Institute for Environmental Studies (IVM)

Can the Technological Innovation System (TIS) approach explain the diffusion and adoption of solar PV in Rwanda?

Applying the TIS Framework in a Developing Country Context: A Case Study

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List of Abbreviations

ADB: African Development Bank
DGIS: Directorate General for International Cooperation
CFL: Compact Florescent Lights
CO^2: Carbon Dioxide
ESWG: Energy Sector Working Group
EU: European Union
EWSA: Energy, Water & Sanitation Authority
ECN: The Energy Research Centre of the Netherlands
GEF: Global Environmental Facility
GDP: Gross Domestic Product
IVM: Institute for Environmental Studies JI Joint Implementation
LED: Light-emitting Diodes
MDG: Millennium Development Goal
MININFRA: Rwandan Ministry of Infrastructure
MINEDUC: Rwandan Ministry of Education
MINISANTE: Rwandan Ministry of Health
MINICOM: Rwandan Ministry of Local Government
MINICOM: Rwandan Ministry of Commerce
RDB: Rwanda Development Board
RECO: Rwandan Energy Corporation
REMA: Rwandan Environmental Management Agency
RE: Renewable Energy
RURA: Rwanda Utilities Regulatory Agency
SEDP: Sustainable Energy Development Project
SHS: Solar Home Systems
SPL: Solar Portable Lighting
SSA: Sub-Saharan Africa
STIS: Solar Technological Innovation System
TIS: Technological Innovation System
UN: United Nations
UNFCCC: United Nations Framework Convention on Climate Change
VAT: Value Added Tax
WB: World Bank

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Summary

This Report is part of a larger and ongoing Study: '**Greening the African Energy Ladder: The Role of National Polices and International Aid.'** The Study is carried out in cooperation with the Dutch Directorate General for International Cooperation (DGIS), the Energy Research Centre of the Netherlands (ECN), and the Institute for Environmental Studies (IVM) at the Vrije Universiteit Amsterdam.

The Report is meant to complement the Study's goals of assessing how best to promote a balance between energy access and sustainable development in Sub-Saharan Africa. To do so, it applies a Technological Innovation System (TIS) framework – an approach designed to map the actors involved in the diffusion of a new technology, and more importantly, the functions (i.e. roles) they perform. It applies the TIS to solar PV technology in Rwanda to see if the approach is appropriate in a developing country context. Rwanda was selected because of its status as a nation eager to increase its energy access while promoting renewable energy. The Report focuses on solar because of its potential to be used as both on- and off-grid sources of electricity. Research was collected online and through in-person interviews in Rwanda in May-June 2011.

This Report concludes that the TIS framework is a useful tool to map the functioning and development of the Solar PV innovation system in Rwanda, but suggests the framework can be further refined for increased applicability in developing country contexts.

It also concludes that of the four existing applications of solar PV in Rwanda (grid-based, large installations, solar home systems, and solar lanterns), grid-based and solar home systems have the most to offer Rwanda's energy access goals. This is because, despite the scale-up of electricity access, in which grid PV has a role, many parts of the country will continue to be off-grid in the near future and can benefit from solar home systems. The Report recommends that financial resources and promotional activity be refocused to encourage domestic commercial markets for SHS. It also recommends the government fix a feed-in tariff rate, remove the VAT for solar PV products, and outline bolder PV goals.

However, the Report also anticipates a continued slow-growth of solar PV due to a) alternate government priorities b) comparatively high transport costs for products entering Rwanda and c) limited financing options for solar lanterns and solar home systems.

1. Introduction

1.1. Rational & Report Overview

Since the Stone Age, humans have adapted to their environment by developing technologies to suit their needs. But why do some technologies, like the wheel, become widespread, and others do not? The questions of *how* and *why* technology is adopted by society are very relevant in the current debate on how to address climate change. Both mitigative and adaptive solutions require adoption of new technology, as well as overcoming resistance from the established system. Developing countries especially are faced with a challenge: how do they balance growth of their economies without increasing their reliance on fossil fuels? How can they increase usage of cleaner technologies while also promoting national interests? This Report is part of the ongoing challenge to answer these questions.

How societies innovate, and how to induce successful transitions to sustainable societies, are some of the central questions that Innovation Systems (IS) theory tries to answer (Suurs 2009). During the past decade, scholars at the University of Utrecht and Chalmers University have developed IS concepts and built "Technological Innovation System (TIS)" theory. TIS theory stresses that technologies require not just fiscal interventions like tax exemptions, but a) a network of actors that work to promote them, and b) networks that can serve certain necessary 'functions' – like knowledge development and resource mobilization – in order to successfully diffuse that technology.

This Report takes the TIS framework and applies it to solar PV technology in Rwanda. Rwanda is fitting choice as it is a developing country with a low (10%) rate of access to electricity, but high ambitions to increase from 85MW capacity in 2011 to 1000MW by 2017 (MININFRA 2011). Its government places renewable energy high on its development agenda, yet traditional biomass and diesel generators remain the largest sources of energy (MININFRA 2011). Diffusion of solar technology also remains low in Rwanda, especially compared to its East African neighbours and to the potential of solar to provide both on and off-grid electricity.

The goal of the Rwandan solar TIS is not to power all of Rwanda with the sun, but to achieve its potential as an available source of electricity for those that are likely to remain off-grid, and to develop into a viable feed-in grid technology.

The potential of the TIS framework to map a developing technology's strengths and weaknesses, the importance of building strategies for clean energy development in Sub-Saharan Africa, and solar PV's potential to provide clean energy in Rwanda, led to the question:

"Can the Technological Innovation System (TIS) approach explain the diffusion and adoption of solar PV in Rwanda?"

This Report hopes to contribute to TIS theory by applying it in a developing country context and offering lessons learned, since its application so far has generally been on European technologies. In choosing solar PV technology in Rwanda, it also hopes to offer practical suggestions for solar PV development.

African states have an opportunity to use their impressive renewable energy resources to power growth without the damaging use of fossil fuels. Solar energy especially is abundant on the continent, and can be harnessed both for on and off-grid power. The sooner we understand how to stimulate technological transitions, the sooner we can tap these vast, clean, resources.

Data was collected online and through in-person interviews while in Rwanda from May – June 2011. The data analyzed from over forty interviews suggests that the Rwandan solar PV industry has been growing steadily, especially in areas of entrepreneurial activity and development partner support. However, for solar PV to become a successfully adopted technology in Rwanda, much more attention must be paid to improving internal awareness, lowering material costs, and encouraging the government to support the growth of a domestic solar lantern and SHS market.

1.2. Report Structure

This Report is structured as follows: Section 2 gives a background on Rwanda and on solar PV technology. Section 3 outlines the theoretical framework underpinning the research question and the methodology used. Section 4 charts the structure of the solar TIS in Rwanda, and Section 5 presents the results and an analysis of the development of each function. Section 6 puts the pieces together, constructing a narrative of the Rwandan Solar TIS and outlines general trends. Section 7 offers policy recommendations for solar PV in Rwanda, and Section 8 answers the original research question, while offering suggestions on refining the TIS for a developing country context.

2. Background & Context

This Section elaborates on the challenges and opportunities in promoting sustainable energy access in Sub-Saharan Africa. It then details Rwanda's historical background and energy outlook. It closes by explaining the basics of solar photovoltaic ("PV") technology.

2.1. Diffusion of Technology in Sub-Saharan Africa

Capturing the sun to make electricity is not a new idea, but despite belief by some that solar PV has the potential to light all of Africa, the technology still struggles (Grist 2011). In Rwanda, solar PV accounts for less than 1% of total installed capacity; in Tanzania, where the mean insolation is higher, installed capacity is still only 1.2MW (Business Insights 2010).

Failure to meet potential and compete with incumbent technologies is not a problem unique to solar PV or to Africa, but solving it has enormous implications for development in Sub-Saharan Africa (SSA). Partly because of the interdependency of systems with fossil fuel based power, much of the developed world is "locked-in" to carbon-based technologies. Substantive changes are usually very expensive and politically problematic (Popp 2009). But there has been increasing focus on the potential for developing countries, and especially those in SSA, to escape the carbon prison and 'leapfrog' to cleaner economies (Unruh 2000).

Access to electricity in SSA is limited – and the number without access is projected to increase, from 600 million to 700 million in 2030 (World Bank 2010). To compete globally, projects to increase electricity access are necessary, but in a business as usual scenario, this would result in drastically increased carbon emissions. Refocusing on developing green technologies, on the other hand, would allow for both increased access and lower emissions.

Although SSA boasts substantial wind, hydro, and geothermal stores, solar power is an especially important resource. It is abundant: indeed, according to the Trans-Mediterranean Renewable Energy Cooperation, there is enough solar energy in *one square kilometre* of Africa's deserts to produce the equivalent of 300,000 tons of coal (African Executive 2011). It is also versatile, and can be used to produce electricity on and off the grid in the form of standalone solar systems and solar lanterns.

There are many challenges inherent in promoting a new technology. A limited entrepreneurial base, strong incumbent interests, and regional requirements can all contribute to a technology's failure to be successfully adopted. But some challenges are especially challenging in Sub-Saharan Africa: consumer access to credit for small products – like solar lanterns – is limited and further hampered by low purchasing power (Solar Lighting for the BoP 2010). The technology – and knowledge surrounding its applications – is often introduced and fostered through external partners. Creating awareness of the product is also tricky in rural areas with limited communication.

The challenge is to develop both a way to understand the processes through which a technology is adopted and diffused in developing countries, and a way to stimulate transitions towards new ones. The next Section gives an historical context of Rwanda, as well as the energy challenges it now faces.

2.2. Country Context: Rwanda

Rwanda is a small nation of eleven million people, land-locked and bordered by the Democratic Republic of the Congo (DRC) to the west, Burundi to the south, Tanzania to the east, and Uganda to the north.

Figure 1: Map of Rwanda (from geography.about.com)

2.2.1. History

From approximately the 18th to the late 19th century, Rwanda was a highly structured monarchy where status was determined by ownership of cattle (Mamdani 2001). In 1919, Rwanda was declared a mandate territory of Belgium, which chose the Tutsi ethnic group – the pre-existing political elite – as their administrators. Under Belgium's management, schools and roads were built, and agriculture processes were somewhat modernised (Melvern 2000). However, the elevation of the Tutsi minority as political elite encouraged ethnic tensions. After independence in 1959, Hutu-based political parties took control. The next few decades saw periods of peace, but also periods of violence and the flight of Tutsis into neighbouring states (Melvern 2000).

In 1994 Rwandan President Habyarimana's plane was shot down. Immediately thereafter, the military and militia took control and executed the planned genocidal violence against Tutsis and moderate Hutus (Mamdani 2001). Up to one million people were killed, and active conflict ceased only after the Rwandan Patriotic Front (RPF), led by future president Paul Kagame, took control of Kigali (Melvern 2000). The violence also wreaked havoc on the economy and infrastructure, as key officials were killed, reports and information lost, and roads, buildings, and electricity lines destroyed (Country Framework Report World Bank 2005).

Pasteur Bizimungu became president in 1994, and Kagame became Minister of Defence and Vice-President. Kagame assumed the Presidency in 2003 and was re-elected to a seven-year term in 2010. Since 1994, and especially under Kagame's tenure, Rwanda has seen impressive growth. Primary schools are open to all, and there are medical centres in every district (GEF 2009). The average GDP growth rate between 2006-10 was estimated at 7.3 percent, outstripping its neighbours (CIA World Factbook 2011). Kigali has grown from a city of 200,000 to over one million, and there are several ambitious plans to create commercial, industrial, and residential facilities throughout the country.

2.2.2. Rwandan Energy Outlook

FAST FACTS

2011 Status:	**Policy Goals:**
86% of primary energy is traditional biomass	Improve efficiency of cookstoves to reduce charcoal and biomass use, increase access to electricity
Average electricity consumption is 20koe/year/per capita	120kWh/year by 2020
85MW installed capacity	1000MW installed capacity by 2017
10% access to electricity	16%, 350,000 connections by 2012
	50% access to electricity by 2017

Sources: MININFRA 2011, EPDRS 2008, NEP 2009

High population growth (2.8%) and governmental ambitions to transform Rwanda's infrastructure and industry into a middle-income country both demand increased energy access and use.

However, as Figure 2 shows, the vast majority of primary energy still comes from traditional biomass, and a significant amount from expensive diesel generators. As Figure 3 shows, electricity sources are largely domestic and imported hydropower and thermal (diesel) generators.

