment is conducive for PUE in Kenya. However, although PUE is included in national strategies such as NEECS, an overall strategy for promoting PUE, including ambitious targets and a concrete timeline, is yet to be formulated. Besides, the institutional capacity of the government for formulating and enforcing regulations for renewable energy needs to be improved. Furthermore, coordination among concerned ministries on PUE needs to be established. On top of that, a collaboration between the private sector and the government on PUE has often been project driven. In 2022, a PUE working group was established, which could be a platform for exchanging PUE issues between the government and the private sector.
High upfront costs remain a crucial barrier to scaling up PUE, partly attributed to taxation on PUE appliances. Service providers offer end-user financing options to address this barrier. However, most have limited access to bank financing and thus cannot always offer finance, particularly for those expensive products. The high costs would particularly affect low-income households. Policies to address this segment still need to be put in place.

The supply chain of PUE has been fairly well developed, and skilled labour is available in Kenya. However, after-sale service needs to be improved. Besides, the development of PUE has been also impeded by the increase of substandard and counterfeit solar products, as there are no national performance standards for PUE and DC appliances to ensure the quality of these products.

Environmental threats associated with PUE include the disposal of solar panels, solar-power appliances, end-of-life batteries, and the insulation and refrigerants used for solar cooling.
Thus, a lack of national regulation on e-waste management is highlighted as a legal barrier.
Last but not least, consumers' awareness and knowledge of PUE are still low, constituting a key barrier to PUE adoption.

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4. Barrier Analysis for E-mobility in Kenya

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4.1 Introduction to Electric Mobility in Kenya

4.1.1 Status of E-mobility in Kenya

The National Climate Change Action Plan (NCCAP) 2018-2022 has prioritized several measures for the transport sector to mitigate climate change, electric mobility being a key measure. The Action Plan includes awareness raising, developing technology for electric mobility, piloting and using electric modes of transport, and building charging infrastructure. Kenya has substantial power generation capacity with a reserve margin of over 30 percent (Mussa, 2023). Therefore, it can meet the electricity demand for E-mobility. Kenya National Energy Efficiency and Conservation Strategy (NEECS) (MoE, 2020), developed by the Ministry of Energy, set the target of increasing the share of electric vehicles to reach 5% of cars registered every year by 2025. The strategy includes regulatory actions and financial mechanisms to promote electric vehicles in Kenya. These include lower import duty for electric vehicles, revision of the Building Code to incorporate charging stations in public buildings, vehicle labelling and CO2 taxation and awareness-raising for e-mobility.

The National Climate Change Action Plan 2018–2022 (MoEF, 2021) outlined measures to incorporate EV technical standards, incentives, pilot projects, and public procurement to stimulate the EV sector. Kenya **Finance** Act, 2019 (RSM, 2019) reduced the excise duty for 100% battery-powered electric vehicles from 20% to 10%. The Integrated National Transport Policy, 2009 is being revised to include EVs and related infrastructure (CDH, 2002).

Electric buses have been launched by Opibus (now known as ROAM) in Nairobi in 2022. The company also launched motorbikes and has arranged to provide loans through a partnership with a financial institution. Another company, BasiGo also launched electric buses in Kenya and some taxi companies have also plans to go electric. The electric boda-boda (e-bike taxis) has also been launched by some companies. As a result, there are more than 1000 electric vehicles on Kenya's roads (Abuya 20022).

4.1.2 E-Mobility in Kenya in SESA Project

The SESA project is built on the grounding notion that energy transformation and solutions must be singular and context-specific, however, each barrier analysis in this study unveils points that demonstrate commonalities across countries' readiness to implement and scale various solutions. The use cases have been developed around two energy hubs in Katito (urban site) and Kisegi (rural site) in Kenya. The energy use cases in these sites include generating sustainable off-grid electricity, with sector linkages such as fishing, water pumping, water purification, E-mobility, and e-waste, and combining energy solutions with local Info Spots for access to information, on energy, climate and digital skills.

In the case of mobility use cases, there are just a few companies working with E-mobility solutions in the region. Power Hive has an E-mobility project in Kisii County with electric motorbikes and a few electric three-wheelers as well. Kisumu County and Kenya Power and Lighting Co. have introduced electric motorbikes for some county officers and meter readers in Kisumu. Other than these two initiatives, there is essentially no company promoting the use of electric vehicles (EVs) in the region. Nearly all vehicles are driven by petrol or diesel engines and even the level of awareness of the development of EVs is very low. Electric mobility has been identified as a key area of action to contribute to Kenya's NDC and as a result, has been highlighted as a key action in the National Climate Change Action Plan (NCCAP) 2018-2022. It was therefore selected as one of the technologies for the study of barriers.

4.2 Barriers to E-mobility in Kenya

4.2.1 Literature survey

There are a few studies and stakeholder surveys available that bring out barriers to E-mobility in Kenya. Significant reports that brought out barriers to E-mobility in Kenya have been briefly discussed. The Energy and Petroleum Regulatory Authority (EPRA, 2020), Kenya brought out a report, *Combined Reports on the Development of Electric Mobility Policies in Kenya*, which indicated high upfront purchase costs, lack of vehicle model choice, technological concerns such as driving range, and customer information gaps as the barriers and proposed the measures to address them. Access to credit and finance, a clear E-mobility policy and industry support policies (subsidies and tax incentives), and an easily accessible, reasonably priced and reliable charging infrastructure were the recommendations to address the barriers. Association for Electric Mobility and Development (AEMD, 2021) in Africa's *Market Survey Report* interviewed Kenya's E-mobility market players and concluded: "The inadequate policy remains the largest detriment to the entry of more and higher quality products". It also brought out issues related to standards, imports of second-hand petrol vehicles, pricing and consumer awareness as other barriers. *Roadmap to E-mobility* (AHK, 2021) primarily covers two and three-wheeler segments and brings out technical, financial, policy and socio-cultural barriers. Charging infrastructure, and a lack of access to finance, information and coordination across E-mobility actors have been cited as major barriers. *Opportunities and Challenges for Electric Mobility in Kenya* (KOA, 2022) indicates high upfront cost as the major barrier to E-mobility uptake in Kenya. Unreliable Electricity Supply and range anxiety (both related to charging infrastructure), affordability and regulatory framework, including for second-hand car imports are cited among other barriers. In its report *"Environmental Impact of E-Mobility in the Lake Victoria Region, Western Kenya",* EED Advisory (2020) indicates a lack of EV models, high cost of EVs, inadequate charging infrastructure and related lack of standards, and a lack of awareness about benefits of EVs as the barriers to E-mobility. Surratt et al. (2022) indicated high upfront costs, charging infrastructure including concerns about the range, and access to finance as the barriers to the E-mobility.

From the literature, high upfront cost emerges as the most cited (and important) barrier to E-mobility in Kenya, followed by access to finance, and lack of charging infrastructure as other important barriers. Other barriers include the lack of awareness about the benefits of E-mobility as well as about governmental policies, a lack of regulations, including for the import of second-hand vehicles, etc. Most of the studies however focus on two and three-wheelers in their discussions of barriers, and the relative importance of barriers, apart from high upfront costs, is also not brought out. Some of the studies consider only a small segment of the stakeholders. These issues were considered in this study of barriers and an attempt was made to include the perspective of a wide variety of stakeholders including policymakers, E-mobility solution providers, experts including academia, NGOs, and funding agencies on barriers to upscaling E-mobility in Kenya.

4.2.1.1 Barriers Framework

The barrier framework discussed in Chapter 2 has been used to analyse the barriers to the adoption and scale-up of E-mobility in Kenya. The barriers framework with specific reference to E-mobility has been covered in section (iii) (Stakeholders' consultations and analysis of responses), where these barriers have been discussed in detail.

4.2.1.2 Identification of stakeholders

As indicated in Chapter 2, stakeholders were identified in six categories as follows:

Policymakers: These included the Ministry of Energy and Petroleum, the Ministry of Transport and Infrastructure, and the Energy and Petroleum Regulatory Authority. A total of four policymakers from these institutions were interviewed by the partners (SEI).
Suppliers of technology (solution providers): Two service providers Kiri Energy and BasiGo were interviewed.
Funding agencies: Partner (SI) informed several were requested but were not available in the interview timeframe.
Experts (Academia and other experts): Two experts, one from GIZ and the other from Advance Consulting were interviewed.
NGOs: An expert from Kenya Renewable Energy Association was interviewed.
End users: The end users, primarily Boda-boda drivers were interviewed in a group (8 in number) by the Kenya living lab partner. A potential user from Safaricom, a telecommunication company was also interviewed.

The list of stakeholders' organisations/ institutions is given in Appendix 2. Each stakeholder institution has been assigned an ID number to understand the perception of specific categories of stakeholders on barriers properly.

4.2.2 Stakeholders' consultations and analysis of responses

Questionnaires were prepared to cover the six categories of barriers and administered to the above 10 stakeholders by partners from the Stockholm Environmental Institute (SEI) (Appendix 3). Using the barriers framework described in Chapter 2, the responses from stakeholders to the questions on barriers to E-mobility in Kenya are discussed and summarised below.

4.2.3 Barriers

Political and institutional barriers

Political commitment to E-mobility should be reflected in targets, timelines, resource allocation, and allocation of responsibilities to ultimately achieve the targets. It also requires the creation of adequate institutional capacity to support the new technology- E-mobility in this case. A lack of targets and funding would indicate a lack of political commitments- referred to here as a political barrier. A lack of institutional capacity will also indicate a lack of political commitment- referred to here as an institutional barrier. These actions- setting targets, creating institutional capacity, etc. - are normally taken by the political leadership.

The Ministry of Transport, Kenya initiated the development of a national electric mobility policy in 2021[3]. The government has the target to increase the uptake of EVs in the country to have 5% EVs by 2025. The NEECS includes this target of 5% of Kenya's vehicle stock to be electrified by 2025. This was corroborated by three stakeholders including a policymaker, an expert and the NGO (P1, E2, N1). Also,

[3]https://www.transport.go.ke/department/images/tenders/2021/EMOBILITY_POLICY_TOR_WORLD_BANK_FINAL_BIDDING_NOV_2021.pdf

there is a government strategy that all new public buildings are required to have charging stations (Wangui, 2020). The government strategy to raise funds for scaling up E-mobility is however primarily private sector driven according to an expert and users (E1, U1, U2). There is a lack of institutional capacity in terms of engagement with the private sector and end users (U1, E2) According to a policymaker, attempts have been made to build the capacity in various areas related to E-mobility by the government, including through engagement with stakeholders (P3). Governmental capacity-building initiatives have been taken up by development agencies also, including through webinars (E2). The coordination among various agencies is also inadequate according to policymakers and an NGO (P2, P4, N1) and currently, is driven by international partners. There is a need for an inter-ministerial platform to engage all stakeholders (N1). The coordination between the private sector and relevant ministries is however not an issue (S1).

The stakeholders' responses thus bring out a mixed picture; Kenyan Government has a general target to increase the uptake of electric vehicles to 5% by 2025 but it is not supported by required resource allocation. The government is primarily dependent on the private sector to mobilize resources. However, that may not be enough. The institutional capacity and coordination among various relevant agencies also need to be improved (E2). All this is indicative of the need for enhanced action at the political level. Financial constraints may however be an issue with the government. For GHG mitigation actions, Kenya has made it clear in its revised NDC (MoEF, 2020) that 79% of funding needs to come from international partners.

Economic and Financial barriers

Economic barriers include the high price of E-mobility resulting in a long payback period for end users, and a low internal rate of return (IRR) for solution providers, ultimately making it uncompetitive with the existing solutions. For a technology that is available and viable elsewhere, the high prices can be typically due to high import tariffs and/or high taxes and duties. E-mobility price is also an economic barrier in many developing countries like Kenya due to the low prices of existing petrol/ diesel vehicles, particularly due to cheap imports of second-hand vehicles. Financial barriers refer to one or more of the following: high up-front cost of the electric vehicle, and a lack of access to finance due to high-risk perception by financial institutions, which in turn also leads to high-interest rates of loans. A lack of market development for E-mobility can also lead to economic barriers; a lack of supply chain for example can lead to shortages, increased need for imports[4] and the consequently high prices of the EVs.

The high cost of EVs, particularly the high upfront cost was considered a major barrier by several stakeholders, including policymakers, experts and solution providers (P2, P3, E2, S1). There is a need to reduce costs through incentives as the current level of cost makes it difficult to recoup investment (P3). The incentives should be for a limited period (P2).

Currently, EVs cost almost double that of petrol vehicles, and their upfront cost is very high (P3, S1). Taxes, including excise duty, are high for EVs (E2). High VAT on EVs is also an issue (N1). There is competition between petrol and EVs (P1) and considering all these factors, it is difficult for electric vehicles to compete with second-hand petrol vehicles.

The government plans to reduce excise duty on EVs by 10% in the next financial year (S1). E-mobility tariff is also being reviewed by EPRA (S1), which may particularly help public E-buses. Unfortunately, there are no consistent tax and incentive policies, and they simply depend on the regime in power (P1). For example, import taxes were reduced by 50% (halved) in 2018-19 to encourage the uptake of EVs. Taxes on school buses were reduced and at the same time taxes on diesel vehicles above 300 CC were increased (P3) to incentivize E-mobility. Excise duty was also reduced from 20 to 10% but these steps did not lead to any significant change (E2). There is a need for consistency in taxation, which will help investment in the sector (N1). There are plans to reduce excise duty to support local assembly and competitive electricity tariffs for E-mobility, particularly for buses (S1). There are some subsidies from

[4] Parts that could be made locally are also imported in this case.

private banks and others through technology providers for individuals for E-mobility (P3, S1), including an MOU by a technology provider with a bank to access loans at a low-interest rate (S1). However, it is difficult for new start-ups to access funding.

Access to finance for E-mobility is a major issue in Kenya (P1, E2). Bank finance could become available in the near future and private equity and other funds are also on the horizon, but business model scalability is an issue (N1). Financial institutions in Kenya need to be sensitized on financing E-mobility (P2).

Given the high upfront cost of these technologies, the current business models are the credit pay-as-you-go system where intended users pay a deposit and then the rest of the balance in equal weekly/monthly instalments (U2). Pay-as-you-go is used by most technology providers (E1, U1, U2), and some technology providers also provide upfront financing (U1).

The local supply chain is not that well developed (U1, E2, S1), as local financing is difficult to get. It is however now picking up (U1, S1). It is particularly weak in the case of charging station equipment (P4). Most vehicles are imported, primarily by the private sector (E1).

There are two financial incentives the government plans to implement, one is the reduced excise duty to support the production of EVs and local assembly of E-mobility technology to reduce fuel import bills, and the other is the competitive electricity tariffs for E-mobility, particularly for charging electric buses (S1).

Thus, EVs in Kenya still are not able to compete with petrol vehicles and require more support through further reductions in taxes and other incentives. Excise duty reduction to 10% from 20% and import duty reduction from 35% to 25% is not enough to increase the uptake of EVs. High upfront costs and access to finance remain an issue, which was revealed by the literature survey.

Social and cultural barriers

Social barriers refer to social biases affecting acceptance of the technology solution. Social norms which include demographic particularities (age, gender, region sex, religion, marital status, etc.), lifestyle particularities, educational background etc. may also hinder or encourage the use of a particular technology solution. Health and well-being issues can also be barriers; technology could be perceived as bad for health. Affordability by a large part of society can also be a barrier in many cases.

Affordability of EVs is an issue due to widespread poverty in Kenya (P1, P3, E2) and ordinary citizens cannot afford EVs. However, one of the stakeholders was of the opinion that technology and infrastructure are primary issues for EVs and that others can be resolved (P2). This could be the case for EV public transport, where technology and charging infrastructure are major issues since tariffs can be affordable.

Technology and infrastructure barriers

Technical barriers include a lack of access to technology, a lack of skills required to operate and maintain the technology, and technology not suitable due to geographical, environmental or other reasons- for example, hilly terrain, high ambient temperatures may not be suitable for some type of E-mobility applications and require modifications. Infrastructure issues in the case of E-mobility relate to a lack of or inadequate charging infrastructure, unstable electricity supply etc.

According to a respondent, manufacturing EVs may not be feasible in the immediate future but the infrastructure to assemble the electric vehicles needs to be built (U1). The service provider indicated that the Ministry of Trade and Industrialization is helping through the creation of an enabling environment (S1). A lack of infrastructure is however an issue (P1). There is a need for charging infrastructure as well as regulations for charging (E2, P1).

Technology is not very complex; however, some capacity building will be needed. Spare parts are not that readily available and that can be an issue if efforts are not made (P2, S1). For the current petrol vehicles, spare parts are readily available (P4).

A lack of charging infrastructure and range anxiety (driving range on a single charge) have been prominent barriers for EVs (in literature) besides economic and financial barriers. Stakeholders (6) were also asked to rate the importance of these barriers on a scale of 1 to 10; with 10 indicating "extremely important barrier" and 1 indicating "not at all important". The responses are summarized in Table 4.1 below.

Table 4.1: Level of importance of charging infrastructure for E-mobility

	Policymakers			**Expert**	**Solution provider**	**NGO**	**Average score**
A lack of charging structure	10	10	9	8	10	5	9
Driving range on a single charge	10	10	6	8	1	1	6

It can be seen that a lack of charging structure was categorised as a major barrier by all stakeholders except one and overall can be considered as a very important barrier. Driving range on a single charge was however considered an extremely important barrier by only two policymakers and very important by one of the experts. Service providers rated it as no barrier at all. This, however, relates to the product that rather has in mind- for example, it may not be a barrier for two-wheelers considering the distance typically covered in a day before it can go to charging. Also, the battery technology has improved over time and the range, which was rated one of the major barriers in past literature, may have lost its importance as evidenced by varying responses on this from stakeholders.

On technical barriers, one of the respondents pointed out the need for standards in terms of safety to ensure no electrocution and standards for the charging ports (P2). The need for improved grid reliability was also pointed out so that the right voltage and frequency are available for charging. The need for power security in case of a spike in demand considering Kenya's reserve margin is only 30% was also brought out (P2). Battery reliability was flagged as one of the barriers by one respondent (E2). There is not enough experience to ascertain reliability though the technology provider pointed out that their buses operate within Nairobi city, and they never had reliability issues (S1).

Capacity needs to be enhanced for skilled labour to provide technical after-sales services and repairs. Technical and vocational education and training programmes could include the required curriculum and provide training on E-mobility (P3). Skilled labour availability is inadequate for maintenance, and this can affect the potentially expanding markets (E2). However, a company like Basi-go has trained local technicians in the manufacture and assembly of electric buses. This training has helped them keep the buses up and running (S1, P1). According to the technology provider, the industry is not so big that increased capacity is required (S1). This, however, may be true for buses where customers and technology providers are limited. One of the respondents, however, commented that there is skilled labour, but not visible. This indicates the versatility of the skilled labour in Kenya who may be able to support the technology with some training.

E-mobility is also seen as a solution to support rural areas meet their mobility requirements. However, there are several challenges that E-mobility faces in providing services to remote and rural areas. The same challenge as in urban areas will be experienced in rural areas- a lack of charging infrastructure for example (P4). There are additional challenges since remote / rural areas are yet to be connected to main electricity or solar mini-grids making charging a challenge (E1, U1). The charging infrastructure is lacking in remote/ rural areas, is costly to develop, and setting up the charging infrastructure is also a challenge (E1, U2). Besides access to power, the quality of power is also an issue in rural areas (P2, E2). Even roads might be a problem if they are poor and will need more maintenance (P2). A Lack of awareness about E-mobility technology (E2) and a lack of financing models to attract access/ uptake of E-mobility technology (U2) are also additional issues in the case of rural areas.

Environmental Barriers

A technology may face environmental barriers if it, for example, leads to increased GHG emissions, or local pollution. Electricity based on fossil fuels can be a barrier to E-mobility in a country that uses renewable fuels such as ethanol for transport. This is because it would increase GHG emissions. Environmental barriers can also emerge from waste generated by the technology- in the case of E-mobility it can be the disposal of toxic materials including batteries, particularly when it is scaled up.

Disposal and handling of batteries is already an issue with one of the service providers according to one of the respondents, indicating that the service provider is even planning to close its shop (P4). Normally, in the early stages, waste generation is limited. However, once scaling up is done, significant waste will be generated and therefore handling hazardous waste can be a barrier if proper plans are not made in parallel.

Legal and Regulatory Barriers

These include existing policies and laws, which may be unfriendly for E-mobility. A lack of standards for equipment, for example, a lack of emissions or fuel standards may favour existing internal combustion (IC) technology over E-mobility. EV standards were brought out by the Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works, including voltage classes for EVs (MoTIHUDaPW, 2021). The Kenya Bureau of Standards has developed and adopted standards that apply to electric vehicles imported into the country. Up until now, a total of 24 standards have been developed and adopted, covering specifications and testing procedures for safety aspects as well as performance and power consumption elements (MoTIHUDaPW and GIZ (2019). However, there is a need for standards, particularly for safety standards and charging standards (P2, P4).

In November 2021, the Ministry of Transport, Infrastructure, Housing, Urban Development & Public Works issued a Terms of Reference for consultancy on the development of a national electric mobility policy for Kenya. It will help establish a regulatory framework for charging stations, the development of standards for charging equipment, and the provision of financial incentives for the installation of charging stations. Training (capacity building) may also be needed for this purpose (U1). Also, there is a need for policies to engage gas stations to install charging facilities (U1).

The regulatory framework is poorly developed (E2) and according to one of the respondents, more than making regulations, it is important to enforce the regulations. There is a need to increase the petroleum tax and reduce the tax further on E-mobility (N1). Building codes facilitating charging and lower EVs tax are other measures needed to promote E-mobility (P1). An enabling environment needs to be created for the adoption of the technology through reduced taxes on importation, and other incentives (U1, U2). Reduced excise duty and other taxes on electric buses will drive more adoption of the technology in the country (S1). A tariff for charging electric vehicles should be established to attract the adoption of electric vehicles (P4).

Awareness and Information Barriers

A lack of awareness about E-mobility and its benefits, governmental incentives etc. can also be a prominent barrier to the uptake of technology. The lack of awareness was not limited to end users; even E-mobility companies were found not to be aware of governmental policies. A lack of awareness, for example, included about the applicability of a 10% duty reduction on EV vehicles; not all were aware that it was applicable to 100% battery-powered electric vehicles. Similarly, in a survey of private companies carried out by the Association for Electric Mobility and Development in Africa (AEMDA, 2021), 64% were not aware of the existing E-mobility standards in the country, though the standards had been released in 2019. Similarly, many were not aware that the 10% excise duty was applicable to only four-wheelers.

There is a need for measures to raise awareness about electric mobility and to educate the public about the benefits of electric vehicles. The development of a public education campaign to promote electric mobility, and the inclusion of electric mobility education in school curricula has also been proposed in some forums. A lack of awareness and capacity building are significant issues (E2, P1,) according to some respondents. Demonstration pilots may be needed to create awareness and inform the policy process (P1). Technology marketing efforts are low (P4) and therefore awareness about E-mobility technology availability and its benefits is limited. E-mobility needs to be included in the curriculum of Technical and Vocational institutes (P3). However, about 30% of Kenyans are already aware of E-mobility especially those in urban settings which is the main target market. There is a need to enhance awareness through social media, Radio/TV adverts and promotional channels. (P3). According to the technology provider, awareness of intra-city routes within Nairobi where they operate buses is relatively good, but this needs to be scaled out and promoted in the rural areas. (S1). Demand for E-mobility is also low due to a lack of awareness (E2). Thus, awareness may not be an issue only in certain pockets (such as Nairobi), or for certain products (such as buses that are operating in Nairobi), but awareness remains an issue in general.

4.3 Conclusion

E-mobility in Kenya was kicked-off with the National Climate Change Action Plan (2018–2022), which outlined measures to incorporate EV technical standards, incentives, pilot projects, and public procurement to stimulate the EV sector. Kenya Finance Act (2019) reduced the excise duty for 100% battery-powered electric vehicles from 20% to 10%. The Kenya NEECS, in 2020, set the target of 5% of Kenya's vehicle stock to be electrified by 2025.

Literature surveys and findings from stakeholders' interviews indicate that the electric mobility sector in Kenya currently faces several barriers that hinder its adoption and growth among end users. In this barrier analysis, The PESTELA framework, which encompasses Political and Institutional, Economic and Financial, Social and cultural, Technical and Infrastructure, Environmental, Legal, and Awareness and Information barriers was used.

Though the Kenyan government took the initiative in 2019, it has not allocated resources to promote EVs and is dependent on the private sector to push EVs. The high cost of EVs, particularly the high upfront cost is one of the major barriers to EV scale-up, and a lack of access to finance to enhance its effect. The lack of EV infrastructure is another major barrier to EV penetration in Kenya. There is a need to invest in the development of charging infrastructure to support the growing demand for electric vehicles in the country. Also, there is a need for capacity building through the training of the labour force involved in the operation and maintenance of EVs. Finally, though the public, particularly in Nairobi, is sensitized about electric vehicles, they need to be made aware of their benefits to increase the demand. Also, governmental policies such as incentives for E-mobility, and initiatives such as standards are not that well-known among stakeholders. Awareness needs to be raised in all these areas.

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5. Barrier Analysis for clean cooking in Malawi

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5.1 Introduction to Clean cooking in Malawi

The aim of this chapter is to outline the status of clean cooking in Malawi, the clean cooking solutions being explored through the SESA project as well as the potential barriers to clean cooking solutions and practices in the region.

5.1.1 Status of clean cooking in Malawi

Sustainable Development Goal (SDG) 7 focuses on increasing access to affordable, reliable, sustainable, and modern energy (UN DESA, 2022). While SDG 7 is more concerned with universal and modernised electrification produced from renewable sources, biomass – in the form of firewood, charcoal, and crop residue – for traditional methods of cooking and heating remains the primary energy source for around 75% of people living in sub-Saharan Africa (Schuenemann, Msangi & Zeller, 2017).

Malawi is considered one of the poorest countries in Africa with a rapidly increasing population (Schuenemann, Msangi & Zeller, 2017). Malawi's population is estimated to drastically increase from 14.8 million to 45 million by 2050 (Jagger et al. 2017). Unlike many other African countries, Malawi has a low rate of urbanisation. Thus, at the current rate of urbanisation, most of the estimated population growth will occur in rural areas in Malawi. Over 80% of Malawians currently live in rural areas of which only a small fraction (4%) is connected to the national electricity grid (Walwyn and Hanlin, 2022). Further, poverty levels in Malawi are high with over 50% of the population living below the national poverty line (Walwyn and Hanlin, 2022).

The combination of limited household resources, high numbers of rural households, and limited electrification in rural areas have led to the use of the three-stone fire as the primary cooking stove for ~95% of households in Malawi (Jagger et al. 2017). However, such a cooking method is not sustainable, considering deforestation, health risks, and carbon emissions. Better fuel technologies, improved cookstoves (ICS), and efficient and affordable solutions are strongly needed for Malawi to adapt to sustainable clean cooking. To this end, several alternative clean cooking solutions are available including various locally produced clay ceramic cookstoves (e.g., Chitetzo Mbaula) as well as fan stoves (e.g., Philips HD4012) (Jagger et al. 2017). The accessibility and affordability of the various options make these more or less feasible.

