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Navigating the Landscape

Drivers and Barriers in Rwanda's Rural Electrification and the Role of the Private Off-Grid Solar Sector

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Cover photo description: Solar Home Systems in rural Rwanda. Which accurately depicts the master thesis project.

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Off-grid electrification in Rwanda
Navigating the Landscape - Challenges and Opportunities in Rwanda's Private Off-Grid Solar Energy Sector
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Abstract

Access to modern energy remains one of the most pressing development challenges in Sub-Saharan Africa, with nearly 600 million people still lacking reliable electricity. Rwanda has made significant progress in rural electrification, in part through a growing off-grid solar photovoltaic (PV) market. However, the diffusion of such decentralized energy systems is shaped by a complex interplay of market, institutional, and socio-technical factors. This study investigates the enabling environment for the off-grid solar PV transition in Rwanda, with a particular focus on the private sector's role. To analyze this dynamic, the study looks through the theoretical lens of an adapted Technological Innovation Systems (TIS) framework that incorporates system functions relevant to developing countries. The data collection was carried out through semi-structured interviews with key actors in Rwanda's off-grid energy sector, primarily including companies, but also institutional experts and a user.

The findings reveal a sector in phase transition. Over the last decade, the solar PV sector has gone from a niche and early diffusion stage, into an artificially stabilized market through subsidies, characterized by consolidation of companies. The most prominent drivers behind this growth include Pay-As-You-Go models, rising solar legitimacy, and supportive government-targeted subsidies for private sector involvement. Yet, key barriers have remained or emerged: declining subsidy support, shifting grid expansion projections and limited affordability in rural areas. The companies are responding to the barriers by diversifying their business models into clean cooking and solar water heaters. Despite these challenges, the solar companies themselves have an optimistic mindset about the future, as economic growth and technological development is deemed promising.

Keywords: Off-grid, Rural, Electrification, TIS, MLP, Private sector, Private companies, Policy, Solar energy, Solar PV.

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Elias Gustafsson and Victor Creutz, Gothenburg, June 2025

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

Table 0.1: Alphabetically sorted list of acronyms

CAPEX	Capital Expenses
C&I	Commercial and Industrial
EPD	Energy Private Developers
EV	Electric Vehicle
MG	Microgrid
MLP	Multi-Level Perspective
NEP	National Electrification Plan
NGO	Non-Governmental Organization
PAYG	Pay-as-you-go
RBF	Result-based financing
REG	Rwanda Energy Group
RES	Rural Electrification Strategy
RET	Renewable Energy Technology
SACCO	Savings and Credit Cooperation
SHS	Solar Home System
SOE	State-Owned Entity
SSA	Sub-Saharan Africa
(Solar) PV	(Solar) Photovoltaic
TIS	Technological Innovation System

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1

Introduction

Universal access to electricity has become a reality for many countries across the globe in recent decades. However, as of 2024, one billion people across the world live without this basic service. In Sub-Saharan Africa (SSA) alone, about 600 million people lack access to electricity, mostly in rural areas [1, 2, 3]. Africa has a large rural population and receives high levels of sunlight, holding 60% of the world's best solar resources. However, with only 3% of its electricity currently generated from solar PV, solar energy has significant potential to provide sustainable power to underserved households. [3, 4, 5].

1.1 Background

The challenges related to electricity access is addressed in the United Nations Sustainable Development Goals (SDGs), particularly Goal 7: Affordable and Clean Energy. The aim of Goal 7 is to ensure access to reliable, sustainable, and modern energy for all by 2030. Furthermore, assuring renewable energy access aligns with Goal 13: Climate Action, by reducing dependence on fossil fuels and mitigating carbon emissions [6]. Coal, natural gas and oil together account for around 60% of Sub-Saharan Africa's total electricity generation capacity in 2023 [7]. At the same time, the region is experiencing rapid population growth, with projections suggesting almost a doubling in population from 1.26 to 2 billion by 2050 [8]. The population growth will place immense pressure on existing energy systems, making sustainable electrification an essential priority for achieving universal electrification, climate goals and supporting economic growth. Unlike most industrialized nations that built their economies on fossil fuels, countries in SSA have the opportunity to leapfrog the carbon-intensive development [9]. For SSA with its large potential for solar energy, this opens up valuable possibilities [4].

1.1.1 Socio-economic and environmental benefits of Solar Energy

The socio-economic benefits of electricity access are well documented. In a report from GOGLA[1] in 2019, the implications of electricity access in five[2] East-African countries

[1] The report highlights the positive impact of off-grid solar energy in East Africa, improving income, job creation, and quality of life for low-income households. GOGLA, the global association for the off-grid solar energy industry, supports its members in delivering affordable solar solutions to underserved communities

[2] Uganda, Rwanda, Kenya, Tanzania & Mocambique

show significant benefits for the people in most need [10]. These households are often rural and in the lowest income levels, where 59% of households earn less than $3.20 per day. The report shows promising results in economic activity, as 34% of households are more economically active 15 months after installation. Mukisa et al. (2022) conducted an economic benefits assessment on Solar Home Systems (SHS)[3] in 11 SSA countries, and the findings suggest an annual energy expenditure savings of 46.04% and 29.79% for SHS kit on the cash and PAYG (Pay-as-you-go) approaches respectively [11]. Additionally, 94% of respondents report they feel an improvement to their quality of life and 89% report their health has improved as they no longer need to use dirty lighting alternatives [12].

The reliance on biomass for East-African countries such as Rwanda (88 %), Kenya (75%) and Ethiopia (91%) of their total energy use, shines a light on the potential environmental benefits renewable energy can have [2]. Reducing the reliance on biomass fuels such as wood and charcoal helps combat local deforestation, which has several environmental benefits in itself, such as preserving biodiversity, increasing carbon sequestration, regulating water cycles, and combating erosion [13].

The avoided annual household GHG emissions by acquiring a SHS kit was recorded in the range of 19.51-199.29 kg CO_2-equivalents (eq) [11]. The upper boundary of 200 kg CO_2 eq per person is roughly equal to the emissions from one short-haul flight. While the impact per household may seem small, electrifying 600 million people collectively represents a significant climate impact. Conversely, the exponential increase in solar products in SSA puts pressure on recycling capabilities. Kinally et al. (2022) highlights that the 545% (12,000 tonnes) increase in solar junk in the region have extremely severe environmental consequences [14]. The formal waste managements initiatives are failing to address the majority of waste flow due to informal practices, inadequate legislation among other factors. While solar holds clear potential, its implementation on the ground relies heavily on the actors involved.

1.1.2 The role of Private companies

In many SSA countries, expanding the national electricity grid is a key strategy to increase energy access. However, despite these efforts, a large number of households in rural areas are unlikely to be reached in the near future, mainly due to high infrastructure cost, scattered population densities, and other causes related to cost-effectiveness [15]. Hence, off-grid technologies such as SHS or mini-grids becomes the most viable option. Private solar-energy companies have in several SSA countries been providing great numbers of households with electricity, with or without support from local governments. In Rwanda for example, 24.8% of the population have electricity access (depending on definition, see 1.5) through off-grid energy (mostly solar) [16]. Even if off-grid solar energy is getting increasingly affordable and efficient every year, there is still a substantial challenge with affordability in rural areas of SSA. These challenges are in depth presented in section 1.5.3.

[3] System with a power output of around 3-50Wp

Moreover, the private companies' role extends far beyond technical service provision. While electrification through SHS and mini-grids could be provided by governments, there are benefits to allow private companies to enter the market. In SSA, private companies are generally involved across the entire domestic value chain. They import solar PV equipment mainly from China, design distribution and service networks, recruit and train staff, and develop local partnerships [4]. Additionally, the companies are operated by local entrepreneurs or international firms, whose coexistence enables the development of adaptive capacity[4] through business symbiosis. By co-existing, they compete for users, which help lower prices and diversify available solutions [2]. As a result, they may be more effective than governments at delivering affordable products to consumers. Although emerging technologies are in need of governmental support in the initial phases, companies are crucial in creating long-term sustainable markets. Beyond electricity access, the private sector contributes to boosting local economies. Not only has the sector potential to create half a million new jobs in SSA, it also shows significant progress in raising female employment [17]. Additionally, private firms are not passively participating in the energy ecosystem. They actively engage with policymakers for favorable market conditions. This includes advocating for import tax exemptions (common in SSA), streamlined licensing procedures and enforcement of quality standards to protect market from opportunists [18].

Private companies are dynamic forces driving the off-grid solar market in SSA. Playing a role by proving essential technology and services, innovate against affordability challenges, stimulate economic growth and provides marginalized families and communities opportunities to increase their standard of living. Understanding their role and how it has evolved is essential for this study. In this context, the ”role” of private companies refers to their contribution to the development and performance of the Technological Innovation System (TIS) functions. This includes not only delivering technology, but also shaping markets, mobilizing resources, and influencing institutions, policy, and user behavior.

From hereon, the Technological Innovation System (TIS)[5] framework is used as an analytical structure, looking through the theoretical lens of TIS to understand how these factors influence the development, diffusion, and impact of off-grid solar technologies in rural electrification. TIS allows for a holistic analysis of the system and help identifying drivers and barriers within different areas (called function in the framework) relevant to the diffusion of a technology [19]. These functions include: (1) entrepreneurial activities, involving projects and experiments by existing actors; (2) knowledge development and (2b) adaptive capacity, covering research, patents, and building technical and institutional skills; (3) knowledge diffusion, through workshops, conferences, and social media; (4) guidance of the search, with government or industry setting regulations and targets; (5) market formation, supporting new technologies with incentives like tax breaks and feed-in tariffs; (6a) resource mobilization through domestic sources such as government R&D funding and subsidies; (6b) resource mobilization through international loans and grants; (7a) creation of legitimacy via formal lobbying by established groups; and (7b) informal lobbying through changes in public opinion and

[4]Human (level of technical and higher education), organizational, and institutional capacity to receive new technology

[5]TIS is explored in depth in chapter 2

social media support. These are in depth explained in the "Conceptual Framework" chapter, see chapter 2. In this study, rural electrification using solar PV is the defined TIS, and the 'role' of private companies is framed as their contribution to the development and performance of these system functions.

1.2 Aim

This study examines how private solar PV off-grid companies contribute to universal electricity access, in a developing country context. The aim is to analyze key factors that have shaped the solar PV sector and the private companies involved, as well as what roles the technology and companies have played in the efforts to provide access for all.

The objective is to analyze how the private solar PV sectors involvement is shaped by policymaking; key stakeholders; grid extension; technical, financial and market development. Furthermore, the objective is to identify drivers and barriers affecting the diffusion of solar energy and the private companies in rural electrification efforts. The third objective is to understand how the private companies have adapted and reacted to these factors, drivers and barriers.

1.3 Research questions

In order to achieve the aim of the study the following questions are to be examined and discussed:

1. How has factors including policymaking; key stakeholders; grid extension; technical, financial and market development shaped the private solar PV sector and the role it plays in rural electrification efforts in SSA countries?
2. What key drivers and barriers, impacting the diffusion of private solar PV sector, can be identified?
3. How have private solar energy companies adapted and reacted to the shaping factors and the sectors drivers and barriers?

1.4 Scope & Delimitation

The scope of the study will be defined in terms of geographical-, sectoral- and stakeholder delimitation. This section will also mention the decided delimitations of the study. The study uses a holistic perspective and theoretical framework which aims to map and understand the whole system. Even if this helps to understand the full picture it also limits the level of detail.

The study is interested in rural electrification of developing countries (more specifically SSA countries), but will look more closely at Rwanda to investigate this. Rwanda is chosen as a focus due to its rapid progress in electricity access in recent years, much of which has been driven by off-grid solutions and the private sector [16, 20]. Solar irradiation in Rwanda is also representative of the SSA region, while they excel in indicators such as "ease of doing business" [21, 4, 22]. This could offer insight into the potential for solar energy in Sub-Saharan Africa within a (relatively) politically stable and business-friendly environment. The conclusions from this study, even though they are from the specific context of Rwanda, could have relevance for understanding the development in other countries, especially in East Africa. While the focus is on Rwanda specifically the sector transcends the borders of Rwanda since many of the important actors operates internationally.

Solar energy and more specifically, solar PV, has become a relevant technology to apply in off-grid scenarios, due to decreasing cost together with high potential of solar energy in SSA [7, 2]. Therefore, the sectoral focus of this study is on solar PV technology, primarily SHS and mini-grids. However, in order to map the system in a holistic manner other parts of the energy sector will have some importance, including alternative technologies both up-stream and down-stream from solar energy. Other up-stream technologies for providing electricity is grid-extension or hydro mini-grids, for example. Alternative down-stream uses of solar energy is also connected, such as using solar to heat water, for agricultural irrigation or to power cold storage.

The stakeholders in focus are companies involved in off-grid electrification through solar energy and government agencies connected to the energy sector. Less attention will be given to individuals and larger electricity users (industries). The private sector's innovative capacity positions it as a key actor in addressing challenges in rural electrification. International companies, NGOs and international actors are not strictly within the national boundaries of Rwanda but play important roles and are therefore included in the study. Data collection was planned to fit the time frame of this study, meaning the study chose to focus on a selection of the private solar PV sector in Rwanda. The same limitation applied to policymakers. To minimize this delimitation, the aim was to collect data on different types of companies, such as local or international, and SHS retailer or mini-grid developer.

Hence, the case used in this study is the off-grid solar PV sector in Rwanda, with a focus on private companies. Mainly private companies dealing with SHS and mini-grid will be in focus.

1.5 Literature Study

This study builds on themes and gaps identified in existing comprehensive literature on the topic of electricity access in developing countries. Therefore, a literature study of the current state of research is presented. An overview of previous research using similar methodological approaches, theoretical lenses, with the purpose of understanding the interactions between policymaking and private sector in the realm of rural electricity access. The structure follows key topics identified in the literature—electricity access, technological development, affordability, governance, social factors, gaps in the literature and lastly current trends—chosen to reflect the main barriers and drivers of off-grid solar PV diffusion in SSA. To ensure a coherent narrative, the relevant TIS functions addressed in each subsection are presented in cursive at the beginning of the section, and for more information about TIS, see chapter 2.

1.5.1 State of Solar PV

TIS: Knowledge Development (F2) & Diffusion (F3), Market Formation (F5)

Solar photovoltaic (PV) has seen rapid growth in the last decade. In the mid 20th century, it started out as a niche technology for small markets such as space exploration and military applications. However, solar PV eventually reached legitimacy and approached technological maturity through the early 1990s subsidy program in Germany. This was among the first policy interventions to support the expansion of solar PV deployment. Through the "Stromeinspeinsungsgesetz" in 1990, which mandated utilities to purchase electricity generated from renewable sources, including solar PV at a fixed price, solar PV sales surged [23]. This resulted in a secure investment environment in Germany, which facilitated the creation of a robust value chain from silicon ingots to modules. The German FIT (Feed In Tariff) model became a template for other developed countries to adopt. It also laid the groundwork for developing countries to follow suit, around two decades later. As global demand has surged and Chinese manufacturers scaled up with lower costs, production shifted to Asia [24]. This shift led to more affordable solar panels globally and, with that, increased adoption, and then a strong positive feedback loop had started.

This feedback loop can also be explained as a learning curve, meaning that with every doubling of installed solar PV, the cost decreases by a certain percentage. The learning rate for solar PV varies among scholars, but it generally falls withing a 18-24% range [25]. By combining data from IRENA in 2025 [26], with a learning rate of 20% we can find a cost of installed solar PV in USD per kW. In 2010, one kW of solar PV cost around USD 4700, while in 2024 it was USD 1464 due to the 18 times greater installed capacity of solar [27]. Additionally, the efficiency of commercial mono-crystalline wafer-based silicon modules - the most common solar PV - increased from about 16% to 22% over the last 10 years [28]. And this loop is still reinforcing as there is fierce competition among solar producers in China, as well as the global installation of solar increases every year [29].

Conversely, these projections are based on the globalized economic order that have existed after the cold war. With the growing geopolitical tensions that shows signs of protectionism, it creates risks that impose disruptions in complex supply chains. As a result, increased production costs and slowing of the global diffusion of affordable solar technologies in the long-term. The last time tariffs on imported goods, such as solar PVs from China, were the most talked-about subject was during Donald Trump's first presidency. According to Agyapong (2025), this initially created a drop in prices of solar PV, which was fortunate for African retailers [30]. However, the drop lasted only for a short time, which retailers were not able to utilize. As another global trade war is unfolding under President Trumps second presidency, there is no evidence supporting that the prices will drop for a long period this time either. Unless governments can facilitate faster due diligence and funding approvals, which could help retailers take advantage of short-term price windows [30].

Even though the technological development of solar energy is promising, there are some evident technical and environmental limitations that need to be addressed such as only generation during daytime. During these daytime hours, the households need for electricity is generally small. Hence, the solution to these issues becomes investing in energy storage solutions. In SHS packages these are typically included, but as the systems get bigger the affordability of energy storage diminishes [31]. The solution then becomes fossil dependent solutions, as it provides the most cost-efficient solution today. Additionally, the efficiency of solar PVs are affected by environmental conditions such as high temperatures. High temperature and prolonged heat stress can also accelerate the wear and tear of the products [32]. In large parts of SSA there is significant rainfall annually, and with that comes humidity, which also can affect the efficiency of the solar panels [33]. Lastly, as solar systems are new to the continent, there is yet to be sustainable end-of-life disposal [14].

1.5.2 Solar Energy in Sub-Saharan Africa

TIS: Creating Adapative Capacity (F2b), Guidance of the Search (F4), Market Formation (F5)

Although Sub-Saharan Africa holds vast solar potential, only 3% of the electricity on the continent is generated by it [5]. However, with the diminishing cost of solar PV, the sector has seen a dramatic increase over the last decade. Since 2013, the electricity generated from solar in Africa has increased from 0.75 TWh to 30.24 TWh in 2023 [34]. According to Global Solar Council, Africa's solar market is set to surge with 42% in 2025. And by 2028, the continent is expected to double the current installed capacity [5]. The potential for applying solar energy technology in SSA is high but manufacturing capacity is very low. According to the African Development Bank (2024), the solar modules produced on the continent are 10-12% more expensive than the Chinese competitors [35]. SSA are however not alone here, since China produce around 80-85% of all solar modules globally [36]. Almost all solar panels are therefore imported, and there are different ways to commercialize solar PV (see table 1.1).