Figure 2: Primary Energy Supply (from Smith College 2011)

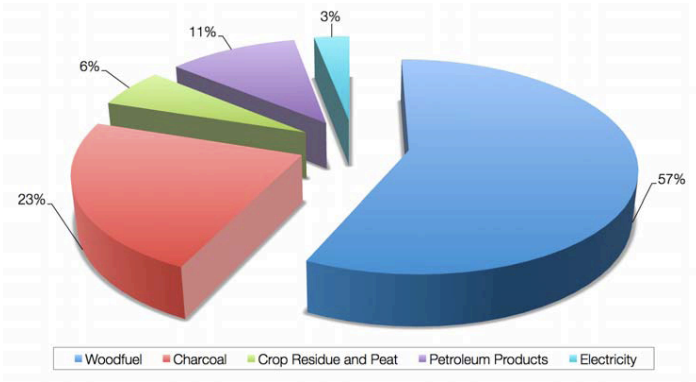
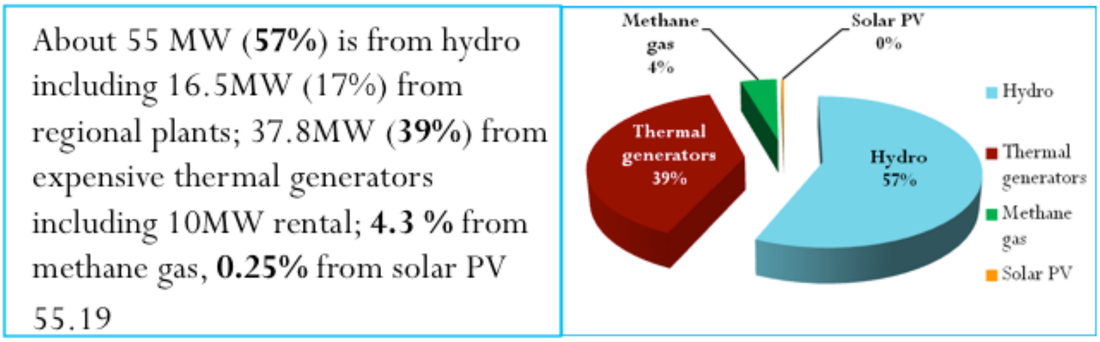


Figure 3: Sources of Electricity (MININFRA Energy Presentation 2011)



As of 2011, around 12% of Rwandans have access to electricity, with most of this access in the capital, Kigali (MININFRA Energy Presentation 2011). In 2011, the cost of electricity was 112RWF, with a VAT of 20% bringing the total cost to 132RWF for both domestic and commercial customers (MININFRA Energy Presentation 2011). This figure however is likely to increase as prices of diesel and kerosene are expected to rise significantly (Business Daily 2011).

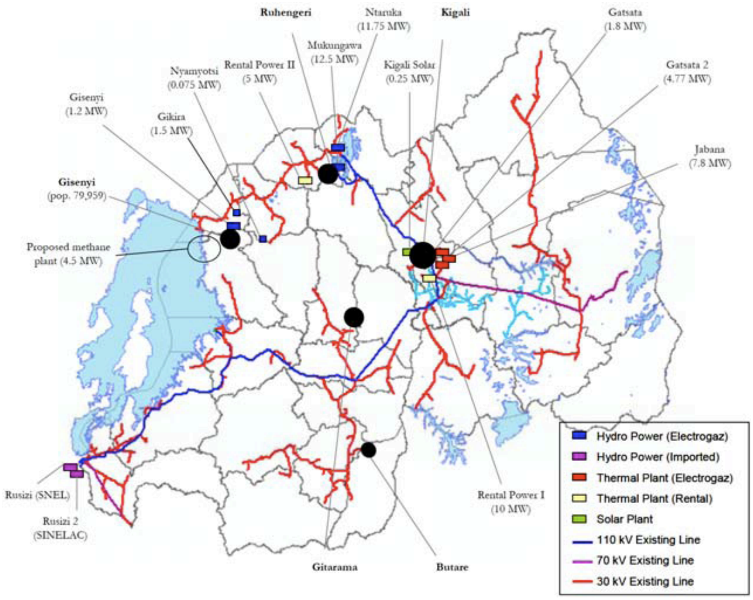


Figure 4: Map of Existing Grid and Energy Sources (from Smith College 2011)

Figure 4 shows the existing grid connections in Rwanda, which are growing but still limited, making costs higher. The government has several projects currently ongoing and planned for the near future to increase installed capacity, increase access, and reduce cost:

<u>Projects to Increase Capacity</u>:

1) 2010 Construction of Jabana, 10MW domestic thermal generation plant (NEP 2009);

2) Tapping between 20-50MW of methane energy from Lake Kivu by 2012 (MININFRA Home Page 2011);

3) Increasing domestic hydropower: Rukarara(10MW), Nyaborongo(27MW) , and putting hydropower projects online in partnership with the DRC and Burundi (NEP 2009);

4) Exploring geothermal potential (MININFRA Action Plan 2009)

<u>Projects to Increase Grid Access to Electricity:</u>

1) Rwanda Electricity Access Scale-up and Sector Wide Approach (SWAp) Development Project (NEP 2009);
2) Rehabilitation of transmission lines (GEF 2009)

<u>Projects to Reduce Cost of Electricity:</u>

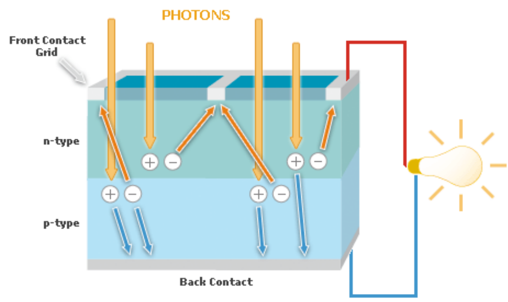
1) Promotion of "Grouped Settlements" to reduce distance from the grid (National Urban Housing Policy 2008);
2) Build railway to connect Kigali to Dar-es-Salaam (NEP 2009);
3) Extend Rwanda/Uganda pipelines (NEP 2009) (*See Annex D for list of relevant policy documents*)

The government has also stressed its commitment to invest in and promote the use of renewables, especially those available domestically, like peat, geothermal, hydropower, and solar energy (MININFRA Action Plan 2009).

2.3. Overview of Solar PV Technology

Harnessing the sun for electrical power is not a new phenomenon. In fact, Edmond Becquerel discovered the photovoltaic effect in 1839, although it was not until the 1930's that solar panels went into commercial use (U.S. Department of Energy 2011). It is called the photovoltaic effect because of its process: photons of light hit a solar 'cell,' which are then absorbed by the cell (made from semi-conductor materials like silicon). The photons jolt the electrons out of their atoms, and this 'jolt' produces a 'volt' – the electrical current (NASA 2002).

Figure 5: Photovoltaic Effect (from Solartoday.com)



Photovoltaic panels ("PV" panels) are collections of these solar cells, arrayed together in parallel (next to each other), or in series (so they are all connected), and protected by a laminate. The larger the solar cell, the more power it contains but the heavier it becomes.

Different materials can be used to make solar cells. Most often mono or polycrystalline re used and are cut into thick 'wafers.' Nowadays, scientists are developing 'thin-film solar' which can be made from silicon, or other materials like organic dyes, but is much thinner and more flexible (NASA 2002).

Panels can last over 20 years. They are easily placed on roofs and other flat surfaces. PV efficiency is usually between 10-20%, but electrical output varies significantly according to the amount and strength of sunlight received (PV FAQ's, National Renewable Energy Laboratory 2009). Rwanda, for instance, receives between 4.8 – 5.5 kWh m2/day (MININFRA homepage 2011).

There are various applications for solar PV systems, ranging from very small (solar portable lighting ("SPL") and solar home systems ("SHS")), to medium-sized (mini-grids), to very large (PV plants, concentrated solar power), and can be designed to work 'off-grid' or be grid-connected.

The variable use of solar power makes it especially suitable to Sub-Saharan regions not connected to the grid. What system works best in what area is dependent on the amount of sunlight the region receives, the total energy needs of the target group and the financial resources available. Even in areas where solar is a good fit and will provide energy for a community, it is not always selected as an option. The next Section will discuss theoretical approaches to understanding *why* certain technologies and systems are chosen or rejected.

3. Theory & Methodology

This Section considers both the theory that informs this Report, and the methodology used to apply it.

3.1 Innovation Systems Theory

The end of the Cold War ushered in a period of rapid global restructuring, and scholars and policymakers became increasingly interested in exploring the ways in which societies process transition. Connected to this is the study of how nations promote technological change, and what systems of innovation help drive that process (Lundvall 2010, Suurs 2009).

This interest took on a new urgency as awareness grew of fossil fuels' contribution to climate change and how developed societies were often 'locked-in' to a carbon-based economy (Unruh 2000). For example, the U.S. transport sector in the early 20th century promoted individual car ownership, in turn allowing for greater urban sprawl. As a result, it is now often impossible to live and work without a car (Unruh 2000). For many, it became important to understand *why* and *how* certain technologies, like the automobile, achieved dominance, and how best to encourage transitions to alternative systems.

Innovation Systems (IS) theory developed in response to that challenge. IS-scholars rejected the notion that economic interventions alone explain successful transitions (Freeman 1987, Lundvall 1992). Instead, they maintain that change occurs through broader "networks of institutions, public or private, whose activities and interactions initiate, import, modify and diffuse new technologies" (Hekkert 2007). Such networks are dynamic and interactive, influenced by external as well as internal factors. They can be framed as national systems, e.g. the innovation system of Japan (Freeman 1988) or on regional, sectoral, or production scales (Makard 2008).

IS theory recognizes that technologies are embedded within larger 'systems of influence.' The 'macro-level' includes social, cultural, and technical influences; the 'meso-level' is comprised of a specific socio-technical regime, its institutions and actors; and the 'micro-level' is the niche area where technological change first emerges (Verbong and Geels 2007). By mapping the networks of actors and institutions involved in a particular technological regime, and embedding them within the larger socio-cultural context, one can develop a clearer understanding of how a technology achieves dominance (Hekkert 2007). In the U.S. auto industry example, it was not just an increase in affordability that led to the automobile's popularity, but a complex network of actors lobbying for its promotion, as well as an economic boom following WWII and socio-cultural trends popularizing consumerism (Unruh 2000).

IS theory is important for the concept of 'transition management' and the idea that not only can innovation systems be mapped, but they can be actively guided so that they "lead to accelerated change directed towards sustainability ambitions" (Loorbach 2009). Theorists recognize that a significant transition involves more than incremental change. Instead, transitions represent a fundamental shift in the physical and normative infrastructure of a society, making them more difficult to achieve (Elzen and Wieczorek 2005). For example, increasing automotive fuel-efficiency is an incremental change that does not disturb the larger 'socio-technical regime.' A transition to hydrogen-powered automation, in contrast, would represent a fundamental change in mobility (Muradov 2009).

Using IS mapping to determine how transitions can be guided, and with what tools, is a transdisciplinary work in progress. Comparisons of different systems may yield reasons for a technology's success or failure, and broad lessons may be extrapolated (Hekkert 2007). Technology-specific policies may be suggested at the regime level by promoting alternative 'visions' of the future, or target the niche-level by creating protective markets (Hekkert 2008).

Or they may not. Innovation systems theory, through promoting a deeper understanding of the processes of change, has its limitations. Some argue that IS analysis is unhelpful to policymakers, as comparisons of innovation systems can be costly and time-consuming and may not yield concrete policy recommendations (Wieczorek 2011). IS theory also views technology as an output of a system, not as an integral input thus omitting a potentially important part of the puzzle (Suurs 2009).

3.2. Technological Innovation System (TIS) Theory

Technological innovation systems (TIS) theory, developed by scholars at the University of Utrecht in the Netherlands, and Chalmers University in Sweden, narrows the focus. Instead of mapping entire national or regional innovation systems, TIS maps the "network/s of agents interacting in a **specific technology area** under a particular institutional infrastructure" (Carlsson & Stankiewicz 1991).

3.2.1. Goals of Technological Innovation System

The ultimate goal of every TIS is "to generate, diffuse, and utilize technology," and have the new technology successfully compete with and/or replace the incumbent technological system (Hekkert 2007). TIS scholars believe that system actors must perform certain functions (e.g. build businesses, lobby for its promotion, raise awareness) to overcome resistance from the establishment (Bergek 2008). The goal of TIS theory is to develop methods to measure the robustness of the TIS functional activity and develop policy guidelines for helping 'blocked' systems move forward (Bergek 2008).

The TIS framework has its roots in IS theory in that both believe change happens within a larger social structure and that a greater understanding of how society processes innovation can lead to an increased ability to influence the trajectory of change (Hekkert 2007). However, unlike IS theory, which sees technology as a by-product of a larger innovation system, TIS theorists believe the diffusion of technologies to be integral in instigating transitions economies (Suurs 2009). Focusing on a particular technology allows for a more nuanced analysis of actors, institutions, and their interactions than studying an entire national innovation system, but can still elicit insights and recommendations about the larger system in which it is located.

A TIS can be mapped both structurally and functionally. Both methods presume that there must be a strong network of actors and supporting institutions for a technology to be successfully adopted and diffused (Wieczorek 2011). They also aim to assess systemic gaps. Studying both are important, and both are separately considered in this Report. However, greater emphasis is placed on the functional analysis, for reasons outlined in Section 3.2.3.

It is also important to note that the technology does not need to be recently invented in order to be considered an innovation in a particular country or region. If it is new to the system, the same challenges of building political support, mobilizing resources, and promoting the technology apply (Suurs 2009).

3.2.2. Structural Approach

A TIS structural approach aims to map, unsurprisingly, the structure underpinning a specific technology (Wieczorek 2011). The relevant structural elements are variously categorized in academic literature and practice. Structural mapping usually always includes 'Actors' and 'Institutions,' and occasionally 'Networks/Interactions' and 'Technology.' (Johansson & Johnson 2000, Wieczorek 2011).

This Report maps actors, their networks, institutions, and technology, but under 'Actors,' separates 'Development Partners' from 'Civil Society.' It does so because, especially in a developing country, development partners often play a determining role in guiding policy and resources, much more so than local or international NGO's. Thus, separating the two will allow for a more refined understanding of the solar TIS structure in Rwanda.