5.1.1.1 Clean cooking in Malawi through the SESA Project

Focusing on clean cooking, the SESA project user case in Malawi aims to reduce the negative impacts of overharvesting biomass resources in the region. SESA has developed a small improved cookstove (ICS) known as MIG Bio-cooker. Through the SESA project, a validation site has been set up in Waliranji, Malawi for local production and distribution of the MIG Bio-cookers. In addition, the SESA project will explore supply and distribution chains for ICS and biofuels including biomass from sunflower waste.

The increased efficiency of ICS technology means they perform much quicker and need less fuelwood thus reducing the time needed for collecting wood and preparing food. With lower fuelwood requirements, transitioning from traditional stoves to ICS across Malawi is a critical intervention to reduce the demand for biomass and lower the rate of deforestation. Increased utilisation of ICS for cooking and heating will also lower the rate of respiratory risks associated with traditional three-stone fire stoves thereby contributing to the overall health and wellness of the population. The sturdy and contained nature of ICS also has less risk of injury and fire.

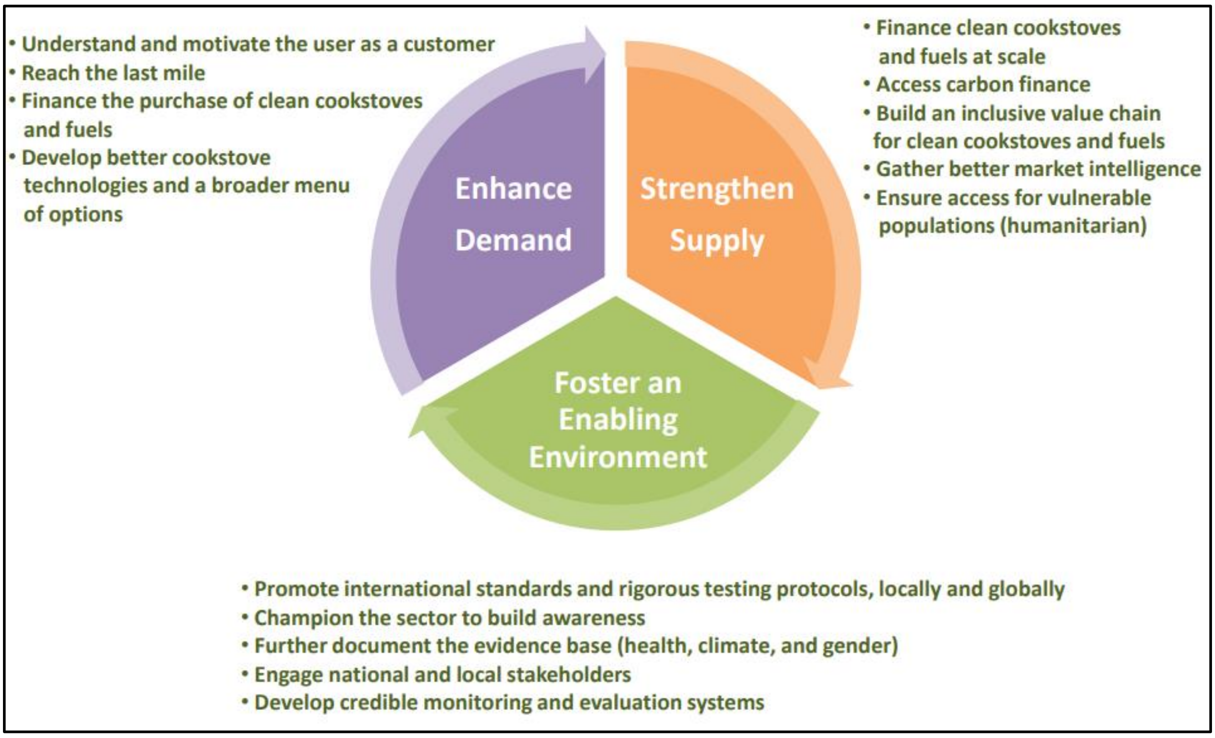
With numerous compelling benefits, there is great potential to develop the cookstove sector. Policies and regulations to improve the ICS sector could include quality standards, VAT and subsidies, reduction in import duties, and forestry regulations for the production, sale and distribution of charcoal (Stevens et al., 2020). Quality standards for ICS production are important to ensure proper manufacturing techniques and quality control checks to improve products and reduce costs thereby reducing maintenance and replacement costs of ICS and thus closing the affordability gaps (Sustainable Energy for All, 2022).

5.2 Barriers to clean cooking in Malawi

5.2.1 Literature survey

Looking at the broader literature, there is a large variance in terms of effective implementation of clean and improved cookstove interventions as energy systems vary across different countries. Nevertheless, the Global Alliance for Clean Cookstoves has developed a three-pronged approach to promote clean cooking (Global Alliance for Clean Cookstoves, 2012). The three aspects are: enhance demand for efficient cooking technologies, strengthen supply for sustainable technologies and fuels, and foster an enabling environment to develop the clean cooking sector (see Figure 1.1). Using this as a contextual approach for analysing policies and regulations pertaining to clean cooking, this section unpacks the barriers that have hindered the effective uptake of clean energy policy and regulation in Malawi. Utilising the PESTELA (Political, Economic, Social, Technological, Environmental, Legal and Awareness and capacity) framework, these barriers are described in Section 5.2.3.

Table 5.1: Strategies for the clean cookstove market.

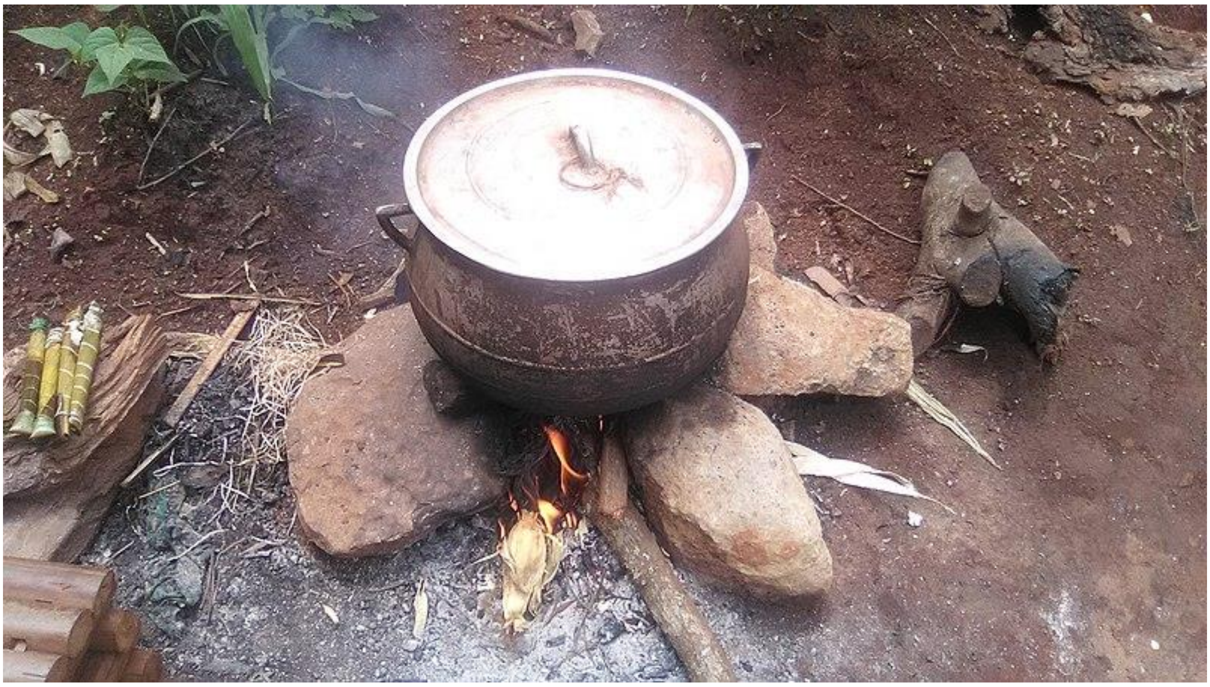


Source: Global Alliance for Clean Cookstoves (2012)

Approaches to cooking

An average kitchen in rural Malawi is a single standalone room comprising brick walls, and a thatched roof, with a large opening for a door and limited ventilation (Jagger et al. 2017). Most rural households (~97%) use a traditional three-stone fire stove for preparing meals (Jagger et al. 2017). Subsequently, most rural households cook on a three-stone set up outdoors to avoid smoke in the kitchen (Coley and Galloway, 2020). As shown in Figure 2.1, the three-stone method comprises three similar-sized stones placed in a triangular shape. In the centre point, a fire is lit. The cooking vessel or pot is placed balancing on the stones very close to the fire to create high heat for cooking.

Figure 5.1: Traditional three-stone fire set-up for cooking (Source: Kondah, 2020).



The choice to utilise a three-stone system is strongly influenced by the fact that clean fuels including electricity are not widely available across Malawi, especially in rural areas. Three-stone systems essentially do not require a financial outlay as the necessary parts – three sizable stones – can be collected from the surrounding environment. The Chitetezo Mbaula, a popular ICS, costs ~$1-2 per unit, however, there are discrepancies in the availability of ICS and maintenance services for ICS across rural areas in Malawi, meaning that it is not always an option in some areas. In addition, access to ICS is affected by retailer presence, cost and loan availability, as well as limited awareness-raising on the benefits of transitioning to ICS. And so, the demand for fuelwood has led to the overharvesting of biomass fuels, including fuelwood, which has contributed to deforestation and forest degradation (Jagger et al. 2017). This is the case in Malawi where rural areas have limited electrification and populations rely on wood fuel for cooking and heating. Jagger et al. (2017) estimate the current deforestation rate at ~2.41 ha per year per village of 100 households. The inefficiency of traditional and three-stone systems also extends to the amount of time spent cooking each day. Three-stone systems take significantly longer to cook an average household meal compared with an ICS. Rural households in Malawi cook each meal every day and almost always over firewood (Coley and Galloway, 2020). This means food security is highly dependent on access to fuelwood (Schuenemann, Msangi & Zeller, 2017). The food preparation responsibilities predominantly fall to women.

Biomass supply

The predominant ecoregion in Malawi is Miombo woodland comprising tropical grasslands, savanna, and shrublands and covering around 92% of the country's forested land (Kachamba, Eid, and Gobakken, 2016). The Miombo provides numerous ecosystem services including water regulation, erosion control, and biodiversity conservation. Many rural populations of Malawi use the shrubs and trees as biomass for cooking and heating and creating tools and furniture. The woodland is also cleared to plant crops. While the woodland provides important natural resources, the demand for fuelwood means there is an annual 0.9% deforestation rate (Kachamba, Eid, and Gobakken, 2016). Among the highest rates across the continent, deforestation in Malawi is linked with flooding, degradation, soil erosion, silting and reduced water flows. Given the current dwindling rates of available biomass supply and the projected increases in demand that will come with population growth, policy measures should not only seek to increase cooking efficiency in Malawi but should also focus on supply measures and increase supply to sustainably keep up with projected population growth in Malawi (Schuenemann, Msangi & Zeller, 2017). Agroforestry is a supply-side measure with the potential to expand biomass supply, while simultaneously improving the protection of forests and increasing food security through improved soil fertiliser. For example, according to their model, Schuenemann, Msangi & Zeller (2017) found that nearly 3 million tons of fuelwood could potentially be produced locally on maize fields, and 2.4 million tons on hybrid maize fields, generating around 5.4 million tons of fuelwood nationally over the next 20 years, equivalent to half the average sustainable supply. In addition, expanding the miombo woodland through agroforestry would cause ~10 million tons of CO2 eq saved, making a significant Malawi contribution to climate change mitigation (Schuenemann, Msangi & Zeller, 2017).

Fuel options

In Malawi, biomass is the predominant cooking fuel, utilised by 94-99% of the population (Schuenemann, Msangi & Zeller, 2017; Jagger et al. 2017; Coley & Galloway, 2020). Given the high reliance on biomass for cooking and heating in Malawi, resource stocks have become degraded. This has and will continue to impact rural communities' access to fuelwood (Jagger et al. 2017). The rate of deforestation in Malawi's miombo woodland – the dominant natural forest type – is 2,8% per year, amongst the highest rates in sub-Saharan Africa (Jagger et al. 2017). Between 1990 and 2010, it is estimated that forest cover declined from 41% to 34% (FAO, 2010).

Even with national goals to expand electrification and renewable energies in Malawi, the utilisation of biomass is still expected to dominate with 88.4% of households expected to continue using fuelwood (Sustainable Energy for All, 2022). Demand for fuelwood is roughly 5-10% below a sustainable supply level and this gap is expected to grow (Schuenemann, Msangi and Zeller, 2017). Projected population growth will cause around a 34% increase in charcoal demand by 2040 (Schuenemann, Msangi & Zeller, 2017).

In terms of fuelwood requirements, the average amount of fuelwood collected annually is estimated at 1,878 kilograms per household (Jagger et al. 2017). As the rate of deforestation increases rural Malawians must travel further distances to procure fuelwood – usually on foot. On average, the collective hours spent collecting fuelwood is 6.3 hours per household per week (Jagger et al. 2017). Generally, the responsibility of collecting fuelwood is placed on women. This amounts to an estimated lost labour time of US$3 604 per year per village (Jagger et al. 2017).

Fuels are procured through various means with major differences in purchasing patterns between urban, peri-urban and rural areas. Liquid petroleum gas (LPG) is used in urban areas, with users purchasing 6 or 9kg cylinders anywhere from twice a month to every three months (Coley & Galloway, 2020). Electricity users – mostly in urban and peri-urban areas – usually purchase the required average units monthly or weekly. In peri-urban areas, charcoal is purchased daily or weekly or monthly with ~12kg required weekly (Coley & Galloway, 2020). As mentioned already, fuelwood is the primary fuel used in rural areas and is primarily gathered freely, though often illegally. Fuelwood is collected either daily, weekly, or monthly (Coley & Galloway, 2020). Fuelwood is gathered in varying amounts and is impacted by the type of technology used for cooking. Studies with a locally produced clay ICS – Chitetezo Mbaula – indicate it requires 53% less fuel which directly reduces the gathering time and volume of wood required (Jagger et al., 2017). Further, the ICS produces 59% less CO, and 50% less PM2.5 when compared with the traditional three-stone fire stove (Jagger et al. 2017). While fuelwood is 'free', it is often illegally overharvested and comes with numerous hidden costs for communities and the environment (London & Fay, 2018). Given the health threats, emissions, deforestation and time associated with open-fire cooking, clean cookstoves and energy-efficient technologies are critical for the policy agenda in environmental, health and gender-related sectors in Malawi.

Traditional cooking set-ups

While the current dominant cooking system of three-stone fire is the most accessible, it comes with its own obstacles. Some of the key challenges include i) risk of illness and slipping when collecting during the rainy season, ii) demand on time for collecting sufficient fuelwood and cooking, iii) access to fuelwood and exposure to danger during fuel collection (threats including sexual assault), iv) safety threats from forest guards and fines, v) rain-soaked fuels during the rainy season causing difficulty with burning vi) heat and discomfort due to high temperatures and poor heat retention by the three-stone setup, and vii) health and safety hazards associated with open fire and smoke.

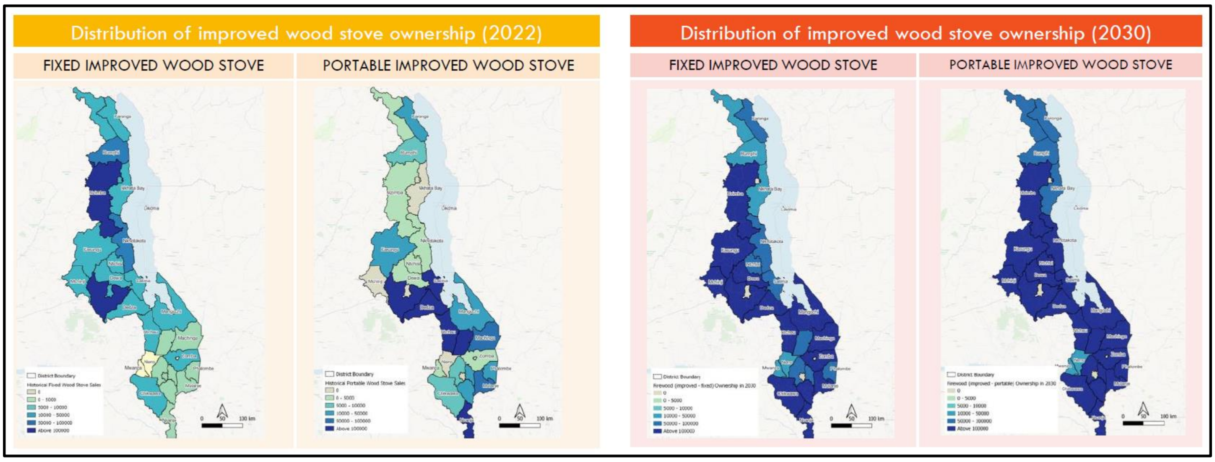
Health threats of traditional three-stone cooking methods are multiple. Due to inefficient combustion of biomass, traditional cooking methods increase exposure to household air pollution and health risks including acute respiratory infection (ARI), chronic obstructive pulmonary disease (COPD), and low birth rates. Furthermore, lower respiratory tract infections – which are strongly associated with household air pollution – are a key cause of death in Malawi (Jagger et al. 2017). Despite health threats, cookstoves are often used by rural customers to not only cook food but also to heat internal spaces. This makes shifting away from open three-stone fires and basic wood stoves a challenge as the cooking stove provides parallel benefits for users (Sustainable Energy for All, 2022).

In addition to the individual health threats, traditional open fire systems produce black carbon and various particulate matter, significantly contributing to regional climate change which threatens economic development and food security (Jagger et al. 2017). Jagger et al. (2017) estimate an average of 80,240 kg C per year per village of 100 households.

Improved cookstoves

There are several improved cookstoves (ICS) on the market in Malawi including the portable clay Chitetezo Mbaula which costs ~$1-2 per unit. While most ICS utilise the same fuel types as traditional cooking (wood, charcoal, agricultural residue, etc.), ICS work by containing combustion in an insulated chamber causing more concentrated and retained heat that is directed to the top where the pot sits. Their efficient design means these stoves require less than half the fuelwood compared with an open fire set-up. Further, the contained design means that smoke pollution is drastically reduced thereby decreasing respiratory health risks. In 2013, the Government of Malawi set the goal of distributing 2 million ICS to households across the country by 2020. By reaching this goal around half of the population was supported in transitioning to ICS (Schuenemann, Msangi & Zeller, 2017). Through the National Cookstove Steering Committee (NCSC) – specifically established to fulfil this purpose – and with support from partners, the Malawian government was able to reach this target. The benefits associated with clean cooking make this an ongoing priority for the Government of Malawi with projections indicating consistent uptake in the coming years (Figure 5.3).

Figure 5.2: Map illustrating ownership of improved wood stoves per district in Malawi in 2022 and the projections for 2030 based on the Compact target (Sustainable Energy for All, 2022).



Role of women

Women and girls are disproportionately impacted by traditional cooking. Generally, in Malawi, women and young girls assume the cooking responsibility, spending on average 5-6 hours cooking per day (Sustainable Energy for All, 2022). This has a major impact on women and girls having time to pursue education and other opportunities. In addition, women and young girls are also primarily responsible for securing cooking fuelwood and producing food crops (Schuenemann, Msangi & Zeller, 2017). With rapid deforestation happening across Malawi (~0.9% per annum), women and young girls must travel further to collect sufficient stocks of fuelwood amounting to an average of 6.3 hours per household per week (Jagger et al. 2017). Not only does this further exacerbate their poverty, but it also puts them at risk for violence and exposure to danger having to travel big distances from home (London & Fay, 2018).

The health risks associated with open-fire cooking also affect women – as well as young children – disproportionately as they do most of the cooking. Inefficient combustion of three-stone set-ups results in particulate matter and air pollution that is associated with numerous serious issues such as pneumonia, heart disease, and burn accidents (London & Fay, 2018). Given their proximity and exposure to air pollution from traditional cooking, women, girls and children are more at risk of respiratory diseases related to smoke inhalation and danger from open fire.

Despite the numerous disadvantages of traditional cookstoves and many benefits of upscaling clean cooking, one major gendered obstacle is the limited agency of women – as the primary cooks – to make decisions about their cooking equipment and preferred fuel. Household finances are often controlled by the males who are more removed from the hardships experienced by women doing the cooking and collecting fuelwood (Coley and Galloway, 2020). There is a critical "...disconnection between those who use cooking devices, and those who have most of the agency to change cooking habits." (Coley & Galloway, 2020). This power imbalance hinders behavioural change (Coley & Galloway, 2020).

From the literature, it emerged that over and above improved efficiencies in cooking and fuelwood collection, women stand to gain in several other ways from improved cookstoves and fuel value chains. There are income generation and entrepreneurship opportunities including, for example, stove production, charcoal production, marketing clean cookers, and money lending for stove purchases (Sustainable Energy for All, 2022). There is a major opportunity to enhance the national GDP and the living standards of women across the country through practical training in gender programmes focused on improved cookstoves and fuel value chains (Sustainable Energy for All, 2022).

Clean cooking in policy

In 2018 the Government of Malawi made public the updated *National Energy Policy (NEP) (2018)* to replace the 2003 NEP. The NEP (2018) recognised the crucial role of efficient and accessible energy in economic development, social upliftment and health. The NEP is the primary guiding framework for increasing access to affordable, reliable, sustainable, and modern energy for all sectors and every person in the country (Government of Malawi, 2018). The national energy priorities outlined in the NEP are explicitly aligned with nationally relevant SDGs and the Sustainable Energy for All (SE4ALL) Initiative. It includes targets for access to electricity for 15% of the population, increasing coordination on the use of different sources of energy, minimum standards (e.g., 30% more efficient), and covers many sectors[5] [E1].

The NEP has identified several priority areas. Of relevance to clean cooking are priority areas; 2- Biomass and 8- Demand Side Management for biomass end-use. The aim is to ensure adequate production and supply of biofuels at affordable prices, promoting a coal supply industry that is more efficient and competitive, harnessing clean technologies that eliminate or greatly reduce harmful emissions, ensuring that biomass is sustainably used, and carbon emissions are reduced using energy-efficient technologies (Government of Malawi, 2018). The NEP is currently under review and an updated version is expected in 2023. One area identified for improvement is government support for innovators in the clean cooking sector [E1].

The *Malawi Integrated Energy Plan (IEP) 2022* includes clean cooking as one of its three focus areas. Key areas covered in the IEP relating to clean cooking include: i) improved cookstove expansion (improved wood stoves, improved charcoal stoves), ii) biomass utilisation, iii) e-cooking for grid-tied homes, iv) LPG expansion, and v) alternative fuels (including bioethanol, biogas, pellet/briquettes). To identify pathways and opportunities for expanding energy access, the IEP considers both supply- and demand-side factors. The IEP motivates these transitions noting direct and co-benefits such as reduced health issues from cleaner air and safer cooking technologies, reduced carbon emissions, reduced wood fuel demand and associated deforestation (SEforALL, 2022).

The *SDG7 Cleaner Cooking Energy Compact*, as part of a broader energy sector compact developed by the Government of Malawi, lays out Malawi's ambitions to achieve Sustainable Development Goal 7 (SDG7) – access to affordable, reliable, sustainable and modern energy for all – by 2030 (Ministry of Energy, 2021). The Cleaner Cooking Energy Compact includes several national targets specified by Malawi to support certain SDG7 targets, thus contributing to universal access to cleaner cooking technology. SDG7 falls under the mandate of Malawi's Ministry of Energy – now the Ministry of Natural Resources, Energy and Mining.

The targets set out in the compact focus on the phase-out of open fire set-ups, increased efficient wood stoves, decreased utilisation of non-renewable biomass, and the expansion of alternative fuels. The details of Malawi's commitments to the SDG7 ambitions are listed in Table 5.1 below. For each of the SDG targets, there are set indicators that can be utilised to measure a country's progress (UN DESA, 2022).

[5] The NEP policies, including the issuing of any required licences, are administered by the Malawi Energy Regulatory Authority (MERA), while the Malawi Revenue Authority (MRA) oversee all fiscal matters including import duties and VAT (USAID, 2020). The Malawi Bureau of Standards (MBS) are responsible for the certification of products which meet national standards.

Figure 5.3: SDG7 targets and respective aims of Malawi to achieve clean cooking.

SDG7 Targets	Malawi Target
7.1. By 2030, ensure universal access to affordable, reliable and cleaner energy services.	Universal access to cleaner cooking solutions for all ● Rural population phases out open fires through universal (100%) access to transitional, efficient wood stoves. ● Urban population reduces the share of unsustainably produced charcoal and transitions to alternative cooking fuels and/or sustainably produced charcoal. ● Commercial and institutional users of cooking/heating energy transition to sustainable sources of fuel, efficient technologies for institutional catering and productive use of renewable energies
7.2. By 2030, increase substantially the share of renewable energy in the global energy mix.	● Decrease the share of non-renewable biomass through sustainable and regulated production and sourcing of a mix of cooking fuels including. ● renewable biofuels (e.g., solid biomass, ethanol, biogas etc.), LPG, and electricity from renewable sources, on a pathway to net-zero emissions by 2050 ● Green economy investment measures for sustainable sourcing and production of alternative fuels, e.g., solar electricity generation, waste-to-energy projects to produce biogas, pellets, briquettes (including the provision of appropriated stoves corresponding to respective fuel types)

From the existing policy, it is evident that clean cooking is recognised as a key pathway for development at a national level for Malawi. Nevertheless, there are gaps for improvement.

5.2.2 Stakeholders' Consultations and Barrier Analysis

5.2.2.1 Barriers Framework

The barrier framework discussed in Chapter 2 has been used to analyse the barriers to the adoption and scale-up of clean cooking in Malawi. The barriers framework with specific reference to clean cooking is covered below in section 5.2.3 (Stakeholders' consultations and analysis of responses), where these barriers are discussed in detail.

5.2.2.2 Identification of stakeholders

As indicated in Chapter 2, stakeholders were identified in six categories as follows:

- **Policymakers:** These included the Ministry of Energy (Department of Energy Affairs), the Ministry of Natural Resources and Climate Change, and the Centre for Agricultural Transformation. Of these listed institutions, two were interviewed by partners (ICLEI Africa).
- **Suppliers of technology (solution providers):** Several service providers and projects were identified for interviews including Facilitators of Community Transformation [FACT], ENDEV Malawi (GIZ), Hestian Project, and RENAMA (RENEWABLE Malawi). Only one responded to our interview request.
- **Funding agencies:** No funding agencies were available for interviews.
- **Experts (Academia and other experts):** An expert from Land O'Lakes Venture37 (Centre for Agricultural Transformation) was interviewed.
- **NGOs:** An expert from Facilitators of Community Transformation [FACT] was interviewed.
- **End users:** The end user surveys were unable to take place in the interview and survey timeframe.