The World Banks multi-tier framework (MTF)[6] aims to specify at what level an adequate amount of electricity has to be provided to meet the minimum requirement. These standards were set to 800 Watt peak (Wp, referring to PV powered systems), nevertheless, the most common solar PV systems bought in SSA are the so-called Solar Home Systems (SHS), that come in different capacities (see table 1.1), but the most common capacity is at 50 Wp or less [38]. These systems only meet basic electricity need, such as lighting and charging mobile devices, see figure 1.1.

Since services like lighting and charging mobile devices also provide benefits, the multi-tier framework helps to show that access is not black or white, it is a spectrum. Thus, it is a matter of definition. In the country of Rwanda for example, there is no lower limit of peak power but rather a list of needs that should be filled, including three lights for 4 hours per day; 2 hours of mobile phone charging and 5 hours of radio supply [39]. To satisfy these needs a system of 20 Wp or more is required. Understanding how electricity access is defined is crucial for measuring progress and work towards meaningful goals. It also serves as tool to design appropriate market solutions and policy frameworks that align with users real energy needs and capacities.

Productive use (PU) is also a concept that has become increasingly popular and refers to systems producing power that increases productivity [40]. This often refers to larger stand alone system and C&I-systems for hospitals or companies. However, this is also a matter of definition since smaller systems (e.g. 50 Wp) technically also could be PU, if it results in increased productivity and economic activity [41].

[6] The Multi-Tier Framework (MTF) assesses energy access across a spectrum of service levels, from Tier 0 (no access) to Tier 5 (highest level of access), considering factors such as capacity, duration, reliability, quality, affordability, legality, convenience, health, and safety [37].

Table 1.1: Market segments for solar PV systems and their characteristics. Installed capacity values refer to typical system sizes. W_p: Watt-peak, kW_p: kilowatt-peak, MW_p: megawatt-peak. [42, 43]

Market segment	Market characteristics	Installed capacity / size	Owners and buyers
Small pico-systems: solar lanterns, LED lamps, solar chargers	Lighting and charging of batteries and mobile phones in mainly non-electrified areas	1–10 W_p	Private (over the counter) consumer devices
Solar home systems (SHS)	Off-grid electricity demand in private homes in dispersed settlements, in smaller non-electrified villages and on the outskirts of electrified towns and villages far from existing distribution lines	10–100 W_p	Residential SHS (private households), ESCOs
Stand-alone 'institutional PV systems'	Institutions located in villages without grid or mini-grid, or on the outskirts of grid-electrified villages	50–500 W_p	Government/municipal procurement for public institutions (schools, hospitals, health clinics)
Commercial and Industrial (C&I)	Grid-tied or hybrid solar PV systems installed at commercial or industrial sites to offset electricity costs, improve energy reliability, or meet sustainability goals. Includes offices, factories, hotels, retail, and agro-processing facilities.	0.2–15 kW_p (small businesses) to 1 MW_p+ (industrial users)	Private sector clients (e.g., businesses, factories, hotels), often through models like PPA or EAAS
Mini-grids (e.g. hybrid PV-diesel)	Villages and towns located far from existing grid	5 kW–1 MW_p	Utilities, cooperatives (community-based), ESCOs (village electrification projects)
Large-scale, grid-connected PV systems	Expansion of production capacity in existing grid	1–50 MW_p	Utilities, IPPs (incl. foreign investors)

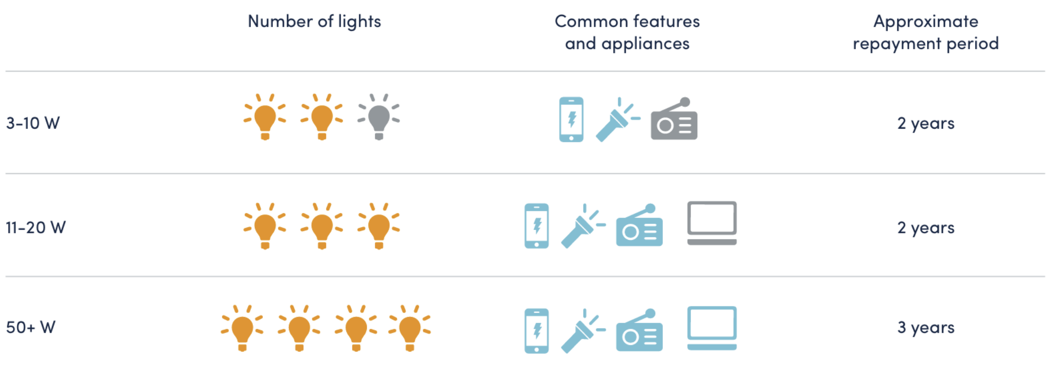

Figure 1.1: Overview of typical service level by system size [12]

1.5.3 The Affordability Challenge

TIS: Market Formation (F5), Resource Mobilization (Domestic (F6a) and International (F6b)), Adaptive capacity (F2b)

For a long time, providing electricity to the most remote parts of Sub-Saharan Africa has been considered a major challenge. However, as explained in the previous subsection, the challenges have over time evolved into opportunities [25]. The main issue with SHS is however not the technology itself, but rather the issues with low purchasing power. According to a recent report from the Stockholm Environment Institute, between 2013 and 2023, wind and solar PV energy in SSA increased by a factor of 16, excluding the biggest actor South Africa[44]. Through many years of political turmoil, pandemic, inflation and public debt, utility-scale projects are being initiated. According to the authors, a roughly installed cost of $1 per watt, the progress since 2013 across SSA would amount to an investment of around $350 million a year, a figure that is insignificant in the global climate change budget, but with enormous positive effects [44].

In SSA, many businesses are funded by capital in foreign currencies like US dollars or euros but generate revenue in local currencies, which creates uncertainty. In SSA many currencies are depreciated, especially in uncertain times, which reduces the companies ability to manage inventory, repay debt, and attract capital. To address this, an article by Acumen (2024) calls for more affordable, local, and equitable financing options, including shared hedging[7] costs between investors and investees, a broader range of hedging products, and structural solutions from development banks. Among the barriers that needs to be collectively addressed are the increased cost for hedging, limited access to local currency debt and solutions are not accessible to smaller companies — as existing solutions are mostly available for well-established companies [45].

Pay-As-You-Go (PAYG) has gone from a technological niche to a widely diffused technology enabled by the co-development of mobile money infrastructures and diminishing costs of solar panels. Among the reasons for its popularity is the function of breaking down payments over time, which provides the possibility of paying for electricity in small amounts. Customers who use PAYG is more willing to continue their use of SHS since it provides a greater flexibility, as they only need to pay when they can afford it [38]. There is also a safety for the SHS providers as they can remotely lock the technology if the payments are due. Even though the PAYG model has shown promising, there are some risks associated with the technology as its underway reaching a dominant design. Among the identified risks of PAYG are the longevity of SHS which lasts for two to ten years depending on the system quality and size, and secondly, the exploitation of user data [38]. Perros et al. (2024) who identified these risks, suggests that regulators should ensure that PAYG providers offer repair services and access to high-quality replacement parts to increase the longevity of SHS. Additionally, governments should put emphasis on data protection, potentially drawing insights from the EU's General Data Protection Regulation to stimulate greater transparency and

[7] Hedging is a risk management strategy used to offset potential losses in investments by taking an opposite position in a related asset. It helps protect against price fluctuations in markets such as currencies, commodities, or interest rates.

responsible data-sharing between parties. Lastly, they bring forward some evidence of indication that PAYG may not be suitable for the low-income households and most isolated users. Additionally, to understand the inefficiencies associated with PAYG, Mergulhao et al. (2023), brought forward some interesting data-driven results regarding the payment patterns of SHS users. One-size-fits-all approach creates inefficiencies and may stagnate the adoption of SHS, therefore tailored plans should be considered in order to increase the payment performance [46]. The tailoring is affected by regional institutional and cultural differences, where governmental support of the private sector becomes crucial.

As an alternative to investment from formal institutions or large investors, ordinary people can come together in good-will, and invest in projects that matters. This form of investing is called crowdfunding (or crowdlending), and it is a growing segment that facilitates funding for many sorts of projects, Renewable Energy Technologies (RET) included. In the recent Mangudhla et al. study from 2025, the authors explore how crowdfunding can support green innovation and renewable energy use in Africa, where limited funding and infrastructure are major challenges [47]. In the case of solar PV investments, project owners—such as homeowners, solar leasing companies, or community groups—list their solar PV projects on a crowdfunding platform. Individuals can then invest in these projects, motivated either by the prospect of financial returns, environmental impact, or both. The funds raised are used to install and operate solar PV systems, and returns to investors are typically generated from the sale of electricity or from savings on electricity bills. Using econometric methods — meaning applying statistical tools to analyze economic data and identify relationships — the results show that crowdfunding can help boost both renewable energy consumption and green technology, though the effects vary depending on the context. To strengthen these efforts, the study suggests improving internet access so more people get introduced to crowdfunding, especially in remote areas. It also highlights the need to align education with renewable energy industries needs through hands-on training and partnerships between schools and businesses. Supportive policies, such as tax incentives and clear regulations, are also key to attracting investment and making clean energy projects easier to launch [47]. Economic factors alone don't determine outcomes, policies, regulations, and institutional dynamics play an equally critical role in facilitating successful off-grid initiatives.

1.5.4 Policy and Governance for Off-grid Electrification

TIS: Guidance of the Search (F4), Creation of Legitimacy, Formal (F7a) and Informal (F7b) Lobbying

Most countries in SSA need to undergo structural changes to the energy sector to reduce the barriers to renewable sources. The most prominent domains that needs this transformation are institutional, economic and legal domains. Notably, as suggested by the 2024 Nobel Prize laureates in economics, the legacy of colonial powers in sub-Saharan

Africa has resulted in weak institutions that have significantly hindered progress in areas such as electrification, as these institutions often prioritized exploitation and left long-term barriers to economic development and infrastructure growth [48].

A recurring theme in the enabling of technological transitions is about the appropriate balance between state involvement and market driven innovation. Although both models have obvious advantages, existing research suggests that neither extreme is the best strategy. A hybrid solution tends to result in the best long-term solution. The reason being the combined benefits of the state playing an enabling role and setting goals to work towards, whereas the private sector provides innovation, adaptability and scalability. In a comparative study of Tanzania and Mozambique, Ahlborg and Hammar (2014) investigate the institutional drivers and barriers of state-led electrification strategies [49]. They find that even when governments are highly involved in the electrification progress, it all comes down to institutional capacity. If its weak, state-led electrification strategies tend to become inefficient, overly bureaucratic, and vulnerable to political cycles. In the context of South Africa, Baker and Sovacool (2017) highlight how over-centralized, state-led and dominated energy policies can unintentionally inhibit the innovative and entrepreneurial activities [50]. Their results point out that even though centralized planning may secure short term energy access targets, it often dismisses the long-term needs of their new customer base. Eberhard and Gratwick published a study in 2011 on electricity sector reform and private investment on Independent Power Producers (IPPs) [8] in SSA [51]. Even though their insights were presented early on in the renewable energy transition, it is still of relevance today. They suggest that when governments act as strategic enablers with a clear and facilitating role, not as micromanagers, long-term sustainability can be reached. Long-term goals, regulatory consistency, transparent and predictable investment climate and de-risk private investment will build investor confidence, attract capital and support an innovative ecosystem. However, it always depends on the context of a country, where the geographical, institutional, and cultural barriers and opportunities varies greatly and have to be taken into consideration.

Regulatory uncertainty is among the greatest challenges for solar PV companies in SSA. This is in line with Ahlborg & Hammar (2014) who showed that in state-led electrification efforts, weak institutional capacity can lead to inefficiency, instability and vulnerability to political cycles [49]. When the electrification projections is repeatedly changing, the businesses have difficulties adapting. According to a study by Gungah (2019), this development have occurred in Nigeria, where the energy industry is managed by a maze of regulations that provide opportunities for interpretation and generate uncertainty. While various policies may look comprehensive and well-intentioned, there is a disconnection between talk and action. Gungah further highlights that the modest impact of these policies are due to implementation bottlenecks, policy inconsistency and inadequate funding [52].

The subsidy program for rural solar PV adoption in Bangladesh was among the earliest, and is considered a success story. The universal challenge with a high upfront cost for investment was tackled through a successful government program. With PAYG system,

[8]IPPs are bigger solar systems also known as mini-grids or micro-grids that can sell the additional electricity produced

micro-financing loans and thoughtful capacity building to increase the legitimacy of solar PV technology. Especially the focus on capacity building paved the way for a boost to the local economy. An ecosystem of vendors, educators, and technicians was created, which illuminates the powerful force that decentralized energy production can have on creating meaningful employment, fostering a path towards several sustainability goals. According to Sharif & Mithila (2013), the early lessons learnt from the case of Bangladesh, which served as a guiding light for similar programs in developing countries are [53]:

- Subsidies are unlikely to lead to sustainable markets unless they explicitly create the conditions whereby they are no longer needed (i.e., smart subsidies).
- Subsidies can be used effectively to build up initial market volume, local expertise, user awareness, appropriate technology adaptation, quality standards, and entrepreneurial activities.
- Subsidies are more effective when tied to operating performance rather than investment. (Conversely, investment-focused subsidies may exacerbate overinvestment in state-owned entities (SOE), as SOEs often prioritize political goals over market efficiency)
- Continuing subsidies may always be needed for poorer segments of the population.

For more context on policy and governance, see section 2.3, with examples of east African countries such as Kenya and Ethiopia, through the theoretical lens of TIS. Policy frameworks may guide transitions, but their success often hinges on how technology is perceived, accepted, and embedded within local communities.

1.5.5 Social Foundations

TIS: Creation of Legitimacy (Formal (F7a) and Informal (F7b) Lobbying, Resource Mobilization (F6a), Adaptive Capacity (F2b)

The legitimacy of new technologies in SSA can only be understood by examining community perceptions. These perceptions looks very different across SSA countries due to several contextual factors. In most cases, the legitimacy of SHS and trust in companies is driven by high quality and reliable after-sales services. Conversely, in Burkina Faso, the opposite was observed. The products less adopted were from retailers of quality-verified SHSs, at rates of 8%. Whereas the retailers of low quality solar PVs were adopted at rates of 36%, possibly because both alternatives delivers the same results the first years, but the branded were sold at a higher price [54]. They go on to suggest that for long-term sustainability, standards and regulations needs to be introduced in order to reduce the number of low-grade solar products. Additionally, Bisaga et al. (2017) suggest setting up a regulatory framework that monitors off-grid systems. With this increased data collection, a better understanding regarding performance would be possible.

The energy transition globally is not only about CO_2 emissions, its also about building communities, gender-inclusion and self-sufficiency. The Solar Mamas project in Zanzibar, organized by the Barefoot College, serves as a successful case and model for these development goals. The models key components include training and empowerment for women from non-electrified villages with a focus of designing, assembling, installing and maintaining solar lanterns and home lighting systems. The program empowered women who were either illiterate or semi-literate, to become solar engineers. This role enhances their status within their communities and provides them with a source of income. Since the start of this program in 2015, it has trained over 3000 women, 200000 households, in 90 countries and is still growing [55].

Although the understanding of the behavioral change associated with a transition to SHS remains relatively unclear, there are some reports that provides initial shifting insight. Perriment et al. (2025) conducted a temporal analysis from several SSA countries with data from energy company BBOXX[9], see figure 1.2. The results showed that on average, there is a 33% decrease in daily electricity consumption by the end of the second year, in relation to the 96th day, which is the day of peak consumption. Combining the load demand analysis with payment data shows that this decrease in energy consumption is observed even in households that are not experiencing economic challenges, indicating there are reasons beyond financial constraints for decreasing energy use when energy access is obtained [56]. A big challenge with SHS is the way it is used. Gustavsson and Mtonga (2005) found that within a year, SHS users learned how to avoid power cuts, though many continued to overuse the system, which shortened battery lifetime [57]. This challenge originates from the daily life of the people who are away during the day for school or jobs. While the sun shines during the daytime, electricity consumption typically peaks in the mornings and evenings.[58]. This means that households rarely utilize the real-time energy produced in the daytime and instead drain their battery in the evenings. Soltowski et al. (2018) discovered in their Rwandan case study that

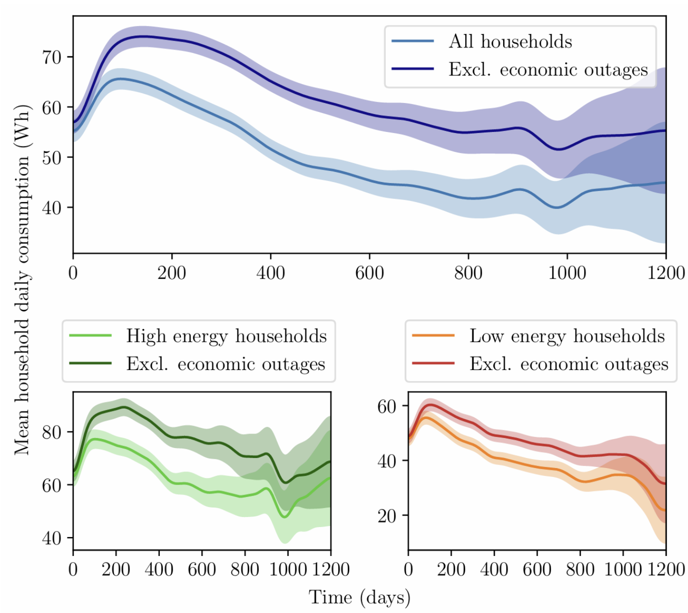

Figure 1.2: Solar Home System usage over time [56]

[9]Bboxx is a solar energy company present in several SSA companies

65% of the SHS electricity generated was not utilized. This provides an opportunity to interconnect customers and form micro- or mini-grids to utilize this excess energy, which is a solution with growing potential.

GOGLA have presented a set of Standardized Impact Metrics for the Off-Grid Solar Energy Sector with the goal of providing a clear and consistent framework for reporting impacts. In their report they also present some relevant data and results. The report highlighted the increase in economic activity for 34% households 15 months after the SHS investment [12]. This additional work was translated into 21 full-time equivalent employment (FTE) per 100 SHS sold, which in the long-term has positive socio-economic impacts for the local communities. This might come as a surprise as electricity usage seems to decrease after the 96th day of usage. It remains unclear whether this is due to more efficient electricity use or other reasons. Taken together, the previous sections reflect a growing body of knowledge, but also expose several persistent gaps that call for further investigation.