The Report also includes an 'Infrastructure' category. Although not always included and differently defined if it is (Smith 1997), this Report finds it a useful category to map physical, financial and knowledge-based resources. It applies it as outlined in Anna Wieczorek's work (Wieczorek 2011). Figure 6 shows the structural breakdown this Report will use.

Figure 6: TIS Structural Breakdown

Actors
- Civil Society
- Businesses (start-ups to large firms)
- Knowledge Institutes
- Development partners
- Government
- Credit organizations

Networks
- System Networks & Actor Relationships

Institutional Framework
- 'Hard' Institutions
- 'Soft' Institutions

Infrastructure
- Physical infrastructure (land, communications)
- Knowledge infrastructure (universities, labs)
- Financial Infrastructure (banks, microfinance)

The actors, networks, and infrastructural dimensions may be seen as loosely correlative of the 'meso-level' referred to in Section 3.1., while the institutional framework corresponds to the 'macro-level.' All reveal important trends.

Approaching a technology from this angle is helpful to map a TIS's structure and the structure of the society in which it is located. It can also help determine if a TIS is missing key stakeholders or infrastructural support, but it tells us less about *how* the system interacts and about what is working, and what is not (Carlsson et al., 2002b, Bergek 2008).

3.2.3. Functional Approach

The functional approach attempts to address that gap. It posits that although studying the actors, institutions, and infrastructure in a TIS is important, it is assessing the *functions* they perform that better captures a system's workings (Hekkert 2007). Called "a growth model based on the notion of cumulative causation" by Suurs, the TIS is seen by academics as an interactive system of actors performing different key functions, which allows a TIS to build-up and take-off, or leads it to suffer setbacks and remain stagnant (Suurs 2009). Whether or not a technology is successfully diffused is determined by the (context-specific) robustness of the functions and their interactive loops, as well as the technology itself and overarching societal structures.

Through an analysis of the innovation systems literature and by isolating roles of actors and institutions that appeared important for successful diffusion in several case studies, seven functions were identified (Jacobsson and Bergek 2004; Bergek, Jacobsson, Carlsson, Lindmark, and Rickne 2008a; Bergek, Jacobsson, and Sandén 2008; Hekkert and Negro 2008; Negro and Hekkert 2009; Suurs 2009). Developers of this list of functions posited that each was a necessary ingredient to a successful innovation system: without one, the technology would unlikely be successful. The list was then re-applied and its appropriateness confirmed in other case studies (for example, Hekkert and Negro's study of the Dutch biogas industry (Negro 2007).

Table 1 lists and defines the functions and gives examples of each, using definitions developed by the Utrecht scholars. Table 2 modifies the functions for a Rwandan context.

Table 1: TIS Functions & Sample Events

Function	Definitions & Example Functions
1. Entrepreneurial Activity	Typically seen as the 'core' of a TIS, this function represents entrepreneurial activity, typically of private actors. These actors can be new entrants or established companies looking to expand into the new technology: - Number of experiments with new technology - Number of new entrants

	- Diversification of incumbents
2. Knowledge Development	Creation of country specific knowledge, including technology-specific research and development (R&D): - Feasibility studies - R&D projects and investments - Pilot projects
3. Knowledge Diffusion	This measures how well and how robustly actors are exchanging information about that technlogy: - Workshops - Accessibility of country specific publications
4. Guidance of the Search (“Policy Support”)	This function reflects the degree to which actors are *guided* to particular technologies, usually through government policies or industry ‘expectations.’ This in turn can be influenced by larger political goals or consumer preferences, and ‘meso-level’ landscape: - Institutional formation - Explicit targets or policy statements, goal-setting
5. Market Formation	New technologies often need help improving efficiency and quality; this can be stimulated by creation of niche markets, through tax breaks, consumption quotas, or technology-promoting environmental standards: - Tax exemptions; subsidies - Feed-in tariffs - Favorable environmental standards
6. Resource Mobilization	Dynamics in availability of financial and human capital for specific technology projects, including building of research institutions, and long-term access to financing: - Donor funds - Technology-specific resources
7. Countering Resistance to Change (“Advocacy Support”)	Extent to which that technology is supported over others, and to extent it is promoted, through lobbying, political support, or mobilization of popular opinion: - Individual/group lobbying - Expressed support of key opinion formers - Increased media interest/focus

However, as with most theoretical frameworks, the TIS functional approach has its limitations. As scholars have noted, this approach does not always include an assessment of the appropriateness of a technology in the country context (Suurs 2009). Nor does an analysis of functions alone tell us enough about infrastructural problems (Wieczorek 2011). Furthermore, the representative functions and related events were developed within the context of developed country technologies, and may not be universally applicable.

This Report aims to contribute to the TIS literature by offering ways to address these potential gaps. It seeks to find where an analysis of technology appropriateness might be inserted, as well offer as suggestions for adapting functional mapping to a developing country context.

3.3 Methodology

This Section explains how data on the solar PV TIS in Rwanda was gathered, the theory behind it, and the challenges that came with it.

3.3.1. Event Mapping as Data Collection Tool

The functions of a technological innovation system may be mapped in different ways; this Report uses "longitudinal 'event mapping'" as its methodological instrument. This is because event mapping allows for systematic analysis even with qualitative data input over a period of time.

Event mapping was originally used to study innovation on the firm-level, plotting individual events on a real-time timeline, then using the timeline to isolate trend patterns and understand the firm's learning environment (Van de Ven 1999). In contrast, since the development of a TIS typically takes place over many years, 'longitudinal' (or historical) event mapping is more appropriate.

To map a TIS, information related to each function is gathered through documents, stakeholder interviews, and literature reviews. The functions are represented by specific events, and gathered for a period of years (usually ten to twenty). For example, events like a 2010 pilot project for a new solar technology, and a 2009 Rwandan application for a solar PV patent would qualify as events within "F2: Knowledge Development," for years 2010 and 2009. Table 2 shows representative events for mapping the solar PV TIS ("STIS"). Events that are tangentially related – a newspaper article on the benefits of renewable energy in general, for example – can be included at the researcher's discretion, but events should generally stay focused on the specific technology.

Table 2: Event Mapping for Solar TIS

Function	Event Types (modified for Rwandan STIS)
1. Entrepreneurial Activity	- Number of experiments with solar PV - Number of new business that install or sell, or market solar PV - Diversification of established business to include solar PV division - Solar PVprojects & demonstrations on
2. Knowledge Development	- Solar PV feasibility studies - PV standard setting by Rwandan government - Data collection (on PV installations, reports about PV in Rwanda) - Solar PV R&D Projects and Investments - Rwandan Solar PV Patents - Solar PV Pilot Projects
3. Knowledge Diffusion	- Renewable energy workshops - Accessibility of publications focusing on solar PV in Rwanda - Mapping PV network size and intensity over time
4. Guidance of the Search	- Governmental institutional formation that is relevant for solar PV - Explicit solar PV targets and policy statements, goal-setting - Number of articles in professional journals 'raising expectations' about solar PV in Rwanda
5. Market Formation	- Tax exemptions for solar PV or energy efficient lighting - Feed-in tariffs for solar PV, and/or independent power producers (IPP) - Subsidies for solar PV or energy efficient lighting - Environmental standards which create a more favorable environment for solar PV in Rwanda
6. Resource Mobilization	- Donor funds for solar PV - Solar PV-specific resources - Financial capability building - Access to (micro) credit for renewable energy projects - Setting up of R&D facilities or generic institutues
7. Advocacy Support	- Individual/group lobbying for solar PV industry - Expressed support for solar PV of key opinion formers - Increased media interest on solar PV/RE issues where solar is mentioned
Possible Additions	- ***Donations*** of Development Partners - Installed Capacity of technology - New installations/projects - Creation of RE Educational programs

3.3.2. Event Mapping in a Developing Country Context

One issue this Report aims to address is how to refine the TIS framework for a developing country context, and one area of potential consideration is event mapping: while some events, like the existence of relevant tax exemptions or policy targets, may be universally applicable, others may not be.

For instance, using the "number of articles in professional journals that raise expectations' about that technology" to assess the robustness of the Policy Support function may be inappropriate in a country with a small academic community, or where resources do not permit wide access to such literature (Negro 2007).

Table 2 highlights the events the Report considers potentially unrepresentative for a developing country TIS. The 'Possible Additions' row reflects events whose inclusion it considers important, but which seem to be absent from current literature. Section 8 re-examines these events.

3.3.3. Data Collection

After the data is gathered through online research and/or in-person interviews, each event is placed with the appropriate function in the appropriate year. This allows for a long-term view of TIS development, and for further analysis of trends and interactions. Table 3 shows an example blank event-mapping chart.

Table 3: Blank Event Mapping Chart

Function/ Year	F1	F2	F3	F4	F5	F6	F7
2008							
2009							
2010							
2011							

After inserting the events into the chart, they are quantified, usually with a +1 (signifying a positive event for the technology) or a -1 (signifying a setback or negative event) (Suurs 2009, Hekkert 2007).

Event mapping helps construct a timeline narrative and identify potential patterns. For example, if the number of events related to knowledge development increases over time in tandem with other functions, one might be able to conclude that they are positively interacting with each other and leading to further TIS development. Suurs calls this connection 'cumulative causation' (Suurs 2009). The concept is related to feedback loops: the more functions work positively with each other, the faster they can build up the entire TIS. This interaction can also be negative: the failure of one function may have negative effects on the system overall.

In order to apply the TIS framework to solar PV in Rwanda and to research the question posed, I travelled to Rwanda from April 29 – June 7 2011. Although it is possible to construct an event map primarily through literature studies and internet data collection, this is less productive in a developing country context where important information may not be available online. Thus most of my data was gathered through lengthy in-person interviews with various stakeholders. The interview questions were based on ones from other RENEW researchers, although I created separate sets of interview questions for each sector (the complete list is attached in Annex A).

I also gathered documents from the stakeholders and conducted online research.[1] Table 4 illustrates a breakdown by sector (identified in section 3.2.2.) of the stakeholders interviewed. A full list of organizations involved in Solar PV Rwanda may be found in Annex C.

Table 4: List of Interviewees by Sector

Sector	Number	Organization	Country of Origin
Civil Society	10	ECN (Energy Research Centre of the Netherlands) ETC GVEP (Global Village Energy Project) Koinonia Foundation (x2) Rural Energy Foundation SaferRwanda Skyheat Associates (USA) SNV (Netherlands Development Org.) UNDP (United Nations Development Org.)	Netherlands Netherlands International U.S. Netherlands Rwanda U.S. Netherlands International
Development Partners	5	ADB (African Development Bank) BTC (Belgian Technical Corporation) (x2)	International Belgium

[1] Specifically, I researched journals and used the search term "solar PV Rwanda" in Google, going through the first 50 pages, or 500 'hits.' I also searched the archives of the 'New Times,' Rwanda's leading newspaper, for any references to solar PV.

		DFID (Dept. for International Development) Dutch Embassy in Rwanda	United Kingdom Netherlands
Businesses (start-ups to large firms)	18	B.Boxx Bralirwa Brewing Company Chloride Exide Davis & Shirtliff Enterprise La Perfection Equinox Great Lakes Energy Greenlight Planet IWACU Solaire Kigali Solaire/Stadtwerke Mainz Manna Energy Mucome Ltd. Nuru Lighting PSF (Private Sector Federation) SECAM Tasha Enterprises TGL (Tech Grand Lacs) ToughStuff	United Kingdom Rwanda Kenya Kenya Rwanda United Kingdom Rwanda Kenya Rwanda Germany U.S. Rwanda Rwanda Rwanda Rwanda Rwanda Rwanda Kenya
Knowledge Institutes	2	KIST (Kigali Institute of Technology) KIST/TBIF (Technology Business Incubation Facility)	Rwanda Rwanda
Government	7	MININFRA (x 5) Rwempesha Health Centre RDB (Rwanda Development Bank_	Rwanda Rwanda Rwanda
Credit Org.	3	Urwego Opportunity (x 2) Vision Finance	Rwanda Rwanda

3.3.4. Analyzing data using the Functional approach

Equally as important as identifying ways to gather data and map a technological system is how to analyze the results.

A complete functional TIS analysis should be able to: 1) assess the stages and robustness of the individual functions, 2) use that assessment to identify interaction patterns and blocking mechanisms, and 3) offer policy recommendations based on those results.

Whether or not a specific function is 'successful' is generally qualitative and contextual (Suurs 2009). As Bergek et al. have pointed out, each function usually undergoes a 'formative' and 'growth' phase. In the formative phase – the duration of which is also context-specific – it is not the simply number of events that is important, but how they contribute to TIS development (Bergek 2008) (Section 5 analyzes the functions and their development in more detail).

Scholars have offered different ways in which to analyze interactions between functions and determine what that says about overall TIS development. Suurs outlined five 'Motors of Innovation' situations, which are characterized by different structural circumstances and functional interactions (Suurs 2009). Bergek et al. suggest identifying a) inducement and b) blocking mechanisms in the particular system (Bergek 2008). Hekkert analyzed a TIS by examining if and how the functions increase in conjunction with each other (Hekkert 2009). For instance, if F1: Entrepreneurial Activity seems to increase after F4: Resource Mobilization increases, the two may be said to be linked.