The list of stakeholders' organisations/institutions is given in Appendix 4. Each stakeholder institution has been assigned an ID number to understand the perception of specific categories of stakeholders on barriers properly.

5.2.3 Stakeholder consultations and analysis of responses

Questionnaires were prepared to cover the six categories of barriers and administered to the above stakeholders by partners from ICLEI Africa. The questionnaire is given in Appendix 5.

5.2.4 Barriers

Using the PESTELA framework described in Chapter 2, the responses from stakeholders to the questions on barriers to clean cooking in Malawi are discussed and summarised below.

Political and institutional barriers

The national government recognises the need to transition away from heavy reliance on biomass and towards sustainable and efficient technologies. In terms of institutional structures, the Government of Malawi set up the Malawi Clean Cooking Association in 2013 to distribute two million ICS by 2020 ([P1], Schuenemann, Msangi & Zeller, 2017). The Malawi Clean Cooking Association is an ideal strategic partner for finance and inclusion initiatives. Drawing on their networks and expertise in the field, strategic partnerships with government leaders, microfinance institutes, local businesses, community-based organisations (CBOs), including local Saving and Credit Cooperative Societies (SACCOS) and religious leaders could be a useful starting point for establishing viable financial mechanisms to scale up clean cooking in Malawi. The steering committee is making efforts to update clean cooking targets aligned with MalawiVission2063.

Despite Malawi being a clean cooking champion with many players in the green economy sector [P1], additional efforts are required given the increasing population and subsequent increasing demands for fuelwood. Despite strong efforts, limited resources and capacity constraints are major challenges for the Malawian government to transition towards universal clean cooking in Malawi. More specifically, the Malawian national budget is severely constrained thus limiting the extent to which national plans and upscale schemes can be implemented [P1]. Additionally, limited cross-level coordination can exacerbate already constrained governmental efforts. While there is institutional recognition and support for clean cooking efforts amongst the energy and natural resources sectors, one interviewee recommended that clean cooking efforts in Malawi could be enhanced by integrating clean cooking into other departments and their policies especially those concerned with gender and private commerce to improve coordination and resource sharing[P1].

From both interviews and literature, it is evident that the value and co-benefits of clean cooking alternatives in Malawi are gaining momentum. This realisation is also being reflected by the increasing integration of clean cooking solutions into Malawi's institutional priorities and actions. Nevertheless, there is a need for planning on how to scale the increased requirement in future by political leadership.

Economic and financial barriers

In many African countries accessing finance can be challenging, particularly for small-scale producers and artisans, who are often considered informal, lacking accounting records, and without sufficient collateral (Stevens et al., 2020). A major challenge is that government resources and budgets change, and finances fluctuate over time thus affecting priorities [N1]. Given that Malawi is one of the poorest countries in Africa, economic resources and opportunities are limited. Despite the business models being established, access to finance to meet upfront costs affects both artisans – who may be unable to access finance for capital outlay – and end-users who may be unable to access loans because of a lack of collateral [E1]. While the Government of Malawi has rolled out wide-scale programmes to distribute free ICS, an entirely subsidised scheme is contentious as there is an inherent issue of sustainability (donation vs purchasing). For long-term viability, there has been lobbying amongst the clean cooking steering committee to shift to a paid scheme. In this model, 10% of the most vulnerable members of society – women- and child-headed households – are given subsidies for ICS thus ICS are made equitably available [E1, N1].

In addition, it can be extremely difficult to make a case to poor users for ICS and sustainable fuels as it involves buying and maintenance costs of the ICS, which may be unaffordable, compared with three stone fire stove using wood, which can be collected for free. To counteract this, the Malawian government has focused on sustainable models that reduce production costs, through several approaches, including i) a grant programme for start-up capital for ICS producers, ii) establishing partnerships with private sector partners to promote financing, and iii) encouraging local construction by local artisans with local materials. Together, these steps bring the overall costs of ICS down [P1, E1]. Additionally, while the government has already removed import duties on the requisite materials for clean cooking technology, VAT (16.5%) on ICS is still a barrier [E1]. The clean cooking steering committee see this as a barrier that makes ICS less competitive and is calling to remove VAT [E1].

In terms of economic and fiscal viability, Malawi faces some significant challenges. End-user finance for cookstoves is not widely available in sub-Saharan Africa, mostly because loan sizes for cookstoves are too low for banks and microfinance institutions, but too high for cash purchases ([P1], Stevens et al., 2020). Where finance is available it tends to come with very high interest rates. One possible solution to increase access to loan finance and overcome limited collateral on the part of the loan seeker is for development finance institutions to partner with commercial banks in Malawi to offer 50-70% collateral for SMEs as credit guarantees [E1]. In parallel, SMEs could receive capacity building and training in terms of administration, running a business, business plan development, market understanding, and market dynamics to enhance their business management skills [E1]. Partnering with SMEs to do last-mile distribution and including incentives to sell more would also help to connect ICS with the market [E1]. Policy and government guidance on credit options and business models such as pay-as-you-go (PAYGO) or rent-to-buy models on clean cooking for consumers in rural areas may also be useful options, but a market analysis is needed to understand the socioeconomic acceptance, consumer awareness and access to microfinance for these options (E1, Stevens et al., 2020). Nevertheless, there is great potential for job creation through expanding clean cooking [N1]. There are logistics, distribution and marketing structures – both formal and informal – already in place which could be used and converted or adapted to accommodate clean cooking [N1]. These structures and channels are important and should be identified to increase viability.

Government support to access loan finance for ICS in Malawi is extremely limited. While the rural population is about 84% in Malawi, over 40% of lending happens in urban areas (USAID, 2020). To fill this gap, there are 47 Saving and Credit Cooperative Societies (SACCOS) in the country. However, less than 1% of the population is registered with one of the SACCOS (USAID, 2020). Nevertheless, SACCOS may potentially play a key role in providing access to finance for clean cooking as they generally cater to rural areas and members include civil servants and women's groups.

Another barrier is the cost of producing sustainable fuels in the form of briquettes and/or pellets. The production, transport and retail costs associated with supplying sustainably harvested biomass products mean the companies would incur costs that simply do not exist with free illegally collected biomass, which makes it extremely challenging to compete (USAID, 2020). Innovative business models are required to effectively develop the market for sustainable biofuels.

In terms of improving sustainable supply chains for clean cooking, there are several focus areas [P1]:

- Alternative livelihoods for those harvesting/producing illegally.
- LPG promotion in urban areas
- Increasing gas-filling suppliers
- Demonstration and awareness raising of sustainable briquettes and pellets.
- Upscale suppliers of sustainable briquettes and pellets

Social and cultural barriers

Access and affordability are major obstacles to the uptake of ICS across Malawi. While the government has tried to close these gaps through distribution programmes, most Malawians live in rural areas, considered to be below the poverty line, and with few last-mile distribution and service channels available (USAID, 2020). Thus, access is very limited for those who would benefit from cleaner cooking without state intervention. Related to this is the matter of access to affordable sustainably harvested fuels. Another complexity is that in rural Malawi, most of the cooking is done by females, whereas males tend to oversee household finances. Thus, there is a limited agency of those who cook to make financial decisions about cooking technology (Coley and Galloway, 2020). Partnerships are needed to necessitate progress by engaging Civil Society Organisations (CSOs) that can speak for communities and private sector players [N1].

When clean cooking is introduced, a full transition to ICS tends to happen slowly with households continuing to use traditional methods alongside the new ICS (Dagnachew et al., 2020). This is known as 'fuel stacking' and may occur due to uncertainty about the new technology, long-standing behavioural preference, or cultural obstacles. The stacking hierarchy in Malawi is as follows: fuelwood, charcoal, electricity, and LPG (USAID, 2020). Similarly, ICS can be perceived as 'foreign' and unable to achieve the same cooking style associated with traditional meals, thus hindering the full uptake and potential effectiveness of cleaner cooking technology. Further, cooking technologies may have uses beyond cooking food, such as heating internal spaces and boiling water for cleaning and bathing. These multiple uses can often be overlooked in energy plans focusing solely on cooking (Government of Malawi, 2022).

In addition to burning fuels more efficiently using ICS, promoting efficient cooking practices offers low-hanging fruit to further reduce demand for fuelwood (Coley and Galloway, 2020). Efficient cooking practices include using lids on pots to retain heat and soaking beans to reduce cooking times, using pressure cookers or heat retention blankets (Coley and Galloway, 2020). Comprehensively energy efficiency programmes have not been implemented in Malawi which has inevitably led to wasted biomass energy (Government of Malawi, 2018). Promoting efficient cooking practices through raising is further discussed in section 5.3.2.7.

Technology and infrastructure barriers

In terms of skill and labour capacity to produce and maintain ICS in Malawi, it was noted in several of the stakeholder interviews that skill and capacity exist amongst the population – as was demonstrated through the initiation of the Chitetezo Mbaula – but that any support to improve skill and capacity for clean cooking could lead to improvement and would be welcomed [P1, E1, N1]. The government supports an ongoing capacity building programme to produce the Chitetezo Mbaula to maintain a certain standard of quality [P1]. These producers stand out as well-trained, producing good quality products [E1]. Safety and quality can be of concern with a new technology and there isn't a lab for testing cookstoves efficiency in Malawi. Thus, the performance of different types of ICS varies. Less reliable and inefficient models are usually due to poor training [E1]. A lack of maintenance facilities for ICS can be a major barrier to the long-term sustainability of cleaner cooking, especially in rural areas. There may also be hesitation around new technology and how to use it, which may require training. This training is useful for keeping up to date with new technology [P1]. Additionally, the Government of Malawi should implement standards for testing and training to standardise the quality and performance of ICS.

Many of the ICS on the market are made from natural materials which wear with use. For this reason, most of the ICS have a lifespan of about one year before needing replacement [N1]. The use of local materials helps to keep costs down but there is room for improvements in the quality and reliability of the ICS design to increase the lifespan of the product [P1]. As was pointed out in several interviews, there has been an increase in willingness to pay for ICS, as beneficiaries are seeing the benefits (e.g., fewer fuelwood requirements, less smoke and improved health, cleaner, etc.), which increases the likelihood of users replacing their stove when it breaks [P1, E1].

Environmental barriers

Based on the interviewees' responses, the ICS has minimal negative environmental impacts [P1, E1, N1]. Rather the environmental threats are more associated with the traditional three-stone method of cooking. The widespread deforestation and ecosystem degradation associated with traditional cooking provides a strong ecological basis to transition to cleaner cooking. Through strategic action, Malawi aims to reduce fuelwood use by ~34% and charcoal use by ~78% by 2030 (Sustainable Energy for All, 2022). Despite this, the 'freely' available wood fuel may seem to be more accessible (at least in the immediate short term) for many people. Different methods for harvesting fuelwood can have a major impact on the sustainability of supply (Dagnachew et al., 2020). Another environmental factor is that a technology with high Greenhouse Gas (GHG) emissions reduction potential may be supported by policymakers as well as donors. Furthermore, a technology offering reduction in air pollution may be supported by policymakers and local stakeholders.

Additional environmental barriers are closely linked to limited knowledge and awareness of environmental degradation practices. For example, while cutting trees is illegal, people may not know this and may not be aware of the detrimental environmental consequences of doing so [E1]. Further, producers of illegal charcoal may have limited livelihood options. There is a need to work with "illegal producers" to bring them into alternative livelihoods in conjunction with awareness raising [E1]. Clean cooking is an easy sector to change practices that can lead to major improvements in waste reduction, resource consumption and GHG emissions [N1]. Therefore, ICS have no environmental barriers. Rather, the use of ICS is beneficial for the environment.

Legal and regulatory barriers

The Government of Malawi recognises the crises posed by the widespread use of non-efficient cooking technologies and this is reflected in numerous national policies and plans. While local level policy and plans are less readily available, several policies and strategies are in existence relating to clean cooking, energy and resilience in Malawi including the *National Energy Policy (NEP) (2018)* and the *Malawi Integrated Energy Plan (2022)* which aim to increase energy resilience and reduce the use of fuelwood by enhancing conditions for clean cooking alternatives including e-cooking (for grid-connected households) and LPG.

Policy measures for increasing cooking efficiency are important but not sufficient to overcome the growing demands that will accompany the increasing population of Malawi. Thus, policy measures for supply-side measures are necessary to increase sustainable supply through, for example, agroforestry for biomass energy. In addition, further efforts are required to ensure alignment with national and local policies around clean cooking practices.

Another issue is that the biomass fuel market is dominated by illegal charcoal with limited regulation (USAID, 2020). Illegal and over-harvesting of fuel wood and charcoal created the need to transition away from heavy reliance on biomass and towards sustainable and efficient technologies. There is good legislation in place, however, more law enforcement is needed to discourage illegal activity [E1]. The steering committee should help advocate for this. The demand side requires legislation to overcome the illegal collection and harvesting of biomass and charcoal which is often sold to urban and peri-urban residents as neither electricity nor LPG supply is consistently available [E1].

There is also a lack of technical standards and user-friendly procedures to govern ICS and renewable fuels which would support this legislation. It was noted in interviews that there is a need for more thorough minimum standards for different types of ICS made of different materials [P1]. legislation that engenders minimum standards, protocols and testing will promote good and reliable ICS production and reduce sub-standard products that may be cheap but unreliable or unsafe for the market [N1]. Related to this, it was suggested that counterfeit products and copyrights be addressed in laws governing the production of ICS [N1].

Awareness and information barriers

While the reasons for not exploring clean cooking options may include access and affordability issues, poor uptake can also be influenced by limited knowledge. In terms of knowledge on improved cookstoves, important thematic considerations include outlay and maintenance costs of the cookstove, quality assurance standards, distributor location and distributor criteria, guidance on how to use the cookstove, common issues and fixes, safety and fire responses, and opportunities to access credit/loans. Strategies and approaches to support knowledge escalation could make use of radio presence, door-to-door educational campaigns, community-led marketing initiatives, community days, and videos to be shared on social media. To improve the success of awareness raising, some key logistical considerations include engaging groups associated with information sharing (for example, young adult females and adolescents), and researching preferred information channels (e.g., radio, tv, posters, and social media).

In many cases, lack of exposure and awareness of the use and benefits of ICS causes a major barrier to ICS uptake (USAID, 2020). Despite the already established business models for clean cooking in Malawi, sensitisation, demonstration and training, and promotional measures may be needed especially in the initial stage of introducing a new technology especially in rural areas with limited exposure [E1]. Over and above the user level communication, it is useful to have ICS and energy resilience awareness-raising at different levels and across relevant sectors to communicate policies and create awareness about ICS and its benefits. Given the strong correlation between cooking food and women, targeted gender programmes on improved cookstoves and fuel value chains could improve the success of awareness-raising campaigns (Sustainable Energy for All, 2022).

In Malawi, there are multiple approaches available to raise awareness and demonstrate clean cooking to the market, but peer-orientated awareness models are recommended [E1, N1]. Key people can be trained as change agents, going beyond market agents. For this to work it is important to focus on embedding the new technology/practice in a cultural transition, for example through engaging local traditional leaders to increase buy-in and sustainable uptake [N1]. It was noted that using different existing structures in communities – including chiefs, women's groups, and faith groups (98% of Malawians belong to a faith) is very helpful [N1]. It was proposed that there are Village Development Committees in each village which may be a key entry point for introducing new technology into a village [P1]. The Village Development Committees can be contacted via agriculture extension workers and village development officers (Min of Energy has connections). Similarly, another useful entry point is to engage with "lead farmers" to advocate new technologies for awareness raising. Lead farmers are identified as early adopters by other district sectors – especially agriculture – as key champions for introducing new technologies into communities [E1]. Entering through existing structures and approaching leaders is an already established and proven effective method for raising awareness and increasing buy-in amongst rural communities in Malawi [P1]. Nevertheless, change often doesn't happen overnight and must be seen as part of a process of transition [N1].

During interviews, it was also noted that there are regular LPG demonstration shows where stakeholders, particularly in the energy sector, are invited to showcase and engage with new developments in the sector. Present are LPG players, briquette makers, and ICS producers, amongst others. These demonstrations are hosted in the main cities and mainly focus on LPG. However, this model could be used, shifting focus onto the supply and demand of ICS and fuel and expanding into rural areas [P1].

5.3 Conclusions

Clean cooking alternatives have multiple co-benefits including end-user affordability, improved public health (air quality), reduced deforestation, less time spent gathering/purchasing fuel, and reduced emissions (Government of Malawi & Global Energy Alliance for People and Planet, 2022). These benefits are recognised, and efforts are in place to upscale access across the country. There is political will and legislation including the *National Energy Policy (2018)* and the *Integrated Energy Plan (2022*), and the SDG7 Cleaner Cooking Energy Compact. There are efforts to make improvements amongst the steering committee to update clean cooking targets aligned with MalawiVission2063.

Literature surveys and findings from stakeholder interviews indicate that the clean cooking sector in Malawi currently faces several barriers that hinder its adoption and growth among end users. In this barrier analysis, the PESTELA framework, which encompasses Political and institutional, Economic and financial, Social and cultural, Technical and infrastructure, Environmental, Legal, and Awareness and information barriers was used.

Clean cooking in Malawi, and particularly the technology for ICS, has been intentionally designed to be easy to produce and easy to use. In terms of barriers, it is more social and economic challenges that hinder the upscaling of ICS, than policy barriers in Malawi.

Rural areas, which are home to most of Malawi's population, have very marginal access to electricity thus often relying on open fires, illegally harvested charcoal and fuelwood to cook food. These communities suffer health consequences from smoke, time poverty from collecting fuel and inefficient cooking setups. Furthermore, reliance on fuelwood contributes to deforestation, health risks, and GHG emissions. Changing energy needs through cooking practices is a relatively simple solution with multiple benefits to users and the environment. To minimise costs and maximise the benefits of clean cooking for the community it is important to concentrate on: i) expanding access to finance for start-up producers and other players in the clean cooking value chain, ii) exploring loan finance and collateral for end users, iii) implementing minimum standards and quality testing, iv) supporting local training and local production, v) increasing ICS maintenance services, and vi) developing strategic sensitization and awareness raising campaigns, including the integration of early adopters.

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6. Barrier Analysis for Second-Life Use of EV Batteries in South Africa

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6.1 Introduction and literature review

One of the key pillars to achieving global climate and clean energy goals is the transition away from fossil fuels and towards primarily low-carbon and renewable sources of energy. Renewable sources of energy, particularly solar, bring with them the benefit of their decentralized nature, allowing energy to be generated closer to demand centres, including in remote and underserved communities. However, their variable nature implies that some enabler technologies are needed to balance their generation with the demand for energy and provide much-needed flexibility for the grid or system. Battery storage, at the utility or even smaller scales, is one of the key enabling technologies that can enable the uptake of renewable energy in the short term and provide this flexibility. This is because it is relatively easier to scale up and deploy compared to other storage technologies.

The production of lithium-ion batteries—the kinds used in most electronic devices and electric vehicles (EVs)— has ramped up in the past decade, resulting in rapidly falling costs through improved economies of scale and research and development efforts (Hutchins, 2021). As of 2017, li-ion batteries were mostly used in EVs (Tsiropoulos, Tarvydas, & Lebedeva, 2018). More recent estimates suggest that lithium-ion battery capacity is around 948 GWh globally, with around 274 GWh used in the automotive sector (S&P Global, 2022). Several scenarios suggest that demand will only continue to grow with the need for electricity storage as well as to power EVs, increasing the need to rapidly scale up production to match demand (IRENA, 2022; IEA, 2022; S&P Global, 2022). These scenarios also suggest that lithium prices could potentially act as an obstacle to further cost reductions for battery technology (IEA, 2022).

To potentially side-step supply chain constraints and high prices of raw materials, other alternative models of sourcing batteries for various uses can be encouraged, particularly circular models that can reduce battery costs, and the need for raw materials, and result in reduced emissions from production activities. Given that EVs will form a large part of lithium-ion battery demand and subsequent future waste streams, tapping their potential for alternative uses and business models seems promising (Engel, Hertzke, & Siccardo, 2019).

6.1.1 Trends in South Africa's mobility sector

The global transition to sustainable forms of mobility, particularly electric mobility, has picked up speed in recent years. Road transport accounts for roughly 16% of global carbon dioxide (CO_2) emissions (IEA, 2022). Electric vehicles accounted for around 10% of global car sales in 2021 (IEA, 2022). However, this transition seems confined primarily to large markets such as China, Europe, and the United States now, where purchasing power and government commitment to this shift align and reinforce each other. Countries in Africa such as South Africa—one of the continent's largest economies—may still be primarily dependent on fossil fuels for mobility but will not remain untouched by global trends. As of 2018, the transport sector accounted for about 10.8% of South Africa's greenhouse gas (GHG) emissions (Department of Transport, 2018). However, the government's strategy has been to promote alternatives to fossil fuels—not limited only to electricity but including other alternatives such as biofuels as well. As mentioned by some of the interviewees in subsequent sections, this is due to the large road distances in the country and other transportation planning constraints, as well as the large trucking industry that is critical for South Africa's mining and agriculture sector and which is considered difficult to electrify.

6.1.2 Second-life uses of EV batteries

As the number of EVs increases globally, so does the challenge of managing their components as they reach the end of their life, particularly their batteries. Formal value chains for end-of-life (EoL) management for EV lithium-ion battery packs are not yet well established, even in major markets (Curtis, Smith, Buchanan, & Heath, 2021; Christensen, Mrozik, & Wise, 2023). Electronic waste (e-waste) in general, from consumer electronics such as computers and mobile phones, continues to pose an environmental and economic problem given its volume. Around 53.6 million metric tons of e-waste were generated in 2019 globally (UNITAR, 2020). This waste stream contains both hazardous materials that need to be disposed of properly, and valuable resources that can be recovered for reuse. Given the projected volumes of EVs in most net-zero compatible scenarios, EV batteries reaching their end-of-life will massively contribute to the scale of the e-waste problem (Christensen, Mrozik, & Wise, 2023).

As mentioned in the previous section, electric vehicles are not the only technology in which lithium-ion batteries are used—they also compete with uses in stationary storage applications. Given concerns about production capacity and battery prices in the short- to medium-term, alternative ways of chanelling the waste stream of EV batteries can unlock new revenue streams and value chains while promoting circular business practices to reduce resource use, costs, and emissions intensity in production. While EV batteries degrade with use and at a certain point are no longer fit for use in vehicles given the loads and stresses encountered, they still retain around 70-80% of their capacity at the end of their life (Enel X, n.d.). At this point, after around 10–20 years of use depending on usage patterns and barring any accidents or damage, they can be assessed, repaired, and repurposed for other functions such as stationary storage. This can help improve the overall business case for the batteries themselves (often the most expensive component of an EV), as they can theoretically generate revenue for longer, and simultaneously incentivize the stakeholders responsible for their collection and disposal to take action in this regard, leading to new employment and value creation.

Second-life batteries have a significant cost advantage over new batteries and can reduce overall costs for stationary storage to be used in combination with decentralized electricity generation technologies, such as solar photovoltaics (PV). This cost advantage is estimated to be around 30–70% at present rates; however, if the costs of new lithium-ion batteries continue to fall, this advantage will shrink (Engel, Hertzke, & Siccardo, 2019; Zhu, et al., 2021). Promoting second life uses ensures that when batteries reach their true end-of-life and are subsequently recycled or disposed of most of their value has been extracted, improving resource use efficiency and reducing the environmental impacts of battery production. In most cases, second-life batteries would use fewer materials and be less energy-intensive to produce, resulting in lower emissions and costs (Engel, Hertzke, & Siccardo, 2019).

The potential uses vary. Second-life batteries could be used in home systems, provided they are adequately tested, and their safety is not compromised. They could also be used in industrial-scale operations, or to provide ancillary grid services, as well as to enable EV charging stations (Thielmann, et al., 2020). They can also be used in smaller vehicles, such as two- or three-wheelers, as well as for solar-powered devices and backup power (Forth, 2022). While second life uses can expand the revenue-generating lifespan of batteries, when they reach their true end-of-life, they will still need to be dismantled, recycled, and disposed of appropriately.

6.1.3 Second-life EV batteries in containerized solar solutions in South Africa

South Africa has a relatively high electrification rate of 84.4% (World Bank, 2020). However, the reliability of its electricity supply is an issue, leading to the rapidly growing demand for small-scale solar generation systems. A large part of this demand comes from households that are interested in and can afford backup power, in order to avoid load-shedding and power cuts initiated by the state-owned power utility, Eskom. Many of these systems are undeclared or not supplying power to the grid while using only a small percentage of their generating capacity (Bavier & Mukherjee, 2022; Winkler, 2023). However, Eskom does provide resources and remuneration to registered systems wanting to export electricity to the grid, through its Small-Scale Embedded Generation (SSEG) regulations (Eskom, n.d.). It is conceivable that with lower costs, such systems would be more accessible to a larger share of the population.

Deploying such decentralized solutions, including off-grid mini-grids, is also a viable option for certain remote areas or areas where grid extension is not the most feasible way to provide access to electricity. In some cases, mini-grid solutions using decentralized renewable energy technologies and enablers have shown success in providing communities with electricity, as was in the case of the Upper Blinkwater project in the Eastern Cape region of South Africa (GIZ, 2020).

This is the solution that is being tested in the SESA project, utilizing second-life batteries in combination with a containerized solar PV setup to provide reliable electricity in the Town of Alicedale in the Eastern Cape Province of South Africa, giving residents access to charging stations for micro-mobility solutions and info-spots for access to the internet. The successful deployment and replication of this use-case requires coordinated policy action across a range of topics, ranging from ensuring an adequate supply of used EV batteries (through imports, or by developing a robust EV market in South Africa), stable demand for decentralized generation with storage, and e-waste management practices.

6.2 Stakeholders' consultations and barrier analysis

Based on a literature review, and building on the PESTELA (Political, Economic, Social, Technological, Environmental, Legal and Awareness) framework, several barriers to containerized solar solutions using second-life EV batteries were identified..

The focus of this analysis is primarily second-life EV batteries, as solar PV already receives significant attention and support, globally and in South Africa. The barriers are further discussed in the relevant sections below, with emerging themes from the literature review discussed alongside responses from interviewees. When approaching the use case of second-life EV batteries in off-grid solar installations, this research mainly investigated the availability of such batteries, and by extension South Africa's efforts to shift to E-mobility, the demand for decentralized solar solutions, and the presence of adequate awareness, skills, resources, and safeguards to address the problem of e-waste and move towards more circular economic practices.