1.5.6 Gaps in the literature

TIS: All functions (F1–F7)

As previously discussed, the main challenges in Sub-Saharan Africa lie not in the solar technology itself, but in the broader socio-technical systems that support its adoption and diffusion. As this study aims to map the system, identifying relevant gaps is of importance. Based on the reviewed literature and two comprehensive reviews on SHS in Sub-Saharan Africa, we have identified the following gaps to be of primary importance for this study [3, 4].

- Holistic integration of private sector challenges: While various studies address individual challenges such as infrastructure weaknesses, financing difficulties, and policy inconsistencies, there is a lack of comprehensive frameworks that integrate all these aspects into a holistic solution.
- Policy impact on private sector performance: The research highlights inconsistent and poorly enforced policies as a deterrent to investment, but there is limited exploration of successful regulatory frameworks that have overcome these hurdles.
- Private sector collaboration with stakeholders: More studies are needed on how different stakeholders — including governments, financial institutions and local communities — can coordinate efforts effectively to drive renewable energy adoption.
- Private sector adaptation to grid expansion: How off-grid systems interact with grid expansion plans, including policy coordination and user transition between systems.

In the following section, we consider recent developments in the off-grid solar sector that reveal evolving trends in market dynamics and policy discussions.

1.5.7 Current trends

TIS: Entrepreneurial Activities (F1), Knowledge Diffusion (F3), Market Formation (F5)

In a recent publication from the William Davidson institute, the Gartner Hype Cycle was applied to the off-grid solar sector (see figure 1.3), and it seems to fit quite well [59]. Like many emerging technologies, the off-grid solar sector surged with early excitement, hit a reality check due to tough unit economics and operational friction, and is now moving into a phase characterized by resilient business models and increased demand. In the recent years PAYG solar sector have seen a downturn in investments, caused by macroeconomic headwinds (e.g. foreign exchange volatility, supply chain disruptions) and business model challenges. While facing some challenges, PAYG-companies continue to provide households with first-time access to electricity which supports inclusive economic and social development. Over the years, the companies using PAYG have made some mistakes, such as trying to target the lowest income customers without subsidies, and without an understanding on how to monitor and manage customer repayment effectively [59].

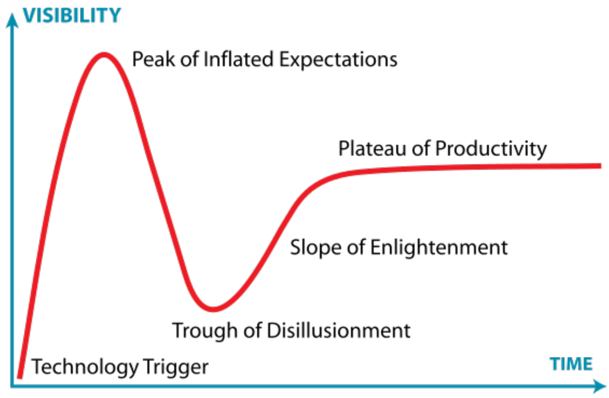

Figure 1.3: A visualization of the Gartner Hype Cycle: PAYGo technology is currently well on its way up the Slope of Enlightenment[59]. Image credit: Jeremy Kemp

However, with the rise of new AI-driven tools, increased technical assistance and clearer benchmarks, the companies are getting smarter about credit risk. This increases operational discipline across the sector which boosts repayment rates and more companies are reaching break-even. According to a GOGLA article in 2024, these shifts point to a growing foundation of financial resilience [60].

In a report from Bowmans Energy, the authors suggest there is a shifting trend in electricity access generation in Kenya [61]. Due to policy uncertainty, regulatory barriers and financing challenges exacerbated by local currency fluctuations, a shift to off-grid solutions has been observed. There is a growing role of Public-Private Partnerships (PPPs) in the sector where solutions such as hybrid systems are likely to increase. In the longer term, the increased focus on carbon credits is projected to enhance the solar PV adoption.

Although the companies are now proving they can stand on their own feet with more resilience and are able to showcase results, to reach the agenda 2030 goals, they still cannot do it alone. To quote GOGLAs final statement in the 2024 article:

> "This is the moment for investors, donors and government to act with urgency and alignment — turning ambition into delivery, and potential into progress."

2

Conceptual Framework

As mentioned in the introduction, this study uses the Technological Innovation Systems (TIS) framework. Which is a holistic approach to understand the development, diffusion and use of new technologies. In this chapter, the concept of technological transitions will be introduced, how the TIS can be adapted to developing countries and what the limitations are. The method will thereafter explain how the theoretical framework has been used in this study.

2.1 Technological transitions

In a rapidly changing world characterized by high uncertainty, the need for strategic foresight is greater than ever. Over the last decades there have emerged a number of systemic (theoretical) approaches that serve to foremost analyze and understand, but also to anticipate, explore and shape the future in a structured way. Among the most well-known frameworks are Technological Innovation Systems (TIS) and Multi-Level Perspective (MLP). Over the years these theoretical frameworks have been refined and evolved into different spheres of the systems thinking perspective. TIS is more technology-focused analyzing the development, diffusion, and utilization of innovations through a functional approach which includes key system functions such as entrepreneurial activities, knowledge development, resource mobilization, and market formation. It emphasizes the actors, networks, and institutions that shape technological change. These processes are usually visualized with an s-curve, see figure 2.1. Which describes the natural evolution of a emerging niche technology with slow initial development, rapid acceleration (diffusion) and dominant designs, and eventual a stabilizing phase referred to as maturing stage [62]. This facilitates a better understanding of the pace and impact innovation have over time, and when strategic interventions may be most effective.

In contrast, MLP focuses on the interplay between niche innovations, socio-technical regimes, and the broader landscape capturing long-term transition dynamics and structural shifts in society. In the last decade or so, some scholars have suggested that combining these two creates a comprehensive complementary method which results in a holistic perspective of technological change and sustainable transitions [63].

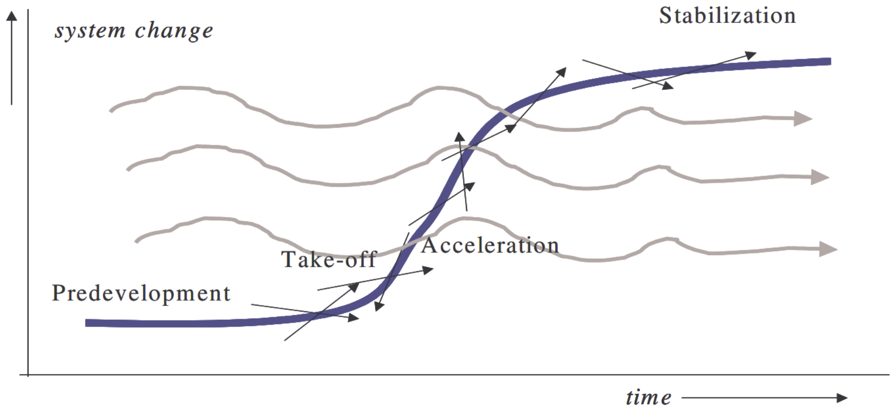

Figure 2.1: Typical pattern of technological transition following an S-curve. The process is divided into stages: Predevelopment (Niche), Take-off (Diffusion), Acceleration, and Stabilization (Maturity) [62].

2.2 Adapted TIS for developing countries

TIS is a framework that serves to map and analyze how different functions (factors) and structural components (norms, networks and actors) affect the transition and diffusion of a specific technology. The mapping of a technology transition is divided into several sub-processes or functions that are related to the innovation process. TIS was originally developed for countries such as Sweden, the Netherlands and the UK. Therefore, scholars such as Edsand (2019) have made attempts to adapt the framework to work better in the context of developing countries [64]. Among the key insights, the original TIS does not fully consider socio-economic conditions of developing countries, broader political and institutional landscape that affects technology diffusion and interaction with existing energy regimes in these countries. In table 2.1 all functions from Edsands adapted framework can be viewed. Edsand modifies the TIS framework to be more applicable to developing countries by adding or modifying several of the functions and also adding landscape factors. Below the modifications done by Edsand are presented [64]:

Knowledge Development (F2a) & Adaptive Capacity (F2b): Beyond research and development (R&D), it considers technological absorption capacity. In developing countries, technology is often imported rather than created. The off-grid solar PV sector in Rwanda is no exception, as only the assembly and distribution of Solar PV modules occur domestically [65]. These functions can for example be measured by looking at higher education levels, technical skills and technical education programs. Additionally, knowledge development should assess the degree of localized innovation. For instance, the ability of rural communities to improve battery durability or integrate mobile money platforms into solar energy systems. Domestic repair and maintenance industries that can support technology longevity is also important assessment, which is generally included in a TIS analysis.

Resource Mobilization - Domestic (F6a) and International funding (F6b): The traditional TIS framework groups all funding sources together. International grants, foreign investments and aid play a big role in developing countries [43]. In the adapted framework, these are divided, and analyzed, to measure national budget allocations and international funding availability. Furthermore, the availability of innovative financing solutions such as microloans, PAYG and crowdfunding platforms should be examined, since they have huge impact on grassroots levels. It becomes easier to assess the maturity of a system when assessing the financing solutions available.

Legitimacy creation - Distinguishing between formal (F7a) and informal advocacy (F7b): In developed countries, TIS assumes all lobbying occurs through formal industry groups. In developing countries, social movements and informal networks (NGOs, activists, social media) serves an important role. The importance of these two groups is measured by tracking the public discourse alongside government policy discussions.

Landscape factors: TIS has been criticized for not including external factors (outside the system), referred to as "landscape factors" that influence innovation. The adapted framework by Edsand (2019) introduces six key landscape factors (LFs) that are of particular interest in developing countries: *Economic Growth, Environmental Awareness, Climate change, Armed Conflicts, Corruption and Education Access* [64]. *Economic growth* affects both the demand for Renewable Energy Technologies (RETs) and the possibility to finance it. With an increased oil price and decreased installation cost for solar, the increased energy demand provides a greater willingness-to-pay for RETs. Meaning that in economic growth, the number of potential investors increases. *Environmental awareness* among citizens, policymakers and companies increases the support for RETs. In the long term, this drives political will, increases demand and builds legitimacy for new innovations. In regions with low environmental awareness there is usually less pressure on policymakers to act sustainable. *Climate change* is unequally affecting the developing countries the most, and will work as a stagnating force on GDP growth globally. Conversely, bilateral and multilateral aid grants and loans for climate change mitigation and adaption will enhance the resource mobilization. Unfortunately, SSA are seeing *armed conflicts* on a regular basis. This has great impact on the business opportunities within a region, as it experiences great uncertainty. In developing countries, where international aid for energy transition is crucial, armed conflicts halts these investments in monetary and human capital. *Corruption* is affecting resource allocation, policymaking and markets free role negatively. Where the short term benefits of a few people stands in focus. This has obviously immense negative impact with regards to technological innovation, as the trust of institutions becomes very low. Development begins with educated people, and without equal *access to education*, a sustainable technological transition remains challenging. In developing countries of SSA a increased number of people are going to primary and secondary school. But the enrollment to university is only for a small elite. Especially in rural areas, where there is a need for specialized human capital. Notably related to off grid solar, technicians in rural areas are often sought after. Not only does the nations have to sustain the system, it needs to innovate and adapt to the contextual factors of the country.

Table 2.1: Technological Innovation System (TIS) functions including adaptations for developing countries. As defined by Edsand (2019)[64]

Function	Definition
F1: Entrepreneurial Activities	Started and planned projects, experimentations and activities from incumbent actors for new technology
F2: Knowledge Development	Planned and ongoing research projects and patents filed; trends in publications relevant to the technology
F2b: Creating Adaptive Capacity	Human (level of technical and higher education), organizational, and institutional capacity to receive new technology
F3: Knowledge Diffusion	Number of workshops, conferences, or other forums (social media) organized about the new technology
F4: Guidance of the Search	Expectations set by government or industry for new technology in terms of regulations and specific targets
F5: Market Formation	Market entry assistance for new technologies (protected space ('nursing'), new environmental standards, tax exemptions, feed-in tariffs, etc.)
F6a: Resource Mobilization (Government)	Resources allocated by government or industry towards R&D (Human Capacity) or subsidies for the new technology (financial).
F6b: Resource Mobilization (International loans and grants)	Availability, size and type (human and/or financial) of international resource mobilization for new tech.
F7a: Creation of Legitimacy/Advocacy coalition (formal lobbying)	Change in lobbying activities by formal and established lobbying groups with economic and political weight
F7b: Creation of Legitimacy (informal lobbying)	Changes in public opinion, support and acceptance for new technology in social media

2.2.1 Quantifying TIS in developing countries

In a study by Tigabu (2018), the adoption and diffusion of renewable energy technologies in Africa was analyzed using the Technological Innovation Systems (TIS) framework [66]. To evaluate the functionality of TIS, Tigabu conducted a survey during interviews with experts, to offer insights into the strengths and weaknesses of system functions. The findings underscore the role of balanced functional accumulation in fostering sustainable uptake of technologies, and highlight the contextual factors shaping TIS development. To make sure the questions are correctly framed and understood, the scientific language of the TIS framework should be changed to a simpler language [66].

Table 2.2: Simplified scheme for perceived functionality assessment (created by Tigabu (2018) [66]). Measurement scale: 0 = None / Not sufficient at all, ..., 4 = Very good / Sufficient / Very high, depending on the function.

System Functions	Description
Guidance of search	Expectations on the business growth (around the technology)
Entrepreneurial activities	Entrepreneurial intensity (around the technology)
Knowledge diffusion	Intensity of promotion or general awareness of the society about the benefits of the (new) technology
Knowledge development	Intensity of research and development (around the technology)
Creation of legitimacy / Advocacy	Intensity of advocacy activities (around the technology)
Resource mobilization	Availability or sufficiency of resources mobilized for the development/diffusion of the technology
Market formation	Sufficiency of market forming incentives (around the technology)

2.2.2 Boundary Challenges in Applying the TIS Framework

Two frequently arising limitations of the TIS approach are the inward-looking and developed country bias challenges, which have previously been presented in the text. The most suitable approach to address these challenges in developing countries is to apply the TIS framework as adapted by Edsand (2019), as previously outlined. In addition to these, there is a complex and often subjective challenge to draw the system boundaries satisfactorily. While the framework suggest focusing on specific technology sectors or innovation activities, it may exclude relevant inter-dependencies or interactions outside the defined system. Connections to global technological systems, external markets or overlapping sectors are among the sectors that may be overlooked. This limitation is often reinforced in developing countries where innovation often relies on international support [64].

2.3 Previous TIS analyses on Solar

There are several different ways to define TIS as a way to facilitate a clear and holistic study. In theory the TIS for a specific technology is global in nature, however, it has previously been modified as a national-level transition in research. In a analysis from Hansen et al. (2015), a comparative analysis between the East-African countries of Tanzania, Uganda and Kenya across different utilities of solar PV was conducted [43]. The findings of the study explained why the adoption was higher in Kenya through the different TIS-functions. The five key factors defined was (i) a growing middle-class; (ii) geographical conditions; (iii) local sub component suppliers; (iv) local champions;

and (v) business culture [43].

Kebede and Mitsufuji (2017) differentiated between R&D and Diffusion when doing a TIS analysis, in the case of Ethiopia [67]. The reason being that in theory these can be associated to different phases of a TIS, where R&D belongs to the formative phase characterized by high technological risk, whereas the diffusion phase is characterized by high market risk. This methodology creates a clear and comprehensive TIS for the case of Ethiopia. The authors highlight the importance of fostering innovation by creating supportive networks, institutions, and technology diffusion. Among the barriers to solar PV in Ethiopia are limited human capacity, weak institutional frameworks, finance constraints and lacking coordinated policy incentives. Pointing to the efforts of the different actors, and their shortcomings, the authors suggest appealing for context-dependent policies and institutional arrangements capable of addressing local conditions and support sustainable energy transitions.

3

Method

To answer the research questions of the study, data was collected through a literature review and interviews. The collected data was then used to map and analyze the system with the help of a TIS framework adapted to developing countries by Edsand (2019) [64].

The study was divided into three phases. The first phase included the mentioned literature review and interview preparation. The second phase, was the field study to Rwanda and consisted primarily of the interviews with private companies and policymakers in the off-grid solar energy sector. The third phase entailed the analysis of the collected data from literature review and interviews, guided by the adapted framework.

The different phases did to some extent run in parallel and supported each other. There were also an iterative aspect to the process connected to refining the interview structure and questions between interviews. This was mostly important in the beginning. The different parts of the project is shown as a flow chart in figure 3.1.

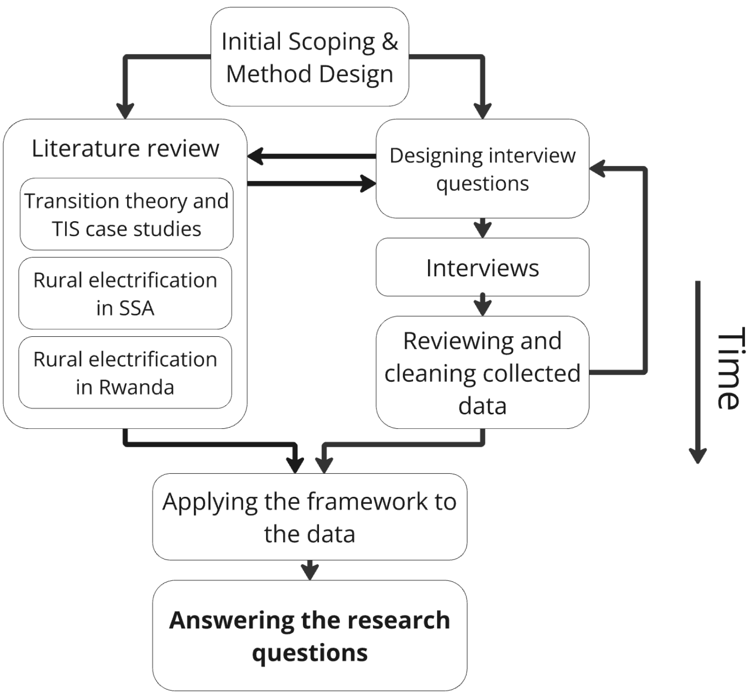

Figure 3.1: A flowchart visualizing the process of the project. The backwards arrow indicate an iterative processes.