This Report, for purposes of brevity, graphically maps functional interplay to establish a narrative of the technology and delineate inducement and blocking mechanisms. Sections 6 and 7 this Report go into more detail.

3.3.5. Methodological Challenges

While I was able to interview over forty stakeholders and gather relevant documents while in the field, the research was not without challenges. Firstly, many of the stakeholders interviewed were based in the capital Kigali. It is the central seat of government and businesses, but this may have skewed findings towards policy data, or reflected greater business activity than exists rurally. And although I spent five weeks in Rwanda, more time would probably have elicited a more complete picture.

Secondly, because the data was gathered mostly through in-person interviews, its accuracy may be restricted for events more than ten years ago because of memory limits. However, the 1994 violence that destroyed the economy also destroyed much infrastructure, including PV installations. The industry did not pick up again until the early 2000's, thus, analysis of times prior would not be expected to yield fully complete insights anyway.

Thidly, converting the information from interviews into qualitative data was challenging. In order to compensate and ensure data accuracy, I crosschecked facts and details with different interviewees in order to 'triangulate' the information obtained (Suurs 2009).

Finally, because the TIS framework is a fairly new approach, certain practical aspects are still being developed. Some events for instance, may fall under more than one function, or an event may be tangentially related. There is not yet a definitive method for putting them into one category or the other, or deciding whether to include, or not include.

4. Structural Dimensions of the Rwandan Solar TIS

This Section will map the structure of the solar PV TIS ("STIS") in Rwanda. It will consider the kinds of solar PV present in Rwanda, and then map their actor networks, discuss the actors by sector, their institutional constraints, and the physical and financial infrastructure present.

4.1. Solar PV Technology in Rwanda[2]

Four types of solar PV are present in Rwanda. These are: 1) Grid-based solar PV; 2) 'Institutional' PV; 3) Solar Home Systems, and 4) Solar Lanterns.

FAST FACTS: Solar Energy in Rwanda

Solar Insolation: 4.8 – 5.5 kWh m2/day

Installed Solar Capacity (as of 2011):
1. Grid Based Solar PV: 280kW
2. Institutional Solar PV: ≈1500kW
3. Solar Home Systems: Unknown (> 12kW)
4. Solar Lanterns: Unknown

Government Goals:
1. 100% health centres electrified by 2012 (goal met, with 50-70kW by PV)
2. 100% admin. centres electrified by 2012 (goal met, 20-30kW by PV)
3. 50% of schools electrified by 2017 (300 schools by PV, planned)

Energy Costs:
1. 1 80W Panel: ≈ $600, €400, 350,000 RWF
2. Cost of 1 solar lantern: ≈ $20, €15, 12,000 RWF
3. Cost of 1 litre of kerosene: $1.60/liter, 900 RWF
4. Cost of electricity: $0.22 cents, 132RWF/kWh

Other kinds of solar PV are present in Rwanda, including solar PV water pumps and solar phone chargers. However, their presence was so small in comparison (one store sold water pumps, one company advertised solar chargers) that in the interests of space they were not included in this Report.

[2] Some readers may ask why solar thermal (e.g. solar water heaters) was not included in the analysis. It is true that solar water heaters are being promoted by the government, and are an important way to increase energy efficiency. Solar thermal harnesses the sun's power in a different way, and its TIS includes different actors, and different functions. Therefore, this Report considers the two different technologies, and provides an analysis of solar PV only.

4.1.1. Grid-based solar PV.

Project	Date	Installed Capacity
Kigali Solaire	2007	250KW
Nelson Mandela Educational Centre	2008	30KW

Figure 7: Kigali Solaire (from Stadtwerke Mainz/Ernst Nkusi)

Grid-based PV connects large series' of PV panels to a central system. This system regulates the voltage (which must be slightly higher than the main grid's) so that the solar generated electricity can be fed directly into an electrical grid. Grid-based solar PV is an important potential source of energy for SSA, because a) the sun is generally abundant on the continent b) the sun is a renewable and non-competitive resource and c) larger-scale plants can be a source of carbon credits and thus external funding.[3]

Figure 7 shows Kigali Solaire, the Rwandan solar PV power plant. Stadtwerke Mainz, a German company, built it in 2007 after a serious drought significantly reduced available hydropower (Stadtwerke Mainz Kigali Interview May 6, 2011). The €1 million plant has a 250kW installed capacity and until 2011, was the largest such solar PV power plant in Sub-Saharan Africa. Compared to the 80MW Finsterwalde Solar Park in Germany however, the size remains moderate (Exnewable 2011).

Preventing Kigali Solaire's growth to the initially planned 1MW is the absence of a formal feed-in tariff for independent power producers. Currently, Kigali Solaire receives an amount only enough to cover basic maintenance of its facilities, and Stadtwerke Mainz has decided against expanding until it receives more (Rwanda News Agency 2010).

A further challenge for PV power plants is space: there is little of it in Rwanda, though the government has worked to create more for energy projects. Nonetheless, grid-based PV has potential to develop past its current status and provide grid-based electricity.

[3] Carbon credits are a growing industry. With the UN-organized Clean Development Mechanism (CDM), developed countries looking to reduce their carbon emissions can build clean technology in developing countries and claim those carbon credits, while the host country, after leaping bureaucratic hurdles, can reap the energy rewards. For more information on this, see: http://cdm.unfccc.int/about/index.html.

4.1.2. 'Institutional' PV

Figure 8: Large PV installation (from solardaily.com)

'Institutional' PV refers to large-scale PV projects, ranging from 1–10kW, and usually targeted for use in hospitals, schools, and administrative centres. It is typically considered when a centre is over 5km from any near-term grid line. A series of PV panels are installed on a roof, fed into an inverter (to convert the DC current to AC/DC current), and then into the necessary appliances.

Funding Organizations	Date	Solar PV Project & Capacity
Global Fund, ICAP/Columbia, FHI, Access Project, Intrahealth/USAID and CRS/PEPFAR, PIH	2005-2010	> 100 health centres, ≈ 300kW[4]
SELF (Solar Electric Light Fund)	2007	5-10 5kW health centres
Stadtwerke Mainz	2009	23 1kW systems for mayoral centres
European Union (EU)	2010	30 1kW systems for administrative centres
BTC	2010	50 5-6kW systems for health centres
EU	2011	300 1.6kW systems for schools
TIGO	2011	2 Mobile Phone Towers, 22kW (11 more planned)

A 5kW installation will cover the basic needs of a rural health centre: lighting, refrigeration, and powering of energy-intensive medical equipment. A 1kW installation should the basic needs of a school, as it mostly requires electricity for lighting and laptop and cell phone charging. Because of the importance of ensuring electricity for vital service providers, and the expense of PV installations, the vast majority of development partner assistance for solar PV

[4] The numbers were derived informally. Since there is no central PV installation registry, the installation numbers were estimated through the organizations' websites and interviews with MININFRA stakeholders.

has gone to this sector. In this Report's knowledge, not one system has been installed without an external funding partner to date.

Table 5: Costs of Solar PV Equipment

Equipment	Cost in 2011	Price Increase/Decrease?
1 80 watt panel	$600, €400, 350,000 RWF (price from Davis & Shirtliff store listing)	Decrease over last 10 years Worldwide, prices dropped from $6/watt in 2006 to $2.5/watt in 2010 (Dalberg 2010)
1 solar battery (non-solar batteries are cheaper)	$600, €400, 350,000 RWF Batteries need replacing every 3-5 years	Decrease over last 10 years Solar battery prices are projected to fall 23% from 2010-2015 (Dalberg 2010)
Maintenance	$50/year	Generally steady
Total installation costs	≈$17/watt	Slight decrease

Costs are also high because development partners, or the companies they contract with, tend to source the equipment from Europe, the U.S., or reputable Chinese dealers (TGL Interview May 30, 2011). Equipment is then transported either by plane or costly roadways (while shipping a forty-foot container from China to Mombasa may cost $3,000, driving it from Mombasa to Kigali can cost up to $6,000 (BrazAfric Interview May 20, 2011). When local businesses order cheaper products from China or India however (often retail, which further increases prices), they sometimes receive mislabelled products (i.e. a 60 watt PV panel is labelled 80 watt), or ones of poorer quality. At the present time, there are no PV installation specifications or testing labs in Rwanda to ensure quality standards.

While lighting off-grid centres is a priority, in the past there has often been a lack of support post-installation. Minor problems often led to system failure, simply because there was no technician to service the site, or funds appropriated for replacement batteries. In 2011 MININFRA adopted a maintenance strategy for future installations (MININFRA Interview May 20, 2011). It will train the relevant ministries (MININFRA, MINEDUC, MINISANTE, etc.) on how to design and create appropriate PV specifications. Each institution will pay into a maintenance fund, to be established in each district and jointly maintained by EWSA and the Districts (MININFRA Interview May 20, 2011).

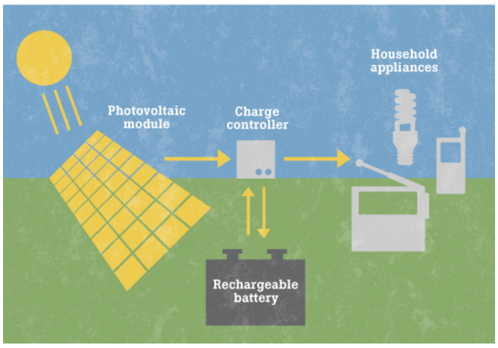
Lightning storms are also a concern for such systems in Rwanda, which suffers heavier storms than its neighbours (Earth Observatory 2009).

4.1.3. Solar Home Systems

Figure 9: Solar Home System (from Lighting Philips)

Project	Date	Installed Capacity
SaferRwanda/Norwegian Church Aid	2008	110 households in Rweru, Bugesera, 40W each
SaferRwanda/UNDP	2010	70 SHS, 40W each
UNEP	2010	300 SHS
EU	2012	1300 households, 40W each
SaferRwanda/McArthur Foundation	2012	90 SHS, 40W each

Solar home systems (SHS) are designed for residential use. In a developing country context, they are installed in areas not connected to a grid, and for homes with modest energy requirements. SHS are ideal for such homes because they create electricity where it would otherwise not be possible, allowing rural businesses to stay open at night, and residents to read, listen to the radio, or even just eat dinner at night. It also reduces the reliance on kerosene, which, as many have pointed out, is not only bad for the environment, but also terrible for health (Nurulight 2011).



Usually one forty watt panel is attached to a roof or pole, enough to power two lights, a radio, and a phone charger for three to five hours a night (SaferRwanda Interview June 6, 2011). There is often (but not always) an inverter, to allow for the use of AC/DC appliances.

Figure 10: Layout of a Solar Home System (from AshdenAwards.com)

Historically, relatively few solar home systems have been introduced in Rwanda because of the initial upfront cost, lack of access to consumer credit, and lack of awareness. But this is changing. In 2010, the NGO SaferRwanda partnered with Norwegian Church Aid and Barefoot College in India to train four local women to install and maintain 110 solar home systems in Bugesera (SaferRwanda Interview June 6, 2011). The European Union is planning to electrify 1300 households with SHS, starting in 2012 (MININFRA Interview May 13, 2011). The cost of a basic SHS has dropped considerably, from $500 or even higher, to under $100 (Ashden Awards 2011).

Although none yet exist in Rwanda, it is also possible to create "mini-grids," which are essentially solar home systems connected to a group of homes (Nieuwenhout 2001). The mini-grids may be an attractive option for communities who are able to jointly finance the system, or for administrative clusters. However, the group grid also renders users vulnerable to abuse of the system, especially the overuse ('deep discharge') of batteries. (Nieuwenhout 2001).

4.1.4. Solar Portable Lighting (SPL)

Figure 11: Solar Lantern (from sunvis.com)

Solar lanterns (or SPL's) have been the focus of much development aid and regional interest, as Africa is poised to surpass Asia as the world's largest un-electrified market (International Energy Agency 2010).

Company	Specifications	Costs/Sales
Barefoot	Firefly model 12 LED, 1 watt 4.2 hours light	$22, 13,000RWF
Greenlight	Sunking model 10LED, 0.7watt	$30, 18,000RWF
K-Light	16 LED 3.5 hours	$40, 24,000RWF
D-Light	Nova Solata	35,000RWF 16,000RWF 200 sales/month (thru BrazAfric)
Philips	Udaymini model CFL light 2.5 watt 1.8 hours	$40, 25,000RWF
ToughStuff	ToughStuff LED lamp 1 watt 5-40 hours	$35, 20,700RWF
B.Boxx	BB5 1.5 watt 25 hours	
Source: MINIBUZA. Document on file with author.		

SPL's are designed to be small and portable (less than ten pounds), and have a correspondingly low wattage (from one to ten watts). Prices have fallen continuously and significantly, from USD$50 to $20, and are expected to continue dropping. In contrast, quality is expected to rise, due to improvements in light bulbs (from CFL (compact florescent lights) to LED (light emitting diodes) and batteries (from sealed lead acid to lithium ion and nickel metal hydride) (Solar Lighting for the BoP 2010). Design improvements like phone-charging capability have also increased appeal. The World Bank estimates SPL prices will fall a further forty percent in the next five years (Solar Lighting for the BoP 2010).