Table 6.1: Barriers' framework for second-life uses of EV batteries in South Africa

Level 1	Level 2	Level 3
1. Political and institutional	1.1 Ambitions, strategies, and plans	Sustainable mobility priorities
		Priorities for energy policy
	1.2 Governance	Vertical and horizontal integration of governance

2. Economic and financial	2.1 Market development issues	Insufficient supply of EV batteries to build value chain (including demand for energy technologies using batteries e.g., solar home systems)
	2.2 Cost competitiveness of second-life batteries	Costs and expertise required to handle EV batteries and viable business case for recycling/repurposing
3. Social	3.1 Socio-economic systems	Informal waste management sector
	3.2 Health and safety	Toxic materials in batteries, and safety hazards from operations
4. Technology and infrastructure	4.1 Technical standards	Lack of standardization in battery design
	4.2 Battery production	Resistance from existing battery manufacturers/OEMs
		Availability of skills to handle battery waste safely
5. Environmental	5.1 Local pollution	Leaching of toxic materials into the environment during handling
		Unmanaged solid waste
6. Legal and regulatory	6.1 Regulation of the services sector	Lack of standards in supporting measures e.g., warranties, certification of installers etc.
	6.2 Standards and enforcement	Enforcement of policies, standards, regulations etc.
		Operating standards for second-life batteries
7. Awareness and capacity	7.1 Lack of awareness	Lack of awareness of various stakeholders regarding battery technology, especially second life uses
		Lack of compelling research in specific contexts about second life uses

The framework was used as the basis for developing questionnaires (see Appendix 6) . ICLEI World Secretariat (ICLEI WS) conducted all the interviews with the stakeholders mentioned below:

- **Funding agency:** An expert was identified and interviewed from the Deutsch Gesellschaft für Internationale Zusammenarbeit (GIZ) in South Africa [F1].
- **Research/academia:** Two experts were identified from academic and research institutions in South Africa. One from the Council for Scientific and Industrial Research (CSIR) was interviewed [A1].
- **Non-Governmental Organization:** An expert from ICLEI Africa was identified and interviewed [N1].
- **Technology:** Two technology experts were identified and interviewed—one from the South African Photovoltaics Industry Association (SAPVIA) [T1] and Gouach, a French battery-manufacturing firm using circular production principles [T2].

6.2.1 Barriers

Political Barriers

Political barriers include the strategic priorities of the government, and coordination and functioning across several policy areas including electric mobility, e-waste management, and off-grid/self-generation.

Sustainable mobility priorities: In terms of sustainable mobility, some of the interviewees pointed out that South Africa's conception of sustainable mobility does not necessarily rely heavily on electric vehicles, but rather includes other forms of low-carbon fuels such as biofuels as well [F1, N1]. This is partly to account for the large distances in the country, and the need for heavy transport vehicles in its primary industry, which hampers electrification efforts [N1]. This suggests that the political push for EV deployment is limited. Import duties are high, and access to reliable electricity is also a challenge [A1, F1, T1]. However, electrification is likely to receive growing attention with rising fuel prices, as well as pressure from South Africa's large automobile manufacturing sector, which primarily exports to Europe [N1, T1]. As the market for traditional internal combustion engine (ICE) vehicles in Europe shrinks, this could create pressure on local manufacturers in South Africa to transition towards EVs, which could in turn help spur the development of the domestic market [T1]. While relying on alternative fuels mitigates the issue of e-waste generated through EV batteries, it does hamper the development of a robust battery recycling supply chain and skilled resources, due to the limited supply of 'raw' material.

Energy policy priorities: Many respondents indicated that the energy crisis has been a priority for the government, and capacity and resources are mostly directed towards addressing it [N1, A1]. Some also indicated that the policy focus has been on expanding the share of solar PV and other enabling technologies in South Africa, with policies for the operation and maintenance of these systems receiving less attention [T1]. The focus on end-of-life management of these systems has not yet received much attention either, however, it is not entirely absent from discussions. It is more prevalent at the city level and in certain circles such as in the discussion of grid-scale storage by Eskom as well as other situations where energy projects are being actively implemented [F1, N1]. Government support is also primarily directed towards solar PV, although some interviewees felt this was better channelled to batteries and inverters at this stage, given the cost reductions that have already been achieved for solar PV [A1]. The coordination between the various departments that would have to create an enabling environment is also a challenge, although this is not a problem that is unique to South Africa [N1].

Vertical and horizontal integration: It was also mentioned that there are great differences in the sustainable mobility space when considering the sub-national level, with larger cities faring better with improved resources, policies and infrastructure compared to other regions [N1]. Coordination between the various regions in South Africa in terms of waste streams, waste handling infrastructure, demand centres and so on could be another barrier to upscaling this technology.

Economic and financial barriers

Economic barriers touch on the supply and demand side, namely the supply of batteries that could support such a technology use case, as well as a demand for storage technologies.

A limited supply of EV batteries hindering the development of a robust recycling value chain: The low penetration of EVs in South Africa's automobile market is both a positive and negative—while it reduces the urgency and scale of the problem of e-waste from vehicles, it hinders the development of robust battery recycling supply chains that will be needed to address this issue. In 2022, around 500 battery-powered electric vehicles (BEVs) were sold, with 120 plug-in hybrid vehicles (PHEV)—this represented about 0.2% of all car sales in South Africa in 2022 (IEA, 2022). The lack of sufficient feedstock that can be recycled is a challenge for the development of a robust recycling supply chain, even when considering non-automotive lithium-ion batteries (Linnenkoper, 2022). This is a global challenge, suggesting that other countries are also competing for batteries to recycle or refurbish in order to develop their recycling industries [T1]. A number of limitations were identified by interviewees that affect the adoption of EVs in South Africa, primarily affordability concerns, as most vehicles are in the luxury market and face higher import duties, as well as the unreliability of the electricity system that created concerns about convenient EV charging [N1, F1, T1, A1] (Malinga, 2022).

Cost competitiveness of second-life EV batteries compared to new batteries: Second-life batteries are essentially competing with new batteries for the same uses. Second-life batteries are estimated to be 30–70% cheaper than new batteries. However, the falling costs of new batteries and the high initial costs of collecting, assessing, and repairing used batteries in the absence of a well-developed value chain could affect the business case for the latter (Engel, Hertzke, & Siccardo, 2019). For example, the value of metals recovered may not be sufficient to cover the costs of collecting, transporting, and dismantling the battery (Barber & Marshall, 2021). A strong business case must be made to spur the development of this value chain (Christensen, Mrozik, & Wise, 2023). However, the supply of batteries is presently not adequately high for this, as mentioned previously (Arnoldy, 2021). This is a global issue, and it might be tough for local actors in South Africa to compete with actors in countries with a higher supply of used batteries, hampering learning effects and the development of the local industry. This could also be a concern for car dismantlers, who may not know how to handle the battery for second-life use or dispose of it properly and would need to acquire the proper knowledge and skills. However, in parallel, interviewees pointed out that due to the growing demand for batteries in general, their import prices have been increasing rapidly [A1]. This could either positively or negatively impact the business case for second life uses—positively, due to the higher cost of alternatives i.e., new batteries, or negatively due to the further restriction of battery supplies and value chain development.

Social barriers

Social barriers include existing community practices or attitudes that could be a hindrance to the uptake of these technologies.

Large informal waste management sector: One of the concerns cited by interviewees was the informal nature of waste management in South Africa, as is the case in many countries globally [N1, T1, F1, A1] (Simatele, Dlamini, & Kubanza, 2017). This presents the challenge of integrating approaches from the formal and informal sectors. One of the interviewees cited the flexibility and resilience of the informal sector in waste management, and its ability to adapt to extract value from waste streams such as e-waste, which could still align with plans for second-life uses of batteries [T1]. However, these processes are quite inefficient and there are serious health concerns when handling hazardous waste from batteries and other electronic waste. These are difficult to manage without adequate oversight of the sector. The presence of informal collectors can be a barrier when it comes to the collection of used batteries to direct them towards second-life uses, but it can also be an opportunity with adequate policy and planning (Littlewood, Donkor, Mdiniso, & Ibrahim, 2022; DoEFF & DSI, 2020; Hande, 2019; Sengupta, Ilankoon, Kang, & Chong, 2022).

Health and safety hazards: The downside of e-waste, including from batteries and some renewable energy technologies, is the potential direct and indirect exposure of handlers to toxic minerals, especially when dismantling and repairing or recycling them. This is an increased risk in areas with informal structures that treat this waste, exposing people to toxic materials and also leading to a lower overall gain in terms of materials recovered (ILO, 2014). The informal sector largely uses unsafe handling and dismantling processes, exposing them to high health and environmental risks (Annamalai, 2015). This could be a bigger concern as EV batteries are generally more cumbersome to handle, and deal with higher voltages (Barber & Marshall, 2021). In addition, improperly refurbished batteries could pose a greater safety risk during operations, including fires; these risks are also present for new batteries, but to a lesser extent (Christensen, Mrozik, & Wise, 2023). Improper installation by unlicensed professionals could exacerbate this risk. However as this is a relatively new sector, the research into the increased safety concerns of second-life batteries is also limited (Christensen, Mrozik, & Wise, 2023). Some interviewees indicated that authorities are aware of these challenges, but once again the challenge lies in implementation, due to social barriers, capacity constraints, and resources [N1].

Technology and infrastructure barriers

These include barriers related to the technology itself, including the skills required to exploit it.

Battery design and standardization: Several battery designs exist on the market, depending on the company, with very little standardization. Not only does this mean that dismantling processes for batteries can differ based on the design, but the software that helps measure battery health may not be the same in all cases. The manufacturers of these batteries, primarily automobile companies, or original equipment manufacturers (OEMs), may also be reluctant to allow access to their battery management systems (BMS) (Christensen, Mrozik, & Wise, 2023). Different battery designs may contain different levels of materials and minerals, as well as welding and adhesive components. [T2]. Some of the interviewees mentioned that batteries are often disposed of even if only a few cells are damaged, which is quite wasteful [T2]. With no regulations that encourage standardization or even the labelling of materials contained within a battery, the effort and cost required to dismantle, repurpose, or recycle these batteries go up due to the need to account for all these differences. This can hamper learning effects and economies of scale, and therefore cost reductions. Other concerns include resistance from battery manufacturers to adopt circular business models, having followed the linear model so far, as well as efforts related to battery standardization [T2].

Lack of adequate skills: Several of the barriers mentioned contribute to the lack of a viable value chain that can hire and train people with the requisite skills to handle battery waste safely and effectively. This is made difficult due to the informal nature of waste management, as well as the variety of battery designs available on the market. It is conceivable that with appropriate battery design, the level of skills required as well as the time and resources required to refurbish batteries could be reduced, as is the case of some emerging battery manufacturers [T2].

Environmental barriers

These include barriers that can stand in the way of this technology related to its impact on the environment.

Hazardous materials leaching into surroundings: The main risk associated with batteries and their recycling as well as repair for second life use, and ultimate disposal, is the leaching of toxic materials into the environment. Combined with informal waste management, this impact could affect the health of people not directly involved in the waste value chain, due to the environmental impacts such as the burning of toxic materials, or their leaching into groundwater (Mrozik, Rajaeifar, Heidrich, & Christensen, 2021). This is, unfortunately, a concern in many countries in Africa that receive a lot of e-waste from other countries, which is then ultimately left in dumpsites (Maes & Preston-Whyte, 2022). Battery production in general requires extensive mining, which brings its own health and environmental impacts; however, second-life batteries and improved recycling methods could help reduce the need for raw minerals (UNCTAD, 2020).

Unmanaged solid waste: The increase in waste generated from batteries is unavoidable as their uptake increases. While many of the materials, especially high-value ones, can be recovered to a great extent and battery lifespans prolonged through second life uses, some materials may not be recyclable and would need to be disposed of. Even repurposed batteries would reach this stage at the end of their second life uses. Adequate planning to handle these increasing waste volumes would be necessary to prevent environmentally damaging disposal practices and reduce landfill volumes, once again in cooperation with the informal sector.

Legal and regulatory barriers

These involve legal and regulatory frameworks that act as a barrier (but can ultimately then facilitate) the uptake and utilization of this technology.

Enforcement of regulations: South Africa has introduced Extended Producer Responsibility (EPR) regulations, initially covering plastics and packaging, and recently being expanded to portable batteries[6] through an amendment to the National Environmental Management: Waste Act of 2008 (DoFFE, 2023). These are in line with international practices i.e., making producers responsible for the management of waste, including reuse and recycling where applicable. Some of the interviewees indicated that while e-waste is not a top priority sector for the government at the moment, it is still receiving attention with the growing problem of waste from consumer electronics. Some also indicated that while the policy framework is fairly in line with global practices, it is the enforcement that poses a challenge. It is a challenge to monitor that producers and other relevant sectors are complying with these regulations; however, this is a concern that is not unique to South Africa [N1, T1]. In addition, the text of the amendment excludes automotive batteries from the EPR regulations, and it is unclear if that refers to EV batteries or batteries and other electronics used in ICE vehicles.

Regulation of supporting services sector: Some interviewees suggested that in the absence of official institutions to handle issues such as e-waste management, it is quite common in South Africa for private organizations to step in and fill the gap [N1]. In some cases, this can be a benefit if they are accredited by the government, such as the EPR Waste Association of South Africa. However, this can also pose a risk. Some interviewees pointed to the concern that in the case of solar systems for small-scale use, several installers had come up to fill this space in the market to meet the rapidly growing demand [T1, A1]. Given low consumer awareness in general, it was not unheard of for installers to do a poor job installing systems, leaving customers with faulty systems or cumbersome processes to go through to get some recourse. The lack of official licensing schemes for installers is another such barrier to improving service delivery [A1]. Similarly, the impression was that the focus has been on installation, with operations and maintenance not receiving as much attention, which could create further risks down the lines in terms of safety and maintenance and therefore the popularity of such systems [T1, A1].

Standards and safety: One of the respondents suggested that for companies engaged in the battery end-of-life value chain, one of the main challenges is that there are no regulations or policies concerning standards related to the operation of second-life batteries [A1]. This relates to the condition the batteries have to be in to operate and so far, private sector participants engaged in this have been managing as best they can [A1]. Although there have been indications that the authorities would investigate this, progress has been slow [A1]. Additionally, interviewees also cited concerns about a lack of standardization in terms of warranties and accurate information being provided to customers [A1]. This is addressed through some accreditations such as PV Green Card. However, this plays into the lack of awareness by consumers to look for such accreditations. Without proper standards or certifications, it could increase safety risks, especially if batteries are connected to the grid [A1] (OPSS, 2023).

Awareness and capacity barriers

This includes barriers to awareness of the technology itself, within potential user groups or policymakers and other relevant stakeholders.

[6] Defined as “a battery which is sealed, can be hand-carried without difficulty, and is neither an automotive nor industrial battery” (DoFFE, 2023).

Lack of awareness among various stakeholders: The market for decentralized solar-plus-storage solutions in South Africa is expanding rapidly to combat load-shedding. However, there is a general lack of awareness of good practices and standards, compounded by the lack of policy support and effective enforcement [A1]. The notion of second life uses for batteries is relatively new in general, and even less well known among consumers. This creates a lack of awareness of the potential uses or risks of second-life batteries, the opportunities available as well as the size of the potential market, which can hinder the development of a robust value chain. Similarly, without clear policy direction and regulations about this technology, it might be difficult to understand how existing regulations could facilitate or hamper the use of second-life batteries (Curtis, Smith, Buchanan, & Heath, 2021). More research and information are needed globally, as well as at specific countries and sub-national levels, to better inform policymaking and foresight. This can also be a challenge when it comes to monitoring procedures for battery disposal and where they end up at their true end-of-life.

6.3 Conclusions

The issue of e-waste management has been gaining traction globally, more so due to the looming concern of large volumes of used EV batteries reaching their end-of-life. This has led to growing interest in finding alternative ways of dealing with this waste stream, including second life uses. The main benefit of second life uses for batteries is that they are cheaper than new batteries at present, use fewer resources and therefore generate lower emissions, and can extend the revenue generating life of batteries.

In South Africa, the second-life use of EV batteries is in a nascent stage, related to the evolving situation of the country's energy, transport, waste and other relevant sectors. The various barriers mentioned previously interact with and reinforce each other. The policy priority for the government remains the energy crisis. The number of EVs is not very high, limiting the need to deal with EV batteries—however, this situation might evolve given global pressures on South Africa's well-developed automobile manufacturing sector. Waste management is a concern as much of it is informal, and care must be taken with e-waste in particular due to the presence of toxic materials. This necessitates good coordination at the sub-national level, as well as between sub-nationals and the national government. While some companies are being formed that deal with batteries and their second life uses, it is still a niche space.

Simultaneously, the demand for batteries is rising due to the need for decentralized power generation—primarily solar PV—as backup against load-shedding. This is true for households as well as industries. Second-life batteries and their lower costs could be attractive in such cases, as well as in situations where grid connections are not always feasible, such as informal settlements or remote areas. Ultimately, a lot of the barriers and risks involved in reusing end-of-first-life EV batteries will be encountered when batteries reach their true end-of-life. Policy action is therefore needed regardless, to avoid the negative health and environmental impacts of this waste stream and to take advantage of the economic opportunities.

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7. Barrier Analysis for PVs for Household use in Morocco

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7.1 Introduction

7.1.1 Status of PV technology in Morocco

Morocco is positioned as one of the world leaders in transitioning to renewable energies, with NDC targets envisioning a reduction of its greenhouse emissions by 45.5 % by 2030 (NDC Partnership, 2021). As a part of the process, the renewables' share in the national electricity production is planned to increase from 43% to 52% (Boulakhbar et al., 2020), out of which ca. 20% would come from solar energy. Thanks to the favourable weather conditions, including high solar radiation in the country as well as political commitment, the prospects of these ambitions are evaluated as high.

However, currently, Morocco depends to a large degree on imported fossil fuels. The country's state-owned utility provider ONEE's electricity production in 2021 came from coal (37.08%), natural gas (17.72%), hydroelectricity (16.4%), wind (13.37%), fuel oil (7.67%), and solar (7.58%) (ITA, 2022). Furthermore, for several years´ electricity price increases were compensated with the state's financial support, potentially affecting the competitiveness of solar PVs. Additionally, since the development of concentrated solar power (CSP) was high on the political agenda in the country, decentralized PV solutions garnered less attention. Specialists and private sector associations criticized the existing legislation as complex and, at times, contradictory. Even though the current engagement in law-making has shifted to the self-production of power from solar PVs, some of these issues persist.

7.1.2 PV charging hub in Morocco Living Lab

Green Energy Park facilitates the Morocco Living Lab and concentrates on two overlapping initiatives. First, E-mobility charging facilities that have been set up in Rabat, and second, a PV charging hub that is being planned in a remote village setting, and its main purpose is to provide electricity to local houses.

7.2 Barriers to decentralized PV household use in Morocco.

7.2.1 Literature Review

The decarbonization of power production is one of the fundaments of the energy transitioning process, with a substantial role envisaged for PV systems (referred to as PVs) that use solar energy.

According to estimates, the country has an average solar potential of 5 kWh per square meter per day (ITA, 2022). With a PV installation covering several square meters, sufficient power may be generated to cover a typical household's daily electricity needs.

Nevertheless, the primary attention in policymaking is put on large-scale investments in solar power plants. The most known example of the approach is the world's largest solar complex in Ouarzazate, involving four sub-projects, the first phase of which is 160MW NOOR I/ Ouarzazate Solar Power Station that has been operating since 2016 and producing ca. 400 GWh of power a year (corresponding to the electricity usage of around 400 000 people) (KfW, 2019). These types of initiatives receive substantial support in political and financial terms both from local sources as well as international financial institutions. A part of the envisaged power production from these power plants is planned to be used for exports to Europe, with relevant interconnections and political agreements being developed (Boulakhbar et al., 2020).

Despite these excellent foundations and support from the authorities for sustainable energy solutions, the Climate Change Performance Index (CCPI) indicates low decentralization of renewable energy in the country and a need for more will to engage citizens to produce renewable energy of their own (CCPI, 2023). This resonates with the voices from the private sector and NGOs, underscoring that climate laws do not translate to decrees allowing industries and people to engage with renewable energies easily (Alami, 2021).
These opinions are traceable despite dedicated legislation being gradually put in place, and the current focus in law-making is on the self-production of power. These key legislative elements included setting conditions for private entities to produce electricity and access low voltage grids, allowing them to sell surplus power (Law 58-15, amended 13-09) (Bentabi et al., 2021), which has been in place since 2016. Nevertheless, due to some gaps, it was criticized as not serving its purpose. The most recent bill, 82.21, concerning the self-production of electricity was adopted in December 2022 (Zouiten, 2022) and aimed at covering these gaps. However, some scepticism regarding its immediate impact was also raised by the interviewees.

In practical terms, over the last few years issues with implementing programmes promoting Panels, such as the country's ambition in the NDC to connect PVs to low voltage grid targeting 1000 MWc by 2030, demonstrated that barriers in mainstreaming the technology persist. The said programme, for instance, was not realised due to the lack of grid injection laws (feed-in tariff and net metering) (ADB, 2021). This is confirmed by the current split of solar power production in the country, which in 2020 summed up to 540 MW produced by Concentrated Solar Power (CSP), 194 MW by on-grid solar PVs and 23 MW by off-grid solar PVs (RES4Africa and AFRY, 2022).

Despite these issues, solar technology is being mainstreamed in the country through various means. While targets for the solutions such as solar thermal collectors are directly mentioned in the National Climate Plan - 2030 (983,000 Solar thermal collectors on a surface of 2950000) (PCN, 2019), PVs were mainly supported by donors and centrally funded programmes. Examples include the installation of PVs in *Programme d'Electrification Rurale Globale* (PERG) (1998-2015) to provide universal access to electricity in rural areas. With associated projects such as the donor-funded Morocco Solar Home System aiming to provide 19438 systems in over 1000 villages across the country (Masdar, 2023), that goal is considered nearly achieved. Consequently, according to some estimates, the level of rural electrification rose from 14% in 1990 to nearly 100% currently, and part of that growth can be attributed to decentralised solar home systems (until 2018 - 51,559 households were estimated to be served) (Jycquot et al., 2021). Nevertheless, the success of rural initiatives does not necessarily translate to a conducive environment for grid-connected household level PVs settled in an urban context.

7.3 Stakeholders' Consultations and Barrier Analysis

7.3.1 Barriers Framework

The barrier analysis is conducted in line with the methodological guidance elaborated in Chapter 2.

7.3.1.1 Identification of stakeholders

Stakeholders were identified through local living lab contacts as well as via the search of relevant local organisations, which was conducted by the author. Overall ca. 20 institutions and individuals were contacted, out of which 6 agreed to participate in the interviews. While various stakeholders, from policymakers, suppliers of technology/solutions, funding agencies, experts, NGOs, and end users were targeted, many of the interviewees shared roles across the categories. The final composition of stakeholders interviewed included the following:

-3 experts/academics, including one with a mixed role with a solution provider,
-1 NGO/academia representative, including the perspective of an end user,
-2 solution providers, including one with a role in energy association and also the perspective of an end-user.

The questionnaire administered to stakeholders can be found in Appendix 7.

7.3.2 Barriers

Political and institutional barriers

While the mainstreaming of PV solutions was driven by the government's commitment to providing electricity to 100% of households (or population), the private sector/association representative pointed out the lack of a dedicated policy for PVs for household use. Consequently, the programmes for decentralised PVs in remote rural areas without any other source of electricity (*Programme d'Electrification Rural Global - PERG*) have been more visible in recent years.

The majority of stakeholders also agreed that the policy focus on solar energy unfolded mainly in terms of support and regulation of large-scale infrastructures. Regarding PV development by private actors, there was some support for mid-scale or large-scale installations, but fully decentralised household-level solutions were poorly covered for several years. This has recently changed with new laws being made to address this issue. While many experts feel that over the years, the policy focus shifted towards decentralised PVs, the private sector and association representatives and NGO/academia representatives opined that big political barriers and day-to-day problems persist.

In political terms, the authorities need to maintain the affordability of prices of essential services for the majority of the population. Regarding electricity, this approach translates to a regulated tariff system that does not represent market prices. This approach may be judged as beneficial for individual users in the short term, but it is also seen as a critical obstacle to popularising the PVs. In other words, the PV solutions would be much more attractive if the markets set prices rather than fixing them arbitrarily. This situation is seen by the respondents as more of a political problem than a financial one. The prices continue to be regulated due to shortages of energy supply related to the Russian invasion of Ukraine, and COVID-induced economic issues such as inflation.

The day-to-day problems are linked to various inconsistencies in legal solutions, taxation and administrative requirements. As indicated by about half of the interviewees, some of the problems could have been avoided through better coordination between various sectors and stakeholders outside the government were consulted and their views are taken on board. Furthermore, one of the interviewees representing NGO/academia pointed out that the energy operators may have no incentive to support decentralized solutions as self-produced energy may be seen as competitive to their offer. A similar opinion was expressed by an expert, who pointed out that relevant authorities must be truly motivated to facilitate decentralized PV solutions.

Economic and financial barriers

The cost of PV installations decreased significantly over the last decade. Consequently, all the interviewees agreed that, in the long run, household PVs are economically viable, particularly considering the country's high levels of solar radiation. Nevertheless, they pointed out several visible barriers, one of the biggest being the high upfront investment. Currently, it is affordable for only relatively affluent customers with direct access to rooftop spaces where PV installations can be placed. The possibility of households having a dedicated energy storage facility was considered unrealistic for the majority of users.

Private sector representatives pointed out additional barriers in the local contexts. One of the barriers is the problem related to selling back electricity to the grid. This was considered a significant barrier to the mainstreaming of PVs. As pointed out by a representative of the private sector, if a private household is unable to sell the electricity back to the grid, the investment into PVs would make sense only in case of very high electricity consumption for its own purposes. The second issue of unequal taxation was mentioned by one of the respondents. It was pointed out that the products offered via the grid were taxed at a level of 14% VAT while self-generated energy was at 20% VAT.

Additionally, as mentioned before, the regulation of electricity prices was considered harmful to the decentralised PV sector, particularly from the perspective of the private sector. From their point of view, adapting electricity costs to the market was perceived as a critical step to making PV solutions genuinely competitive. Finally, a private sector representative pointed out that importing new products links to many legislative hurdles and additional financial costs linked to taxation and certification. This also indicates the need for more local products and less dependence on imports.

Governmental programmes and financial incentives with support from external donors were available in the country but targeted predominantly large-scale installations for various types of businesses (Morocco Sustainable Energy Financing Facility (MorSEFF) programme (EBRD, 2023). New companies entering the PV market can also benefit from preferential loans to establish their businesses. Nevertheless, private individuals need to depend on conventional loans when planning an installation, and these loans follow normal regulations.

Social and cultural barriers

The respondents did not identify any significant social and cultural barriers. Some experts underscored the spirit of entrepreneurialism, which may help spread the technology as long as the administrative procedures related to PV installations become more straight-forward.

Technology and infrastructure barriers

In terms of objective considerations, a key factor to consider is the availability of PVs as a product. Most PVs are manufactured and imported from China, and most respondents do not consider this a problem. The product is considered of good quality and affordable, and the supply service is seen as reliable. However, an expert interviewee pointed out that giving up on the idea of local production of appliances might be seen as an uncaptured opportunity. While no respondent questioned the need to use imported products, several interviewees suggested there is an opportunity to develop some components of PVs locally.

At the household level, the main issue is related to feeding excess electricity into the power grid. Even though this might be permitted by the policy (for instance, for industrial parties), it can be technologically challenging. Feeding excess power without proper safeguards in the system may be problematic for the stability of the utility grid. Even though there was general agreement among the private sector respondents that the opportunity to sell excess power to the grid is the key factor for the sustainability of household investment into PVs, the technological feasibility of this must be kept in mind.