The literature review aimed to collect data on the history of solar energy, case studies of the private sectors role in developing countries, rural electrification in developing countries and understanding the actors and policies involved in the Rwandan energy sector, thus mainly collecting data for research question 1 and 2. The interviews instead focused on collecting data to answer research question 2 and 3. By interviewing the private sector we aimed to collect data about how they view past, present and future of solar off-grid solutions. Combining interviews with companies and experts (policymakers and organizations) we could get multiple perspectives on drivers and barriers related to the system.

The reason for using a case in this study — in the form of rural electrification in Rwanda — was due to the following reasons: 1) it was deemed necessary to narrow down the scope of the study; 2) choosing a specific country allowed us to travel there and interact directly with the private sector and 3) visiting the region and engage with actors in the energy sector was essential to gain a contextual understanding of the system.

3.1 Literature review

The literature review was an integral part of the study and continued throughout the project. To ensure the collected literature remained relevant, we focused on three sub-topics, namely private sectors role in electrification, rural electrification in Rwanda and SSA, and transition theory. The main literature was expanded using the snowball effect, whereby references from relevant papers were systematically traced to identify additional studies. This was done by examining both the sources cited by an article, as well as the sources that cited the article. Additionally, targeted searches were conducted on Google Scholar and Scopus using keywords such as *rural electrification*, *Sub-Saharan Africa*, *TIS analysis*, *solar home systems*, and *Rwanda*, combined with Boolean operators (AND, OR) and year of publication to refine the search results. This approach enabled us to narrow down the literature to the most relevant, up-to-date and high-quality sources for this study.

A review of transition theory and frameworks was done to gain insights into the existing knowledge in the field. This review then supported the analysis of the collected data. To better fit the context in which the study took place, earlier studies on applying transition frameworks such as TIS in developing countries was of importance. Reviewing the literature of electrification in developing countries was performed to understand the history of electricity access in that context. Findings were used to understand gaps as well as reported drivers and barriers in the field of rural electrification. The review investigated how countries experience different drivers and barriers in their strive for increased electrification and how they have (or have not) overcome these barriers or utilized the drivers to their advantage. The last part of the literature review is connected to the case study, understanding rural electrification in Rwanda. Early findings of the literature review was used as a basis for interview preparation. Literature was used to map the energy sector in general, and the off-grid solar energy private sector in particular.

3.2 Interviews

The main part of the data collection was performed on site in Rwanda and consisted of interviews with actors relevant to rural electrification in Rwanda. Semi-structured interviews were used to allow for freedom in the interviews. The data collected from the interviews was later used together with what was found in literature review. Literature and interviews helped to verify or deny each other. Meeting with actors from both the private and governmental side was important to get a fair understanding of the sector. Users were to a lesser extent important for this project but one interview with a SHS owner was performed to complement the views of companies and policymakers.

Semi-structured interviews fit the project well as it gave the interviewees the chance to be the expert and talk freely while also ensuring that key questions were covered [68]. As Leech states in [68] the knowledge you have shape the questions you ask and thereby the answers you get. Semi-structured interviews were based on broad open-ended questions, this allowed interviewees to more freely share their insights as they were not restricted as much by our assumptions and questions.

When constructing the interview questions, knowledge from literature review and the initial mapping of the system was used together with knowledge about the analytical framework. The questions were guided by the framework but not restricted to it as to not create potential blind spots of topics not part of the framework. Instead the questions were made broader and open-ended. As mentioned above, the process of writing interview questions was iterative both before interviews started and during the period of interviews. This iterative process along with the use of semi-structured interviews meant that the questions asked were not identical in all interviews. The discussion points and questions that guided the interviews can be found in appendix A

Interviews were around one hour, where interesting leads were followed up on and noted down. Notes were later cleaned and sorted into a structure guided by the TIS-framework. This structure is the same as used to present the results in chapter 5. At this stage the recurring statements where quantified into a tables to give an easier overview of which and how many companies had expressed a certain opinion.

3.2.1 Interviewing companies

The first step was to map companies and private organizations relevant to the study. To identify companies for interviews data on companies active in Rwanda were used. Data on private solar energy companies was collected from EPDs and REGs websites[1] and provided by supervisors. By analyzing data about companies in the sector, including their share of the market; origin; and type of products they sold, a list of companies was created. Meeting with companies of different size, origin, product offerings and business models was an attempt to meet with a representative sample of companies.

[1]EPD: Energy Private Developers; REG: Rwanda Energy Group

Some of the selected companies could not be interviewed for reasons such as companies having disappeared or contact information not being available. In total nine companies were interviewed with differences in size, origin, products and business models. The companies deemed interesting to the study can be found in table 3.1. The table shows some characteristics of the companies, and if we met with them. The discussion points that guided the interview can be found in the appendix A.1

Table 3.1: A table showing the identified companies. The list of products is not exhaustive but focus on if the company focused on smaller SHS or larger mini-grids/C&I (MG) as well as if they diversified into clean cooking (CC) or solar water heating (SWH). PAYG: Pay-as-you-go; EAAS: energy-as-a-service; PPA: power purchase agreement; EPC: Engineering-Procurement-Construction.

Company	Origin	Business outside of Rwanda	Products	Business Model	Met with?
BBOXX	UK	Yes	SHS, CC	PAYG	Yes
Solektra	Rwanda	Yes	SHS, MG, CC, SWH	PAYG	Yes
Engie	France	Yes	SHS, MG	PAYG	Yes
Kolmena	Rwanda	No	SHS, MG, SWH		Yes
Munyax ECO	Rwanda	No	MG, SWH	EPC	Yes
Hello Renewables	Rwanda	No	SHS, CC	Retail	Yes
East African Power	Canada	Yes	MG	EPC	Yes
Great Lakes Energy	Rwanda	Yes	MG	EPC	Yes
Mesh Power	Rwanda (US)	Yes	MG	PAYG, EAAS	Yes
Spotico	Rwanda	No	SHS	-	No
BUIM LTD	Rwanda	No	SHS	-	No
Off-grid Box	US	Yes	MG	PAYG	No
Ignite	Arab Emirates	Yes	SHS, MG	PAYG, EAAS, PPA	No
ARC	London	Yes	MG	-	No
AESG	Rwanda	Yes	SHS, MG	-	No

In order to get a summarized understanding of the companies subjective idea about the state of the solar sector, from a managerial perspective, a short survey was conducted at the end of interviews. The survey questions were based on the survey created by Tigabu (2018) as found in table 2.2. The questions relate to the different TIS functions, but asked in a more simple language. In the survey the interviewees were given the opportunity to rate statements on a scale 0-4, where 0 is low and 4 is high.

3.2.2 Interviewing policymakers

The first step was to identify policymakers to contact for interviews on the subject of rural electrification. This was to get policymakers perspective on the subject and help map out relevant policies and regulations. Meeting with policymakers was significantly more difficult than meeting with private actors, which resulted in only two interviews with this group. The first expert was at Rwanda Energy Group (REG) and the second while remaining anonymous had experience in governmental policymaking. The questions guiding the interviews kan be found in appendix A.2

3.2.3 Field study on site and interviews with users

To get a first-hand experience of SHS, and the users thoughts on the technology, a site visits were planned. An interpreter was present to translate questions and answers. When talking to the user (a family) we focused on questions about their experience, what benefits they have felt, which products have benefited them the most, and what upgrades they would like for the future. The specific questions can be found in appendix A.3.

3.3 Application of the framework

The adapted TIS framework, as presented in the conceptual framework chapter (see chapter 2), guided the work throughout the study. The parts of the adapted TIS-framework used in this study was the adapted functions and the concept of landscape factors. Thus, the structural components and its dynamics, although discussed are not analyzed in depth in this study. This conceptual framework enabled a holistic perspective and supported the identification of drivers and barriers, thereby contributing to answering the research questions.

At the beginning of the study the functions from Edsand's framework helped writing the interview questions. After the interviews a broader version of the framework was used to structure the results. The following structure of broader topic was used: 1) Entrepreneurship, competition and new actors, 2) Capacity building and knowledge diffusion, 3) Impact of Policy and Governance, 4) Market Formation and Demand, 5) Domestic & International funding, 6) Legitimacy and Social Acceptance, and 7) Infrastructure and Logistics. The section of infrastructure and logistics falls outside the boundaries of the TIS-framework but was included in the results since it was a recurring topic during the interviews. This was part of keeping an open mind and not restricting data collection to what the functions of the framework focus on.

After sorting the data into the results sections the data was used to quantify statements that were recurring for an easier overview. First a table with all recurring statements were made. In the analysis these were then divided into drivers and barriers. Because of the nature of semi-structured interviews not all of these statements were explicitly asked about in all interviews, instead the statements represent key points often brought up by the interviewees.

The data collected from interviews and literature review were then combined to analyze the system within each of the TIS-functions.

4

Case: Solar energy sector in Rwanda

4.1 Rwanda

Since the genocide in 1994, Rwanda has risen from the ashes to become a model of recovery and development, with an average GDP growth of 7,6% between 2004 and 2017 [2]. Its policymaking and government planning is deemed sufficient, compared to many other countries in the region. Rwanda is often characterized by political stability, however under a centralized and authoritarian governance model. Notably, Rwanda ranks among the top in Africa, according to the World Bank's ranking of "ease of doing business", indicating a low level of corruption [22]. This has resulted in a high level of engagement from foreign investors. In 2017 the World Bank approved Rwanda's Renewable Energy Fund (REF) grant of 50 million USD to support off-grid solar energy installations, as one example [71]. In parallel, Rwanda allocates the third highest budget to R&D on the continent, at 0.79% of GDP. However, it is far behind countries such as Sweden, with a R&D budget of 3.41% [72]. Despite that, looking forward, it's not all sunshine in Rwanda. In a recent report from the World Bank, several challenges were identified. Insufficient job creation and low productivity levels, weakened poverty reduction momentum, high public dept levels (over 73% of GDP in 2023) and high vulnerability to climate change were among the identified challenges [73].

Figure 4.1: The National flag of Rwanda [69], and its geographical position in Africa [70]

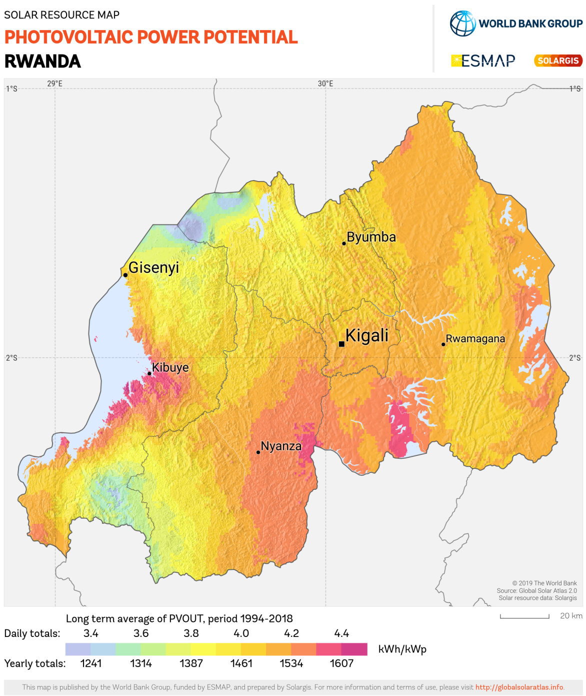

Figure 4.2: Solar potential in Rwanda [74]

Rwanda sees a huge potential for solar powered electricity generation, as it sits approximately 2 degrees south of the equator. The daily sunshine hours are approximately five hours per day year-round, even during the rainy season, see figure 4.2. This corresponds to a solar irradiation capacity variation of 4,3 to 5,2 kWh/m^2/day [21]. In Rwanda electricity access is rapidly increasing, see figure 4.3, however, in relatively small capacity. Electricity access is at the time of writing around 80%, where on-grid makes up 57.4% and off-grid 24.8% of electricity access to all households in Rwanda. The goal is set to reach universal access by 2028/29, with an increase of with 100,000 off-grid installations among households, and the rest being covered by grid extension [20]. Another goal of the Rwandan government is to become a high income country by 2050. In order to reach that target, reliable and safe electricity serves as a top priority. The long-term strategy has been decided to focus on the grid-extension in order to sustain a high level of safety and reliability. However, in remote areas where grid extension is challenging and cost inefficient, the off-grid solar PV solutions serves an important role. Even though the number of added households which will get off-grid access is low, the long-term increase in electricity capacity will have to continue, hence, serves as a long-term business opportunity for solar PV firms.

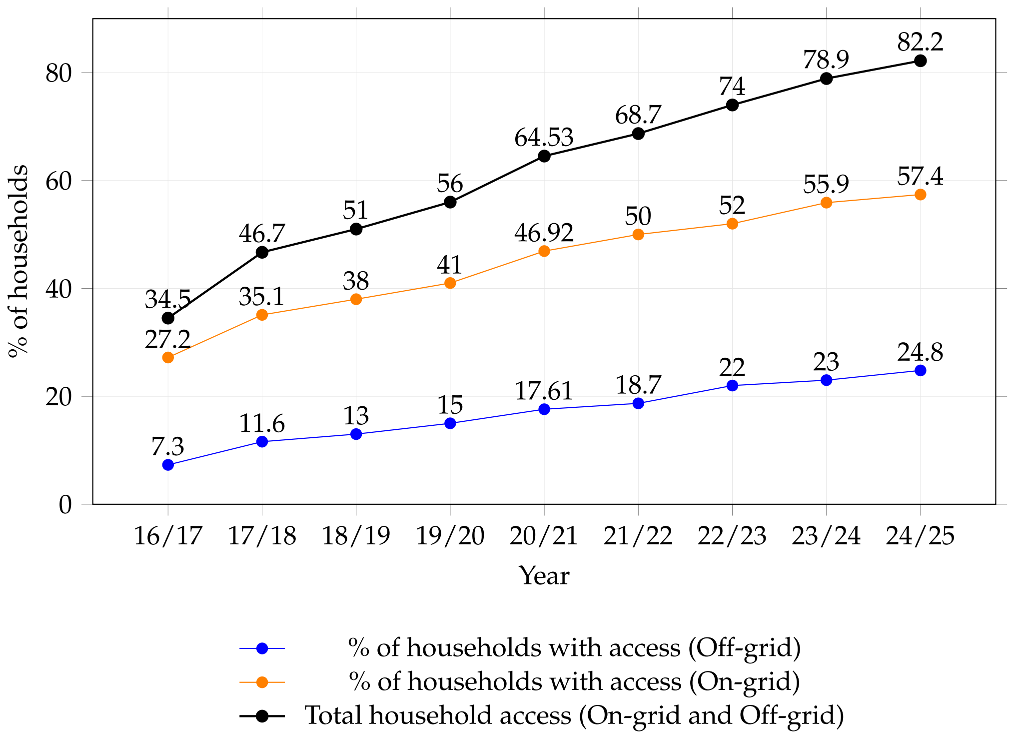

Figure 4.3: Household access to electricity in Rwanda from 2016/17 to 2024/25. Data from Rwanda Energy Group which includes both on-grid and off-grid (primarily solar) connections. [20, 16]

Until 2050, when Rwanda aims to become a high-income country, this capacity needs to increase. There are several challenges that needs to be addressed in order to reach this goal. Many households in Rwanda has a limited budget and spend around 1 USD per month for lighting and charging devices. For comparison, the cheapest SHS costs 3-4 USD per month, not to mention the main barrier, which is the high initial investment cost of SHS [75]. On the other hand, some reports suggests increased incomes after starting businesses, with the help of SHS [75]. Effectively communicating the benefits of solar investment, combined with well-designed financing models, can support Rwanda in achieving its ambitious electrification targets.

4.1.1 The Rwandan Energy Sector and its actors

As of June 2024, The total installed electricity generation capacity in Rwanda is approximately 406 megawatts (MW) [76]. Rwanda's energy mix is dominated by hydropower (37.95%), and methane gas from Lake Kivu (31.77%) [76]. The contribution from solar is only 1.3%. Solar PV has been implemented in sizes ranging from 3 Wp SHS to 10 MWp solar parks [77].

The Rwandan energy sector consists of several governmental institutions, private companies, and associations. All of which are working toward the country's goals on electrification and renewable energy. The system includes both grid and off-grid solutions. In Rwanda the governmental actors are responsible for transmission and distribution [77]. Large producing units are either governmental or private selling electricity to the government though power-purchase-agreements (PPAs). The off-grid areas on the other hand is were the private sector are most active.

The Ministry of Infrastructure (MININFRA) has the overarching responsibility of the Rwandan energy sector when it comes to strategic planning and drafting of policy [78, 79, 80]. MININFRA is also responsible for delivering on the targets set out in the Rural Electrification Strategy (RES). Rwanda Utilities Regulatory Authority (RURA) has the mandate to regulate four Energy sub-sectors including, electricity, renewable energy, gas and petroleum. They are for instance responsible for setting the tariffs of grid electricity. This is to create a reliable and just market for both grid and off-grid with the ultimate goal to be fair to the consumers. RURA therefore influence both grid and off-grid actors. Both Rwanda development board and bank (BRD and RDB) are also involved in the energy sector funneling funds into the off-grid sector namely through the renewable energy fund (REF) (more on this in section 4.1.2) [80]. The actor that manages the generation, transmission, and distribution of electricity, as well as the development of new generation capacity and transmission, is Rwanda Energy Group (REG), which has two subsidiaries: Energy Utility Corporation Limited and Energy Development Corporation Limited, responsible for the former and the latter, respectively [79].

On the private side companies play a role in the energy sector as the off-grid sector now provides close to 25% of electricity access in the country [16]. Energy Private Developers (EPD) has a linking role in Rwandas energy sector. They serve as a bridge between private companies and the government. To have such linking actors can be important according to Bergek et al. (2008) who says that it can be challenging for a single actor to effectively advocate for beneficial policy [19]. EPD represents over 40 private solar energy companies operating in Rwanda (and over 200 if you count all energy companies), both inactive companies and actively participating companies in the rural electrification program. The main functions of EPD include sector coordination, policy engagement, advocacy, capacity building, project facilitation and renewable energy promotion [81].

Figure 4.4 shows the actors in the sector and the dynamics between them.