However, cost is still too high for many in Rwanda, where the majority agrarian population receives its income only twice a year, after harvest. Additional barriers specific to Rwanda include: higher overall transport costs and lower consumer awareness. There have also been complaints that solar lanterns do not light as long or as well as they are marketed to do.

But these challenges also mean that in Rwanda, if companies address these challenges, there is potential to significantly increase SPL market share beyond the current 1% (Solar Lighting for the BoP 2010).

4.2. System Networks & Relationships

An important structural dimension of a TIS is its network: the systems of interactions between the actors, the institutions and the technology.

4.2.1. System Networks

Networks can be formal: trade associations and research communities, or informal: policy networks and firm coalitions (Carlsson and Stankiewicz 1991). In Rwanda, there are few formal networks directly involved in renewable energy. Table 5 lists the networks that are.

Table 6: Formal Networks with Solar PV Involvement

Formal Network	Role	Sector
Rwandan Private Sector Federation (PSF)	Lobbying govt. on behalf of member businesses; developing 'Energy Cluster'	Businesses
Association Rwandese pour L'Energie Durable (ARED)	Organizes workshops and promote awareness of RE issues	Civil Society
Kigali Institute of Science & Technology (KIST)	Coordinates with technical colleges to train students in RE technology	Research

Informal networks will be detailed in more depth in Sections 5, 6, and 7.

4.2.2. Actor Relationships

Networks are easier to map than actor relationships, which can be informal relations between actors and institutions, actors and technologies, and themselves (Suurs 2009). Figure 12 is an informal pictoral representation of the size and interconnection of actors in the Rwandan STIS.

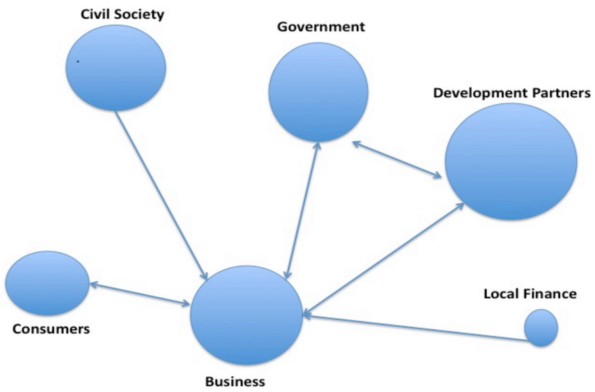


Figure 12: Solar PV Actor Interactions

In this informal representation of actor interrelationships, we see five important connectors. Government and development partners have by far the strongest interrelationship. Both of these sectors influence, and are influenced by, businesses. Civil society influences business and consumers to some degree. Local finance currently plays only a very small role in the solar TIS.

4.3. Actors

Any structural analysis of a TIS must include an examination of the actors involved. This Section considers the actors by sector. Figure 13 shows an approximation of the entrance by different sector actors into the solar PV TIS.

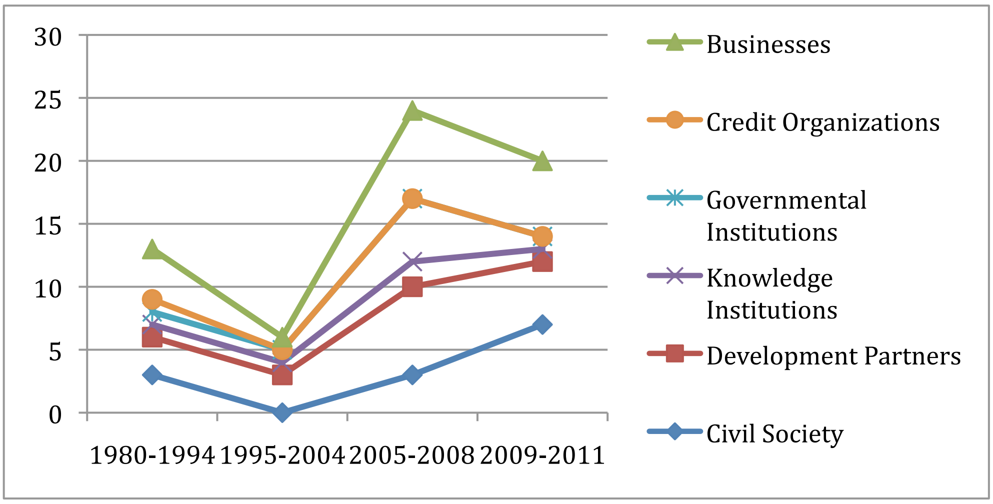


Figure 13: Approximation of Entrance of Actors into Solar PV

The next Sections will consider each in more detail.

4.3.1. Governmental Institutions

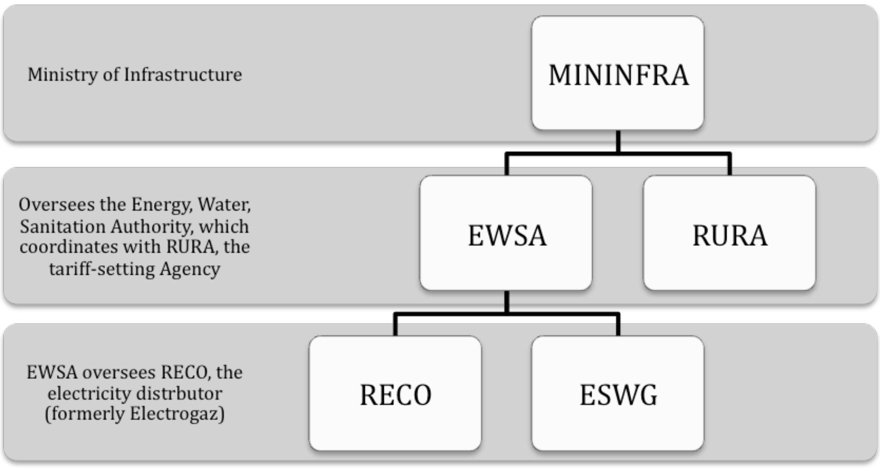


Figure 14: MININFRA Organogram

Several government ministries are involved in solar PV technology, but the Ministry of Infrastructure (MININFRA) retains oversight of most energy-related projects (MININFRA Home Page). Within MININFRA, the Energy, Water & Sanitation Authority (EWSA), created in 2011, sets policy; the Rwanda Electricity Corporation (RECO), formerly Electrogaz, distributes electricity and the Rwanda Regulatory Authority (RURA) sets tariffs for customers and energy producers (MININFRA Home Page 2011). While MININFRA seems to have a fairly clear organizational vision, there are still ways it could streamline its policies. The fairly rapid creation and merger of energy related organizations (ELECTROGAZ into RECO and RURA, their merger into the newly created EWSA) led to some overlap of roles and confusion of responsibilities (for example, the debate over who would be responsible for institutional PV maintenance). It is very understandable however, that ministries re-created after 1994 give rise to still-developing organizational structures.

MININFRA also hosts the Energy Sector Working Group (ESWG), which meets twice a year to set the energy agenda with six development partners : 1) the World Bank, 2) the Belgian Technical Corporation (BTC), 3) the European Union (EU), 4) the African Development Bank (ADB), 5) the Japanese International Cooperation Agency (JICA), and 6), the Netherlands Development Organization (SNV).

A host of other government ministries have less direct connections, often through their status as PV installation recipients: MINEDUC (Ministry of Education), MINISANTE (Ministry of Health), MINICOM (Ministry of Local Government), and MINALOC (Ministry of Local Government). The Rwanda

Development Board (RDB) was created to find interested private investors for infrastructure projects (including RE-related projects) and is hosting an energy conference in fall 2011.

Table 7: Government Agencies and Solar PV

Ministry/Agency	Role(s)	Projects
MININFRA (Ministry of Infrastructure)	Ministry of Infrastructure; in charge of energy related projects	
EWSA (Energy, Water, Sanitation Authority)	Hybrid public/private agency w/in MININFRA in charge of coordinating solar PV projects Charged with both producing and distributing electricity through RECO	Aiming for 16% connected by 2012; 50% connected by 2017
RECO (now merging into EWSA)	In charge of providing electricity to customers	
ESWG (Energy Sector Working Group)	Group w/in MININFRA on charge of setting energy agenda	
RURA (Rwanda Utilities Regulatory Agency)	In charge of setting electricity rates for customers/producers	Feed-in tariff planned
REMA (Rwanda Environmental Management Agency)	In charge of ensuring environmental protection and quality	
MINISANTE (Ministry of Health)		Solar PV for 50 government health centres; partnered with BTC Will pay maintenance fee to MIININFRA
MINALOC (Ministry of Local Government)		Solar PV for 30 administrative centres Will pay maintenance fee to MIININFRA
MINEDUC (Ministry of Education)		Solar PV for 300 schools; will partner with EU Will pay maintenance fee to MIININFRA
MINECOFIN (Ministry of Finance and Economic Planning)	Involved in budgeting for each ministry	
RDB (Rwanda Development Board)	Match private investors with government projects	
RRA (Rwanda Revenue Authority)		Determines if EAC exemptions apply to products

4.3.2. Development Partners

As discussed in Section 3.1.2, this Report differentiates development partners from civil society, due the size of their financial contributions and thus, their impact and presence.

They have long been a dominant presence in the solar industry in Rwanda, both in terms of financial assistance and scale. As Table 7 demonstrates, their focus has been on large-scale projects.

Table 8: Development Partner Solar PV Projects

Organization	Project	Funding	Year
Stadtwerke Mainz (Germany)	Kigali Solaire	€1,000,000	2007
World Bank/GEF	Sustainable Energy Development Project (SEDP)	≈ € 12,000,000 (from 71,000,000 total)	2009-2012
BTC	Electrification of 50 health centres	≈ €2,500,000	2009-2011
EU	Electrification of 300 schools	≈ €7,500,000	2011-2012
EU	Electrification of 1300 households	*Unknown*	2011-2013
Russian Government/WB	Promoting rural entrepreneurship	€600,000	2011-2012

Rwanda's reputation as efficient and un-corrupt attracts significant donor funding, and many major international and national development agencies are present.

Of the large-scale projects listed in Table 7, only the last focuses on promoting internal capacity, while the rest relate to one-time institutional PV installations. This is due to financial capacity as well as government priority: it is extremely important to have vital-service centres like hospitals electrified, even if they are far from the grid. And it is usually only government and development partners who have access to such funding. A corollary however, is that such projects necessarily direct focus away from ones that promote local businesses and funding schemes for consumers to purchase SHS and SPL's.

In terms of interaction between development partners, the inclusion of the six in the ESWG helps reduce thematic overlap in the energy agenda. However, there seems to be little knowledge shared between EWSG and non-EWSG organizations. For example, BTC and PEPFAR (President's Emergency Aid for AIDS Relief) both install PV for health centres but do not seem to communicate publicly, which can lead to missed learning opportunities.

4.3.3. Civil Society

Although there is a very high degree of community-based action in Rwanda, its formal civil sector remains comparatively underdeveloped (CIVICUS 2011). This also affects its impact on the solar industry. International organizations, including charities, church groups, and health-based NGO's have filled the gap, but as with development partners, their focus in solar PV has generally focused on donating PV installations for schools and health centres. This gives rise to potential overlap and duplication of effort. However, with new entrants like GVEP, their focus is also gradually changing to include promotion of local entrepreneurial activity.

A notable exception of domestic action is the PSF, the Rwandan Private Sector Federation. It is dedicated to promoting its members' business needs, and has opened twenty-two "Business Development Centres" offering members and non-members information and assistance in starting their businesses (PSF Interview June 2, 2011).

4.3.4. Businesses

Until recently, the solar business sector was characterized (and dominated) by a few large companies that catered to institutional PV projects. With the Rwandan government's emphasis on building private sector capacity, this has begun to change.

Interviewees repeatedly listed the same five to ten companies when asked about the major players in the solar market: SECAM, MTS, TGL, Davis & Shirtliff and Great Lakes Energy, as well as smaller general electronics stores in Kigali. Except for TGL and Great Lakes, solar PV sales comprise less than half of these businesses' earnings, partly because of the small scale of the industry and the fluctuating demand by international partners. This kind of market has made it very difficult for smaller entrepreneurs with less upfront capital.

With the slow development of the PV market (this includes more hotels and restaurants ordering PV for solar-diesel hybrid systems, like Nyungwe Forest Lodge), more stores in Kigali are now carrying PV panels. However, they usually import small quantities, sometimes even retail, mainly from China or India (Beacon Interview May 31, 2011). The equipment is cheaper than European products, but can suffer from the 'dumping' syndrome: manufacturers offloading mislabelled or lower quality products in African markets. This also reduces consumer confidence (Solar Lighting for the BoP 2010).

4.3.5. Knowledge Institutes

The National University of Rwanda was founded in 1963 and the Kigali Institute of Science and Technology (KIST) in 1997. Both have renewable energy programs. As a practice-oriented facility, KIST also focuses on training technicians and entrepreneurs: it opened its Technology Business Incubator

Facility (TBIF) in 2006. Both have developed partnerships with international universities and other knowledge institutes. There are also several (three to five) smaller technical colleges, including Tumba College of Technology (TCT) and Kicukiro College of Technology (KCT) that now offer renewable energy training programs (KIST Interview May 19, 2011). This growth reflects the increasing importance the government has placed on its renewable energy agenda and on developing its domestic engineering capacity.