Otherwise, in terms of technology, PV panels are highly reliable. As reported by a private sector respondent, if any issue is reported back, those predominantly concern minor problems related to metering. Respondents underscored, however, that the technology could cause safety issues because there is no proper oversight of the installations, and each company varies in how they approach the process. Over time, with a lack of attention to maintenance, other technical issues may appear. Additionally, one of the experts pointed out that most companies specialise in installations and the maintenance skills are not yet truly tested or prioritised. Nevertheless, almost all respondents agree that the local training for the PV sector is excellent at the level of technicians and engineers are highly skilled. Therefore, potential future issues related to the maintenance of PV installations may be linked to the lack of awareness about maintenance requirements rather than the lack of technical skills.

Environmental barriers

The PV literature including reports indicates the risks associated with establishing large-scale solar power plants and the associated water and pastoral land requirements (Waters-Bayer and Tadicha Wario, 2022). However, these issues are not applicable to decentralized household-level solutions, which were considered environmentally friendly and inclusive. For most respondents, the benefits from the reduction of CO2 were more important than any potential environmental issues that the technology may cause.

The private sector/association representative indicated that recycling PVs, which is currently not an issue, may become one as technology use is widespread. This indicates the need for proper recycling of PV-linked materials. The potential of Morocco to become a recycling hub for PV-related technologies was also raised by one of the expert interviewees.

Legal and regulatory barriers

The movement towards regulating renewable energies started in the first decade of the new millennium (Bentabi et al., 2021). While several expert interviewees consider the legal and regulatory measures currently well developed, the private sector and NGO/academia respondents pointed out significant gaps in the legislation concerning the self-production of power. This includes scope for misinterpretation. For instance, law 16-08 and its amendments indicate that self-power producers must generate power ‘by their own means’, which was interpreted in a restrictive way by the administration, effectively limiting the scope of the private sector’s initiatives (RES4Africa Foundation & AFRY, 2022). While some of these problems have been addressed in the newer legislation, the central issue of selling the power back to the grid is not fully resolved. This solution was initially available only to larger enterprises and businesses which installed large scale PV installations. The new law 82.21, formally approved in December 2022, defines the level of power that a household is allowed to sell back to the grid. Due to pressure from associations and experts, the initially proposed level of 10% was increased to 20%.

However, as a private sector/association respondent and NGO respondent pointed out, the law needs to be more precise to truly facilitate the self-production of power. In particular, it needs to be resolved what kinds of authorizations are required for various power production levels and installations. This is expected to be covered in a decree that could be issued in relation to law 82.21.

Additionally, as pointed out by one of the interviewees, in the future, the acceptance of PV technology might reach high enough levels to incentivize people to install the PVs despite unfriendly official regulations. This means that some households might decide to install PVs outside the official system in case procedures turn out to be too complicated.

Awareness and information barriers

While the general perception about the level of awareness is high, several stakeholders underscored that it can always get better. Solar technology is commonly discussed in local media, but its visibility in cities is lower as compared with European countries.

Some donor-funded projects partially addressed this issue by introducing PVs in landmark places. For instance, the Green Mosque programme, aiming at the installation of PVs in mosques across the country between 2015 and 2021, had a significant positive impact on increasing awareness of PV technology among the local population.
As underscored by one of the experts, the key problem remains in the legislative and policy spheres. In a more conducive environment for decentralized PVs, awareness is expected to spread organically. Some further gaps were also discussed in terms of educating children and youth on the benefits of solar energy.

Additionally, private sector representatives taking part in the interviews emphasized that the clients do not have awareness of the maintenance requirements of PVs, which could lead to various safety and technological hazards.

7.4 Conclusions

Despite political attention given to renewables, there are several visible barriers to mainstreaming PVs for households. At the highest level, the main barrier relates to the diminished competitiveness of solar PVs due to the government subsidy for electricity, which is currently produced mainly from fossil fuels. In the last years, major issues included also the lack of access to the low voltage grid due to inconsistency in laws, a lack of a dedicated framework for independent production, and the legal and fiscal status of residential and tertiary self-producers in the service sector economy (Bentabi et al., 2021). While some of these issues have been addressed in the new legislation, the stakeholders point out that it is still not precise enough to facilitate decentralised PVs. In particular, it is currently not clear what authorizations are needed for the self-production of power. Currently, the level of electricity that can be sold to the grid is now set at 20% of production. However, several respondents suggested that the limit should be higher, but such an opportunity may not materialise due to a conflict of interest with other stakeholders. On the technical side, grid stability issues need to be addressed so that the grid is ready to receive power generated by households.
In terms of the supply chain, the PVs are mainly imported from China. Even though most respondents did not consider this a problem due to the low prices and reliability of the products, some stakeholders suggest the need to promote localization to benefit from the opportunity technology provides (RES4Africa and AFRY, 2022). Complete dependency on imports can also make the PV market vulnerable.
The barriers related to awareness and capacities in the country are not particularly significant. The maintenance of PV installations might become a problem in the future due to the low awareness of the users about maintenance requirements. Environmental barriers in the case of decentralized PV solutions are not considered significant, and their environmental benefits are seen to outweigh the potential risks.

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8. Barrier Analysis for E-mobility in Morocco

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8.1 Introduction to E-mobility in Morocco

8.1.1 Status of E-mobility in Morocco

Morocco is a northwest African country bordering the Atlantic and Mediterranean oceans. Morocco acted as a host of COP7 in 2001, where the Marrakech Agreement was reached, and the COP22 in 2016 in Marrakech. More recently, Morocco acted as a powerful advocate for Africa at COP23 in Bonn and COP24 in Katowice. Notably, COP22 marked Morocco's increasing presence in the global arena, its leadership in the deployment of clean energy technologies, and its role as an advocate for Africa and for least developed countries. Conscious of the magnitude of challenges the African continent faces, Morocco is now pursuing several cooperation initiatives, including creating excellence centres to serve African countries in the energy and climate fields (International Energy Agency (IEA), 2019).

Morocco has made impressive progress in electrification. According to the International Energy Agency (2019), Morocco's population has full access to electricity, a key pillar of Sustainable Development Goal 7 on energy. Morocco is pursuing an ambitious energy transition pathway. More investments will be needed from both the private and public sectors to meet its renewable and energy efficiency targets (IEA, 2019).

In Morocco, the transport sector consumes 38 percent of energy and represents the country's second-largest CO2 emitting sector. Aware of the continued growth in the motorisation rate, Morocco is now accelerating its energy transition to avoid CO2 emissions and environmental issues in future, which are often difficult and costly. Electrical mobility in Morocco is considered a fundamental aspect of its energy transition. While the number of electric vehicles in Morocco reached only 0.01 percent of the national market in 2017, the government, through the Ministry of Energy, Mines and Sustainable Development, adopted a National Strategy for Sustainable Development, incorporating sustainable mobility.

8.2 Barriers to E-mobility in Morocco

8.2.1 Literature survey

The SESA validation action in Morocco supports a larger use and uptake of electric mobility solutions in the country. In conjunction with the production of renewable energy, electric mobility and micro-mobility have the potential to strongly support decarbonisation in the country.

Academic literature on E-mobility in Morocco is scarce; few indicators or key statistics from trusted sources are available, making it difficult to contextualise the use of E-mobility in particular. Electricity production, the use of renewable in electricity generation and the use of PV technology are more widely studied areas; barriers to PV for household use in Morocco are described elsewhere in this report.

According to figures from International Renewable Energy Agency (IRENA)[7] and International Energy Agency (IEA)[8], Moroccan total annual energy supply is 880 TJ, of which around 10% comes from renewable sources. The annual renewable electric consumption for 2019 shows that electric energy is mostly used in the industrial sector, for household consumption, and other uses. Less than 1% is used in the transport sector, accounting for the low uptake of E-mobility technology in Morocco. This also indicates that mobility in Morocco is almost exclusively based on the traditional internal combustion (IC) engine.

The use of electric mobility remains a rather niche choice for consumers across the country. Electric cars and other high-end electric vehicles are limited in numbers due to their high price compared with conventional fuel-based options in the country (Chachdi et al., 2017); concurrently, in denser urban areas – Marrakech, Casablanca and Kenitra – the use of small-scale electric vehicles – scooters, bicycles - is more widespread.

Governmental action ~~(what action)~~ as well as the promotion of renewable energy can increase the acceptance of the technology (Chachdi et al., 2017). Similarly, according to Awal (2018), E-mobility solutions will be more widespread in the medium to long run, while the majority of Moroccans will still rely on IC engine cars due to their lower overall costs and perceived risk.

While the Moroccan government is not active in promoting E-mobility solutions to end users, the landscape of e-vehicles production has largely been fostered in the country. According to Morocco World News[9], the government aims to double electric car production by 2024. The country is planning to manufacture around 100,000 electric cars per year within the next two to three years. Investments from multinational car manufacturers, such as Renault, are boosting the internal production market, which is however mostly devoted to export to the European market. The current landscape of E-mobility manufacturing in the country is provided more in detail by Tanchum (2022), which stresses the role of car manufacturing in the country in the near and long term.

Role of women

There is no significant literature regarding the role of women in the choice and use of electric mobility solutions in Morocco. Following Saadaoui (2019), when comparing mobility patterns across genders in Morocco, women suffer from several limitations in relation to accessibility, safety and choice of mobility due to their traditional role in Moroccan society. While targeted programs and support might change this situation, it is safe to assume that the switch from fossils to E-mobility would not significantly affect the position of women in transport without a wider cultural change.

At present, there is no study available regarding changes in women's transport patterns with a wider uptake of electric micro-mobility solutions.

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[7]https://www.irena.org//media/Files/IRENA/Agency/Statistics/Statistical_Profiles/Africa/Morocco_Africa_RE_SP.pdf

[8] https://www.iea.org/countries/morocco

[9] https://www.moroccoworldnews.com/2022/09/351254/morocco-to-scale-up-electric-car-production-over-next-two-years

8.2.2 Stakeholders’ Consultations and Barrier Analysis

8.2.2.1 Barriers Framework

The barrier framework discussed in Chapter 2 has been used to analyse the barriers to the adoption and scale-up of E-mobility in Morocco. The barriers framework is covered below in section (iii) (Stakeholders’ consultations and analysis of responses), where these barriers are discussed in detail.

8.2.3 Identification of stakeholders

As indicated in Chapter 2, stakeholders were identified in six categories as follows:

- Policymakers: n/a
- Suppliers of technology (solution providers): IRESEN
- Funding agencies: n/a
- Experts (Academia and other experts): Cadi Ayyad University
- NGOs: Green Energy Park
- End users: The end user survey was communicated to local stakeholders but did not receive sufficient answers in the timeframe available for the study.

The list of stakeholders' organisations/institutions is given in Appendix 8. Each stakeholder institution has been assigned an ID number to understand the perception of specific categories of stakeholders on barriers properly.

8.3 Stakeholder consultations and analysis of responses

Questionnaires were prepared to cover the six categories of barriers and administered to the above stakeholders by partners from ICLEI Europe. The questionnaire used can be referred to in Appendix 9.

Using the barriers framework described in Chapter 2, the responses from stakeholders to the questions on barriers to E-mobility in Morocco are discussed and summarised below.

8.3.1 Barriers

Political and Institutional barriers

All the interviewees have been unanimous in stating that the Moroccan government is not actively promoting E-mobility across the country. Policies have focused mostly on the development of charging station networks in the northern-west part of the country – near the cities of Casablanca, Tangier, and Rabat. In the area, the extra-urban road network is more developed, leading to a higher chance for the use of electric cars across the country.

Currently, the country is lacking a national strategy for the development of E-mobility and e-solutions. Activity around charging stations is mostly due to the pulling role of the private sector, willing to invest in the network. Both interviewees 1 and 2 also stressed that the charging station network might be a good starting point to push high and middle-income classes in opting for electric cars over other solutions.

Small-scale demonstration actions on the use of electric cars and scooters have been deployed by private sector companies and research organisations. In particular, the Research Institute for Solar and New Energy (IRESEN), in collaboration with industry partners, developed the first network of electric charging points on the Agadir-Tangier Highway in 2018.

Both interviewees 1 and 2 agreed on the possibility of a proactive regulation in the E-mobility field brought out in the mid to long run, following a positive development in this area in the next few years.

Looking at the larger picture of electricity production and electric mobility in Morocco, significant progress has been made from a political and institutional point of view. More details regarding legal and regulatory barriers are given in the corresponding section of this report. There is targeted research in this area, which might influence policy in the medium term, stressed interviewee 2. Some examples are provided by Jelti, Saadani & Rahmoune (2020) while assessing the impacts of electric mobility in Morocco in the medium term. Rim, Abdelilah et al. (2021) also provided a detailed overview of potential policies that the government of Morocco could use to incentivise the use of electric mobility in the country.

Economic and financial barriers

Currently, no cash incentive for the purchase of electric vehicles is available in Morocco. However, for electric cars, a partial exemption in the property tax - "vignette", or car sticker tax (the annual basic tax for every car owner - is), available, compared to cars with IC engines.

Both interviewees 1 and 2 mentioned that the high price of electric cars is a barrier for most Moroccan car users. However, the price has significantly decreased in recent years, with electric cars now competing with IC engine ones. The biggest barrier at this stage is related to the lack of charging facilities (interviewee 1).

Small-scale e-vehicles, such as scooters, are gaining popularity in the country, especially in cities such as Marrakech, where two-wheelers are widely used. Especially, electric scooters are priced competitively and do not need governmental subsidies (interviewee 1).

Social and cultural barriers

Both interviewees 1 and 2 were of the view that there are no social or cultural barriers to the uptake of E-mobility solutions in the country. Price, availability of charging points and relevance of E-mobility solutions to meet consumer preferences are considered key barriers.

Interviewees 1 and 2 stressed positive attitude of the Moroccan population towards the use of E-mobility solutions, especially cars, as they are seen as vehicles for economic growth and job creation in the manufacturing sector. However, Interviewee 3 was of the view that due to high demand, there is a lack of trained labour, both white and blue collar workers, which might hamper the fast growth of the sector.

Technical and infrastructure barriers

The main infrastructural barrier to the development of E-mobility in Morocco is the lack of charging infrastructure in the country. At the household level, the lack of space and availability of adequate electricity, as well as connection to the grid (in the case of rural households), represents a major obstacle to the purchase of electric mobility solutions. More widespread use of PV panels might partly offset this issue, especially in rural areas.

Due to the presence of several production sites for batteries and electric cars devoted to supplying to the European market, there is no significant technology gap with respect to the electric mobility solutions available in Morocco and elsewhere in Europe. Both interviewees 1 and 2 were also of the view that the presence of skilled workers for the production of batteries and electric cars spills over to a wider acceptance of the technology in the country.

Interviewee 3 also stressed the importance of skilled workers for the development of e-car manufacturing in the country, as well as for the production of PV panels. In this regard, two main barriers identified by the interviewees were the scarcity of materials to produce batteries and the lack of end-of-life solutions for them. This is not only for cars but for electric vehicles in general.

Environmental barriers

Currently, electricity produced in Morocco is among the most polluted in the World, emitting 750 g of CO2 per kW hour (interviewee 2). The country does not suffer from any major environmental barriers to the deployment of electric mobility solutions. Due to the abundance of sunlight in the country, PV technology is widely used and seen as a potential source of 100% renewable electricity in the country in the medium to long term. This increases the willingness to use electric solutions for mobility across the country. This is also stressed by Boulakhbar et al (2020) when analysing the large-scale adoption of renewable energy in Morocco.

The main environmental barrier highlighted by all interviewees is the remoteness of some areas of the country, especially in the south, which will make it difficult to provide a strong network of charging stations and facilities for electric mobility in those areas.

Legal and regulatory barriers

There are a few regulations and laws in Morocco directly affecting the use of electric mobility. Interviewee 3 provided a comprehensive list of laws affecting the production and use of electricity in the country. While not directly focused on E-mobility, law 13-09 of 2010 on Renewable Energy and law 86-12 of 2015 have indirectly fostered the uptake of E-mobility solutions in the country by providing incentives for renewable energy generation and facilitating the formation of public-private partnerships (PPPs) for energy infrastructures. The latter has proven especially useful for the creation of charging infrastructures in the country.

For instance, some examples of how law 86-12 of 2015 has lowered legal barriers for private investments and PPPs in electric mobility are available in the literature. According to Wansi[10](2023), an intersectoral association for electric mobility (APIME) has been recently launched to facilitate investments in the sector. The establishment of PPPs is also accelerating investment in public charging stations for e-cars[11].

Interviewee 2 opined that while no existing regulation limits the use of E-mobility solutions, policymakers in the country are debating about regulating the use of Mobility as a Service (MaaS) solutions for micro-mobility on the model of some European cities, which might affect the use of electric scooters.

Awareness and information barriers

No interviewee indicated inadequate awareness among the public or information gaps on E-mobility as a barrier. In particular, interviewee 1 was of the view that the public is fully aware of the availability of electric mobility solutions, and in most cases, their economic viability is an issue. Electric micro-mobility, such as e-scooters is widely known and used as a cheap mode of transport, especially among younger generations (interviewee 2).

8.4 Conclusions

Despite a low share of E-mobility solutions, Morocco is way ahead of other countries in Africa, and leading the electric transition in the continent (Berahab, Abdelilah, Atar, Ibtissem, Morazzo, Naciri, Zarkik, 2021). Despite very little governmental attention around the use of E-mobility solutions in Morocco, the sector is progressing and is projected to grow in the foreseeable future.

[10] https://www.afrik21.africa/en/morocco-faced-with-pollution-a-coalition-for-electric-mobility-is-born/

[11] https://www.moroccoworldnews.com/2023/04/354807/morocco-to-open-2-500-electric-car-charging-stations-by-2026

Unfortunately, the limited availability of data hampers a deeper understanding of the expected growth of the sector. Governmental support for the development of E-mobility networks should be in the development of charging infrastructures, as stressed by all the interviewees.

Manufacturing of batteries and electric cars is a growing sector in Morocco, with many European firms establishing production facilities in the country. As part of its industrial growth strategy, the government is also investing in attracting foreign investment in that area, as opined by interviewees 1 and 2.

Awareness and information about E-mobility are not a barrier in Morocco, and though diminishing, economic and financial viability does remain a barrier. Stronger governmental action through solutions such as tax incentives might accelerate the transition to electric mobility. All interviewees indicated agreed that electric micro-mobility is the fastest growing sector in the country.

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9. Barrier Analysis for second-life battery use as energy storage for solar photovoltaic systems in Ghana

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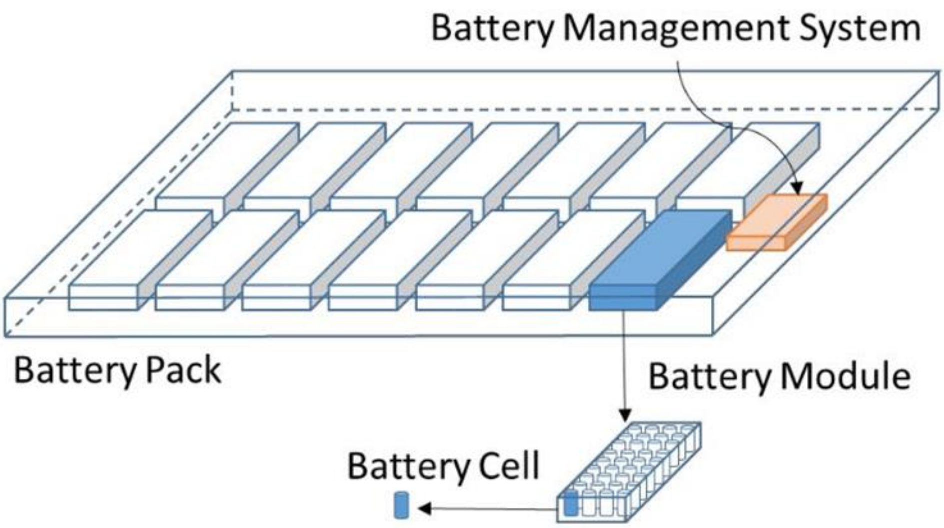
Reviewer: Jyoti Painuly (UNEP-CCC)

9.1 Introduction

Lithium-ion batteries (LIBs) (see Figure 9.1) are found in electric vehicles to provide power and energy demands. According to Kelly and Winjobi (2020) and Li et al. (2022), LIBs are huge and very costly with substantial energy storage capacity when no longer useful for the energy requirements of a vehicle due to diminished range. This situation arises when the LIB reaches a state of health of approximately 80% as noted by Kampker et al. (2023).

This, however, presents an opportunity for reuse in other applications that do not require as much energy as a vehicle would.

Figure 9.1: Battery pack showing component elements



Source: Kelly and Winjobi (2020, p. 2)

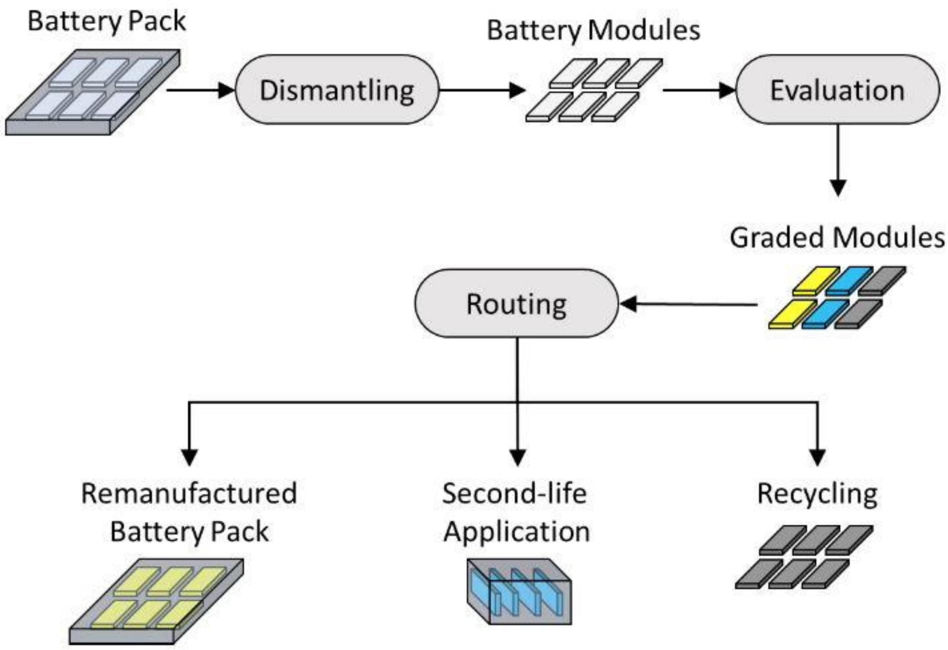
9.2 Literature Review

9.2.1 Second-life Batteries

In comparison, the prices of second-life batteries are estimated to be 60 to 75% of the price of new batteries. This strengthens the case for the second-life use of LIBs as they create a virtuous cycle of further increasing electric vehicle sales and increasing the number of end-of-life LIBs for second-life usage. Second-life batteries are seen as a potential solution to microgrid installations which rely on energy storage systems (Lacap et al., 2021). They can also be used to support EV charging by way of allowing for low electricity prices to be applied during low demand periods as they store the energy and later use that stored energy to charge an electric vehicle thus reducing electricity costs for an operational electric vehicle. Low-powered electric vehicles such as forklifts also find a use for second-life batteries for operations (Kelly & Winjobi, 2020). Second-life batteries are also predominantly used to support off-grid as well as grid-connected renewable energy systems. Renewable systems are noted for power fluctuations due to time variability and the intermittent nature of renewable sources. Second-life batteries could be used in these instances to store the energy as is produced and later converted to attain the appropriate grid voltage and frequency before transmitting to the stable grid. In the case of off-grid applications, the stored energy could be directly connected to, for instance, a household connection system to be used by electrical appliances in the house (Shahjalal et al., 2022).

Despite the attractiveness of the sector as predicted by Shahjalal et al. (2022) of a global value of over $30 billion for a potential 200 GWh of energy to be generated through second-life lithium batteries by 2030, Kampker et al. (2023) predict that availability of second-life batteries would be limited until enough end-of-life batteries become available in the long term. Thus, presently, there are several challenges in addition to the ready availability on the market that hampers the growth of the sector. These can broadly be classified under risks for safety and risks for the environment. According to Li et al. (2022), the process of disassembling a used battery pack (see Figure 9.2) to inspect cells one by one could be very laborious, time consuming and an expensive exercise. On the contrary, the technology to use a whole used pack for other purposes is not fully matured. There is a lack of standardized procedures for handling second-life batteries because of the specificity of various OEMs in the design and installation of LIBs in new electric vehicles. This also brings to the fore yet other challenges relating to the transport and dismantling of used LIBs where the Original Equipment Manufacturers (OEMs) are not involved. Handling the batteries in these scenarios poses several technical and safety concerns (Kampker et al., 2023). Battery systems are normally accompanied by a cooling system, a Battery Management System (BMS), and are specifically designed to suit a particular vehicle brand depending on space availability as highlighted by Kelly and Winjobi (2020). Thus, there is a safety risk in the process of converting a LIB for second-life use.

Figure 9.2: Potential flow of used EV batteries



Source: Kelly and Winjobi (2020, p. 4)

Kampker et al. (2023) categorise the barriers to second-life batteries under three broad headings namely:

- Barriers to the determination of end-of-life of LIBs, collection, and transport of second-life batteries
    - Inability to determine accurately the number of end-of-life batteries that have sufficient State of Health (SOH) for second-life batteries.
    - Difficulty in predicting whether a battery system is still suitable for rededication.
    - Safety concerns and regulations regarding the transport of these batteries make them expensive to process.
- Barriers concerning screening and condition diagnosis.
    - Identification process is not standardized, difficult and time-consuming.
    - Several varieties of batteries make uniform SOH determination and rededication challenging.
    - SOH determination without access to BMS data is time consuming and requires special equipment.
    - Lack of battery data from the first life complicates the decision to reuse.
- Barriers pertaining to the dismantling of LIBs, processing into second-life batteries and integration of the end product into second-life application systems.
    - Inconsistent disassembly and difficult automation because of the absence of a unified battery standard.
    - Difficulties in assembling a matched battery string.
    - Potential need to develop a new BMS and/or EMS to control second-life batteries.
    - Long-term experience in processing and integrating SLBs is currently unavailable.

9.2.2 Renewable Energy Technology in Ghana

There have been several studies, some of which include those by Bukari et al. (2021), Kuamoah (2020) and Kariuki (2018), regarding barriers to renewable energy adoption in keeping with the goal of the Paris Agreement on climate change. These studies underscore the numerous barriers regarding renewable energy technology as elaborated by Painuly (2001) in a framework for analysis. Particularly in Africa, there is the paradox of abundant sunshine and yet slow development and adoption of solar energy as indicated in the study by Munro et al. (2022) in contrast to conventional fossil-based energy systems. One such study by Bensah et al. (2015) sought to identify barriers to renewable energy technology transfer (RETT) in Ghana and proposed a roadmap for addressing them. The identified barriers were classified under financial, technical, economic, socio-cultural, legal, and regulatory categories. To overcome these barriers, specific actions were suggested, such as increasing government commitment and political will, reducing investment costs, and enhancing technical capacity. The roadmap included developing a renewable energy (RE) master plan, adopting standards and codes for RETs, providing tax incentives and financial support for RET investment, and strengthening training facilities and capacity for researchers and trainers. The goal was to increase the use of renewable energy in Ghana and promote sustainable development.