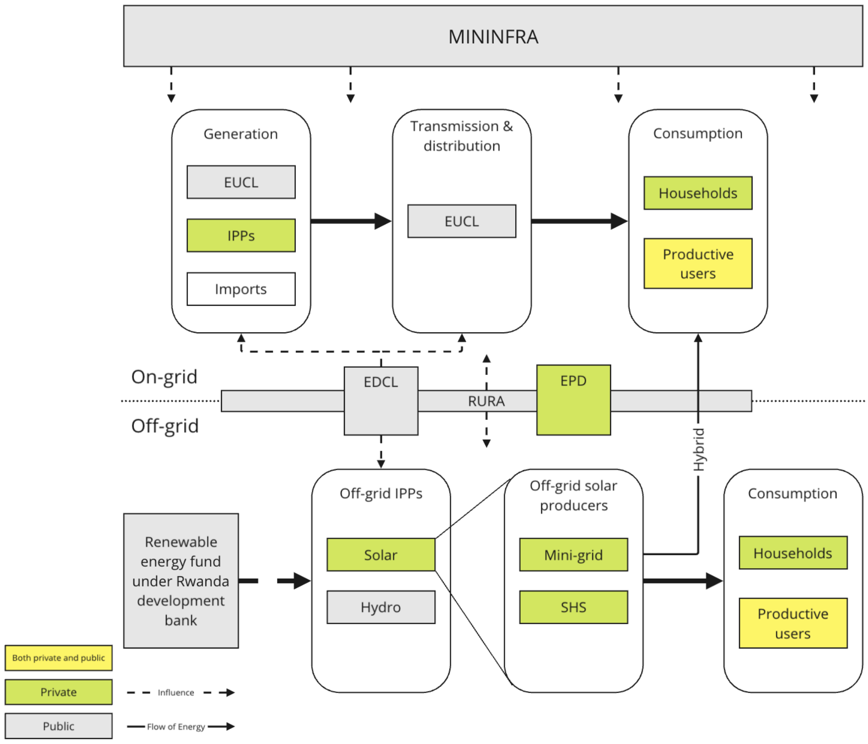

Figure 4.4: A system portraying the actors involved in the energy system in Rwanda. It shows how on- and off-grid work in parallel and that some actors act across this boundary [78, 79, 80]. MININFRA: Ministry of infrastructure; EUCL: Energy Utility Corporation Limited; EDCL: Energy Development Corporation Limited; IPP: Independent Private Producers; RURA: Rwanda Utilities Regulatory Authority; EPD: Energy Private Developers. EUCL and EDCL are part of the larger entity REG.

4.1.2 Policy and Finance Support

Policy and funding relevant to the solar off-grid sector come in different levels, from national policy and goals such as Vision 2050, down to specific subsidies and regulations for off-grid solar energy. This is visualized in figure 4.5. International policy and agreements like Agenda 2030 could also be included but are outside the scope. When it comes to funding however, international funds have a large impact, since many subsidies with direct impacts on solar PV are financed largely by international actors [79]. Although International investments have been important there is also a downside in the form of exchange rates as the Rwandan Franc has depreciated with around 50% against the US dollar in the last 10 years [82].

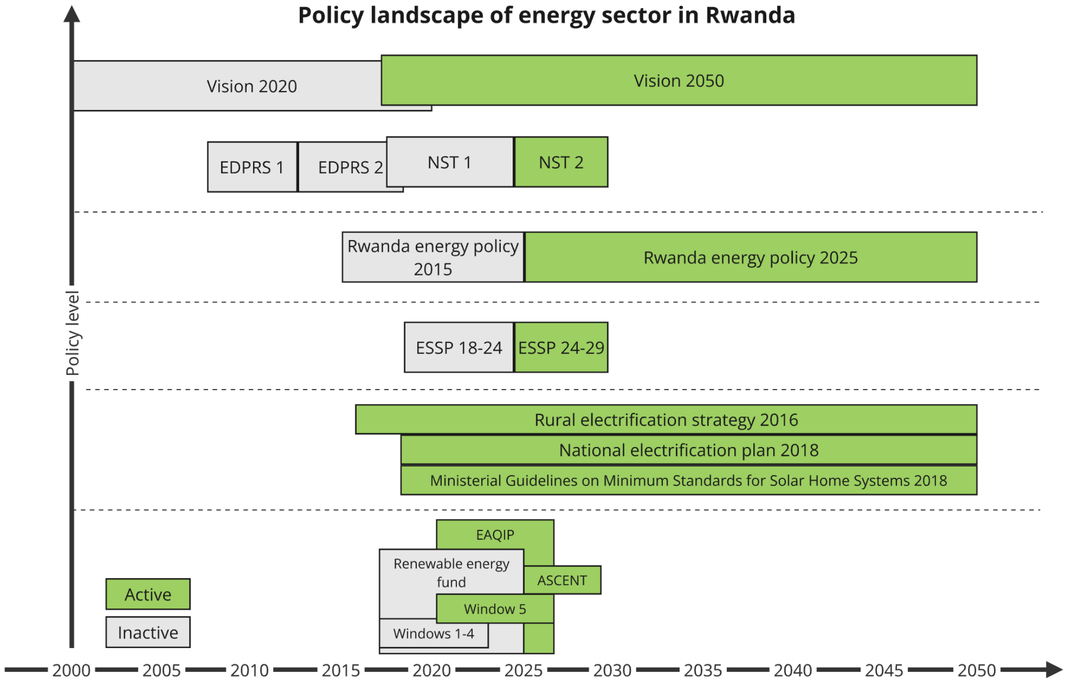

Figure 4.5: A Timeline showing the different levels of policy documents governing the off-grid solar energy sector and related subsidies [77, 79, 80].

Vision 2050 (Replacing vision 2020) sets out national high-level objectives for development to a high-income country by 2050 [83]. The newly approved National strategy for transformation (NST 2) (replacing NST 1) is then meant to concretize the national targets and take the country closer to achieving Vision 2050 [84]. NST 2 is based on the three pillars: economic, social, and transformational governance. The Rwandan Energy policy includes long-term goals for the sector and is the governments way to ensure that the energy sector contributes towards the goals of the NST2 and Vision 2050 [85]. Working alongside the Energy Policy is the Energy Sector strategic Plan, which is updated on an annual basis and sets short-term goals to support the more long-term goals of the Energy policy. These policies have sector wide impacts and sets the overall direction of development.

Within the energy sector there are several policies and regulations relevant to the off-grid sector in general, and solar specifically. This includes the Rural Electrification Strategy (RES 2016) which focuses on access for all households [78]; National Electrification Plan, which governs what areas are for grid, mini-grids and SHS, [86] and Ministerial Standards on Minimum Standards for Solar Home Systems which as the name suggests regulates the minimum standards of SHS [39]. Figure 4.6 shows a map of how the areas have been divided in the 2023 version of the NEP. In table 4.1 the shares for each respective technology can be seen. In contrast to the table SHS and SHS 2023 have been merged to one group in the figure.

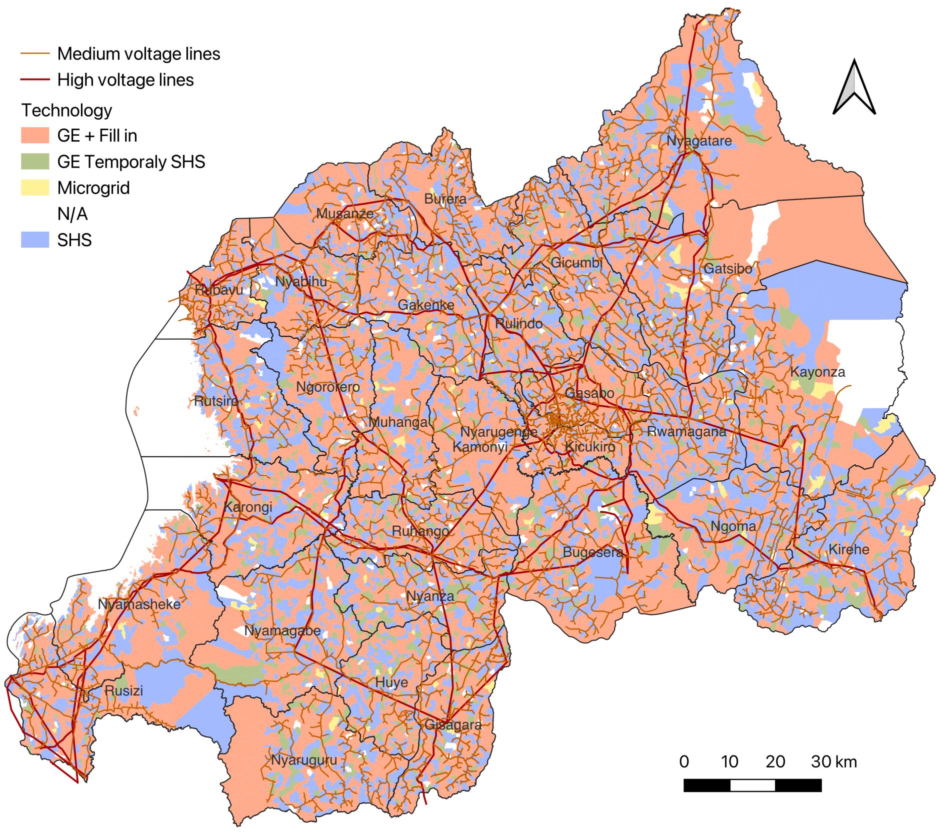

Figure 4.6: National Electrification Plan 2023 [86] with an overlay of HV- and MV-lines (LV was excluded due resulting in low visibility and these lines only extend outside of the MV lines a very short distance). The areas are colored based on what technology is assigned to the area. Open data from the website of REG and MININFRA was used to make the figure.

Table 4.1: Villages by Technology assigned to them.

Technology	Number of Villages	Share (%)
Fill In + GE	9,664	65.2
GE Temporaly SHS	820	5.5
Microgrid	91	0.6
SHS	1,279	8.6
SHS 2023	2,900	19.6
All Villages	14,754	99.6
N/A	62	0.4
Total	**14,816**	**100.0**

Legend:
GE: Grid Extension
SHS: Standalone Solar Home Systems
SHS 2023: Standalone Solar Home Systems / New added scope to REF
N/A: Villages where all households are relocated

One of the most defining policy changes in regards to the off-grid sector can be found in the newest Energy Sector Strategic Plan (ESSP24-29). This policy changes the guidelines from the last ESSP (ESSP18-24). The goal changes from off-grid technologies providing 48% of the households access to only 25%. Another important factor regarding policy has been the frequent change of the NEP, which seems to be changing every year [86].

Clear and up to date policy is important to the private sector but changing to often could create uncertainty. It is acknowledge in ESSP 18-24 that well-communicated plans are needed to not damage the confidence of the private sector [77].

There have been multiple financial initiatives directly supporting off-grid solar PV in recent years where the most important so far has been the Renewable Energy Fund (REF) [87, 88]. This project started in 2017 and finished at the end of 2024. During the REF project five windows of subsidies were created to finance off-grid energy through different channels.

1. Window 1 - Focused on onlending to micro-enterprises and households through SACCOS (savings and credit cooperations). The loans were given to finance Tier 1 or above solar systems. SACCOS are micro-financing institutes and are considered very accessible since 90% of the population lives within 5 km of a SACCO office [88].

2. Window 2 - The second window financed onlending to households and SMEs through banks (commercial and microfinance) for solar systems of Tier 1 and above. SMEs had to cover 20-25% of the total costs of the systems themselves.

3. Window 3 - Provided direct financing to mini-grid developers as loans until grants would become available from RBF program such as EnDev.

4. Window 4 - Allowed financing through loans to off-grid solar energy companies for selling Tier 1 or higher solar systems (and providing after-sales service).

5. Window 5 - The last window was added later to the project and consists of grants financed by REF and EAQIP programs. These grants are meant to reduce the costs for the end users by applying the concept of result-based financing (RBF), meaning that the companies are reimbursed in steps when the desired results have been produced. First disbursement is provided after the installation, second and third after 1 and 3 years of after-sales service respectively.

As REF closed down at the end of 2024 and new sales are no longer allowed, only the payments of already started sales remain. To complete windows 5 the last payments will be financed through the EAQIP project which is active until the end of 2026 [89]. For the window 5 subsidy in the REF project, the percentage covered of a system is based on households' income levels. In Rwanda, people are classified by income level through a system known as Ubudehe [75, 87]. The large percentage subsidies are primarily directed towards the poorest levels of Ubudehe with the absolute poorest receiving 90% subsidies when purchasing a SHS (with maximum subsidy of 100,000 RWF). The percentages covered for Ubudehe 1-3 can be seen in figure 4.2. REF (with its 5 windows) seems to have been a success in terms of systems sold under subsidy. Between March 2021 and September 2024, 476 581 SHS were sold under Windows 5 [89]

The newly introduced initiative that replaces REF is called ASCENT. This initiative is funded both by the Asian Infrastructure Investment Bank, The government of Rwanda

Table 4.2: Windows 5 subsidy for different household income levels [87]

Category	Percentage coverage (of final price)	Maximum subsidy (in FRW)
Ubudehe 1	90%	FRW 100,000
Ubudehe 2	70%	FRW 80,000
Ubudehe 3	45%	FRW 50,000

and the World Bank [90]. This new Subsidy will target off-grid and clean cooking but the majority of the funding (70%) is for grid extension.

The World Bank noted that the market for off-grid solar solutions was slowing down as higher income customers have already been reached [91]. They continue by stating that only 5% of the SHS were bought by Ubudehe 1 in 2018. It is uncertain how the Windows 5 subsidy changed this.

5

Results

Data collected from the interviews were processed and sorted into sections based on the covered areas as presented in section 3.3. While the sections are based on the TIS functions, the presentation allows for flexibility and is not confined to its stricter structure. As some opinions have been expressed by multiple actors, these have been quantified and placed in a statement table. This table is presented at the end of the results section but will be referenced throughout the results. From hereon, companies will simply be referred to as companies (C1-C9) while the other organizations and experts will be referred to as experts (E1-E4). In the last part of this chapter, the results from the company survey are presented. Conducted with the purpose to get an understanding of the interviewees subjective view of the past, present, and future.

5.1 Entrepreneurship, competition and new actors

This section covers the characteristics of companies and market competition in terms of products, business models and company characteristics. Many companies in the solar energy sector are international, some with headquarters in Rwanda, but many are working in multiple countries across Africa. A few companies are local and work only in Rwanda, but these are generally companies with a smaller market share (with only one exception). Interviewed companies can be found in table 3.1.

According to one company Rwanda has distinguished itself by actively promoted off-grid and private companies to enter the market (C3). The representative continues by saying only Tanzania comes close to Rwandas levels of facilitating off-grid. Furthermore, two companies suggest that many of the smaller companies entered the markets when the subsidies were introduced (C1, C3). However, it seems many of these were opportunists, and not really serious long-term players (C9). In recent years there has been a consolidation of the actors, for example where Engie first acquired the solar energy companies Mobisol, Fenix and Power Corner and as late as 2025, Ignite then acquired Engie. According to companies C4, C9 the competition has decreased or remain unchanged with this consolidation.

The sector includes companies with different business models and products/services. While most companies have specialized in either retailing smaller system or performing engineering-procurement-construction (EPC) for bigger systems, companies have expressed they are now diversifying. As seen in table 3.1 many have diversified into clean cooking or solar water heaters. Many companies are also looking at solar irrigation and cold storage. Company C3 expressed that due to some smaller companies not diversifying in terms of products, business model or geographically this might have affected their ability to survive. One of the interviewed experts, E1, suggested that more support should be given to smaller companies in order to facilitate a competitive and innovative market.

Different products, services and business models have been tried during the years including systems between SHS (10Wp), mini-grid and solar parks (10 MWp). All SHS are imported and two of the companies confirmed they import their products from China (C4, C9). Most companies that retail SHS use PAYG to sell their products, but not C4. For mini-grid and C&I these can either be bought in their entirety or the customer can choose to enter into energy-as-a-service (EAAS) agreement with the provider. One of the companies (C1) expressed plans of moving over to EAAS also for SHS. According to this company it would make the solution more sustainable in the long-term since the product would be replaced if it breaks and maintenance would be free. To quote the representative, ”Energy is a service”. Rwanda also has a few solar parks but according to companies C3 and C8 the government have stopped giving out permits for further exploitation since Rwanda has enough generation and transmission and distribution is the problem for the grid according to the government. However, system lower than 100 kWp, can still be built. The energy produced by these installations is then sold either to the customer or to the government through a Power Purchase Agreement (PPA). However, an important note is that when a customer purchases the solar system as a product and not through EAAS/PPA then there is no upper limit on power (C7).

5.2 Capacity building and knowledge diffusion

Knowledge development and diffusion among users and stakeholders relates to formal and informal education connected to the technology. Additionally, it includes learning among companies, educating engineers and technicians as well as educating the users in using and maintaining their system.

Company C5 mentions that early capacity building was key to the expansion of the solar technology in Kenya. While one of the experts claim there is a deficit of technicians (E1) and a need for closer cooperation with universities, another expert and two companies (E2, C5, C9) show some positivity towards capacity building. The expert and one of the companies (E2, C9) claim that the TVET-schools (Vocational education program) have been a success in bringing more qualified skill to the sector and that finding personnel is not a problem. The other company (C5) says that ”Batches of new students with background in energy are coming out from university now.” and that students in general education such as primary and secondary school also learn more about renewable energy today. Conversely, the problem with "brain drain" was mentioned by company C8, which refers to the work migration of skilled individuals at international companies to Europe or the US due to better salaries and standards of living.

Several of the companies work with education in rural areas so that users know how to use the equipment correctly. Two of the companies (C1, C9) also mention that they try to employ local people as technicians. One expert (E3) mentioned that there are ongoing plans to initiate a solar mamas project in Rwanda, only the problem of funding needs solving.

One company indicated that users seemed to be learning-by-doing since electricity consumption increased in the first weeks after installation (C7). Their system also brought internet to the users and after three weeks they had to double the amount of data provided to the community since more users learned how to use the internet. This is an example of informal education.