4.3.6. Credit Organizations

Although there is a growing financial network in Rwanda, there is little credit aimed at solar PV projects. This is due to a) low awareness by credit organizations on how to finance solar PV and b) PV's somewhat problematic scale: PV projects tend to be either quite large or rather small. International development partners finance the larger-scale projects. Solar home systems and solar lanterns for private use operate on a much smaller scale, generally too piecemeal even for microfinance interest (Urwego Interview June 3, 2011).

Of the three major Rwandan microfinance institutions: Urwego Opportunity Bank; Vision Finance; and Amasezerano, none are currently offering solar products. Most loan products are aimed at productive businesses; solar PV loans for domestic use receive little traction (Urwego Interview May 6, 2011). In fact, of the two microfinance institutions interviewed, neither had nor were considering solar PV projects.

4.3.7. Customer Base

The customer base for solar PV, mainly government as electricity-provider and the individual as on and off-grid consumer, remains underdeveloped. Approximately 10% of the population has access to electricity (and access is defined as proximity to the grid, not actual connection) (MININFRA Interview May 13, 2011).

Purchasing power remains very low, as 90% of the population still derives its income from agriculture (CIA World Factbook 2011). And as grid electricity is cheaper than SHS (132RWF/kWh vs. 60-120,000RWF upfront for a solar home system), people prefer to get electricity from it. Areas that would be best served by SHS – rural areas that are likely to remain unconnected for the next few years – are generally ones with an even lower income levels. This makes it especially difficult for individuals to finance upfront costs.

4.4. Institutions

"If they want it to be done, tomorrow it will be done."[5]

Institutional infrastructures are defined as either hard or soft rules, regulations, and norms that frame and inform societal interactions. The 'hard' institutions are the legal rules and norms, and the 'soft' are the "set of common habits, routines, and shared concepts used by humans in repetitive situations" (Crawford & Ostrom 1995). The existence of a robust infrastructure allows for the provision of information, management of conflicts, and smooth channelling of resources (Crawford & Ostrom 1995). Identifying rules and shared concepts is helpful in understanding the environment in which a TIS operates, and to locate possible problem areas for TIS development.

'Hard' Institutions.

Rwanda's energy agenda is set by both the Presidency and the relevant ministries (usually MININFRA), but it is to be expected in a country that suffered such upheaval that its institutions and their roles are still evolving. As noted in Section 4.3.1., this can lead to some confusion over roles and responsibilities.

Rwanda joined the East African Community (EAC) in 2007, which required harmonization of its trade laws with the EAC's and thus removal of import duties on energy saving lighting products and solar PV (EAC 2007). The VAT has also been removed for LED lights, although there are reports that the Rwandan Customs Authority still sometimes levies taxes.

Figure 15, below, shows institutional events that impacted renewable energy development.

Figure 15: Timeline of Relevant Policy

- **2002**: MININFRA established
- **2006**: RECO and REMA established (RECO split from ELECTROGAZ)
- **2007**: Rwanda joins the EAC, requiring removal of import duties for solar PV; EDPRS published, aims to use solar PV to electrify off-grid hospitals, schools, and administrative centres
- **2008**: 1) National Energy Policy (NEP) pledges that by 2012, 90% of electricity will come from RE
- **2009**: Climate Change and International Obligations Unit (CCIOU) established with Rwanda Environment Management Authority (REMA); MININFRA Action Plan also focuses on solar PV

[5] UNDP Interview May 13, 2011.

- **2011**: EWSA Established; RECO will be merged into MININFRA

'Soft' Institutions.

There is a strong sense of authority Rwanda, which has its roots in Rwanda's history as a monarchical hierarchy. The country has a top-down structure: **Province – District – Sector – Cells – Umudugudu** (Constitution of Rwanda 2003). Each level has a local government structure partly overseen by MINALOC (the Ministry of Local Government). This allows for both increased oversight and the ability to enforce existing regulations and projects, an ability often lacking in other nations. In Rwanda, an absolute crackdown on corruption exists publicly. One example is the New Times, Rwanda's daily newspaper: it publishes a list of those convicted of a corruption, including their family names and crimes (JRLOS 2010).

The current administration has also promoted impressive targets for Rwandan growth, leading some to liken its ambition to become 'Africa's Singapore' (Business Daily Africa 2011). This ambition does not include solar PV as a top priority. Many believe it is too expensive to be a viable source of energy or electricity, and its uses should be limited to necessary applications for government offices that are too far from the grid. This negatively affects people's perception about solar PV's long-term prospects.

4.5. Infrastructure

Finally, it is helpful to map the physical, knowledge, and financial infrastructure in which the TIS is located.

Infrastructural Advantages	**Infrastructural Disadvantages**
Rwanda becoming regional hub for development activity	Little available land for large PV plants
Easy to set up businesses (usually within 24 hours)	Limited access to consumer credit
Technical institutes encouraged to increase renewable energy training	Institutes based mainly in Kigali
Travelling w/in major cities easy	Travelling in rural areas w/o automobile difficult

Physical Infrastructure: transport systems, communications, industry

Rwanda is a densely populated country with little unused land. Most available land is owned by the State (although it does lease to private organizations) (RDB Interview June 6, 2011). Goods are transported by road, either from Dar es Salaam, Mombasa, or Kampala, or occasionally from the DRC. Within country, highways connect the major towns. However, Rwanda's landlocked status significantly raises transport costs and product prices. Solar PV can also be flown in from Europe, which takes less time but costs more. A railway from Rwanda to Dar es Salaam is being discussed, but is unlikely to be completed for several years (MININFRA Action Plan 2009).

Communication is mainly through an extensive mobile phone network, which has expanded at a rapid rate across all of Africa. Rwanda also has ambitions to become the IT hub of East Africa (Rwanda Vision 2020).

Rwanda's non-agricultural industry (mostly cement, small-scale beverages, furniture, and textiles) is still in its infancy, and the volume and speed of its growth depends heavily on increasing access to electricity (CIA World Factbook 2011).

Knowledge Infrastructure: universities, research labs, libraries

In any system, it is important to have organizations that oversee the production and management of knowledge (Wieczorek 2011). While knowledge infrastructure includes universities and technical colleges, research institutes, and training centers, it also encompasses 'soft' aspects like strategic intelligence and "tacit technical knowledge" (Wieczorek 2011).

Technical knowledge is rapidly increasing, pushed by President Kagame's desire to have Rwanda become a middle-income country. And under his tenure, primary education is now open to all (CIA World Factbook 2011) (for more information, see Section 4.2).

Financial Infrastructure: banks, venture capital, microfinance

Affordable access to credit is a serious challenge in Rwanda. Interest rates are relatively high, loans usually short-term, and savings rates low, due to low and inconsistent incomes (US Embassy 2011). The financial system does host several international development banks, national banks, microfinance institutions, and Savings & Credit Cooperatives (Sacco's) (Annex D contains the document title that lists the financial institutions present in Rwanda). However, none currently offer special packages for solar PV, or have thus far offered product lines directed towards renewable energies.

The government has stressed its commitment to renewables, but has directed its financial resources in that area more towards other renewable energy sources likes biomass and hydropower.

5. Functional Analysis of Solar TIS

This Report now analyses the collected data. Section 5.1 presents the data and Section 5.2 examines each function to determine their relative robustness and stage of development.

5.1. Data Results

Table 9: Event Mapping Data Results

F1: Entrepreneurial Activity	F5: Market Formation
F2: Knowledge Development	F6: Resource Mobilization
F3: Knowledge Diffusion	F7: Advocacy Support
F4: Guidance of the Search	

Function/ Year	F1	F2	F3	F4	F5	F6	F7	Yearly Aggregate
1980-1994	+ 3	+2	+ 2	0	0	+ 2	0	+ 9
1995-2004	+ 2	+ 1	+ 2	0	0	+ 2	+1	+ 8
2005	+ 3	+1	0	0	0	+ 1	0	+ 5
2006	+ 2	0	+ 1	+ 2	0	+ 2	0	+ 7
2007	+3 - 1	+1	+ 2	+ 1	+ 1 -1	+ 1	+ 1	+ 10 - 2
2008	+ 5 - 1	+ 2	+ 2	+ 1	0	+ 3	+ 2	+ 15 - 1
2009	+ 2	+ 1	+ 6	+ 1	0	+ 4 - 1	+ 7 - 1	+ 21 - 1
2010	+ 8 - 1	+ 5	+ 6	+ 3	+ 2 - 1	+ 7	+ 8 - 2	+ 39 - 4
2011	+ 8	+ 7	+ 5	+ 2	+ 1 - 1	+ 3	+ 10 - 1	+ 36 - 2
Total	+ 36 - 3	+ 20	+ 26	+ 10	+ 4 - 3	+ 25 - 1	+ 29 - 4	+ 148 - 10

As noted in Section 3.3.3., each recorded 'event' is associated with one of the seven functions, and given a numerical value. A positive event is given a '+' value, and a negative event (like a newspaper article questioning the validity of solar PV) is given a '-.' This allows the researcher to see and map overall trends.

This Section now turns to an analysis of the interaction and trend patterns for the functions over time.

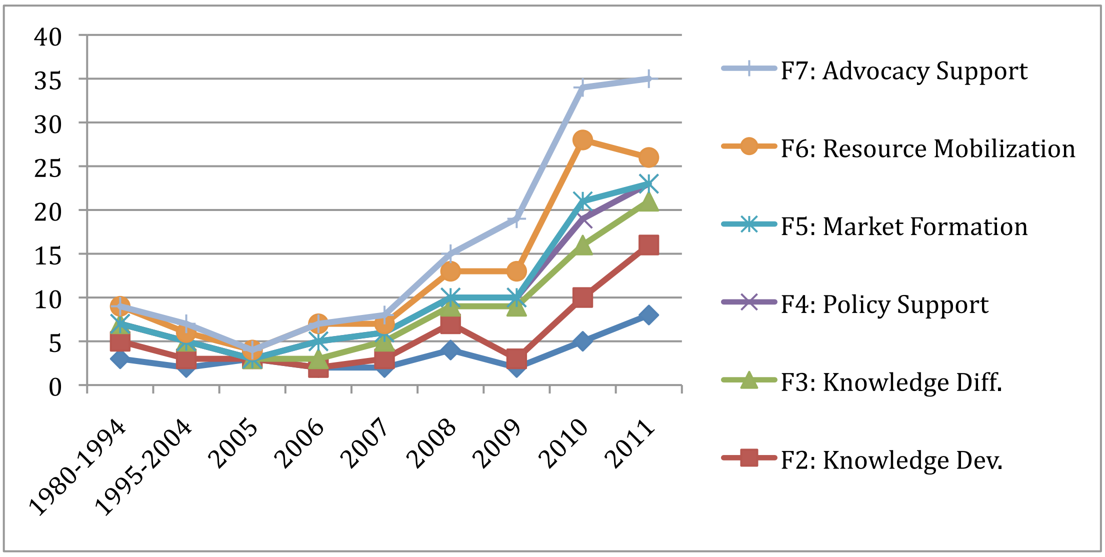


Figure 16: Functional Activity over Time

5.2 Activity by Function

The Solar PV Technological Innovation System ("STIS") in Rwanda as a whole, and most of its component functions, appear to be in a later period of formative growth. Its development has been dominated by development aid and outside knowledge. Although solar portable lighting and home systems remain too expensive for most of the population, awareness by Rwandans of them seems to be growing. Government and development partners are starting to include aid for promoting domestic commercial markets, suggesting that solar PV has the potential to develop into a more self-sustaining technology.

When examining individual functional activity, entrepreneurial activity seems to have the steadiest growth over time, while knowledge development and advocacy support are seeing the sharpest increases. Resource mobilization has remained fairly constant (with a recent increase) but market formation has remained weak. Policy guidance has been mainly focused on institutional PV.

5.2.1. F1: Entrepreneurial Activity

Figure 17: Entrepreneurial Activity

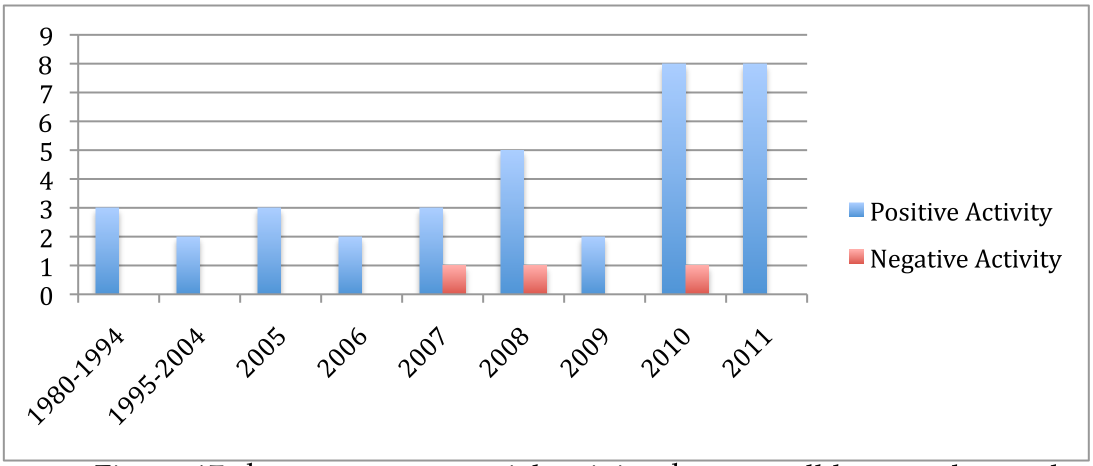


Figure 17 shows entrepreneurial activity that a small but steady number of new entrants over the last ten years, before a period of growth in 2010. As this function is widely seen as the core of a TIS, such growth is a good sign

As noted in the structural breakdown of the relevant actors, entrepreneurs have been mostly large and diversified companies for whom solar comprises a minority of revenue, due to the market's focus on institutional PV. In 2007, the Rwandan government removed import duties on solar products in 2007 and the 18% VAT for LED lights in 2010, which lowered the cost of PV materials (EAC 2007).