The study by Bensah et al. (2015), also identified the then prevailing stages of horizontal technology transfer and the need for capacity building in the local manufacturing of RET components. The proposed policy actions included developing a RE master plan, setting up dedicated centres of excellence, and implementing tax incentives for prioritized RETs. The Ministry of Power, Energy Commission, and Ghana Standards Authority were identified as responsible for implementing these actions with support from the United Nations Development Programme and NGOs.

Another study commissioned by the Energy Commission of Ghana on Renewable Energy Policy and Regulatory Gap was undertaken by Hagan (2015) to provide recommendations for strategic interventions to address barriers and policy gaps in the renewable energy sector in Ghana. The recommendations were based on a gap analysis validated by stakeholder consultations and best practices from China. The interventions included establishing a competitive bidding system for R&D funding, granting technical assistance and financial support to research institutes and universities, expediting the enactment of a bill on electronic waste management, improving the creditworthiness of state distribution utilities, incentivizing financial institutions to support renewable energy investments, and developing a clear plan for transitioning off-grid systems to be grid-connected. The report also suggested creating a platform for online licensing processes, developing a renewable energy master plan, and providing incentives and support schemes for productive uses of off-grid systems.

Despite these past efforts to boost renewable energy uptake in Ghana, there is still a seeming lack of adoption on a wide scale with the emphasis on conventional energy sources which are fossil based. The subject of second-life batteries to be used as energy storage for off-grid solar photo-voltaic systems is also not addressed in any of these interventions for RE use in Ghana. Thus, this report fills in the gap to throw light on the existing barriers to the deployment of this technology in Ghana being mindful of previous measures targeted at renewables in Ghana.

9.3 Stakeholder's Consultation and Barrier Analysis

The following categories of stakeholders were identified for the study:

i. Policymakers (relevant government authorities),
ii. end users of the technology,
iii. suppliers of the technology,
iv. experts from academia and other institutions,
v. NGOs, and
vi. funding agencies.

The approach adopted for the study was that of qualitative research design (Creswell, 2013) adopting the use of semi-structured interviews with the identified stakeholder categories. However not all stakeholder categories could be reached because of the short duration of the study, availability of time or the technical know-how among stakeholders about second-life batteries. That notwithstanding, the semi-structured interview guide for the data collection was broadened to capture all necessary aspects that would fill in, to an extent, what might be missed from the stakeholders who could not be involved in the study. During the interviews, other relevant emerging areas were touched on to make up for any gaps.

The six interviews conducted for this study were held online using Google Meet digital medium (Gibbs, 2014). In keeping with the good ethics of qualitative research as described by Mertens (2014), an informed consent form was shared with all interviewees prior to the interviews. This was done to secure the written confirmation of participants and their agreement to be recorded and allow for the use of the information provided for the research.

The stakeholders included Environmental Protection Agency and the Energy Commission in Ghana, with a focus on e-waste and renewable energy regulation respectively. The Ghana Standards Authority has responsibility for testing electrical and electronic appliances and reviewing product technical standards in relation to the study focus. The private companies involved in the study deal in solar photovoltaic systems, hybrid batteries and recycling and use of second-life batteries for solar applications. Yet another company assembles and maintains electric vehicles and battery systems in Ghana.

The list of stakeholders interviewed and interview guide (questionnaire) can be found in Appendix 10 and Appendix 11 respectively.

In the subsequent sections, the identified barriers from the PESTELA analysis of the data collected are presented.

9.3.1 Barriers

Policy and institutional barriers

From the analysis of the interviews, there are currently no laid-out plans or regulations regarding the use of second-life batteries in Ghana. The Energy Commission is working with the Ghana Standards Authority to adopt standards for electric vehicles and batteries but there is nothing on the table yet regarding second-life batteries use.

Despite the willingness of some private companies to invest in the use of second-life batteries as an alternative to diesel generators, and for that matter new batteries as a cost reduction measure for solar photo-voltaic systems, there are currently no government plans to promote the technology in Ghana even though there may be some internal discussions on the subject that has not been made known to the general public yet.

One interviewee suggested the need to source local raw materials for the manufacture of solar components including batteries locally. Unfortunately, though, there are currently no indications from the government to encourage the spring up of such local manufacturing companies. This would certainly involve significant investment but there is a seeming lack of prioritisation of renewable energy development with appropriate matching actions on the part of the government.

> ***"So, between now and maybe 15 to 20 years we'll still depend on imports because I don't see any direction from government in the policies and their master plans to establish such companies in the country. The supply chain will still depend on imports for solar and battery." (SF-P Interview, Data Collection 2023)***

Because of the low adoption rate for renewables resulting from policy and institutional barriers and the lack thereof of any direct policy promoting the use of second-life batteries, there is uncertainty about Ghana's ability to meet the pledge of 10% renewable in the energy mix by 2030 as part of its Nationally Determined Contributions (NDCs) for the Paris agreement on climate change.

Economic and Financial barriers

A major takeaway from the study is that solar photo-voltaic technology is economically viable and implementable on a large scale, especially in countries with high solar radiation like Ghana. However, the lack of financial incentives for individuals and the high interest rates from banks are barriers to adoption. According to the Energy Commission, there are currently six utility-scale solar plants in operation in Ghana. However, the high initial cost of solar systems remains a major barrier that needs to be dealt with before significant progress can be made. This initial cost stems from the material costs and taxes associated with importing renewable energy technologies in Ghana. The use of second-life batteries, which could reduce costs, is however faced with several barriers inhibiting the growth of the sector.

The banking sector is not fully positioned to accelerate the uptake of solar technology due to scepticism about resource availability and revenue generation. Only a few banks like CAL Bank and Ecobank offer lower interest rates for renewable energy projects. The high initial cost of solar technology is a major barrier for end-users, with prices for PV modules and other materials skyrocketing due to increased taxes and import duties. There is a need for business models such as leasing or pay-as-you-go models to be established to help spread the high initial cost over a period.

A high adoption rate of solar energy in Ghana could make the country self-reliant and improve energy security. However, the lack of a local supply chain for solar components is a challenge, with most components being imported. There is a potential to manufacture solar components locally but that would require significant investment. The government's lack of prioritization of renewable energy is however hampering this capital injection into local manufacturing of solar components.

Government financial incentives for solar PVs are deemed insufficient to increase the adoption rate to drive the goal towards achieving 10% renewables in the energy-mix for Ghana by 2030. It is expected that the government would develop and push out more incentives to generate the level of enthusiasm and participation necessary to drive the shift towards solar energy technology adoption.

Social barriers

A social issue highlighted by the study concerns the moral justification and sustainability of green energy at the expense of people dying in lithium mines, the primary source of lithium-ion batteries. Further to this is the competing demand for water for other activities such as agriculture and tourism (Petavratzi et al., 2022). In some instances, forced migration results from this competing demand for water as communities are forced to relocate to other areas where water supply could be assured (Agusdinata et al., 2018). Despite the positive side of lithium in contributing to climate change mitigating activities through electrification of the transport sector, these social concerns need to be adequately catered for to make them worthwhile.

Safety concerns also exist regarding the high possibility of explosive potential for second -life lithium-ion batteries, resulting from the electrochemical system stability of used batteries, if not handled in a professional manner (Li et al., 2022).

Technological barriers

The Energy Commission has licensed over 200 companies[12] to install and maintain solar systems in Ghana with the objective of ensuring that these companies meet required standards and provide quality services to end-users. The Commission, however, acknowledges the challenges of making solar technology widely available in Ghana, including the availability of skilled labour and access to solar technologies.

Lithium-ion batteries are preferred to lead-acid batteries because of their durability, reliability, power capacity and safety. These serve as a good alternative also to the use of diesel generators which are not only expensive but also create local environmental impacts due to emissions. Notwithstanding, the development of lithium-ion battery technology for solar photo-voltaic systems, particularly the use of second-life batteries to reduce cost is heavily challenged.

According to the Ghana Standards Authority (GSA), there is a lack of technical staff or capacity to test second-life batteries, as the technology is not yet present in the Ghanaian market. The GSA is open to collaborating with potential business partners to develop standards and testing laboratories for the certification of products relating to second-life battery use in Ghana. The involvement of other regulators like the Energy Commission, Environmental Protection Agency, and Energy Ministry to ensure proper procedures are followed would be a prerequisite for this to be carried out.

Environmental barriers

According to Kampker et al. (2023), the second-life processing of batteries delays the recycling process for end-of-life batteries that would otherwise have made available certain materials such as lithium and other metals needed for producing new batteries. This is particularly the case where end-of-life batteries are reused for between 6 to 10 years in second-life applications. In such instances, the materials needed for producing new batteries must be mined to make up for the expected demand. This in turn takes a negative toll on the environment.

Legal barriers

[12] http://www.energycom.gov.gh/licensing/licensing-renewable-energy-sector/register-of-licenses

The interpretation of regulatory instruments LI 2250 and Act 917 by the EPA are to preserve the environment and prevent the dumping of electrical and electronic waste in Ghana. For this reason, any used electrical item to be imported into the country needs to be properly classified either for refurbishment or repair before it would be allowed into the country. In addition, the item needs to be accompanied by its replacement parts to qualify to be in the category to be imported into Ghana.

> ***"They have collected those batteries already from those companies into a warehouse. Now the question I will ask as a regulator is, the thing that you want to do here by trying to test and remove some of them and give it a second-life, why can't you just do it there and bring the battery that are now refurbished into Ghana?" (EPA-P Interview, Data Collection 2023)***

Unfortunately, used EV batteries are also broadly classified under the term 'used electrical items', thus making it complicated for companies in Ghana to import them to recycle and use as second-life batteries for energy storage to reduce the high initial cost of solar photo-voltaic systems. According to the EPA, this should not be a problem because the law does not ban the used EV batteries as is purported by technology suppliers but only a misinterpretation of the objective of the legal framework. There is, however, little education and awareness of the actual interpretation leaving a vacuum for several wrong interpretations.

Even though the Energy Commission has licensed over 200 companies to install and maintain solar systems in Ghana, the role the Commission has been playing so far is to ensure that these companies meet the required standards and provide quality services. There are however no standards developed for testing second-life batteries as there are for testing new batteries by the Ghana Standards Authority (GSA). According to the GSA, there is currently no testing laboratory for that purpose and the standards for testing would have to be developed for this technology to be recognised in Ghana.

> **"GSA, for example, we are basically developing standards and testing products to meet our standards. And this new technology, we do not have capacity." (GSA-P Interview, Data Collection 2023)**

The government regulations in place seem biased towards the importation of new electronic devices and focus only on the first life of products to the neglect of used electronic devices, including used EV batteries and used solar PV modules. However, there is a growing interest in the use of used EV batteries for solar energy production, and some companies are working on establishing plants to process these batteries.

The private development of mini-grid systems reliant on renewable energy sources is also a challenge in Ghana. There exists a seemingly monopolistic energy sector that crowds out local independent power producers from participating as far as obtaining licenses and approvals to engage in power purchase agreements with prospective customers. The state-owned agencies producing and distributing fossil-based energy to consumers create a hostile environment that makes it unattractive for private sector players who would otherwise make use of solar energy to provide competitively cheaper energy rates to consumers to participate.

The nature and design of buildings in Ghana do not present conducive conditions for the installation of solar photovoltaic systems. There is therefore a need for refining and integration of regulations in favour of the renewable energy sector by way of incorporating in the building codes in place and enforcement of these regulations to ensure compliance.

In the absence of specific legal and regulatory measures for second-life batteries in Ghana, policy makers need to be aware of barriers identified from literature to be prepared to address them as the sector develops and more EV batteries become available with time. According to Kampker et al. (2023), the following legal barriers exist for second-life batteries and would have to be addressed to promote their use:

- Uncertainty of transfer of liability from OEM to second-life battery provider. If liability would have to stay with OEMs, there may be the situation that second-life battery providers would not easily get access to the end-of-life batteries unless the OEMs are directly involved.
- When OEMs are not involved in the second-life battery process, it becomes difficult for the second-life battery provider to have access to previous statistics on battery usage. This situation makes it difficult for insurance companies to fully commit to ensuring second-life battery applications because of the potential unknown risks.
- Beyond the second life of the repurposed batteries, it is unclear who bears the responsibility for the eventual recycling of the completely exhausted battery and taking it off the market. Second-life battery use makes it difficult to decide who bears this responsibility since the original battery was released to the market by the OEM but has also undergone a transformation by the second-life battery provider.
- Privacy issues related to usage data sharing for the first life of batteries also impede the second-life use of batteries as providers may not get access to relevant data to process the batteries for second-life applications.

Awareness and capacity building barriers

Apart from the lack of standards specific for second-life lithium-ion batteries in addition to other barriers highlighted in this report, limited skilled labour and the lack of education on the existing legal regulations on e-waste handling is a major hindrance to the adoption of this technology. As a result of this lack of education and information dissemination, suppliers of the technology are under the impression that there is a ban on the importation of second-life EV batteries for use but according to the EPA, there are specific protocols to be followed that would allow for the importation of same. Technology suppliers are, however, not aware of these protocols.

The banking sector, unfortunately, lacks adequate education and awareness of the sustainability and economic gains of renewables. Banks are sceptical about renewables in light of the IRR analysis they run on proposed projects. By extension, this lack of education and awareness on renewables extends to the possibility of the use of second-life batteries as energy storage for such interventions. Thus, financing products on offer from banks are not particularly favourable towards the technology causing users and suppliers to grapple with the high cost of loans and investments for development.

"We hope that the interest rate on the loan facility will be reduced further once they are able to ascertain that there will be a high return on investments that they will make. But the banking sector themselves also needs some form of education and some realignment of their policies. If we are all thinking sustainability, the banking sector will not see themselves as only doing business, handling money; but trying to make impact by reducing carbon emissions through investing in renewable energies in the form of green bonds and the other derivatives that are being used in the financial markets

regarding renewable energy. Then it will be good for us to have grants instead of loans to sponsor some of these renewable energies." (SF-P Interview, Data Collection 2023)

The availability of skilled labour for solar systems is limited in Ghana, and there is a need for capacity building in this area. Capacity building is, currently, mostly focused on installers but there is a need to also devote attention to technical training in the areas of designing solar systems and selection of solar components for installations.

A national awareness program is needed to educate the populace on renewable energy systems since making information readily available to people can significantly improve adoption.

9.4 Conclusions

Ghana has enormous potential for the adoption of solar photovoltaic systems on a wide scale to generate a significant component of the energy mix. Particularly, areas that are beyond the reach of the national grid could easily be connected to off-grid solar photo-voltaic systems that rely on second-life EV batteries to reduce the high initial costs. Significant efforts, however, must be put in place to make this a reality by addressing the barriers identified through this study.

As previously indicated at the start of the study, there have been several studies in the past on these barriers, excluding the use of second-life EV batteries as energy storage, and appropriate mitigative measures were determined to be carried out by specific implementing bodies. It is recommended that these mitigative measures that were proposed be reviewed as far as the status of implementation is and readapt them to the current situation and trends. This would then factor in mitigative measures that would include the aspects related to second-life battery use, bearing in mind the barriers identified from literature since it is still in its evolving stages in Ghana.

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10. Barrier Analysis for Bio-ethanol Technology for Cooking in Ghana

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10.1 Introduction and literature review

10.1.1 Overview of Bio-ethanol Technology for Cooking in Ghana

One of the key elements of the seventh United Nations Sustainable Development Goal (SDG7) is to "Ensure access to affordable, reliable, sustainable and modern energy for all", which is intimately related to scaling clean cooking solutions by 2030, this goal seeks to ensure that everyone has access to dependable, affordable, sustainable, and modern energy sources (Acheampong, Ertem, Kappler, & Neubauer, 2017).

The category of clean cooking fuels and technologies includes a range of options, such as electricity, natural gas, Liquified Petroleum Gas (LPG), biogas, solar, and alcohol-based fuel stoves. Conversely, cooking methodologies that result in pollution include the use of charcoal, firewood, crop residue, animal excrement, and kerosene (Stoner, Lewis, Martínez., Gumy, Economou & Adair-Rohani, 2021).

As of the year 2022, an estimated 2.4 billion individuals, which accounts for one-third of the world's population, lacked access to clean cooking technologies. The use of inefficient and polluting fuels poses a health risk and is a significant cause of disease and death, especially among women and children in low- and middle-income countries. Inhaling the smoke generated by cooking with polluting fuels can result in cardiovascular disease, stroke, cancer, chronic lung disease, and pneumonia (World Health Organization, 2023)

The utilization of polluting fuels, such as firewood and charcoal, has been identified as a significant contributor to deforestation. This phenomenon has resulted in adverse effects on the plant cover, which in turn has had a notable impact on the global ecosystem. Forests serve as significant carbon sinks due to their capacity to sequester a substantial amount of carbon dioxide. In the event of tree mortality or destruction, gaseous emissions are released into the atmosphere. According to the Climate Council, the annual global carbon dioxide emissions resulting from deforestation are estimated to be approximately 4.8 billion tonnes (Dean, 2019). Deforested areas go from serving as carbon sinks to becoming carbon sources.

In light of the consequences associated with the use of unclean cooking fuels, various governmental bodies, development partners, non-governmental organisations, and other institutions have emphasised the importance of adopting cleaner fuel alternatives for cooking purposes. This has resulted in the development of diverse technologies that facilitate the management of wood fuel consumption or the complete transition to alternative, more environmentally friendly technologies. Nevertheless, the global community has yet to achieve the objectives of providing widespread availability of clean fuels and cooking technologies.

According to estimates, the projected rate of progress suggests that a mere 72% of the world's population will have access to clean cooking fuels and technologies by the year 2030 (World Bank, WHO, IEA, IRENA, UNSD, 2021).

The situation in Ghana exhibits no significant difference from the global phenomenon. In the last ten years, there has been an increase in the population predominantly dependent on clean fuels for cooking. Indeed, it rose from 18% in 2010 to approximately 37% in 2021 (Ghana Statistical Service, 2021). The present trajectory of expansion points to a trajectory that indicates that the percentage of individuals with access to clean cooking technologies will reach approximately 49% by 2030, which falls short of the SDG 7 objective of 100%.

According to the 2021 population and housing census, an estimated 4.5 million households used fuels and technologies for cooking that emit pollutants. This implies that roughly 18.4 million individuals were subjected to the harmful effects of these polluting fuels. Consequently, more than 50% of the populace in Ghana is susceptible to contracting illnesses resulting from indoor air pollution emanating from unhygienic cooking methods and fuel sources. (Ghana Statistical Service, 2021).

The Ghanaian government has developed policies and strategies aimed at promoting the adoption of clean cooking technologies. The objective of these measures is to enhance carbon sequestration, mitigate deforestation, and minimise indoor air pollution. One of the pivotal policy documents is "Sustainable Energy for All" (SE4ALL), which aimed to augment the use of clean cooking methods through the promotion of LPG and enhanced cookstoves. Enhanced cookstoves have been found to mitigate wood fuel consumption to a certain degree; however, they do not entirely eradicate the practice of deforestation for charcoal production. Conversely, the utilisation of LPG obviates the dependence on wood-based fuels and the associated indoor air pollution. The escalating expense of LPG is prompting consumers to transition towards utilising charcoal and other environmentally detrimental fuels (Crentsil, Fenny, Ackah, Asuman & Otieku, 2020). The mean cost of LPG experienced an upward trend, rising from Ghanaian Cedi (GHS) 3.17 per kilogramme in January 2017 to approximately GHS 11.5 per kilogramme as of March 2022. This escalation was primarily influenced by the surge in crude oil prices and the depreciation of the currency. Hence, the availability of an alternative fuel source is crucial to supplement the endeavours of other environmentally friendly fuels and expedite Ghana's pursuit of attaining widespread accessibility to clean cooking fuels. Bioethanol, derived from local sources, is one such clean fuel option covered in this chapter.

10.2 Literature review on the use of bioethanol for cooking in Ghana

Adu, Lamptey, Kaburi & Otoo (2022) investigated the potential of cassava ethanol as a greener alternative to traditional cooking fuels in Ghana. Their research compared the rising costs of liquefied petroleum gas (LPG) and electricity to the viability of large-scale cassava ethanol production. Due to its widespread availability and underutilization in Ghana, the study concluded that cassava is the most appropriate crop for ethanol production. The researchers discovered that the Crop Research Institute-Agra (CRI-Agra) Bankye cassava variety produced the most ethanol. This study contributed to the existing body of knowledge on clean culinary fuels by proposing cassava ethanol as a superior replacement for environmentally hazardous fuels such as wood and charcoal.

Bofah, Appiah-Konadu & Ngwu (2022) used the Ghana Living Standards Survey 7 (GLSS 7) household data and the multinomial logit regression model to determine the factors that influence the choice of cooking energy. Their analysis sought to determine the determinants of Ghana's transition to cleaner heating energy. The results showed that education, household domicile type, household size, employment, and income group were the most influential factors in household energy choices in Ghana. As strategies to encourage the adoption of cleaner energy alternatives, the study suggested expanding access to education and implementing policies to enhance housing conditions, employment opportunities, and income levels.

Tulashie, Dodoo, Ketu, Adiku, Miyittah, Forfoe & Arthur (2023) presented a study on the adoption of a circular sweet sorghum supply chain in the northern region of Ghana via the production of bioethanol from sweet sorghum surplus. The research centred on producing bioethanol from red and white sweet sorghum cereals (RSG and WSG) grown in excess in northern Ghana. To produce bioethanol, the authors pretreated and fermented sweet sorghum cereals with Saccharomyces cerevisiae yeast. The study also evaluated the bioethanol's fuel properties, which were found to be suitable for commercial use in bioethanol cookstoves, thereby diminishing northern Ghana's reliance on firewood. The results indicated that the production of bioethanol by smallholder farmers is a sustainable and efficient method that requires minimal resources and basic techniques.

Wiredu, Yang, Sampene, Shams, Nishimwe, Agyeman & Awuah (2022). investigated the barriers associated with the implementation of bioenergy initiatives in Ghana using both case study and survey methods. Their empirical findings revealed many significant obstacles to bioenergy implementation, including limited financial resources, insufficient technical knowledge, a paucity of research data, the absence of an adequate legal framework, and insufficient political will. To promote bioenergy production, the study highlighted the significance of political decisions supporting acceptance and implementation, training and capacity development, flexible funding mechanisms, and dissemination plans. In addition, the authors emphasised the need for legislative reforms to establish a legal framework that protects bioenergy project entrepreneurs and investors. The purpose of the study was to aid the government in incorporating the viewpoints of bioenergy stakeholders into policy formulation processes.

In conclusion, the reviewed studies contribute to a greater understanding of sustainable energy alternatives and their potential socioeconomic and environmental benefits in Ghana. They emphasise the viability of cassava ethanol and bioethanol derived from sweet sorghum as cleaner cooking fuels, identify the determinants of household energy choices, and address the obstacles and requirements for the successful implementation of bioenergy in the country. These findings provide important insights for policymakers, researchers, and stakeholders in Ghana who are interested in promoting sustainable energy practises and transitioning to a more circular and environmentally friendly economy and form the foundation for the development of the interview guide for this study.

10.2.1 Stakeholders' Consultation and Barrier Analysis

The utilisation of bio-ethanol technology presents a promising opportunity as a viable and cost-effective energy solution for food production in Ghana, where a recent push to encourage the implementation of bio-ethanol technology is already taking place. The purpose of this report is to present a barrier analysis to the advancement of bioethanol for cooking in Ghana, whereby findings are supported by interviews concerning the adoption of bio-ethanol technology for cooking purposes in the country. The stakeholders were selected from six categories as indicated below:

- Policymakers - These included the Ministry of Energy and Energy Commission, A total of four policymakers from these institutions were interviewed.
- Solution providers: selected SMEs
- Experts-Academia and other experts
- End users: The end users, head teachers and matrons of selected demonstration schools were interviewed.
- NGO
- funding agencies

The response could not be obtained from NGOs and funding agencies as representatives were not available for the interview despite several attempts. A total of sixteen stakeholders were interviewed; details are provided in Appendix 12.

The responses from stakeholders to the questions on barriers to the adoption of bioethanol for cooking in Ghana are reviewed and presented below using the barriers framework established in Chapter 2. The questionnaire prepared by partners from UNEP Copenhagen Climate Centre (UNEP CCC) covers six kinds of barriers. These were customized for bio-ethanol technology and can be referred to in Appendix 13.

10.2.2 Barriers

Political and institutional barriers

The Ghanaian government has implemented Ghana's Renewable Energy Master Plan (ECG, 2019) to provide a framework for the promotion and development of renewable energy resources. However, the respondents (P2, E1, E5) acknowledge that the extent of these efforts has been insufficient in scope. The absence of specific targets and timelines for the implementation of bio-ethanol technology has been observed within the governmental framework.

The current state of institutional capacity in both the public and private sectors regarding the integration of bio-ethanol technology into mainstream usage is still in the developmental stage. The present level of institutional capacity in Ghana is insufficient to facilitate the advancement and implementation of bio-ethanol technology. To enhance the institutional capacity for the integration of bio-ethanol technology, the majority of respondents (experts, solution providers, users, and the Energy Commission) recommend that the government allocate resources towards research and development, and capacity-building initiatives for relevant stakeholders, and facilitate knowledge-sharing and collaborative efforts.

Also, respondents largely from academia (E1, E2, E4, E5) indicate that enhanced coordination among relevant stakeholders is imperative to facilitate the advancement and implementation of bio-ethanol technology in Ghana. At present, multiple stakeholders including government agencies, academia, donor agencies, NGOs and SMEs are engaged in the advocacy of bio-ethanol technology, however, their level of coordination is deemed insufficient.

Economic and Financial Barriers

In response to the question about the potential hindrance posed by the upfront expenses of bio-ethanol technology to end-users, a considerable number of respondents concurred that it indeed presents a significant challenge. The adoption of technology by households and small businesses is impeded by the high cost of the technology, limited financing options, and a dearth of financial incentives from the government. The cost of bio-ethanol technology may increase due to the imposition of import duty and domestic taxes, including VAT, as reported by the S1 and S2.

In response to the inquiry regarding the provision of financial incentives by the government to mitigate the expenses associated with bio-ethanol technology, E1, E2 and S1 asserted the non-existence of such incentives. Nevertheless, it has been observed by some that the government has instituted certain measures, such as tax exemptions on imported equipment and machinery intended for renewable energy projects. In general, the respondents suggested that the provision of additional financial incentives, such as subsidies, grants, and low-interest loans, by the government, would be beneficial in encouraging the uptake of bio-ethanol technology.