EPD is an actor that supports knowledge diffusion in several ways. They share information on new technologies, funding and organize workshops to increase diffusion of knowledge between private actors. However, none of the companies expressed very positive or negative opinions but rather said EPD do help to some extent, while its support was seen as modest and not transformative. One company said EPD lost it purpose to some extent (C6). Suggesting they did not see the benefit of being a member if you had not advantage in tenders. Company C4 means that EPD needs more resources. They further state that they would not agree to pay higher membership costs before they see the benefits of membership. EPD themselves say that income from membership fees are small. When companies were asked what EPD should focus on if they had more resources they answered: capacity building; customizing their support to companies based on their needs and facilitate access to new technology. Things that were working well as mentioned by one company was: networking between actors, training for professionals, managing investors and advocacy. As "capacity building" and "training for professionals" partially overlap in meaning, the interviewees seem to disagree on what EPD does well and what they need to do better.

5.3 Impact of Policy and Governance

Impact of policy and governance covers the points related to the governments' role and impacts on the energy system and solar off-grid in particular. Financial support, regulation and long-term plans and goals are among the things that influences the sector.

Expert E3 has expressed that least cost of energy (LCOE) and the National Electrification Plan (NEP) is what governs the energy sectors expansion and thus private off-grid has played a role in covering areas difficult or expensive to reach by grid. Some companies expressed that Rwanda is among the countries in Africa with the highest population density, yet there remains a problem of people being evenly spread out (C1, C2). One company (C2) and one expert (E3) argue that the homogeneous density of people in Rwanda (with many small villages) makes electrification (of school and health care) expensive.

During the interviews all companies and two out of four experts mention government subsidies in one way or another. Mainly they talked about Renewable Energy Fund

(REF) and the five windows included in this project as well as the new ASCENT program (More details in section 4.1.2). Company C2 says that subsidies mostly has focused on SHS and there has only been very few subsidies for mini-grids and C&I. Supporting this is the fact that two companies (C4, C9) mention they only sell under subsidy program and subsides has a large influence on what products that are profitable. A third company (C1) also states that the subsidies enabled a lot of small unserious players to enter the market. Expert E1 states that due to initial sales of low quality products, quality control and after-sales service is now mandatory (However this is primarily for sales under subsidy). Companies C1, C9 and expert E3 also mention how the regulations on after-sales service has become stricter, especially now with the new ASCENT program.

One of the companies (C1) lifted an idea of how the government could further help increase rural access to electricity. They said that the tariffs for grid electricity could be increased slightly in urban areas where people generally are richer. This extra income could then be invested in new project in rural areas or to lower the tariffs for rural people. At the moment the tariffs you pay instead are based on how much you consume (C1).

Regarding mini-grids and C&I, C2 mention mostly international actors as financing actors for larger systems. However, as mentioned in the case study (4.1.2) windows 3 was directed towards mini-grids. The two companies C7 and C2 stated that financial support need to cover around 40% of the capital investments (CAPEX), which make the projects barely profitable. The second company states that as much as 70% of CAPEX needs to be covered to make mini-grids financially sustainable. There are regulations hindering mini-grid developers setting tariffs higher than grid tariffs. Which according to C7, is to prevent poorer people in rural areas without grid access, to be charged more than urban dwellers. This is out of ethical reasons to not exploit the poorest. The company means that even if this makes sense it still puts a lot of pressure on them. Two companies (C3 and C6) suggests that government could support the sector by allowing feed-in-tariffs for larger solar systems. Experts (E3) mention Ci-Dev which relates to carbon credits as a recently implemented governmental support for the sector. REF, for example, is part of Ci-Dev, where the Rwandan Environmental Management Authority are responsible for calculating carbon offsets from previous projects like REF. These carbon credits will be sold and the money goes back into the system in order to further increase access to electricity and clean cooking.

Government policy and goals have been unstable according to companies C4 and C6. For example in the NEP, areas are sorted into grid extension; temporary SHS with planned grid extension; mini-grid and SHS. Grid extension areas are as explained by company C2 areas that are expected to be reached by grid in approximately 5 years. However, it could also go faster while areas that are assigned to mini-grids or SHS are not expected to be reached in the upcoming 5 years. This is an estimate and the possibility of the grid arriving early is an uncertainty for the companies, as this might hinder them from earning back their CAPEX investments. Company C9 states however, that if grid arrives to their area, they receive compensation, provided they can prove their presence prior to grids arrival. Company C2 states there are three outcomes when grid arrives: 1) Government buys the company's mini-grid assets, 2) government signs a PPA to buy electricity from the company, or 3) the company dismantles and leaves (or moves to a new area).

With regards to these uncertainties in policy one of the experts (E3) states that the companies are given a draft of new policy and that the Development Bank of Rwanda offer consultation meetings for the companies to provide their feedback. However, this expert states that companies rarely take advantage of this opportunity.

EPD has an interesting position and role in policymaking and governance, since they act as the collective voice of the private energy companies. With regards to policy and governance they take part in sector coordination, policymaking and advocacy for the technology and private sector. However, as mentioned in a previous section 5.2 there seems to be some disagreement regarding the extent of EPDs contributions.

5.4 Market Formation and Demand

Market formation and demand is about what efforts are made to create a market and demand for a technology by actors in the sector. Rwandas rapid increase in electricity access has reached a transition point. The SHS market in Rwanda is in a phase of saturation according to multiple of the interviewed companies and experts (see table 5.1). In the interviews, companies and experts has expressed that ”SHS is a temporary solution”. One company (C3) said that they are now moving to the maintenance phase for SHS and looking at table 5.1, we see that two shared key point are the ones regarding a shift of direction towards larger systems and urban clients. One company state they are focusing more now on urban areas due to purchasing power (C6) and another that households and business in cities want to reduce their costs or have a back-up system (C3).

Even though urban clients are increasingly important — i.e. clients that can afford to buy systems without subsidies — one company says that business in rural areas would still be very slow without subsidies. They go on to state that this will probably change in the future (C5), as purchasing power increases. One of the mini-grid developers (C8) also state that mini-grids would not be possible without subsidies. As seen in the previous section 5.3 a large portion of the costs need to be covered according to two of the mini-grid developers. The market for mini-grid developers have mostly been around tenders where company C2 states that tenders floated by businesses have been the most lucrative for them whereas tenders from the government are more rare.

Company C9 expresses that the products they sell are to a large extent governed by what subsidies are active. Company C4 stated that they sell only under subsidy, which implies they will shift towards bigger systems — in their case, raising the lower limit from 10Wp to 20Wp — as the new ASCENT subsidy targets productive use of energy. For the coming years there will be the ASCENT program but after this it is unclear what will follow according to one expert (E3). One of the companies says that the decreasing costs of solar hopefully means that the market can stand on its own feet without subsidies in the future (C5). However, five companies say that subsidies will be needed for the foreseeable future for the market to survive.

Lastly, diversification is mentioned in many interviews. Companies need to diversify into new products and markets according to C9. Several companies mention that they have diversified from SHS and mini-grids to solar water heaters or clean cooking. The suggested solutions for new markets have been feed-in-tariffs (mentioned in the previous section 5.3), charging stations for EVs (Electric vehicles), bigger systems of up to 500kWp. The problem for private companies with EV charging right now is that when buying grid electricity to charge an EV you receive a large subsidy, making it hard for private companies to compete, according to C6. This makes private companies less competitive in this market.

5.5 Domestic & International funding

Domestic & International funding collects the data related to local and international funding that has supported the sector. Mostly it is about subsidies, grants or loans that finance products or systems due to the lower purchasing power of Rwandas population, especially the rural population. During the interviews the companies mention several subsidy programs, grant and financing tools that has been important for the sector. One initiative that was mentioned by eight of the thirteen actors interviewed, was the Renewable Energy Fund and especially the last part of the project, Windows 5 (E1, E3, C1, C3, C4, C5, C6 and C9). E1 calls REF the most impactful support initiative. For Windows 5 the subsidies have covered up to 90% of the cost but not more than 100,000 RWF (71 USD[1]) of the cost of SHS according to (C3 and C4). With the new ASCENT program this is increased to 120,000 RWF as the focus is towards productive use (larger systems) and has a lower limit on 20 Wp for the systems sold (C4). One company handed us brochures showing payment plans for their 10Wp and 50Wp systems, which helped contextualize the subsidies. The 10Wp system costs 125,000 RWF (roughly 89 USD[1]) while the 50Wp costs 500,000 RWF (355 USD[1]). This was for cash payment where the total price for the same products with PAYG was 151,000 RWF and 737,000 RWF respectively.

As seen in figure 5.1 the statement that recurred the most is about purchasing power and financing. ASCENT has recently replaced REF but none of the interviewees were informed about what would come after ASCENT. According to company C1, finding local financing solutions is crucial to create a long-term solution of funding the sector. They mention that South Africa is an example of where this has worked well. They explain that in order to de-risk loans to customers, the solar energy system can be put up as collateral for the loan. This means that if the customer (household or business) fails to pay the loans, the lenders (e.g. the bank) can claim the systems and resell to reduce losses. They also mention SACCOs as a long-term solution for when the subsidies are phased out, which has been tried once before in Window 1 of the REF project. Expert E4 talks about crowdfunding and how this is a solution to funding

[1] As of May 2025

projects that are deemed too risky by banks. The expert state that crowd lending is possible for SHS but more viable for mini-grids and C&I.

When talking about long-term and local financing company C1 also mentions currency exchange rates (FX: foreign exchange) as a large problem. C2 and E4 also express that FX is a large problem when it comes to international loans in foreign currencies.

The number of subsidies for larger system such as mini-grids and C&I has been rather small and funding mostly has gone into SHS according to company C2. But they have not been without funding as they mention international entities and initiatives such as EnDev, GIZ, Energy 4 Impact and the Green Climate Fund. Larger systems are often on a project to project basis and are floated as tenders by government, banks or private actors and the mini-grid developers often talk about grants and loans rather than subsidies (C2 och C7). As mentioned in section 5.4 company (C7) states that around 40% of CAPEX needs to be covered by external funding to break even on a project. They reason that REG should get more involved in finding funding for mini-grid developers since governmental actors has better opportunities for finding finance. Many of the companies have diversified into solar water heaters and clean cooking, see table 3.1, which have seen financial support. One company (C5) lifts the SolaRwanda Program for solar water heaters while clean cooking is included in the new ASCENT program.

5.6 Legitimacy and Social Acceptance

Legitimacy and social acceptance concern the public's acceptance or rejection of a certain technology. It is relevant both within the world of policymaking and entrepreneurship, but also among potential customers. As one company states "Everyone want modern energy" but the mindset might still be skeptical towards a specific technology (C1). The same company also states that a customers will always choose grid before off-grid due to superior power provided. While this company also states that it is also due to grid being cheaper. While some companies agree with this, other companies mean off-grid is cheaper as seen in tables 5.1. One company (C5) says off-grid solutions often are viewed as more expensive and another means that the subsidies from the government have been too good. Too good in the sense that people do not believe they themselves should pay for solar energy systems but it should be provided by the government, according to company C4. The company states that the situation is different in Kenya where people see solar as an investment and understand they need to pay for it. Company C9 told us about how people living in areas with no subsides sometimes went to a neighboring area eligible for subsides and claiming they lived there to be able to buy SHS under subsidy.

The negative mindset is also partly because of early products that entered the market were of low quality (E1) (before the Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems came). This has led to companies required to provide warranty and service for the first 3 years after purchase according to several of the actors (E2, C1, C3, C5 and C9).

In many of the interviewees we asked if people understand the benefits of solar energy. One company answer this more in depth by stating some of the positive impacts customers have told them about, including: light for children to do homework after dark, snakes stay away from light and it allows people to invite their neighbors over for dinner after sunset (C9). For small businesses they mentioned electricity to barbershops, TV for a bar or cold storage to sell cold drinks. Expert E1 expressed that there is a gap in terms of user perception and that they need more data about what has been improved. During the field visit to the SHS user we took the opportunity ask about the benefits they have experienced since they invested in a SHS. This user was a household consisting of husband, wife and three kids. The wife expressed benefits to the every day life in the form of: cheaper to charge phones at home; children can play outside when it is dark; homework can be done at any time and with better light; cooking can be done after dark and best of all, the radio she said. When asked about what she hopes to purchase in the future she says TV and a clean cooking system.

However, even if the view of solar historically has been negative three of the interviewees (C6, C8 and E3) say that this it is changing now. Companies give different reasons for this changing in mindset, such as testimonials from people who went to other countries, more educated policymakers, better education in school, more students choosing energy oriented programs and lastly ”Then new generation grows up seeing the beauty of the technology, it will boom in the future” (C5).

5.7 Infrastructure and Logistics

In this section collected data related to infrastructure and local and international logistics are presented. When it comes to the energy infrastructure three of the companies have said that Rwanda produces more energy than they consume but have a lack of transmission and distribution around the country. The ASCENT program includes investments into T&D (only a small part goes to off-grid and clean cooking) but at the same time one of the experts (E3) has expressed that building or repairing transmission lines is more expensive than off-grid solar energy.

Rwanda is a landlocked country which leads to logistical problems of import and export. One of the companies (C8) state that trucks often come into Rwanda with cargo but leave empty, which increase costs for importers. Because of the logistical problems, company C2 indicated some interest in moving to local production of solar water heaters in Rwanda. To mitigate the high costs of import, many of the solar products are exempted from import taxes according to E1.

An important infrastructure in Rwanda is the digital payment they use. The technology — that was first introduced in Kenya as M-Pesa — is called MOMO-pay in Rwanda. This allows people to deposit money into a digital wallet and send or receive payments using USSD commands on basic mobile phones, without requiring internet access [92]. This infrastructure works well to support the PAYG system according to one company (C9). They say that this way of payment removes the middle man and makes payments safer. They also say that some of their products (SHS) are IOT and they can shut them of remotely if payments are delayed. However, if the payment plan is followed through then the customer owns the product. When asked about a second-hand market for SHSs, company C4 and C9 say it happens but to a small extent only if the user is in need of money.

5.8 Statements

Table 5.1: Quantitative summary of companies' and experts' (can be one person or organization) perspectives on key points. X indicates agreement with each statement. C and A represent the different companies and actors/experts respectively. Note that not all of these statements were explicitly asked about in all interviews since they were more like discussion, instead the statements represent key points often brought up in the discussions.

Statement	C1	C2	C3	C4	C5	C6	C7	C8	C9	E1	E2	E3	E4	Total
Purchasing power and financing remain the main problems	X	X			X	X				X		X		6
Subsidies are needed for the foreseeable future	X	X	X		X				X					5
Foreign exchange losses are a major issue	X	X												2
The SHS-market is saturating			X		X	X				X			X	5
Shift to larger systems	X			X	X			X	X				X	6
Shift to urban clients			X			X	X	X						4
Diversifying in terms of products			X	X	X		X	X						5
Logistics is a significant challenge				X	X			X						3
Electricity access increases standard of living	X			X					X					3
The grid is cheaper than off-grid solutions	X				X				X					3
Off-grid is cheaper than grid solutions			X									X		2
Off-grid will stay relevant in the future	X	X	X			X	X							5
Market consolidating around a few players	X		X						X				X	4
Capacity building is working well	X				X				X		X			4
Mindset of actors and customers is changing						X		X				X		3
EPD is working well	X							X						2
EPD is not working well enough		X		X		X								3

5.9 Survey

In the survey the interviewees expressed more explicitly their views on the sector by rating statements. Although many companies expressed saturation of the solar market and new subsidies targeting new businesses, the overall survey results show a relatively optimistic view. There is no doubt that the companies themselves believe that solar is the future. They expressed many times that the benefits of solar is already a fact, and will only get better. Suggesting it is due to the increased economic growth in Rwanda and lower production cost of solar PV. They believe that in 5-10 year's time, they can stand on their own feet, without subsidies. The greatest challenges were expressed as the available resources and public awareness. The first function refers to the logistical difficulties of operating in Rwanda, due to it being a landlocked high-altitude country with low domestic production. The latter function refers to the mindset of Rwandans to pay for their electricity. Many interviewees expressed that because of the governments high level of intervention and support, people wait for different types of subsidies in order to make an investment.

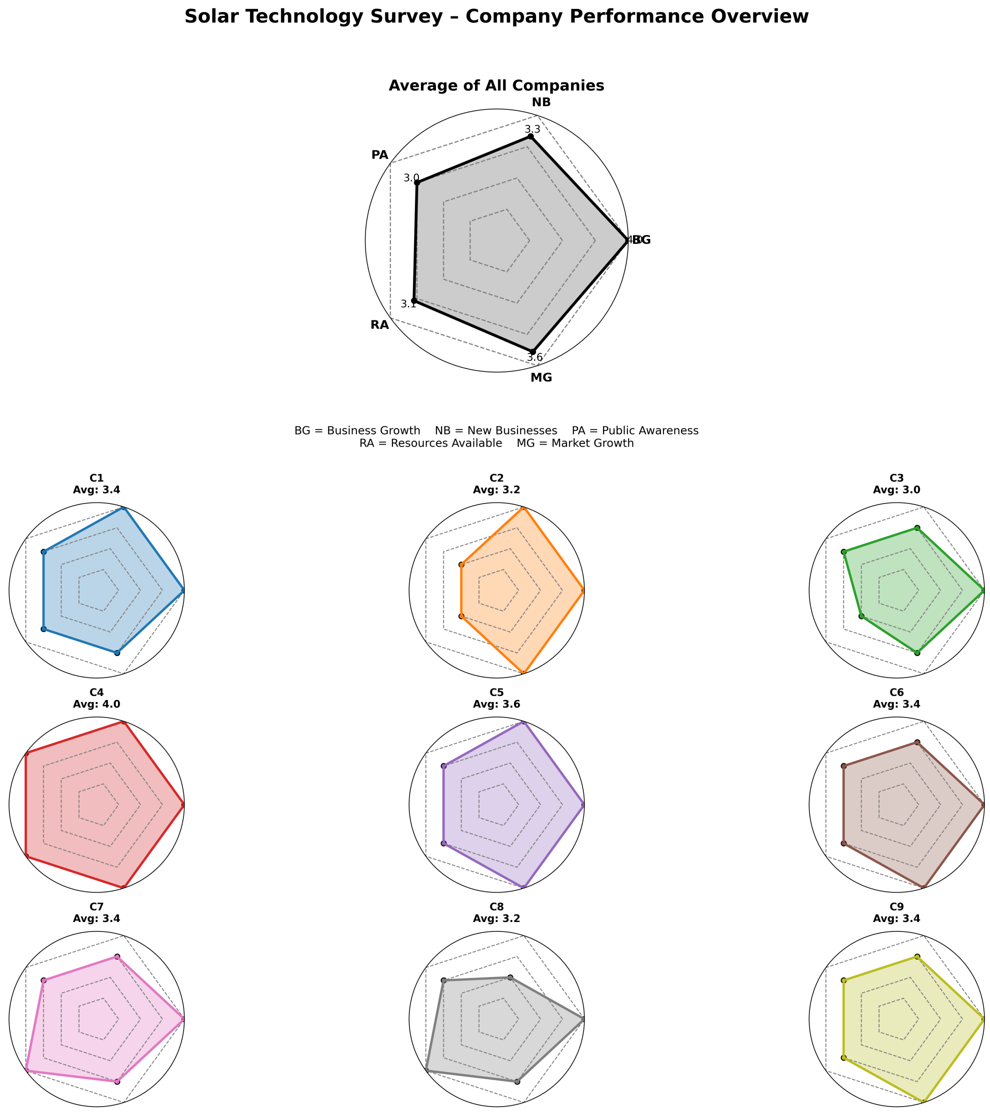

Figure 5.1: Survey results from interviewed solar companies. Pentagon charts showing performance of nine solar technology companies across five dimensions. The top chart displays the average performance across all companies, with individual scores labeled. Lower charts show each company's profile, enabling comparison across business growth, new businesses, public awareness, resources available, and market growth.