This is one factor that has led to a twofold growth since 2008 of smaller players (like Enterprise La Perfection) on the one hand and larger regional companies (like ChlorideExide) on the other. International NGO's and development partners have also played an important role, by beginning to switch their focus and funding to include building SME capacity. In 2011, for example, GVEP partnered with the Private Sector Federation (PSF) to build rural entrepreneurial capacity, specifically focusing on solar products. Another factor is the ascendency of Kenya as an African hub for solar PV technology: Kenyan companies become regional as well as local players, and have positive effects on the system as a whole (Berkeley 2000).

This upward trend appears poised to continue. But until local infrastructure, industry, and consumer market are more mature, it will remain very reliant on development projects and development funding.

5.2.2. F2: Knowledge Development

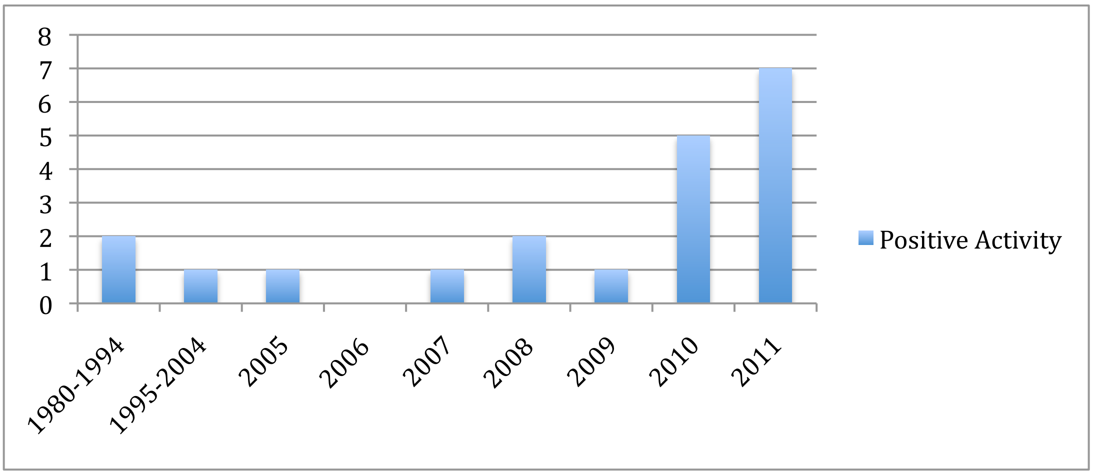


Figure 18: Knowledge Development

As can be seen from Figure 18, knowledge development grew before the genocide, but then fell and remained underdeveloped until 2009, where it experienced rapid growth.

Before 2008 there was little internal development of solar PV standards, guidelines, or Rwanda-specific data. The lack of internal standards affected the market: while larger companies could import from Europe, where quality was assured, local electronic stores imported from China, where product labels would not always match actual product performance (Beacon Interview May 31, 2011). This in turn reduced Rwandan consumer confidence in solar PV. Furthermore, as universities and technical institutes were still rehabilitating, there were few centres where solar PV knowledge could be developed.

Recognition of this problem is increasing, in part as a reaction to President Kagame's push to promote private sector capabilities, and an increase in development partner funding to promote these capabilities. In 2011, RECO put out tenders for consultants to develop labelling requirements, and to identify strategies to strengthen the rural PV market (RECO 2011). Additionally, as the Kenyan market continues to expand in East Africa Rwanda, there is increased interest in regional and country-specific data gathering, in order to assess market potential and gaps (Greenlight Interview May 30, 2011).

5.2.3. F3: Knowledge Diffusion

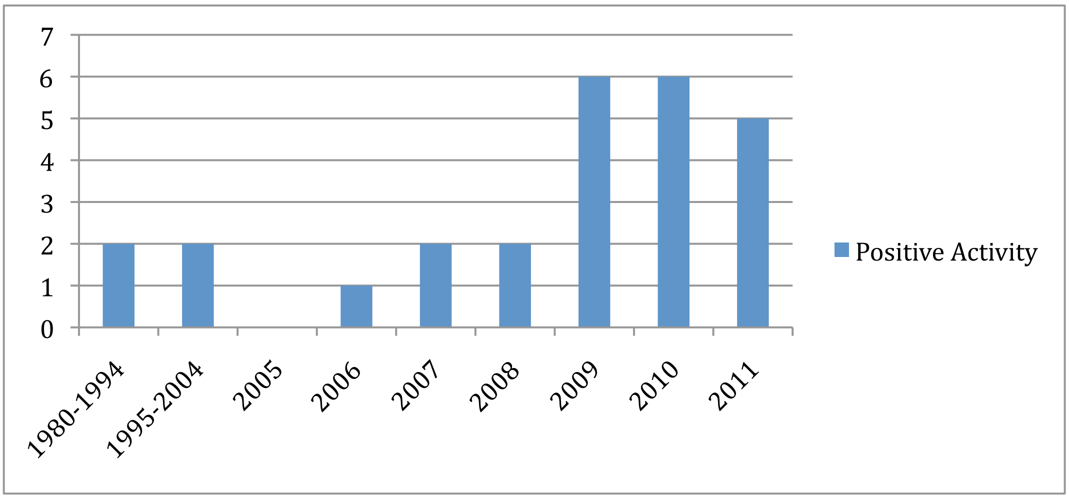


Figure 19: Knowledge Diffusion

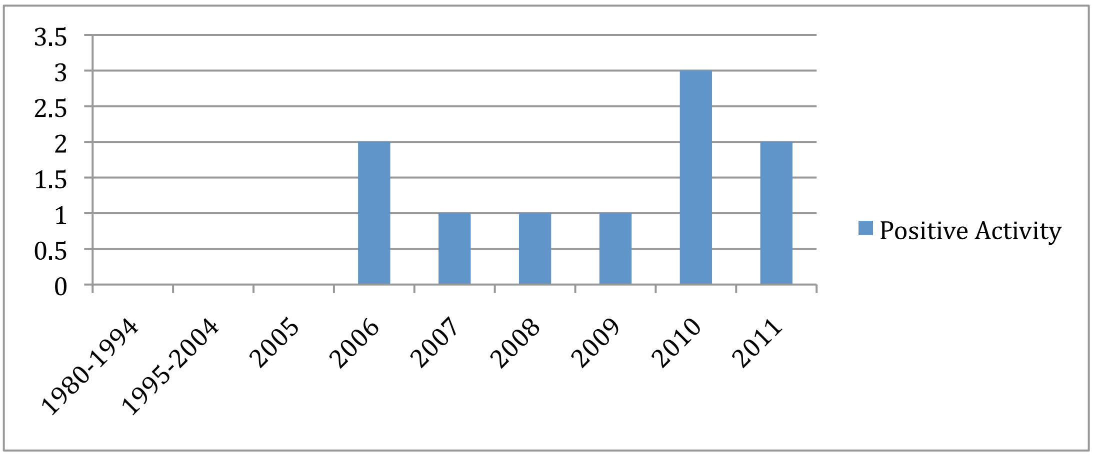
Figure 19 shows a slow but steady increase in knowledge diffusion after 2005. Diffusion of knowledge is very important in fostering a sustainable TIS, but can be especially difficult in developing countries where much institutional infrastructure is still maturing. Knowledge diffusion – events like workshops and training programs – suffered especially from the genocide, as universities and colleges were forced to close their doors. In the aftermath, the focus of the Rwandan government was first on rehabilitation and provision of basic services, and then on the development of renewable energy knowledge.

Renewable energy programs have nonetheless developed within old and new institutions. KIST opened in 1999, and its Technology Business Incubation Facility in 2006; both have renewable energy programs. KIST also trains other technical colleges, and MININFRA has begun a program sponsoring renewable energy training in 2010 (MININFRA Interview May 13, 2011). Stadtwerke Mainz trained twenty-three technicians as part of the Kigali Solaire project. Philips gave a training workshop on solar lanterns to the Private Sector Federation in 2010. SaferRwanda, the Norwegian Church Aid, and Barefoot College in India partnered to send four Rwandan grandmothers to India to be training as solar technicians. Upon returning, they installed 110 SHS in their village (SaferRwanda Interview June 6, 2011).

A positive feedback loop seems to be emerging, driven by Rwandan interest in renewable energy-based training as a potential business opportunity, and increased interest by domestic and international institutions to provide that learning. As more of the Rwandan educational and business community learn about RE issues, the more potential RE technology has to grow organically within that community.

5.2.4. F4: Guidance of the Search ("Policy Support")

Figure 20: Guidance of the Search



Policy support for PV projects manages to be both direct and equivocal, suggesting that while the government certainly sees a role for solar PV in Rwanda, it believes that role is a limited one. As one source in MININFRA put it: "*Solar PV is floating around like a fly*."[6]

The government of Rwanda occupies, in some ways, an enviable position: it is the command centre of a well-organized, top-down society, with the determination to make policy <u>and</u> see it enforced. This position lends added significance to government action. And on the one hand, several policy documents, including Vision 2020, the 2008 EPDRS and the 2008 NEP, outline an ambitious vision for Rwanda's renewable future. They all stress the importance of promoting both on and off grid energy access, in which solar PV has a role. However, the same documents also indicate that this role is to be limited: for off-grid service centres. According to several sources within the government, its main RE focus is on Lake Kivu methane-extraction, regional hydropower, and geothermal energy, due to their large generation potential and the perception that solar PV is relatively cost-ineffective.

Is this changing? Figure 20 suggests it is. For example, MININFRA is supporting a SEDP project to promote a rural Solar PV energy market. Comments by some government officials suggest reconsideration of PV's role. Why the change? If Rwanda is to meet its ambitious energy targets, it must

[6] MININFRA Interview May 9, 2011.

consider all options. Development partner perceptions may also play a role in increasing expectations, which remain nonetheless mixed.

5.2.5. F5: Market Formation

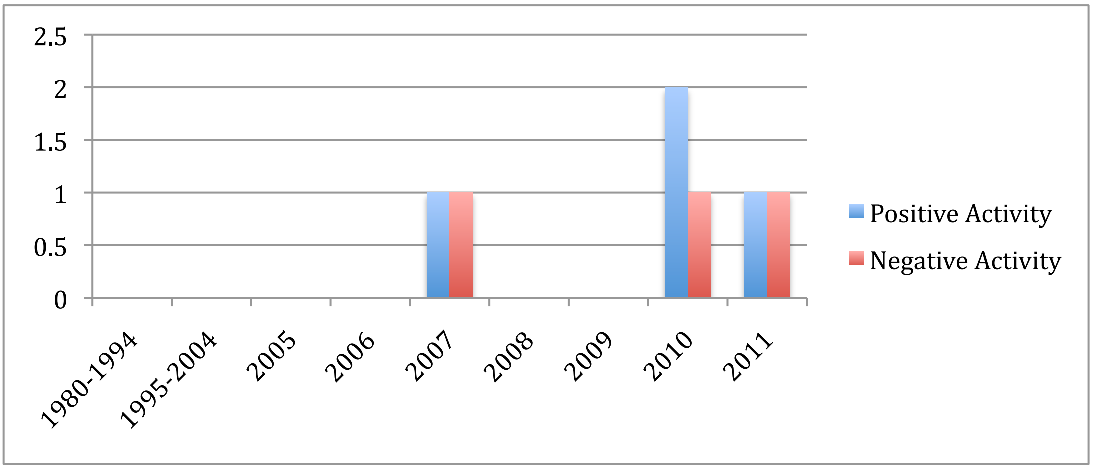


Figure 21: Market Formation

Figure 21 indicates that Market Formation is the function with the fewest positive events. It is also a function that strongly influences the direction of the others. For the STIS to move past the formative into the mature growth stage, this function must be become more active. As new technologies often have difficulty competing with incumbent ones – solar PV's struggle to capture market share from kerosene is a clear example – steps to create protective market niches are often essential (Schot 1994).

One positive event was the 2007 removal of import duties on energy saving lights and PV products (because of Rwanda's entrance into the EAC), and this proved important in reducing the cost of solar products.

By contrast, the decision to delay fixing a formal feed-in tariff, despite the policy commitment to do so (NEP 2009, GTZ Target Market Analysis 2009) has removed incentives for independent power producers (IPP's). Stadtwerke Mainz decided against increasing Kigali Solaire's capacity to the originally proposed 1MW because of the low rate it currently receives. Government sources claim that this is due to Rwanda's small installed capacity (85MW in 2011): were it to pay a feed-in tariff, the end user would also see a price increase (MININFRA Interview May 9, 2011). However, the rented diesel generators cost just as much, if not more, leading to one of SSA's highest tariffs (GEF 2009).