The respondents emphasized that one important factor influencing the adoption of bio-ethanol technology is the availability of financial resources. Access to affordable finance is limited for numerous households and small businesses in Ghana, which poses a challenge in financing the initial costs of acquiring the technology (S1, S2). S1 and S2 further observed that private banks and non-banking financial institutions exhibit a general willingness to provide financing to end-users. Nevertheless, the accessibility of finance for numerous prospective adopters is restricted by high interest rates and rigorous lending requirements. According to the interviewees, the government should engage in partnerships with financial institutions to offer end-users financing options that are both cost-effective and adaptable.

Despite the potential benefits, the widespread adoption of this technology is impeded by significant barriers such as high initial costs and limited financing options. Respondents largely from potential user groups, academia and SMEs proposed that the government ought to investigate novel financing models, such as public-private partnerships and microfinance schemes, to encourage the implementation of the aforementioned technology.

Concerning the establishment of the indigenous supply chain for bio-ethanol technology, the respondents (E4, E5) have pointed out numerous obstacles that require resolution. The primary factors impeding the advancement of the domestic supply chain were identified as restricted availability of appropriate feedstock, insufficient infrastructure, and deficient institutional capability. In response to the aforementioned obstacles, the respondents proposed that the government allocate resources towards the advancement of feedstock cultivation, processing, and transportation infrastructure. Additionally, they suggested the establishment of institutional capacity for research and development.

Social Barriers

The study revealed that a notable proportion of interviewees (40%) expressed concerns regarding the perceived inconvenience associated with the use of bioethanol in comparison to conventional fuels. The perceived inconvenience was attributed to various factors, including the requirement for specialized stoves, fuel accessibility, and potential obstacles in fuel storage and transportation.

The study revealed that certain behavioural habits and cultural preferences may impede the adoption of bio-ethanol technology, as reported by a minority of participants (20%). Specifically, individuals' adherence to customary cooking techniques, cultural norms, and culinary habits were identified as potential obstacles. The participants (E1, E3) highlighted the importance of implementing capacity-building initiatives and fostering community engagement as effective strategies to address the cultural obstacles at hand.

Gender dynamics emerged as a salient social issue impeding the uptake of bio-ethanol technology, as reported by a substantial proportion of participants (75%). They highlighted the fact that in Ghanaian households, the responsibility of cooking primarily falls on women. Therefore, it is imperative to take into account their preferences and requirements while promoting alternative cooking fuels. Incorporating considerations of gender dynamics and promoting the participation of women in decision-making processes can catalyze the effective implementation of a given initiative.

The social issue of fuel availability and distribution was identified by all participants from the potential user group and E4.

Technical and Infrastructure Barriers

The stakeholders from academia and policymakers have articulated concerns regarding the accessibility of a proficient workforce for bio-ethanol technology in Ghana. They observed that professionals and technicians possessing specialised knowledge and expertise in bio-ethanol production, processing, and associated domains are presently not sufficient.

Almost all respondents (93%) indicated the need for enhancing the capacity of bio-ethanol technology. The significance of training programmes, workshops, and educational initiatives was underscored to augment the competencies and expertise of the current workforce and to cultivate a fresh cohort of practitioners in the domain. Efforts aimed at enhancing capacity should prioritise diverse aspects such as the cultivation of feedstock, production of bioethanol, plant operations, quality control, and safety protocols.

The stakeholders from the potential user group have emphasized that the acquisition of bio-ethanol technology in the Ghanaian market can be challenging. The users indicated that the availability of suppliers / manufacturers of equipment for bio-ethanol production, processing plants, and associated technologies is inadequate within the country. Consequently, individuals interested in adopting bio-ethanol technology encounter obstacles in procuring appropriate and cost-effective equipment and technological alternatives.

In addition, the following technical challenges associated with making bio-ethanol technology available in Ghana were pointed out by the stakeholders:

a) The development of bio-ethanol production facilities requires infrastructure for the cultivation, transportation, and processing of feedstock. The inadequate provision of infrastructure, including storage facilities and transportation networks, may impede the uptake and proliferation of bio-ethanol technology.
b) The maintenance of consistent and high-quality bio-ethanol production necessitates strict adherence to quality control measures. The stakeholders (P2, E1, E2, E5), have identified many challenges associated with the implementation of comprehensive quality control systems. These include issues related to laboratory facilities, testing procedures, and compliance with global standards.

c) Insufficient allocation of resources for research and development on bio-ethanol technology poses a constraint on the progress of technological advancements, innovation, and cost-effectiveness. The stakeholders, largely from academia, emphasised the necessity of augmenting research activities to tackle technical issues and improve the efficacy of the bio-ethanol production process.

Environmental Barriers

The inadequate management of bio-ethanol production was identified by respondents to have the potential to pose environmental hazards. Respondents from academia indicated that the utilisation of specific crops, such as maize or sugarcane, in the production of bioethanol may result in amplified demands on land usage and water resources, thereby causing unfavourable effects on biodiversity and ecosystem services.

Also, some respondents from academia further stated the generation of bioethanol has the potential to have an impact on air quality, particularly during the stages of fermentation and distillation. This is due to the possibility of volatile organic compounds (VOCs) and particulate matter being released into the atmosphere. The utilisation of biomass feedstock in the production of bioethanol has the potential to result in the discharge of greenhouse gases, including methane and carbon dioxide. The mitigation of air quality impacts associated with bio-ethanol production necessitates the adoption of suitable emission control technologies, such as scrubbers, filters, and monitoring systems, alongside the promotion of low-emission feedstocks.

Legal and Regulatory Barriers

In response to the question on the availability of a legislative requirement that could catalyze the widespread implementation of bio-ethanol technology, all respondents agree that to facilitate the uptake of bio-ethanol technology for cooking purposes in Ghana, it is imperative to establish supportive legislation in various critical domains. They asserted that legislation that offers financial incentives, such as tax exemptions, grants, or subsidies, can effectively encourage the establishment of bio-ethanol production facilities. The provision of incentives could serve as a means of mitigating the substantial upfront expenses linked to the establishment of infrastructure, cultivation of feedstock, and processing, thereby enhancing the economic feasibility of bioethanol.

Legislative support for research and development on bio-ethanol technology is necessary for its progression. Most respondents, especially those from academia, recommended that legislative bodies allocate financial resources to research institutions and foster partnerships with both academic institutions and private organizations. The facilitation of innovation, improvement of production methods, and enhancement of overall efficiency and cost-effectiveness are potential benefits of bio-ethanol production.

To drive the adoption of bio-ethanol technology for cooking in Ghana, all respondents agreed that there is a need for supportive legislation in several key areas. These include:

a) Renewable Energy Policy: A dedicated renewable energy policy or amendment to existing energy policies should include provisions that encourage the production, distribution, and utilization of bioethanol as a sustainable cooking fuel. This legislation could set targets for bio-ethanol adoption, establish mechanisms for financial incentives, and outline regulatory frameworks for the industry.

b) Incentives and Subsidies: Legislation providing financial incentives, such as tax breaks, grants, or subsidies, can significantly promote the establishment of bio-ethanol production facilities. These incentives would help offset the high initial costs associated with infrastructure setup, feedstock cultivation, and processing, making bioethanol more economically viable.

c) Research and Development Funding: Legislative support for research and development activities related to bio-ethanol technology is crucial for its advancement. Funds could be allocated to research institutions and collaboration between universities and private entities promoted. This would facilitate innovation, improve production methods, and enhance the overall efficiency and cost-effectiveness of bio-ethanol production.

d) Feedstock Regulation: Legislation can play a role in ensuring the availability and sustainability of feedstock for bio-ethanol production. By establishing regulations and guidelines for responsible cultivation, harvesting, and processing of feedstock, the government can ensure a consistent and adequate supply while mitigating any negative environmental or social impacts.

Awareness and capacity building barriers for the Bio-ethanol Technology in Cooking in Ghana

The level of awareness regarding bio-ethanol technology in Ghana is inadequate. A significant number of participants recognised the insufficient awareness and comprehension among the populace regarding the advantages, accessibility, and application of bioethanol as a cooking fuel. A significant proportion of the populace continues to utilise conventional cooking fuels such as wood or charcoal and lacks knowledge regarding the possible benefits of bioethanol.

The survey participants unanimously agree that there is a pressing requirement for initiatives aimed at raising awareness and promoting the adoption of bio-ethanol technology in Ghana.

The participants recommended the following actions to increase awareness and promote bio-ethanol technology in Ghana:

- The dissemination of information regarding the advantages, accessibility, and utilisation of bioethanol for cooking purposes can be efficiently achieved through diverse platforms such as television, radio, social media, and community-based initiatives.
- Demonstrations and pilot projects are commonly used in various fields to test the feasibility and effectiveness of new ideas, technologies, or processes.
- The implementation of training and capacity-building initiatives can enhance the local ecosystem and promote the adoption of bio-ethanol production, stove maintenance, and marketing. These programmes can be extended to community leaders, local technicians, and entrepreneurs to provide them with the necessary skills and knowledge.

10.3 Conclusions

The analysis of barriers to the adoption of bio-ethanol technology for cooking purposes in Ghana has uncovered significant gaps across multiple areas, which must be overcome to facilitate the adoption of bio-ethanol technology in the country.

The absence of well-defined targets and timelines for bio-ethanol technology has been recognized as a barrier from a policy and institutional perspective. Target setting can help establish an enabling investment environment and accelerate the introduction of the technology. The economic barriers to bioethanol for cooking include high initial costs, a lack of access to financing, and a lack of financial incentives. These barriers can be addressed by the government through the provision of subsidies and facilitating access to finance and the establishment of the domestic bio-ethanol supply chain.

The bio-ethanol technology for cooking also faces various social barriers, including issues of affordability, perceived inconvenience, cultural preferences, gender dynamics, and challenges related to fuel availability and distribution. These issues will need to be addressed while promoting bioethanol.

Technological barriers to the adoption of bioethanol include inadequate human resources with requisite skills, insufficient access to equipment and technological substitutes, and inadequate infrastructure. Therefore, it is necessary to augment the workforce's capabilities through training programmes and educational initiatives. It is also important to facilitate equipment access and establish infrastructure for feedstock cultivation, transportation, and processing.

The production process involves the emission of volatile organic compounds and greenhouse gases. To address these environmental issues, it is recommended to use mitigation measures including the use of low-emission feedstocks and the adoption of sustainable production techniques. Sustainable production techniques could include crop rotation, integrated pest management, and water conservation. It is also important to conduct environmental impact assessments before the establishment of bio-ethanol plants and implement suitable mitigation measures. On the legal front, there is a need for supportive laws / regulations for the production and use of bioethanol. Finally, the level of awareness of bioethanol for cooking is very low in Ghana. There is a need for creating awareness and promoting and disseminating the technology. Finally, partnerships among various entities such as government agencies, non-governmental organisations, research institutions, and the private sector can be a valuable strategy to promote the technology. It can leverage resources, expertise, and networks to create comprehensive awareness campaigns.

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11. Barrier Analysis for Solar Irrigation in Rwanda

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11.1 Introduction and literature review

Rwanda is a landlocked country lying south of the Equator in East-Central Africa with an area of 26,338 km^2 and an average altitude of about 1700 meters. The population is estimated to be around 13.8 million (Macrotrends, 2023). In Rwanda, solar energy is used in agriculture mainly in two areas of application: solar powered irrigation which is being promoted for the last 3 to 4 years; and solar powered refrigeration for post-harvest storage.

Though solar irrigation has been documented as having the potential to engender growth and support poverty reduction efforts in African countries where there is still heavy dependence on subsistence farming, there are challenges that continue to hinder the smooth adoption of the technology including uncovered risks, lack of incentives, and lack of capacity (Durga, et. al, 2023). Some other sources classify these challenges into technology development and innovation challenges, affordability and financing challenges, consumer awareness challenges, and business and operational model issues (Maina, 2023). In Rwanda, between 2018 and 2020, a donor-funded programme themed the Solar Irrigation Rwanda (SIR) was carried out to promote market development and demonstrate a good case for the adoption of the technology. The programme provided mobile and stationary solar water pumping systems to selected smallholder farmers (Energy4Impact, 2021). Findings from the programme suggested that those who adopted the solar irrigation systems recorded comparatively higher yields translating into higher profitability and better gains on investments. Also, other studies conducted to analyze the environmental and economic costs of solar PV, Diesel and hybrid PV-Diesel water pumping systems for agricultural irrigation in Rwanda showed that Solar PV water pumping systems have significant potential benefits for the growth of the agriculture sector and can help spur economic development in Rwanda (Jean Baptiste, 2018). To achieve the full potential and benefits, however, the Solar Irrigation Rwanda programme made some recommendations including raising farmer awareness among farmers and key stakeholders of solar irrigation potentials; making the technology affordable through subsidies and third-party financing; building farmers' and stakeholders' capacity; among others (Energy4Impact, 2021).

11.1.1 Existing policies for Solar Powered Irrigation in Rwanda

The Government of Rwanda's 7-year National Strategy for Transformation (NST1) (2017 - 2024), has a target to increase agriculture under irrigation from 48,508 hectares in 2017 to 102,284 hectares by 2024. To reach this target, there is an increasing need for the private sector to be involved. As the country is densely populated and farmers own small pieces of land, a land consolidation policy was developed to increase consolidated land from 635,603 hectares (in 2017) to 980,000 hectares (in 2024) (The Republic of Rwanda, 2019). This presents an opportunity to carry out targeted irrigation interventions focusing on lands that are consolidated by the government.

Rwanda developed its first Irrigation Master Plan in 2010. The Rwanda Irrigation Master Plan (IMP) is a ten-year national sectoral plan which provided planning tools for rational exploitation of soil and water resources by promoting irrigation in its various forms (The Government of Rwanda, 2010). Currently, the plan is being reviewed and updated to incorporate the changing trends in irrigation technologies (The Government of Rwanda, 2020; JICA, 2022). An initial review of data on solar energy versus energy from diesel for pumping water for irrigation indicates that solar energy has lower total costs and lower overall energy consumption despite the higher initial investment cost and higher depreciation of machinery and equipment. This makes a case for promoting solar irrigation in Rwanda.

In Rwanda, the promotion of solar-powered irrigation technology started from 2019. It is among the technologies which benefit from the provision of government subsidies to the individual farmer or to a group of farmers, or cooperatives under national program for small-scale irrigation technology. The area of irrigation in these cases varies mostly from 0.5 Hectares to 10 Hectares. The solar-powered irrigation systems are composed of solar arrays without batteries, pumping units, water storage units and distribution pipes. The most used storage units are: Elevated tanks and Surface tanks. Also, drip irrigation and tap irrigation are the two types of irrigation practised.

11.2 Stakeholder's Consultation and Barrier Analysis

11.2.1 Methodology

In this report, we identify the barriers to the adoption of solar irrigation in Rwanda. The methodology employed is a mixed approach where desktop review and structured questionnaires were used to carry out interviews. The structured interviews were used as a tool to capture the ideas of experts from academia, solution providers, and funding agencies while the desktop review highlights some policies, programmes, and initiatives that are supportive of solar-powered irrigation. In total two solution providers, four experts from academia, and one expert from a funding agency were interviewed.

The list of stakeholders interviewed and questionnaire used can be found in Appendix 14 and Appendix 15 respectively.

11.2.2 Barriers

Political and Institutional barriers

The government of Rwanda has a clear plan to implement solar-powered irrigation technology with targets and adequate resources (human and capital) allocated for its implementation. Governmental subsidies are also in place. Solar- powered irrigation systems get 75% subsidies on irrigation equipment and infrastructure while other irrigation systems (without solar) get 50%. Also, the government of Rwanda has put safeguards for users in place. To protect end users of the solar- powered irrigation technology, the government of Rwanda requires every solar powered irrigation solution provider to give a guarantee of one year on their systems to the users. In addition, Rwanda Institute for Conservation Agriculture (RICA), a governmental institute, is responsible for the quality control of solar-powered irrigation components. Evidently, From the interviews and desk research carried out, it can be concluded that there are no political and institutional barriers to solar-powered irrigation in Rwanda.

Technical barriers

In Rwanda, access to solar-powered irrigation technology has never been an issue. However, in some regions of Rwanda, access to reliable water sources can be a challenge. Solar-powered irrigation systems require a sustainable water supply to function effectively. Additionally, efficient water management practices need to be implemented to avoid over-extraction and wastage of water. Reliability of the solar-powered irrigation technology has been a problem in some cases: for example, in some solar-powered irrigation systems, small moving pumps are labour intensive and can affect the reliability of the system whilst in some other cases, such as in direct pumping systems, the set-up is mostly undersized. The installation, operation, and maintenance of solar-powered irrigation systems require technical expertise and there is a shortage of skilled technicians who can provide guidance and support to farmers. Insufficient technical knowledge and limited availability of maintenance services can therefore impede the widespread adoption of these systems.

Economic and Financial barriers

The solar-powered irrigation technology is viable in Rwanda due to governmental subsidies and its tax-free status. However, compared to diesel pump irrigation, the initial cost of setting it up can be high, including the purchase and installation of solar panels, pumps, and storage systems. Many farmers in Rwanda do not have the financial resources to invest up-front in these equipment. Thus, there are financial barriers to technology. For smallholder farmers, a lack of access to inexpensive financing is a barrier. Access to finance by end users of solar-powered irrigation is still an issue in Rwanda because private banks and other non-banking finance institutions are not willing to finance the end users due to their risk perception and doubt on the profitability of solar-powered irrigation systems. In addition, even if banks agree to finance the solar-powered technology, they give a loan at their normal rate which makes it non-viable for the farmers. Therefore, to facilitate the deployment of solar technology, the government developed a business model to share costs between the government and farmers through subsidies. The irrigation market in Rwanda is huge but faces economic and financial barriers requiring government support. Therefore, to expand the market there is the need to develop new innovative business models, which could include special loan arrangements to farmers for solar-powered irrigation systems.

Social barriers

From the interviews conducted, many interviewees did not clearly answer the questions related to social barriers to solar-powered irrigation in Rwanda. However, some interviewees indicated that limited social networks and knowledge sharing on irrigation in Rwanda can be categorized as social barriers to the promotion of solar-powered irrigation in Rwanda. In addition, gender issues can be considered a social barrier to solar-powered irrigation in Rwanda. In many Rwanda rural communities, women play a significant role in agricultural activities. However, they often have limited access to resources, information, and decision-making power.

Environmental barriers

Solar-powered irrigation offers environmental benefits, but there are also environmental barriers that need to be considered for its implementation in Rwanda. Some environmental barriers to solar-powered irrigation in Rwanda as highlighted in the interviews include the concern that solar-powered irrigation systems may generate electronic waste (e-waste) when components reach the end of their lifecycle. Proper disposal and recycling of solar panels, batteries, and other equipment are essential to prevent environmental pollution and ensure sustainable waste management practices.

Legal and regulatory barriers

In Rwanda, the country's current Irrigation Master Plan is being revised to accommodate technological trends that could facilitate the adoption of solar-powered irrigation. Whilst efforts to demonstrate the viability of the technology are being made through dedicated programmes such as the Solar Irrigation Rwanda programme mentioned above as well as government subsidies, there is the need to accompany these efforts with regulations to adequately incentivize the sector, establish standards, build the required capacities, monitor and evaluate progress, etc. as these are not yet in place. The absence of regulatory frameworks can therefore hinder progress.

Awareness and capacity building barriers

Many farmers in Rwanda are not aware of the benefits and technical aspects of solar-powered irrigation. They may have limited knowledge about the availability of solar-powered irrigation systems, their efficiency, and their potential impact on crop yields. Also, there are no demonstration projects, success stories, and peer-to-peer learning opportunities related to solar-powered irrigation, contributing to the slow adoption of the systems. A lack of information and awareness might hinder the adoption of solar-powered irrigation in Rwanda. Again, as mentioned above in the technical barriers section, there is a shortage of skilled technicians who can provide guidance and support to farmers on solar-powered irrigation systems. The need to build capacities of relevant stakeholders in the sector is therefore necessary.

11.3 Conclusion

Rwanda has made tremendous efforts to promote irrigation in agriculture in the last several years by instituting a master plan that provides planning tools and advocates rational exploitation of Rwanda's soil and water resources. The emergence of new technologies such as solar-powered irrigation has brought its own challenges. In this report, we highlighted that, although there is political and institutional support for the technology, some barriers still exist and may hinder the smooth transition to irrigation systems powered by solar energy. It includes creating awareness and building relevant stakeholders' technical expertise, facilitating the financing of the systems, and addressing social issues (empowering women) and environmental challenges related to the deployment of the technology. It also requires establishing necessary legal and regulatory frameworks that will address the barriers to solar irrigation development in Rwanda.

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Appendices

Appendix 1: SESA Partner Institutions Roles and Responsibilities

Partner Institution Name	**Country for barrier analysis, policy roadmap, and policy brief**	**Technology for barrier analysis, policy roadmap, and policy brief**
Wuppertal Institute	Kenya	Solar productive use
UNEP-CCC	Kenya	E-mobility
ICLEI WS	South Africa	Solar solution for rural communities
ICLEI AS	Malawi	Clean cooking
ICLEI ES	Morocco	E-mobility
TUB	Morocco	Solar PV hub/smart home
	Ghana	Second-life batteries
AAMUSTED	Ghana	Bioenergy
UEMI	Rwanda	Solar irrigation

Chapter 4

Appendix 2: List of Interviewed Stakeholder Organizations

ID	Organization/ Institution	Stakeholder Group
P1	Ministry of Energy and Petroleum	Policymaker
P2	Energy Petroleum and Regulatory Authority (EPRA)	Policymaker
P3	Ministry of Transport	Policymaker
P4	Ministry of Transport	Policymaker
S1	Basi Go	Service Provider
E1	Advance Consulting	Expert
E2	GIZ	Expert
N1	Kenya Renewable Energy Association	NGO
U1	Safaricom (Telecommunication company in Kenya)	Potential user
U2	Kiri Energy	Potential user

Appendix 3: Questionnaire for Stakeholders

SESA – Smart Energy Solutions for Africa: Interview questions for various stakeholders- Electric Mobility

Barrier Analysis of the 5 groups of stakeholders

i. Policymakers (government authorities)
ii. Experts (Academia)
iii. Solution Providers
iv. NGOs
v. Funding Agencies

General Questions for all stakeholders

Political and institutional

1. Are there government plans to implement the E-mobility technology with targets and timelines with adequate resources (human and capital) allocated for implementation? Which aspects of current national plans and policies could be improved in your opinion to promote and adopt the E-mobility?
2. What is the current state of institutional capacity in the government and private sector to mainstream the E-mobility technology? Does it need to be improved?
3. Is the current level of coordination on the E-mobility technology related issues within government and between government and other stakeholders including the private sector sufficient or it needs improvement? If yes, how?

Economic and financial

4. Is high price of E-mobility technology compared to current petrol / diesel vehicle a barrier for end users in your opinion?
5. Are taxes such as import duty or taxes such as VAT / GST/ excise duty high for E-mobility?
6. If E-mobility technology prices are high, does government provide any financial incentives? what in your opinion are best ways to address the issue of high price for the E-mobility technology?
7. Is the access to finance by end users for the E-mobility an issue? Are private banks and other non-banking finance institutions willing to finance the end users? If no, what needs to be done?
8. Is cost of finance (interest rate) high for E-mobility end users?
9. Is the local supply chain fairly developed for the technology with involvement of main private sector stakeholders/businesses? If not, what are the issues and how that could be resolved?
10. In your opinion, how big is high upfront price a barrier for e-mobility (on a scale of 1-10)? (Note: 10 being extremely important and 1 being not at all important.)
11. In your opinion, how big is a lack of access to finance a barrier for e-mobility (on a scale of 1-10)? (Note: 10 being extremely important and 1 being not at all important.)
12. In your opinion, how big is high cost of financing (high interest rate on loan) a barrier for e-mobility (on a scale of 1-10)? (Note: 10 being extremely important and 1 being not at all important.)

Social and cultural

1. Do you think there are any social issues related to E-mobility that may affect acceptance of E-mobility by end users? If yes, what are they?

Technology and Infrastructure

2. Is E-mobility technology easily available to service providers and end users?
3. What is your opinion on the availability of skilled labour to work and maintain the E-mobility technology? Is there a need for capacity building for this?
4. Is charging infrastructure a barrier to E-mobility uptake? If yes, in your opinion, how big is a lack of charging infrastructure a barrier for e-mobility (on a scale of 1-10) and how can it be addressed? (Note: 10 being extremely important and 1 being not at all important.)
5. In your opinion, is driving range on a single charge (i.e. how far a vehicle can go after charging) a barrier to E-mobility uptake? If yes, how important is the driving range on a single charge a barrier for E-mobility (on a scale of 1-10)?

Environmental

6. Are there any environmental issues related to E-mobility in the country? Disposal of waste related to E-mobility for example.

Legal and regulatory

7. Is there need for any policy/ legislation / regulation that you consider can be a driver for adoption and upscale of the E-mobility?

Awareness and capacity building

8. What is the status of awareness about the E-mobility technology in the country? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion?
9. Are there any other issues that you think are significant barriers to the E-mobility technology in the country today? Please specify.

Note: Please add the following questions to the above general questions for the following stakeholders as follows:

Additional questions for Solutions Providers

Economic and financial

1. What is the current status of access to finance to E-mobility technology and service providers from banks and other sources? Does it need to improve? If yes, how?

Technology and Infrastructure

2. What is your opinion on the reliability of technology in the country today?
3. What are the main technical challenges that E-mobility is facing today?

Additional questions for Funding Agencies

Economic and Financial

1. Do you think the E-mobility technology is economically viable and ready to be introduced in the market?
2. What is the current status of access to finance to E-mobility providers from banks and other sources? Does it need to improve? If yes, how?

Chapter 5

Appendix 4: List of Interviewed Stakeholder Organizations

ID	Organization/ Institution	Stakeholder Group
P1	Ministry of Energy (Department of Energy Affairs)	Policymaker
E1	Centre for Agricultural Transformation	Expert
N1	Facilitators of Community Transformation [FACT]	NGO

Appendix 5: Questionnaire for Stakeholders

SESA – Smart Energy Solutions for Africa: Interview questions for various stakeholders- clean cooking
Policymakers (government authorities)
Experts (Academia)
Solution Providers
NGOs
Funding Agencies

SESA – Smart Energy Solutions for Africa: Interview questions for various stakeholders - clean cooking
Political and institutional
Are there government plans to further upscale clean cooking with targets and timelines with adequate resources (human and capital) allocated for implementation? Which aspects of current national plans and policies could be improved in your opinion to promote clean cooking and why?
What is the current state of institutional capacity in the government and private sector to mainstream clean cooking? Does it need to be improved?
Is the current level of coordination on the issue of clean cooking within government and between government and other stakeholders including the private sector sufficient or it needs improvement? If yes, how?
Economic and financial
Is the upfront cost of improved cookstoves a barrier in your opinion? Is import duty or high domestic taxes such as VAT / GST an issue?
If prices are high, does the government provide any financial incentives (e.g., grants, concessional loans)? What in your opinion are the best ways to address the issue of high prices?
Is there access to finance by end users (including both SMEs and individuals)? Are private banks and other non-banking finance institutions willing to finance the end users? If not, what needs to be done?
Is the local supply chain fairly developed for the improved cookstoves and efficient fuel pellets with involvement of main private sector stakeholders/businesses? If not, what are the issues and how could they be resolved?
What are the major challenges faced by financial institutions to provide loans to SMEs with clean cooking business models?