Table 5.2: Functionality assessment based on Tigabu (2018), with some functions combined to increase simplicity during interviews. The way the survey questions were formulated is explained under description.

Functions	Description	Measurement Scale
BG: Business Growth	Expectations regarding growth opportunities for companies operating around solar technologies.	0 = None at all, . . . , 4 = Very good
NB: New Businesses	Entrepreneurial intensity and the rate of new business creation related to solar technologies.	0 = None at all, . . . , 4 = Very good
PA: Public Awareness	General societal awareness and acceptance of the benefits of solar technology.	0 = None at all, . . . , 4 = Very good
RA: Resources Available	Availability and sufficiency of financial, human, and infrastructural resources to promote solar technologies.	0 = Not sufficient at all, . . . , 4 = Sufficient
MG: Market Growth	The degree to which market incentives and customer demand have developed for solar technologies.	0 = None at all, . . . , 4 = Very high

6

Analysis

In this chapter, the aim is to analyze and discuss the data collected from the interviews and the literature. The research questions will more implicitly discussed here and then explicitly answered in the conclusion. The discussion is structured according to the TIS-framework adapted to a developing country context as suggested by Edsand [64]. Although the analysis is organized into TIS functions, overlaps will occur due to their inherently interconnected and complex nature. Given the importance of drivers and barriers in this thesis, this part of the results has been given its own section.

6.1 Entrepreneurial Activities

This function focuses on the interests and activities that are planned or have been initiated by companies in regards to the new technology [18].

Entrepreneurial activity in solar energy systems of various sizes have occurred in recent years, both across SSA and Rwanda. In Rwanda this activity has been spurred by the ease of doing business together with targeted government programs, resulting in many companies choosing to enter the market. This is backed by one of the companies when they say that Rwanda has distinguished itself when it comes to promoting private companies enter the off-grid market. The majority of interviewed companies are international and according to Edsand (2019) this reflects the internationalized nature of early entrepreneurial activity in many developing countries, where the domestic capabilities initially are limited [64]. According to REGs website there are 27 companies that have signed an MOU with EDCL [93]. However, it is unclear when this information was last updated and as earlier mentioned it seems like BUIM LTD no longer are active while still remaining on the list. The market saw several new players when subsidies were introduced but as the market is saturating for SHS (which has been the target for the majority of the subsidies) some players are leaving while other are consolidating. According to transition theorists, this is normal in later transition stages, where the system start stabilizing and a dominant design emerges, often accompanied by consolidation [19, 94]. While this is visible for the SHS market in Rwanda, — as the interviewees suggest there is a convergence towards a dominate design recently — the market still relies heavily on governmental support.

Interestingly, despite positivity towards diversification, there is a noticeable sense of skepticism between companies retailing SHS and those specialized in EPC and mini-grids. It does however seem as though all sizes on the spectrum are profitable (at least for now with subsides). This mutual skepticism could be due to the different operational models, risk perceptions and required human capital. Where international firms generally have broader product catalog, stable financial support and solid supply of technical knowledge.

These trends mirror the Gartner Hype Cycle, which is mentioned in the literature review, see 1.5. The early hype in solar PV was stimulated by generous subsidies, with the goal of electrifying a half of the population. Now that this goal has been changed to a quarter and is soon to be reached, the development can be said to have reached the "through of disillusionment". Even though some companies suggest subsidies will have to be sustained in the sector, some are also hopeful that the economic growth and technological development will provide a foundation for the companies to stand on their own feet. According to the authors who suggest the Gartner Hype Cycle can be applied, the reason they see this improving foundation for the solar PV companies, is better credit risk knowledge. C9 showed us how they monitor this, hence, this trend seems to be happening in Rwanda. Not to mention that with ASCENT, increased monitoring is required. And if the grid expansion is not going according to plan, its reasonable that Rwanda will follow the trajectory of Kenya — which were introduced in the current trends subsection, see 1.5.7 — with increased off-grid solar PV as a result.

The companies subjective view of the entrepreneurial activities shows generally favorable conditions. In the survey question regarding *New Businesses*, a overall rating of 3.3 when it comes to the rate of new business creation related to solar technologies. And when it comes to survey question regarding *Business Growth*, the companies' overall rating is 4, suggesting that the solar PV business is very promising.

6.2 Knowledge Development and Adaptive Capacity

Knowledge development is about the existing and newly developed knowledge about the new technology domestically [64, 18]. Creating Adaptive Capacity on the other hand relates to a country's ability to learn about and implement a new technology already developed in another country [64]. This includes the human, institutional and organizational capacity of the country to handle the new technology.

The findings indicate that knowledge development and adaptive capacity creation is developing along multiple dimensions, including formal education, government targeted developments and informal used-based learning. As in many other developing countries the amount of R&D within the field remains low. As seen in the literature, China is the leading developer and manufacturer of solar PV and are way ahead of the rest of the world, including Rwanda. Even if Rwanda has a relatively well functioning education system, they do not have the capability of closing the gap. Because Rwanda is a landlocked country and lack the materials used in solar PV, production is probably not possible or even desirable. In Rwanda, solar is about energy access for rural areas, not about becoming a global exporter. This means that creating adaptive capacity and entrepreneurial activities are more important for Rwanda than R&D.

Creating the conditions for the technology to thrive in terms of innovative business models and applications is crucial, rather that the technical development itself. For this to happen, early capacity building was mentioned as important in Kenya by one of the companies. The technology is not new in Rwanda but capacity building is still of importance to ensure competent people in the sector. The planned Solar Mamas project is a promising sign that could boost capacity building. Capacity building can support an innovative business environment and adequate technical service, which is important for further growth and legitimization. As expressed by three interviewees, the TVET-schools (Technical and vocational education and training) seem to have a positive impact on creating skilled labor. When it comes to enrollment in higher education (tertiary education), it is relatively low in Rwanda, but growing [95].

Moreover, the migration of skilled workers to Europe and the US, poses a threat to Rwandas adaptive capacity. If Rwanda can not keep their skilled labor in Rwanda, the investments associated with educating people are lost. Suggesting that education alone is insufficient without parallel efforts to create attractive employment conditions and career opportunities in Rwanda. However, due to the unequal nature of the global economy and the gigantic income differences between developing and developed countries, this is a difficult challenge to solve.

In terms of academia-industry collaboration, it is limited according to one company, this is a barrier to adaptive capacity and innovation. While institutions such as the Africa Center of Excellence in Energy for Sustainable Development, and University of Rwanda are involved in solar energy research and training, their linkages to the private sector appear to be underutilized or insufficiently formalized according to some company perspectives. EPD has several roles in the private energy sector, one of them being connecting industry and academia. The mentioned barrier might therefore need more attention from EPD, especially in terms of facilitating structured and mutually beneficial collaboration between companies and research institutions.

EPD also engages in other knowledge diffusing and capacity building activities and even though they seem to be focusing on relevant areas like organizing workshops, finding funding and new technology, interviewed companies disagree on whether they are doing a good enough job. It seems EPD needs more resources to better support the private sector. As one company expressed they will not agree to pay higher membership costs before they see an increased benefit from being part of EPD. Membership fees are not the main income for EPD, therefore increasing fees would likely not have a significant impact on their resources. Instead, EPD might need to seek more funding from international entities to better support their members.

The focus of R&D within government and academia is shaped by the societal mindset and perceptions of what is considered important for the future. This relates to the function of legitimacy mentioned in section 6.7. But society's mindset also influence what government invests in and what subjects students and scholar choose to pursue. As mentioned by one interviewee more educations on all levels touch on RETs and this could potentially be beneficial to capacity building in the long-term. Changing the curriculum for lower levels of educations can help students get an early interest and understanding of RETs and help support capacity building.

6.3 Knowledge Diffusion

Knowledge diffusion is about how knowledge about the new technology is shared between actors and to what extent this happens (e.g.e through workshops or conferences) [64, 18].

Knowledge diffusion refers to how existing and newly generated knowledge from R&D and education is shared among the system actors. In a system of sharing knowledge, competition and symbiosis becomes relevant concepts. Between private companies there will be competition for the market and funding, but solar companies also have incentive to collaborate with the purpose of influencing policy and create legitimacy for the technology. An example is to push for policy that regulate the minimum standard of SHS, which keep unserious companies from the market, companies that might otherwise undermine legitimacy. EPD has an important role in being the link between companies and supporting collaboration among its members.

Furthermore, the government has incentive to facilitate knowledge diffusion as they need the private sector to fulfill national goals of development including energy access. Helping spread knowledge about the technology and best practices (e.g. about using PAYG to reach more customers) can increase the rate of electrification.

6.4 Guidance of the Search

Regulations or targets set by actors (government or companies) that affect the expectations of the new technology and its potential [18].

Regulations and goals set by the government are among the strongest factors guiding the search in Rwanda because of the strong governmental control. While many of the high level policy documents set out long-term goals for Rwandas development the lower level documents change more often. Even if this might be reasonable, the lower level documents are the ones that directly impact the private sector. An example of this is the changing guidelines for the share of households electrified by grid and off-grid. The goals started as a 52–48 split for grid–off-grid but has now changed to 75–25. It seems that the problem has not been unclear goals and policy but rather that it has changed often and unpredictably. These shifting projections mirrors the challenges expressed in the literature from other SSA countries. To create an environment where the private sector can thrive, they need stable and clear direction of development to feel safe while investing. The Grid extension areas are according to one company areas that will be connected to grid within the coming five years. This implicitly means that areas designated for SHS and mini-grid projects should have at least five years to recover the initial investment, with SHS typically requiring less time and mini-grids more. A measure that decreases the impact of the uncertainty is that Rwanda has implemented a system where companies with installations in certain areas are compensated when the grid arrives. This is on the condition that they can prove they had installations there before grid arrived.

Even though goals have shifted over time, in one of the interviews we heard that Rwanda has distinguished itself when it comes to facilitating off-grid and private companies to enter the market. Rwanda ranks very high in the indicator "ease of doing business" and the low corruption is inviting for companies to enter the market. With regards to solar PV specifically, the government have implemented tax exemptions, regulations and subsidies, to guide the search in the sector. Tax exemptions are important since the import costs are high due to Rwandas landlocked position, high elevation and limited export volumes. Regulations regarding quality control and after-sales services have been important according to several companies to increase legitimization due to early problems of poor quality products being sold.

The subsidies have been vital to supply the poorest people in Rwanda with electricity because of their extremely low purchasing power. Sharif & Mithila (2013) suggest that in the case of Bangladesh smart subsidies helped build initial market volume, user awareness and local capacity with the long-term goal of phasing out the subsidies when the market can ensure market resilience [53]. However, just like many of the interviewees Sharif & Mithila (2013) acknowledge that continued subsidies may always be needed for the poorest segments of the population — as their purchasing power may never (in the foreseeable future) reach commercial viability levels [53]. While the companies might be biased to say this, Sharif & Mithila (2013) supporting this claim makes it more believable. Nevertheless, creating a clear plan for the future and letting private sector take part in their creation could help reinforce the image of Rwanda as a country where business is easy and not hindered by the government. One expert says that companies are given the opportunity to review policy drafts but that they rarely do so. This could be because they feel powerless; the time window for review is too short; or something else. Here EPD has an important role in being the link between policymakers and the private sector. According to the companies, EPD implement "sector-wide" advocacy, however, as seen in the results there seems to be some disagreement to how well the EPD is facilitating support for the private companies. Since individual companies have little political power and potentially also too little resources to impact policy, EPD need to increase their efforts.

6.5 Market Formation

Actions taken by an actors to create new markets or increase the size of existing markets by for example exempting the technology from taxes [18].

In the literature study we noted that millions of people in the SSA region lack access to energy and the majority of these (80%) live far from the grid. This indicates some opportunity for companies to enter. In Rwanda the hilly landscape and dispersed population means grid extension is rather expensive. But lack of purchasing power prevent many potential customers from accessing the product. Thus, in Rwanda the size of the market is essentially governed but two things: the NEP and active subsidies.

As the market for the smallest systems seem to be saturating, companies voice diversification into larger systems, solar water heaters and clean cooking. One expert put it frankly ”Lets be honest, SHS are a temporary solution” and meant productive use is the future. A reason for the market nearing saturation is that the goal of access through grid and off-grid has shifted as earlier mentioned. This has significantly reduced the off-grid market, which has essentially reached its 25% share (see Figure 4.3). The larger systems sold are mostly for urban dwellers and businesses for the purpose of power security (back-up when grid has black outs) and lowering costs (without subsidy). This is in contrast to the purpose of transitioning from fossil- or bio-based fuel to electricity for rural households. This transition is therefore interesting as it changes the dynamics of the market from a more humanitarian based subsidy market, to one more based on strategic choices and supply and demand. Which is in line with the previous literature on the healthy development of solar PV markets [53].

Large parts of the market in Rwanda are however still not commercial markets but sustained by government support. This makes the private sector dependent on the government and its ability to create and sustain markets. This together with the style of governance in Rwanda, seem to result in the private sector having relatively limited influence over policy. This is consistent with the literature as Baker & Sovacool (2017), show that over-centralized, state-led governance models often limit space for private actors to influence the direction of energy transitions, even though private sector participation is encouraged [50]. Moreover, if the government wants to continue benefiting from private sectors contributions, it needs to sustain the market and help facilitate new opportunities moving forward. In the long-term, the goal should be to make the market self-sustaining, however, what is heard in the interviews, this is still many years away. According to Eberhard & Gatwick (2017), they should take the role as "strategic enablers", to ensure policy consistency and investor confidence remains, while simultaneously provide companies room to be innovative [51].

The companies subjective view of the Market Formation shows very favorable perceptions. In the survey questions regarding *Market Growth*, a overall grade of 3.6 is reflected in the combination of Rwandas economic growth and technological development of solar PV. Where people understand the beneficial investment of solar, rather than relying on government subsidies for the investment to occur.

6.6 Resource Mobilization (Domestic & International)

Domestic: The allocation of financial resources from domestic actors including governments, investors and companies for the technology. International: The financial resources granted or lended from international actors (NGOs, countries, etc) to be used in scaling up the new technology. [18].

Purchasing power and financing was mentioned by seven out of thirteen interviewees as still being one of the biggest challenges for the sector (as seen in table 6.2), suggesting continued financial resources are needed for solar energy in Rwanda. Since the private sector is still dependent on government funding (from domestic or international investors) as of now, Rwanda has a private sector that contributes towards increasing energy access but removing funding would be pulling the rug from under their feet. This seems especially problematic for the poorest households (often rural) as urban sales without subsidy is increasing according to 4 of the companies. Now that the market for SHS is saturating, but grid extension to certain areas is still not possible, scaling up with the long-term purpose of substituting SHS with mini-grids, could be a solution. In that case, more actors might venture into mini-grids and C&I. As the mini-grid companies have a hard time breaking even, funding is still important.

For mini-grids funding has been provided by entities and initiatives such as: EnDev, GIZ, Energy 4 Impact and the Green Climate Fund. The limit on the tariffs mini-grid developers are allowed to set mean that between 40-70% needs to be covered by external investments. In cases when funding is in the form of grants this works well but if instead funding is provided through loans, this creates problems. Several of the interviewees mention foreign exchange rates (FX) as a problem when repaying loans. In some projects the government have agreed to take on the currency risk but in the cases when the risk is taken on by the company they risk not being able to pay the loan back. Due to the Rwandan Francs (RWF) depreciation towards most larger currencies the amount to be paid back increases in terms of the local currency. This raises the question on how to create local financing solutions. SACCOs have been involved before through REF, suggesting this could be a future possibility. Another is crowd funding (domestic or international) or crowd lending (preferably domestic to remove FX risk). Since banks have been skeptical in giving out loans to solar energy companies financing though crowd lending could be a solution. For business people in Rwanda this could be a way to invest money into something impactful but that also provides return on investment.

The companies subjective view of the Resource Mobilization are relatively optimistic. In the survey question regarding *Resources Available*, a overall grade of 3.1 suggest that the financial, human and infrastructural support for solar have been good, however, it is slowly diminishing.

6.7 Creation of Legitimacy (Formal Lobbying, Informal Lobbying)

The creation of legitimacy for the new technology through formal lobbying, leading economic and political actors to view the technology as more credible, The creation of legitimacy for the technology among people, through informal lobbying [18].

For a technology to succeed it needs to be accepted by policymakers, the private sector and consumers alike. It is normal that society is skeptical to new technologies and even if it can compete technically with incumbent technologies, if not accepted, adoption will be low. The creation of legitimacy through lobbying is divided into two parts, formal and informal lobbying. An interesting note by Edsand is that social media is playing a larger role in creating legitimacy also in developing countries. As seen with our own eyes, mobile phones (both old and new) were widely used in Rwanda. As explained to us in the interview with C7, electricity sometimes facilitate the use of internet. This means a large increase in access to information and social media, which have an impact on legitimacy creation.

This division of legitimacy into formal and informal could potentially be interesting also for more developed countries as internet and social media becomes increasingly influencing. From our own experience when in Rwanda, it seems like people are less individualistic, and engage more in community activities than e.g. Sweden. This could mean that informal lobbying between family members, friends or neighbors could have a greater influence on legitimacy in general, including solar PV, rather than in more individualistic societies.

One of the interviewees expressed that ”Everyone wants modern energy” but that there has been a skepticism towards solar energy. It seems people prefer and trust grid more than solar energy. It is not our role to advocate for SHS against grid energy, but solar energy, including SHS, does have its areas of use and can complement grid. When the technology was new to Rwanda many of the products imported were of low quality. Several countries in SSA observed the same problems early on, among these are Tanzania and Burkina Faso. This was solved with regulations on minimum standards and after-sales service of the products. It seems this has brought back some of the trust in the products. The story mentioned in the results chapter about people going to neighboring areas to buy SHS under subsidy show how people prefer solar energy to biomass solutions but are not willing or able to pay full price. Who wants to pay full price when people in neighboring areas pay only 10% of the price?

The growing presence of RETs in education and in society as a whole has started to created a positive feedback loop of increasing legitimacy. Children are growing up with the technology around them. According to Bångens and Edsand (2024), this trend has been observed in neighboring country Tanzania also. One of the companies means this will make solar energy ”boom” in the future. We heard in several of the interviewees that mindset is now changing, because benefits of solar are becoming clear through learning-by-doing and word-of-mouth. When solar energy technology has gained enough acceptance the general mindset of the government being responsible for paying for the technology also needs to change. In contrast to Rwanda, people in Kenya view solar energy as an investment according to one of the companies. Rwandans mindset are supposedly a result of the large subsides during the last years. This is not to suggest that subsidies should be eliminated entirely, but rather that there may be a need to gradually phase them out over time. Alternatively, subsidy mechanisms could be redesigned to help shift public attitudes. Supporting access to the technology through more indirect forms may encourage a more sustainable mindset.

The companies' subjective view of the Capacity Building are moderately optimistic. In the survey question regarding *Public Awareness*, an overall rating of 3.0 reflects the initial challenges faced in solar adoption. However, according to the companies it is now changing, and people understands the benefits of solar better.

6.8 Drivers and Barriers

While earlier sections 6.1-6.7 mostly present the sector as is, this section aims to highlight the frequency of each statement and answer research question 2. Additionally, a text that explains why the statements — in order of frequency — is considered a driver or a barrier, is included.

6.8.1 Drivers

Table 6.1: Summary of drivers identified by companies (C1–C9) and experts (E1–E4), ordered by frequency. X indicates agreement with each statement.

Driver	C1	C2	C3	C4	C5	C6	C7	C8	C9	E1	E2	E3	E4	Total
Shift to larger systems	X			X	X			X	X				X	6
C&I up to 100 kW		X		X	X	X	X	X						6
Changing mindset	X			X	X	X		X				X		6
Consolidation of companies	X		X	X					X				X	5
Monitoring/Data collection	X			X					X	X		X		5
Capacity building	X				X				X		X	X		5
Shift to urban clients			X			X	X	X						4
PAYG	X		X		X				X					4
Feed-in tariffs*		X	X			X								3
Energy as a service*	X		X						X					3
Economic growth and technological development				X	X							X		3
Solar increases quality of life	X			X					X					3
EPD is working well	X							X						2
Increased awareness of climate change					X									1

The most common driver was that the companies are shifting to *larger systems*. This is a strong driver and a natural development in a technological innovation system. The newly increased limit of *C&I to 100 kW* has been received well by the companies and is a strong driver for their survival. The *changing mindset* that solar is a legitimate electricity providing technology is a strong driver for further growth in the sector. *Consolidation of companies* is natural in a technological innovation system which is therefore considered a significant driver. The required *data collection* with the new subsidy ASCENT is considered a significant driver as the decisionmakers can take more knowledgeable decisions if the data is used in a thoughtful way. The success of TVET schools and availability of skilled technicians are positive for the sector and considered a significant driver of innovation (*Capacity building)*. The *shift to urban clients* are thought of as a noticeable driver as the focus is more on the investment opportunities, which is a natural development of a TIS. PAYG has been a noticeable driver in solar PV adoption due to the reduced investment barrier. *Feed-in tariffs* is seen as a prospective moderate driver, as the mechanism is very uncertain as of 2025. *Energy as a service* might be the future way to provide electricity access, however, relatively unexplored. Hence, a prospective moderate driver. The domestic *economic growth and global technological development* is seen as a moderate driver. According to three companies, *solar increases quality of life*, and is seen as a moderate driver. When it comes to EPD, only two companies stated that *EPD is working well*, which is a minimal driver. Lastly, the *increased awareness of climate change* was mentioned once, and is therefore seen as a minimal driver.

6.8.2 Barriers

Table 6.2: Summary of barriers identified by companies (C1–C9) and experts (E1–E4), ordered by frequency. X indicates recognition of the barrier.

Barrier	C1	C2	C3	C4	C5	C6	C7	C8	C9	E1	E2	E3	E4	Total
Affordability challenge remains in rural areas	X	X			X	X		X		X		X		7
Saturating SHS market			X		X	X				X			X	5
Low cost of grid	X	X			X		X		X					5
Diversification of business model			X				X	X	X					4
50 kW cap until recently		X		X	X			X						4
Mindset that government provides				X	X	X	X							4
Capacity building								X		X	X			3
EPD is not working well enough		X		X		X								3
FX challenges	X	X											X	3
Logistical challenges of Rwanda		X			X			X						3
Batteries still expensive				X		X								2
Political uncertainty				X		X								2

The most prominent barrier according to the interviewees were the remaining challenge of *affordability*, hence, the primary barrier to solar PV companies. The *saturating SHS market* and the *low cost of grid* is seen as significant barriers. Additionally, while *diversification* is normal to the maturing phase, in the case of Rwanda, this is mostly due to regulatory uncertainty. The companies follows the government-targeted subsidies, which as of right now, are not directed towards the off-grid solar PV sector. The *50 kW cap* that was recently lifted have been a noticeable barrier for the solar PV companies. Another noticeable barrier is the existing *mindset that government provides*. *Capacity building challenges* are seen as a moderate barrier. Other moderate barriers are that *EPD is not working well enough*, *Foreign Exchange challenges* and the *logistical challenges of Rwanda*. Among the minimal barriers are that *batteries is still expensive* and the *political uncertainty* in the country.

6.9 Landscape Factors

Economic growth in Rwanda has been consistently performing well since the genocide in 1994. Rwanda was in December of 2024 characterized as low/inactive armed conflicts index [96]. However, it has been added to 2025 armed conflict watchlist, as the Great Lakes Region[1] armed conflict has recently escalated [97]. Conversely, none of the interviewees who brought it up, expressed any worries over it. This is maybe because the conflict has been going on since the genocide, over 30 years ago. When it comes to national corruption, it is among the lowest on the continent, which benefits business creation. Additionally, with the relatively equal access to education comes growing environmental awareness. Hence, many of the landscape factors that usually affect developing countries are under control in Rwanda, except for the armed conflicts in the Great Lakes Region. What was brought up in the interviews however, was mostly connected to the geographical context of Rwanda, which affects infrastructure and logistics. This suggests that Rwanda will remain challenged in terms of manufacturing capacity in the solar PV sector. Additionally, the high import cost will remain a barrier, as interviewees noted that no infrastructure upgrades are currently planned to address this challenge.

6.10 Discussion

Following the presentation of the analysis, this section offers a critical reflection on the methodological choices and their implementation, as well as a discussion of potential directions for future research.

6.10.1 Reflection on Methodological Choices and Implementation

In hindsight there were both strengths and weaknesses to the method of choice; how the study was conducted and the choice of theoretical lens for the analysis.

The chosen methods for collecting data, interviews and literature review, were reasonable choices for our aim and context of this study. Weaknesses and improvements mostly relate to the onsite data collection through the interviews.

Semi-structured interviews fit well with this type of explorative study as it allowed for exploration of interesting points brought up by the interviewees. The downside of these types of interviews is that the answers can be more difficult to compare. The interview process also had room for improvement. The, to us, unfamiliar context and limited experience, resulted in a progression of interview skills and questions throughout the data collection. Hence, the discourse in the interviews was relatively different in the beginning compared to end. A way to approach this challenge would have been to perform "pilot interviews" beforehand.

There were also some limiting factors that were unforeseen or beyond our control. For instance not all actors agreed to interviews, which might have impacted the results

[1] The African Great Lakes region around Lake Kivu includes parts of Rwanda, Burundi, the Democratic Republic of the Congo, and Uganda.

by leaving gaps in the data collection. Furthermore, the interviews were mainly done with well educated and financially independent people living in urban areas which might have skewed the results. Due to the nature of the political situation in Rwanda the interviewees might also have felt compelled to provide the ″easy″ answer or perhaps embellish the answer to be more politically correct. Another reason for interviewees to consciously or unconsciously give the ″easy″ answer is based on how the questions are framed. Our assumptions or way of formulating the question s might have unintentionally guided responses or limited deeper reflection. To address the first limitation is difficult and even though Rwanda is one of the least corrupt and safest countries in Africa, it is still authoritarian [98]. This fear of speaking openly might have disincentivized some people from meeting with us in the first place, which is a limitation. To mitigate this interviews were kept anonymous. This however has the downside of making the study less transparent. To address the second limitation we aimed at making our questions as free of assumptions and open-ended as possible.

Regarding the choice of the conceptual framework of TIS it works well for analyzing a growing technology like solar PV. Applying it in a developing country can act as an interesting case as the literature on using TIS in such a context is quite limited. It should be noted that this study was limited in time to collect all the data sufficient for a full TIS, hence, a partial use of the framework and a focus on the private sector was chosen. Collecting more quantitative data and and more data on the structural components of the system would be necessary to conduct a full TIS-analysis. In this study it was used to provide a structure and ensure a holistic perspective. However, TIS is not usually used to analyze a technology from the perspective of one actor but as a whole. We reason that even though this is not the normal use for the framework it provided a good structure for this study. The reason quantitative data was not gathered is because of the time and resources constraints as well as the availability. Hence, the focus was solely on qualitative data. The lack of quantitative data in this study limits the ability to validate findings with numerical evidence, making it difficult to assess market trends, financial viability, and the impact of private solar companies on rural electrification in Rwanda. TIS also has its downsides and as presented in the section 2.2.2. Relying on a theoretical framework can sometimes lead to a focus on areas where data is more readily available or easier to interpret, potentially biasing the analysis and leading to data being shaped to fit the framework rather than emerging organically from the context. To avoid this the results chapter used a structure that was more natural to the collected data while the Analysis chapter used the TIS-structure.

6.10.2 Future lines of research

This study has aimed to understand the factors impacting solar PV and the private sector and how they can contribute to rural electrification. There are multiple areas of interest for future research to indulge in.

For instance, it could be interesting to study how countries that have invited and supported private companies compare to countries that rely on the government for access. A comparative analysis of how access to electrification; solar PV availability or price for access, could offer valuable insights for both researchers and policymakers. Furthermore, it could be interesting to create an understanding of what conditions and contexts need what types of polices to increase access. Rwanda and Tanzania for examples have different political and geographical conditions that means different approaches might be necessary to effectively increase access to electricity.

The opportunity for SSA countries to "leapfrog" the industrialized nations without building their economy on fossil fuels is an essential global matter in order to minimize CO_2 emissions. To facilitate this, understanding the social and economic benefits of solar technology will need further research, to provide educated insights to policymakers. One such study could be a comparative on the long-term socio-economic cost of grid vs off-grid in Rwanda. As there seems to be different perspectives on what is most affordable.

Even though it was not discussed often in the interviews, there is a need to address the growing "solar junk" on the continent. Millions of households will get electricity access through solar in the next decades, and the lack of end-of-life perspective is evident in the literature.

Except for the qualitative impacts of off-grid solar exploring the quantitative side is also interesting. Although some quantitative studies exist (e.g. GOGLA, 2020), further research could point out the social and economic benefits, potentially legitimizing the technology among policymakers.

With the new ASCENT subsidy, the companies are required to provide user data to the government. Early studies on this, such as Perros et al. (2024), emphasize the importance of data protection and recommend take GDPR as a foundational reference. However if used ethically this new collected data could also act as a driver for smarter payment plans, or understanding of how customers use their products.

7

Conclusion

This study has investigated the development of Rwandas private solar PV sector, focusing on its role in rural electrification within the broader context of a developing country. The analysis has highlighted how key factors such as policy, economic and socio-technical factors have shaped the sector. Attention has been given to both national and landscape level influences. Below, the main conclusions are structured to answer each research questions explicitly.

RQ1: How have policymaking, key stakeholders, grid extension, technical, financial, and market development shaped the private solar PV sector and its role in rural electrification efforts in developing countries?

Policymaking has played a decisive role in shaping the sector, with targeted government subsidies and international actors driving strong entrepreneurial activity over the last decade. However, the phasing out of the Windows 5 subsidy, and the expanding national grid are pushing the companies into uncertain territory. This transition forces companies to diversify beyond off-grid solar home systems (SHS) into larger systems and new sectors such as clean cooking and solar water heaters. Although policymaking has provided a positive business environment, restrictive regulations — such as the one related to private developers installing systems larger than 100 kWp — and low transparency in long-term planning hinder further market growth and investment. Key stakeholders like EPD serve as advocates, but face resource constraints which limits their ability to network and coordinate the system of actors effectively. Landscape factors in Rwanda provide both opportunities and challenges for the private solar PV sector. The country's political stability, strong economic growth, low corruption, and increasing environmental awareness — especially among the youth — support sector legitimacy and market development. However, regional conflicts in the Great Lakes Region pose a potential risk, though companies currently perceive this as a limited threat. Logistical and infrastructural challenges due to Rwanda's geography increase operational costs and hinder local manufacturing, with no major improvements planned. Overall, these landscape factors create a cautiously optimistic outlook but require ongoing attention to sustain sector growth.

RQ2: What key drivers and barriers, impacting the diffusion of the private solar PV sector, can be identified?

The most prominent drivers for solar PV companies are the transition towards larger systems and commercial clients. There are signs of a changing mindset that embraces solar energy. The ongoing company consolidation reveals a sector in a more stabilized position. These drivers might be fundamental for further sector growth going forward. Capacity building and improved monitoring also support development but are secondary. In contrast, the primary barrier is affordability, which restricts customer access and demand. Additional significant barriers include a saturating solar home system (SHS) market, low grid electricity prices, and subsidies targeting off-grid solar is diminishing. Grid extension and regulatory uncertainty, especially concerning subsidy policies and system size limits, further complicates investment decisions.

RQ3: How have private solar energy companies adapted and reacted to the shaping factors and the sectors drivers and barriers?

Companies have actively adapted and reacted to the increased saturating SHS market in rural areas by targeting larger-scale and urban markets, responding to changing mindsets that increasingly accept solar as a legitimate energy source. Nevertheless, affordability issues and policy unpredictability remain critical challenges. Firms tend to follow government subsidy trends closely, with smaller local companies facing disadvantages against better-funded international competitors. That many companies call for stronger support to intermediary organizations such as EPD highlights the need for improved coordination. Informal learning and community diffusion continue to be vital, especially in rural contexts, partly because of the companies advocation.

Overall, the development of Rwanda's private solar PV sector reflects the complex interplay between policy shifts, market dynamics, and socio-technical development. While significant progress has been made, the path ahead remains shaped by both opportunity and uncertainty. In this context, the sector's ability to contribute meaningfully to rural electrification will depend on how effectively companies can position themselves, build resilience, and navigate a changing landscape shaped by evolving demands, limited resources, regional dynamics, and how government support will evolve in the coming years.

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A

Appendix 1

A.1 Interview questions for companies

1. Background of company and interviewee

   a) Can you describe your role and give us some background on company's operations in Rwanda and beyond?
   b) What products and services do you provide?
   c) Can you describe the different types of projects your company is involved in? Do you work on government-subsidized projects, sell directly to customers, or use other business models?
   d) Have the products and services evolved over time?

2. Challenges

   a) What challenges have you met in the past and what challenges do you face today?
   b) Do you know if these challenges are unique to Rwanda or also exist in other countries?
   c) If Rwanda achieves full national grid coverage, what role do you see off-grid solar playing?
   d) How have these challenges been overcome?

3. Policy, financing and market

   a) What policy has been relevant for you?
   b) Are you taking part in subsidies?
   c) What solutions do you see for a sustainable market?
   d) Will subsidies always be needed?
   e) How do you see policy changing or affecting you in the future?

4. The Future

   a) What challenges and possibilities do you see for yourself and solar energy in the future?

b) What comes after SHS?

5. EPD

a) Can you tell us a little bit about EPD?
b) Are you members of EPD?
c) What help have you received from EPD?
d) What do they do well?
e) If they had more resources what should they focus on improving?

6. Miscellaneous

a) Would it be possible for us to visit one of your on-site installations to better understand how your systems work in practice?

A.2 Interview questions for policymakers

1. Can you describe your department's role in Rwanda's electrification efforts and what is your responsibility?

2. How has electricity access in Rwanda evolved in recent years, and what do you see as the biggest barriers to further increasing access rates?

3. What is the government's strategy for balancing off-grid solutions like solar home systems (SHS) and mini-grids with national grid expansion?

4. How does the government view the role of private sector actors in expanding electricity access? If Rwanda eventually achieves full grid coverage, what role do you see for private companies in the energy sector?

5. What are the main energy sources that the government is prioritizing for Rwanda's future energy mix?

6. Solar energy has primarily been used for off-grid solutions in Rwanda. Do you see a larger role for solar in grid-based solutions, such as feed-in policies for "prosumers" or large-scale solar energy projects?

7. Currently, relatively low electricity consumption levels are considered as "access to electricity." What is your view on the impact of small-scale solar home systems (10–50Wp) on users' daily lives and overall well-being?

8. In your opinion, what are the most effective strategies to ensure electricity access reaches the very poorest communities in Rwanda? Can you share examples of policies or initiatives that have been successful?

A.3 Interview questions for Solar-PV users

1. Can you describe how having access to electricity has affected your daily life? What are the most important changes in your household or business?

2. What challenges do you face with your current electricity access? What improvements would make the biggest difference for you?

3. What do you enjoy the most about having electricity?

4. What types of appliances or services would you like to power with electricity in the future? How would this improve your life?

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