Do you think the business models for clean cooking technology are economically viable and ready to be introduced in the market?
Social
From your perspective, do you think affordability is a barrier for clean cooking technology, and improved cookstoves in particular, for low-income households? If yes, what could help to address it?
Are there policies targeting low-income households to support them in accessing and/or purchasing clean cooking appliances? If yes, please specify. If not, why?
Technology and Infrastructure
What is your opinion on the availability of skilled labour to produce improved cookstoves? Is there a need for capacity building for this?
What are the main technical challenges to maintenance services for improved cookstoves?
In your opinion, what is the quality and reliability of improved cookstoves (on a scale of 1-10), and how can it be addressed? (Note: 10 being excellent and 1 being not at all important.)
Environmental
How important do you think it is that clean cooking technology will help reduce overall resource consumption or waste (less fuelwood required)? Please indicate on a scale of 1-10.?
How important do you think it is that this clean cooking technology helps reduce overall GHG emissions, please indicate on a scale of 1-10.
Legal and regulatory
Is there a need for any legislation that you consider a driver for the adoption of the technology, e.g., minimum performance standards, for improved cookstoves?
Awareness and capacity building
What is the status of awareness about improved cookstoves and clean cooking in the country? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion?
Are there any other issues that you think are significant barriers to scaling up clean cooking in the country today? Please specify. Also, what do you see as the key success factors or drivers?
Additional Questions: These could be administered depending on available time
Political and institutional
Have the strategies been formulated to raise funds to implement the plans for adoption of clean cooking?
How do clean cooking plans seek to align with national plans and policies (energy policy, environmental policies, NDCs, etc.?
Economic and financial
Do you think this clean cooking technology is economically viable and ready to be introduced in the market?

Will the upscaling of clean cooking lead to job creation? How does it affect the current workers in the sector?
Are you aware of the current business model adopted by the technology providers? If yes, do you have any opinion on that, including the need for improvement?
Who or what type of organisation within the country or local environment do you consider best suited to develop and provide affordable training for clean cooking?
What is the market size and expected potential for improved cookstoves? Are any studies conducted to assess this potential?
Social
From your perspective, do you think that clean cooking, and improved cookstoves in particular, will improve the overall well-being of intended users or the local area?
From your perspective, to what extent do you expect clean cooking to improve health and safety for the intended users?
Is the improved cookstove (sufficiently) community-centric; that is, does it satisfy the need of the community?
From your perspective to what extent do you expect clean cooking will help reduce time poverty, especially for women and girls, in the areas it is implemented? Please indicate on a scale of 1-10. (Note: 10 being extremely important and 1 being not at all important.)
Technology and Infrastructure
What are the main technical challenges to providing access to clean cooking services in remote/rural areas?
Environmental
Legal and regulatory
Is there any legislation in place that you consider a barrier to the adoption of the technology?
Awareness and capacity building
Are there any other issues that you think are significant barriers to clean cooking in the country today? Please specify. Also, what do you see as the key success factors or drivers to scale up clean cooking?

Chapter 6

Appendix 6: Questionnaire administered to various stakeholders

The questionnaire administered to interviewees is given below. Not all questions were deemed relevant to each stakeholder.

Political and Institutional

- On a scale of 1-10, one being not very effective, how would you rate South Africa's efforts to shift to electric mobility, compared to global best practices?

- On a scale of 1-10, one being not very conducive, how would you rate South Africa's policy environment for e-waste in general compared to international best practices?
- With the small-scale embedded generation option (Eskom), would you say there is a demand for individuals/businesses to set up their own solar panels/home systems/containerized solar?
- Would you consider e-waste management a priority topic for the government? Is there sufficient cross-departmental collaboration and harmonization (e.g., public transportation, electric bus fleets)?

Economic and Financial

- Is there demand for electric vehicles, whether 2 or 4-wheelers, in South Africa? How would you rate the following barriers in order of least to most important on a scale of 1 to 5–
- import duties,
- lack of local manufacturing capacity,
- lack of affordability,
- unreliable electricity,
- lack of charging infrastructure
- low incentives to switch to electric mobility for individuals,
- lack of large-scale political efforts (e.g., electrifying fleets)
- On a scale of 1-10, one being the lowest, how would you rate South Africa's electricity grid's ability to handle a potentially growing electric vehicle load?
- Are you aware of any business models for off-grid solutions using solar and storage technologies? If yes, who are the most promising customers, and are these models sustainable?
- Is there scope for off-grid solutions such as containerized solar, for access or other purposes besides access where needed (e.g., captive generation or grid services)?
- Is the local supply chain fairly developed for the technology with involvement of main private sector stakeholders/businesses? If not, what are the issues and how could that be resolved?
- The used vehicle market is quite robust in several African countries, do you find that is also the case in South Africa? Do you see a similar trend for used EVs? Do you think this will impact the business-case for second-life EV batteries, and to what extent?

Social

- Is it challenging to ask people to switch from existing fuel use patterns to electric-powered vehicles? If so, what would you say is the biggest obstacle?
- Waste collection is largely an informal sector–are there efforts to formalize these jobs that you are aware of?
- There are health and safety concerns with batteries - can these be effectively dealt with and how to ensure safe handling?

Technology and Infrastructure

- What is your opinion on the availability of skilled labour to work and maintain this technology and refurbish used batteries?
- How have producers reacted to the extended producer responsibility for e-waste? Has it helped spur interest and new supply chains? Will enforcement be a challenge?
- What are some global trends you see in terms of dealing with battery waste?
- Is South Africa's innovation and entrepreneurial environment conducive to technology companies interested in this sector? (Such as circular battery design, or more effective refurbishing of used batteries.)
- On a scale of 1–10, how big a risk do you think falling battery costs pose to business cases of second-life battery uses?

- What sort of regulatory frameworks or legal rules would be best to encourage similar production practices? E.g., standardization?
- How do you envisage the final disposal of the battery? Are you also involved in recovering materials?
- Are there any international producer organizations working in standardization that you are aware of/working with?
- How do you ensure safe handling of battery waste, especially when working with informal waste management systems?
- Does the IT system on the battery add to the cost?
- What is the business case for second life uses in off-grid lighting in African countries? Who are the customers?

Environmental

- How important do you think the reduced local pollution from containerized off-grid solutions is to increasing the uptake of this technology? On a scale of 1-10, one being not very important.
- Are existing environmental protections strong enough to handle more electronic waste if/as EV uptake increases?
- **Legal and Regulatory**
- Are regulations for circular design being promoted at a national level, such as attempts to set standards for batteries keeping in mind circular design and second life uses?
- Do regulations for the treatment of hazardous waste present an issue here for the use of second-life batteries?
- What other legal or regulatory measures do you think present an obstacle to this use case, if any?
- What other legal or regulatory measures do you think are most conducive in this use case, if any?

Awareness and Capacity

- What is the status of awareness about the second-life use of EV batteries in South Africa? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion?
- Are there any other issues that you think are significant barriers to the second-life use of EV (or other) batteries? Please specify. Also, what do you see as the key success factors or drivers to scale up this solution?

Chapter 7

Appendix 7: Questionnaire administered to Stakeholders - PVs - household use

5 groups of stakeholders

- Policymakers (government authorities)
- Experts (Academia)
- Solution Providers
- NGOs
- Funding Agencies

General Questions for all stakeholders
Political and institutional

- Are there government plans to implement the PV for household use, with targets and timelines with adequate resources (human and capital) allocated for implementation?

- Which aspects of current national plans and policies could be improved in your opinion to promote and adopt the PVs?
- What is the current state of institutional capacity in the government and private sector to mainstream the PVs for household use?
- Is the current level of coordination on the PV technology across the main stakeholders (governmental entities, private sector and similar) sufficient or does it need improvement? If yes, how?

Economic and financial

- Is the high price of PV technology a barrier for end users in your opinion?
- Are taxes such as import duty or taxes such as VAT / GST/ excise duty a barrier for the widespread adaptation of PV technology for household use?
- If PV technology prices are high, does the government provide any financial incentives?
- (What in your opinion are best ways to address the issue of high price for the PV technology)?
- Is the access to finance by end users for the PV technology an issue? Are private banks and other non-banking finance institutions willing to finance the end users? (If no, what needs to be done?)
- Is the cost interest rate high?
- Is the local supply chain fairly developed for the technology with involvement of main private sector stakeholders/businesses? If not, what are the issues and how that could be resolved?

SERVICE PROVIDERS ONLY: Economic and financial

- What is the current status of access to finance to service providers from banks and other sources? (Does it need to improve? If yes, how?)

Social and cultural

- Do you think there are any social issues related to PV technology that may affect its acceptance by end users? If yes, what are they?

Technology and Infrastructure

- Is PV technology for households easily available to service providers and end users?
- What is your opinion on the availability of skilled labour to work and maintain the PV technology? Is there a need for capacity building for this?
- What is the main barrier for the uptake of PV technology for households?

SERVICE PROVIDERS ONLY: Technology and Infrastructure

- What is your opinion on the reliability of technology in the country today?
- What are the main technical challenges of PV technology for households facing today?

Environmental

- Are there any environmental issues related to PV technology in the country?

Legal and regulatory

- Is there need for any policy/ legislation / regulation that you consider can be a driver for adoption and upscale of the PV technology for households?

Awareness and capacity building

- What is the status of awareness about PV technology in the country? Do you think there is a need for awareness and promotional measures? (If yes, what are the best measures in your opinion?)
- Are there any other issues in terms of awareness that you think are significant barriers to the PV technology in the country today? Please specify.

Chapter 8

Appendix 8: List of Interviewed Stakeholder Organizations

ID	Organization/ Institution	Stakeholder Group
Interviewee 1	IRESEN	Business
Interviewee 2	Cadi Ayyad University	Expert
Interviewee 3	Green Energy Park	NGO

Appendix 9: Questionnaire for Stakeholders

SESA – Smart Energy Solutions for Africa: Interview questions for various stakeholders- Electric mobility

Barrier Analysis of the 3 groups of stakeholders

- Experts (Academia)
- Solution Providers
- NGOs

The questionnaires for various stakeholders' categories (who were interviewed) are given below:

<u>General Questions for all stakeholders</u>

Political and institutional

- Are there government plans to implement the E-mobility technology with targets and timelines with adequate resources (human and capital) allocated for implementation? Which aspects of current national plans and policies could be improved in your opinion to promote and adopt the E-mobility?
- What is the current state of institutional capacity in the government and private sector to mainstream the E-mobility technology? Does it need to be improved?
- Is the current level of coordination on the E-mobility technology related issues within government and between government and other stakeholders including the private sector sufficient or does it need improvement? If yes, how?

Economic and financial

- Is the high price of E-mobility technology compared to current petrol / diesel vehicle a barrier for end users in your opinion?
- Are taxes such as import duty or taxes such as VAT / GST/ excise duty high for E-mobility?
- If E-mobility technology prices are high, does the government provide any financial incentives? What in your opinion are the best ways to address the issue of high prices for the E-mobility technology?
- Is the access to finance by end users for the E-mobility an issue? Are private banks and other non-banking finance institutions willing to finance the end users? If not, what needs to be done?
- Is cost of finance (interest rate) high for E-mobility end users?
- Is the local supply chain fairly developed for the technology with involvement of main private sector stakeholders/businesses? If not, what are the issues and how that could be resolved?
- In your opinion, how big is the high upfront price a barrier for E-mobility (on a scale of 1-10)? (Note: 10 being extremely important and 1 being not at all important.)
- In your opinion, how big is a lack of access to finance a barrier for E-mobility (on a scale of 1-10)? (Note: 10 being extremely important and 1 being not at all important.)

- In your opinion, how big is high cost of financing (high interest rate on loan) a barrier for E-mobility (on a scale of 1-10)? (Note: 10 being extremely important and 1 being not at all important.)

Social and cultural

- Do you think there are any social issues related to E-mobility that may affect acceptance of E-mobility by end users? If yes, what are they?

Technology and Infrastructure

- Is E-mobility technology easily available to service providers and end users?
- What is your opinion on the availability of skilled labour to work and maintain the E-mobility technology? Is there a need for capacity building for this?
- Is charging infrastructure a barrier to E-mobility uptake? If yes, in your opinion, how big is a lack of charging infrastructure a barrier for E-mobility (on a scale of 1-10) and how can it be addressed? (Note: 10 being extremely important and 1 being not at all important.)
- In your opinion, is driving range on a single charge (i.e. how far a vehicle can go after charging) a barrier to E-mobility uptake? If yes, how important is the driving range on a single charge a barrier for E-mobility (on a scale of 1-10)?

Environmental

- Are there any environmental issues related to E-mobility in the country? Disposal of waste related to E-mobility for example.

Legal and regulatory

- Is there need for any policy/ legislation / regulation that you consider can be a driver for adoption and upscale of the E-mobility?

Awareness and capacity building

- What is the status of awareness about the E-mobility technology in the country? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion?
- Are there any other issues that you think are significant barriers to the E-mobility technology in the country today? Please specify.

Additional questions for Solutions Providers

Economic and financial

- What is the current status of access to finance to E-mobility technology and service providers from banks and other sources? Does it need to improve? If yes, how?

Technology and Infrastructure

- What is your opinion on the reliability of technology in the country today?
- What are the main technical challenges that E-mobility is facing today?

Chapter 9

Appendices 10: List of Interviewed Stakeholder Organisations in Ghana

No.	INSTITUTION	CATEGORY	CODE
1	Energy Commission	Policy Maker	EC-P
2	Environmental Protection Agency	Policy Maker	EPA-P
3	Ghana Standards Authority	Policy Maker	GSA-P
4	Nastech Power Solutions	Suppliers of the Technology	NPS-P
5	Stella Futura	Suppliers of the Technology	SF-P
6	Solar Taxi	Suppliers of the Technology	ST-P

Appendices 11: Interview Guide for Stakeholders Interviews in Ghana

SESA – Smart Energy Solutions for Africa: Interview questions for various stakeholders- 2nd life battery use for Solar Energy (PVs)

Barrier Analysis of the 5 groups of stakeholders
Policymakers (government authorities)
Experts (Academia)
Solution Providers
NGOs
Funding Agencies

Interview Guide
Preamble:
Li-ion batteries are found in several applications as energy source for electrical equipment and predominantly also in electric vehicles. Depending on the use of battery, a used-up pack could still have sufficient energy in some battery cells (approximately 70% to 80% residual capacity) that could be harvested and re-used for other stationary systems. Mostly, these find use in renewable energy systems such as wind or solar as energy storage.
In this project we focus on 2nd life battery use as energy storage for off-grid solar PV systems.

Name:
Company:
Position:
Role in company in relation to the interview topic:

Political and institutional

- Are there government plans to promote 2nd life battery use for Solar Energy with targets and timelines including adequate resources (human and capital) allocation?
- Which aspects of current national plans and policies could be improved in your opinion to further promote this technology and why?
- Are there strategies in place to raise funds for the promotion of the 2nd life battery use for Solar Energy adoption?
- How does the 2nd life battery use for Solar Energy in Ghana align with national plans and policies (energy policy, environmental policies, etc)
- What is the current state of institutional capacity in the government and private sector to mainstream the 2nd life battery use for Solar Energy technology?
- Is there a need to improve on the current state of institutional capacity in this wise? Yes/No. Please explain.
- What is the current state of coordination amongst relevant stakeholders for the promotion and adoption of 2nd life battery use for Solar Energy in Ghana?
- Would you give any recommendations in respect of coordination activities and roles?

Economic and financial

- Do you consider the initial cost of solar technology to end users a barrier in your opinion?
- If yes, why?
- If No, why?
- Is import duty or domestic taxes such as VAT / GST an issue?
- If prices are high, does the government provide any financial incentives?
- What, in your opinion, are the best ways to address the issue of high initial acquisition costs for solar energy technology?

- Is the access to and cost of finance (interest rate) by end users for solar energy technology an issue?
- Are private banks and other non-banking finance institutions willing to finance the end users?
- If not, what needs to be done?
- Do you think Solar energy technology is economically viable and implementable on a large scale?
- Is the local supply chain fairly developed for the 2nd life battery use for Solar Energy with the involvement of main private sector stakeholders/businesses?
- If not, what are the issues and how could they be resolved?

Social

- From your perspective, do you think affordability (by the end users) is a barrier for Solar energy technology acquisition and use?
- If affordability was not an issue, what do you think would make people reluctant to embrace solar energy technology?
- Do you know of any other social issues that pose a challenge to the adoption of the 2nd life battery use for Solar Energy technology?

Technology and Infrastructure

- What is your opinion on the availability of skilled labor for 2nd life battery use for Solar Energy technology?
- Is there a need for capacity building for this?
- How easy is it to get access to this technology on the market?
- What are the main technical challenges to providing access to solar energy technology on the market?

Environmental Legal and regulatory

- Is there a need for any legislation that you consider a driver for adoption of the technology?
- Is there any legislation in place that you consider a barrier to the adoption of the technology?

Awareness and capacity building

- What is the status of awareness about solar energy technology in the country?
- Do you think there is a need for awareness and promotional measures?
- If yes, what are the best measures in your opinion?
- If No, why?
- Are there any other issues you think are significant barriers to the promotion of 2nd life battery use for Solar Energy technology in Ghana?

Conclusion

- Are there any other barriers you would like to draw attention to?
- How would you recommend for such barriers to be addressed?

Chapter 10

Appendix 12: The stakeholders interviewed.

Stakeholder Group	Subgroup	Number	ID (Code)
Policymakers	Ministry of Energy	1	P1
	Energy Commission	1	P2
	Local assembly	2	P3, P4
Expects (Academia)	AAMUSTED	3	E1, E2, E3
	KNUST	2	E4, E5
Solution providers (SME)	Econexus Ventures	2	S1, S2
Potential Users	Head of selected school	2	U1, U2
	Matrons (cooks)	3	U3, U4, U5

Appendix 13: Questionnaire for stakeholders

Political and institutional

- Are there government plans to promote Bio-ethanol technology with targets and timelines including adequate resources (human and capital) allocation?
- Which aspects of current national plans and policies could be improved in your opinion to further promote this technology and why?
- What is the current state of institutional capacity in the government and private sector to mainstream Bio-ethanol technology?
- What is the current state of coordination amongst relevant stakeholders for the promotion and adoption of Bio-ethanol technology in Ghana?

Economic and Financial

- Do you consider the initial cost of Bio-ethanol technology to end users a barrier in your opinion?
- If yes, why?
- If No, why?
- Is import duty or domestic taxes such as VAT / GST an issue?
- Are taxes such as import duty or VAT a barrier to the adaptation of bioethanol technology for household use
- What, in your opinion, are the best ways to address the issue of high initial acquisition costs for Bio-ethanol technology?
- Are private banks and other non-banking finance institutions willing to finance the end users? If not, what needs to be done?
- Do you think Bio-ethanol technology is economically viable and implementable on a large scale?
- Is the local supply chain fairly developed for the Bio-ethanol technology with the involvement of main private sector stakeholders/businesses? If not, what are the issues and how could they be resolved?

Social

- Do you know of any other social issues that pose a challenge to the adoption of Bio-ethanol technology?
- Habits?
- Gender?

Technology and Infrastructure

- What is your opinion on the availability of skilled labour for Bio-ethanol technology?
- Is there a need for capacity building for this?

- How easy is it to get access to this technology on the market?
- What are the main technical challenges to providing access to Bio-ethanol technology on the market?

Environmental

- What are the environmental hazards linked to bio-ethanol production in Ghana?

Legal and regulatory

- Is there a need for any legislation that you consider a driver for the adoption of Bio-ethanol technology?
- Is there any legislation in place that you consider a barrier to the adoption of Bio-ethanol technology?

Awareness and capacity building

- What is the status of awareness about Bio-ethanol technology in the country? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion? If No, why?
- Are there any other issues you think are significant barriers to the promotion of Bio-ethanol technology in Ghana?

Chapter 11

Appendix 14: List of Interviewed Stakeholder Organisations in Rwanda

Institution	Category	Number interviewed
College of Agricultural and Veterinary medicine/ University of Rwanda	Academia	2
African center of Excellence in Energy for sustainable development/ University of Rwanda	Academia	1
Mechanical Department/ University of Rwanda	Academia	1
INNOVATECHS LTD	Suppliers of the Technology	1
NIKKI PRODUCTION LTD	Suppliers of the Technology	1
Development Bank of Rwanda (BRD)	Funding agency	1

Appendix 15: Interview Guide for Stakeholders Interviews in Rwanda

Questionnaire for Solutions Providers

Political and institutional

- Are there government plans to implement Solar Powered Irrigation technology with targets and timelines with adequate resources (human and capital) allocated for implementation? What is missing and could be improved?
- Is the current level of cross-coordination between relevant departments and ministries regarding the technology adequate or needs to be improved? If yes, in what way?
- What is the current state of institutional capacity in the government and private sector to mainstream the Solar Powered Irrigation technology? Does it need to be improved?
- What is the current level of coordination on the Solar Powered Irrigation technology related issues between government and other stakeholders including the private sector? Does it need to improve? If yes, how?

Economic and Financial

- 5. Do you think Solar Powered Irrigation technology is economically viable and ready to be introduced in the market?
- Is high price of Solar Powered Irrigation technology (compared to current internal combustion (IC) solution) to end users a barrier in your opinion? If yes, why? Is import duty or high domestic taxes such as VAT / GST an issue?
- If prices are high, does government provide any financial incentives? what in your opinion are best ways to address the issue of high price of the Solar Powered Irrigation technology?
- Is the access to finance by end users for the Solar Powered Irrigation an issue? Are private banks and other non-banking finance institutions willing to finance the end users? If no, what needs to be done?
- Is the cost of financing (interest rate) high to end users? If yes, how could that be addressed?
- What is the current status of SME's access to finance from banks and other sources for the Solar Powered Irrigation? Does it need to improve? If yes, how?
- Is the local supply chain fairly developed for the technology with involvement of main private sector stakeholders/businesses? If not, what are the issues and how could that be resolved?
- What are the current business models adopted by the Solar Powered Irrigation providers? Do you have any opinion on that, including need for improvement?
- Who or what type of organization within the country or local environment do you consider best suited to develop and provide affordable training for the Solar Powered Irrigation?
- What is the market size and expected potential for the Solar Powered Irrigation? Are any studies conducted to assess this potential?

Social

- From your perspective to what extent do you expect the Solar Powered Irrigation to improve safety for the intended users?
- From your perspective, do you think affordability is a barrier for the Solar Powered Irrigation? Technology and Infrastructure.
- Is access to Solar Powered Irrigation technology an issue?
- What is your opinion on the reliability of technology in the country today?
- What is your opinion on the availability of skilled labor to work and maintain the Solar Powered Irrigation technology? Is there a need for capacity building for this?
- What are the main technical challenges to provide access to the Solar Powered Irrigation services in remote / rural areas?
- In your opinion, how big is a lack of charging infrastructure a barrier for Solar Powered Irrigation (on a scale of 1-10), and how can it be addressed? (Note: 10 being extremely important and 1 being not at all important.)

Environmental

- How important you think is that the E-mobility technology reduces GHG emissions and thereby helps the country meet its mitigation commitments? Please indicate on a scale 1-10?
- How important you think is that that E-mobility technology helps prevent local pollution from particulate emissions, please indicate on a scale 1-10?

Legal and regulatory

- Is there need for any legislation that you consider a driver for adoption of the technology?
- Is there any legislation in place that you consider a barrier to the adoption of the technology?

Awareness and capacity building

- What is the status of awareness about the Solar Powered Irrigation technology in the country? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion?

- Are there any other issues that you think are significant barriers to the Solar Powered Irrigation technology in the country today? Please specify. Also, what do you see as the key success factors or drivers to scale up the Solar Powered Irrigation?

Questionnaire for National Experts/Academia
Political and institutional

- Are there government plans to implement the Solar powered irrigation technology with targets and timelines with adequate resources (human and capital) allocated for implementation? Which aspects of current national plans and policies could be improved in your opinion to promote and adopt the Solar powered irrigation and why?
- Is the current level of cross-coordination between relevant departments and ministries regarding the technology adequate or needs to be improved? If yes, in what way? It needs improvement like:
    - What is the current state of institutional capacity in the government and private sector to mainstream the solar-powered irrigation technology? Does it need to be improved?
    - What is the current level of coordination on the Solar powered irrigation technology-related issues between government and other stakeholders including the private sector? Does it need to improve? If yes, how?

Economic and Financial

- Do you think the Solar powered irrigation technology is economically viable and ready to be introduced in the market?
- Is high price of Solar powered irrigation technology (compared to current internal combustion (IC) solution) to end users a barrier in your opinion? If yes, why? Is import duty or high domestic taxes such as VAT / GST an issue?
- If prices are high, does government provide any financial incentives? what in your opinion are best ways to address the issue of high price of the Solar powered irrigation technology?
- Is the access to finance by end users for the Solar powered irrigation an issue? Are private banks and other non-banking finance institutions willing to finance the end users? If no, what needs to be done?

- Is the cost of financing (interest rate) high to end users? If yes, how could that be addressed?
- What is the current status of SME's access to finance from banks and other sources for the Solar powered irrigation? Does it need to improve? If yes, how?
- Is the local supply chain fairly developed for the technology with involvement of main private sector stakeholders/businesses? If not, what are the issues and how could that be resolved?
- Are you aware of the current business models adopted by the Solar powered irrigation providers? If yes, do you have any opinion on that, including need for improvement?

Social

- From your perspective to what extent do you expect the Solar powered irrigation to improve safety for the intended users?
- From your perspective, do you think affordability (by the end users) is a barrier for the Solar powered irrigation?

Technology and Infrastructure

- Is access to Solar powered irrigation technology an issue?
- What is your opinion on the reliability of technology in the country today?
- What is your opinion on the availability of skilled labor to work and maintain the Solar powered irrigation technology? Is there a need for capacity building for this?

- In your opinion, how big is a lack of charging infrastructure a barrier for Solar powered irrigation (on a scale of 1-10), and how can it be addressed?
- In your opinion, how important is the driving range (on a single charge) an issue (on a scale of 1-10)?

Environmental

- How important you think is that the Solar powered irrigation technology reduces GHG emissions and thereby helps the country meet its mitigation commitments? Please indicate on a scale 1-10?
- How important you think is that that Solar powered irrigation technology helps prevent local pollution from particulate emissions, please indicate on a scale 1-10?

Legal and regulatory

- Is there need for any legislation that you consider a driver for adoption of the technology?
- Is there any legislation in place that you consider a barrier to the adoption of the technology?

Awareness and capacity building

- What is the status of awareness about the Solar powered irrigation technology in the country? Do you think there is a need for awareness and promotional measures? If yes, what are the best measures in your opinion?
- Are there any other issues that you think are significant barriers to the Solar powered irrigation technology in the country today? Please specify. Also, what do you see as the key success factors or drivers to scale up the Solar powered irrigation?

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