Additionally, there are no solar PV subsidies (although they do exist for solar thermal), nor any other tax or credit schemes for businesses or consumers, which hampers consumer ability to purchase.

5.2.6. F6: Resource Mobilization.

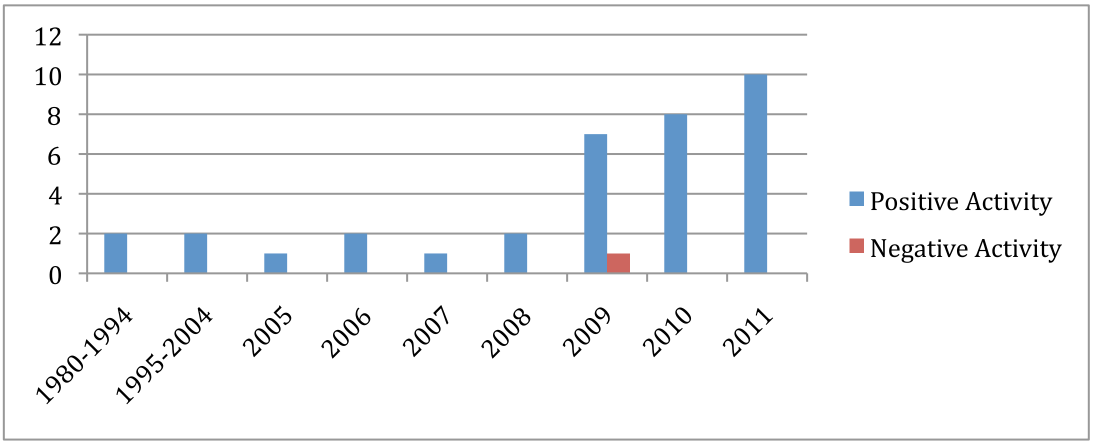


Figure 22: Resource Mobilization

The mobilization of resources has seen more activity than the market formation function, as Figure 22 indicates. This activity comes primarily in the form of development partner funds, and is in great part motivated by developed nations' interest in promoting renewable energy agendas. Nor does international funding does proscribe development of a sustainable solar TIS, if the funding is appropriately directed.

The 2009 Sustainable Energy Development Project (SEDP), which aims to develop national guidelines for institutional PV and build capacity of commercial SHS markets, is a good example of international interest (GEF 2009). A $71 million project, it is funded by the: $4.5 million from the Global Environmental Facility (GEF); $3.8 from the African Evaluation Association (AFREA); $1.8 from the International Development Agency (IDA); $11.88 from the European Union (EU), $4.2 from the German Agency for International Cooperation (GIZ); $21 from the Belgian Technical Corporation (BTC); and $21 million from the Rwandan government (GEF 2009). The three largest donors in this project are the Belgian government, the Rwandan government, and the European Union. European nations and the World Bank have consistently been the largest foreign investors in Rwanda's renewable energy sector. Proactive though the government is in shaping policy, these agencies, by virtue of their purse strings, also have power. Thus, while funding was funnelled mostly to institutional PV installations, the market remained focused in that direction. If and when funding drops, due to partners' financial or political interest, projects stall. Figure 22 shows that resource mobilization decreases somewhat in 2011 a possible effect of the global financial crisis.

A shift to include SHS is also apparent in resource mobilization. In 2011, a government-supported partnership between GVEP and PSF will focus on providing business planning assistance to interested solar entrepreneurs. GVEP will potentially also develop a 'Working Capital Loan Guarantee Fund' (GVEP Interview May 19, 2011). This model has been applied in countries like Kenya, and seeks to stimulate local access to finance by insuring MFI loans to those entrepreneurs.

5.2.7. F7: Overcoming Resistance to Change ("Advocacy Support")

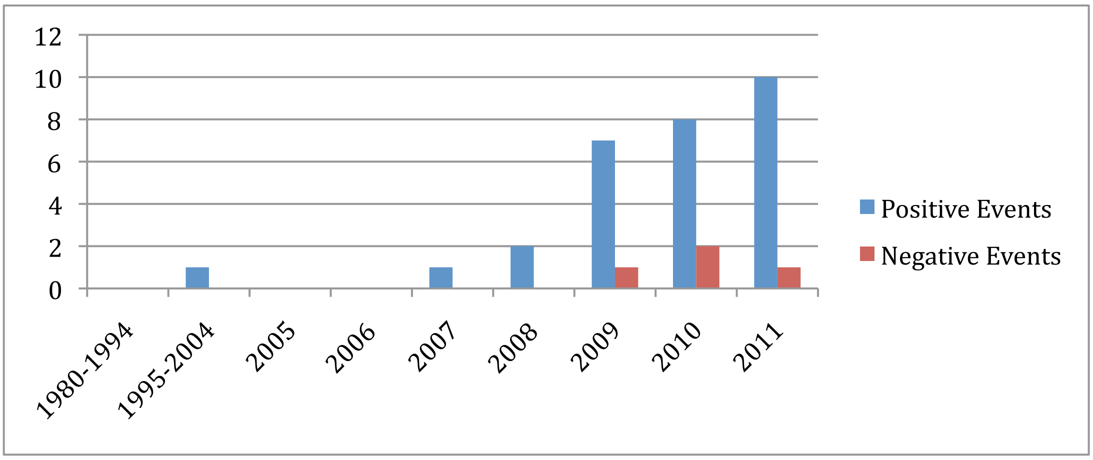


Figure 23: Resource Mobilization

Although all parts of the solar PV production chain have reduced in price, and are projected to continue doing so, the prevailing mentality in Rwanda is still that solar PV is and will remain too expensive compared to other renewable energies and traditional fuel sources. And yet, the 2010 Lighting Africa Report projects a "40% decline in SPL component costs by 2015" (Lighting Africa 2010).

An examination of Figure 23 shows a significant increase in the events related to advocacy support (though this may be partly due to limited online archival of newspaper articles before 2005). Some of this increase is due to entrepreneurs' utilization of radio, an important source of communication in developing countries. Great Lakes Energy hired Rwandan hip-hop artist Diplomate to include solar references (Great Lakes Energy Interview May 4, 2011) in his songs, and BrazAfric reported positive effects from its radio advertisements of solar lanterns (BrazAfric Interview May 20, 2011).

Ministers and other government officials have issued mixed messages on solar, sentiments echoed by many of this Report's interviewees: "we definitely want to use more solar power but we can't raise the price of electricity. The price is already high and a raise would mean that even less people can afford it…" A. Hategeka, Rwanda's Minister of Energy (Alertnet 2010). There were several articles in the New Times (Rwanda's daily newspaper) that praised solar, but others that questioned its value. These articles focused mostly on the institutional projects, or international donations, both of which tend to frame solar PV as a donor-driven concept.

A notable exception was the media attention surrounding Kigali Solaire. As the largest solar PV plant in Sub-Saharan Africa until 2011, it helped raise Rwandan awareness that grid-based PV was not only possible, it was happening.

5.3. Interaction Patterns

This Section uses the previous functional analysis to identify patterns of interaction. Functions are supposed to interact and build on each other; a goal of TIS theory is to suggest how to increase positive interactions and create the TIS 'growth model' referred to by Suurs (Suurs 2009). Below are the patterns of interaction that appeared most dominant in an examination of the Rwandan solar TIS. They suggest that, while donor resource mobilization is contributing to a positive pattern of knowledge development, weak domestic credit access is hampering entrepreneurial growth, on both supply and demand sides.

Policy support (F4) is a key influencer on entrepreneurial activity (F1) and market formation (F5)

As the structural analysis in Section 4.2 illustrated, Rwanda has a hierarchical power dynamic with the Presidential office wielding a great deal of influence over ministerial policy and distribution of development partner funding. It follows that its opinion of the future of the solar industry will have a significant effect on development of the STIS. As Hekkert noted, strong policy support can be a starting point for sustained TIS development, as it can encourage businesses, credit organizations, and consumer opinion (Hekkert 2008).

The 2007 onwards growth of businesses installing institutional PV systems and the increase in technician training to maintenance them was likely influenced by MININFRA's policy commitment to use PV for those service centres. Conversely, this has likely slowed the growth of businesses that focus on solar lanterns and solar home systems. And the 2007 policy decision to delay setting a fixed feed-in tariff has deterred potential investors (GTZ 2009).

Donor funding (F6) and donor interest in renewable energy (F7) are linked to and influenced by policy support (F4), and instrumental in promoting knowledge development (F2)

The government of Rwanda is very proactive in setting its own agenda, and discourages individual aid projects in favour of coordinated long-term strategies (MININFRA Interview May 9, 2011). Nonetheless, international players still play a very important role in shaping solar PV policy, because of their interest in promoting renewable energies, and the financial resources they can use to express that interest.

For example, the six sitting on the Energy Sector Working Group within MININFRA (BTC, EU, SNV, JICA, WB, ADB) work especially closely with government officials to coordinate projects and provide funding for institutional PV and SHS. Other international governmental organizations (like GIZ and PEPFAR) are also involved in the solar TIS (GTZ Target Market Analysis 2009). Kigali Solaire was financed entirely by Stadtwerke Mainz, a German company.

This foreign interest encourages solar PV to stay the governmental agenda. However, the general recipient of most of this aid – PV for institutional use – encourages the creation of donor-oriented businesses, and supports a general belief by government and communities that solar PV is for institutional needs only. This in turn reduces incentives to lower the cost for PV installations (as international organizations can better afford the higher prices). Moreover, the focus of donor funding has slowed the growth of domestic markets for solar lanterns and SHS.

However, donor funding has helped establish key knowledge institutions (e.g. KIST was created with UNDP support). Such development is crucial to creating sustainable domestic institutions and technological knowledge.

Rwandan civil sector remains underdeveloped, affecting knowledge development, diffusion, and advocacy support (F2, F3, F7).

The absence of a robust Rwandan civil sector has slowed the development and diffusion of knowledge, because civil society organizations often bridge the gaps between technological knowledge, the consumer and the government. Without them, information exchange between businesses, banks, and end-consumers are slowed. As an interviewee from the Koinonia Foundation's sponsored Beacon Cooperative explained, many people in rural areas often do not know about solar (Beacon Interview May 31, 2011). Beacon is a unusual example of a small local organization that *does* raise awareness of PV, through actively advertising solar PV products in churches, schools, and other public opportunities (but although its sponsor is an NGO, it is itself a business).

5.3.4. Weak market formation (F5) contributes to few solar PV-specific credit and financing opportunities (F6) and slows entrepreneurial activity (F1).

Weak market formation is example of a negative pattern of interaction in the solar TIS, and should be remedied to prevent system failure.

Although each individual 'Market Formation' event may arguably have more impact than, say, a newspaper article about solar PV, it is still the least active function. There is still no fixed feed-in tariff, and no solar PV subsidies (although they do exist for solar water heaters). Import duty exemptions *do* exist – but the entrance into the EAC made them mandatory.

Banks, microfinance institutions, and Sacco's appear to have taken a cue from the weak market formation. As noted in Section 4.3.5, not one bank offers PV specific PV financing schemes. This is partly due to the scale of solar PV: institutional PV is funded by outsider organizations, but individual solar lantern and SHS products are not cost-effective for a larger bank. Of the three microfinance institutions, Vision Finance was approached by – and rejected – an organization's proposal to develop a solar lantern product (Vision Finance Interview May 26, 2011); Amasezerano has not had any projects, and Urwego Opportunity is working with Nuru, a rural lighting, but not solar lighting company. Philips is considering targeting teacher Saccos for potential development, but agreements are not yet finalized.

Less credit means less access to start-up cash; less cash translates into fewer smaller companies which can enter the Rwandan PV market or expand the rural market, which in turn keeps consumer awareness low.

6. Historical Development of the Rwandan Solar TIS

Part of the researcher's task in analyzing a TIS is to gather data. One of the next steps is to analyze the data (both functional and structural) to construct a narrative of the TIS evolution (Suurs 2009). The Rwandan solar TIS can be broken down into four historical movements: 1) Growing interest before the Genocide (1980-1994), 2) 1994 and its Aftermath (1995-2004), 3) Rays of Hope (2005-2008), and 4) Forecast: Sunshine with a Mix of Clouds (2009-2012).

6.1. Growing Interest before the Genocide: 1980-1994

Construction of solar PV sites in Rwanda begins in the early 1980's. This growth coincides with the beginnings of a viable solar market in the U.S. and Europe (U.S. DOE 2002). In Rwanda, the STIS is led by European development partners already active in Rwanda (including the DGIS), international charities building hospitals and schools, and international knowledge institutes (**F6**).

This support also spurs creation of businesses to support PV installations (**F1**). There is enough interest for SECAM – a large French/Rwandan business – to begin selling and installing PV panels (SECAM Interview May 26, 2011). Interestingly, there are also awareness-building and training programs (**F3**), organized by both international and government ministries in this time-period. The University of Florida organizes a global four-year training for developing countries on the promotion of renewable energies, and six Rwandans participate in this training (University of Florida 1984).

With GTZ assistance, the Union Banque Populaire du Rwanda (UBPR) offers a credit scheme for solar home systems (**F6**) and a 1991 article by F.D.J. Nieuwenhout claims 700 solar home systems are already installed and "the conditions…in Rwanda are poised for a sustained take-off" (Nieuwenhout 1991).

These signs suggest that the solar TIS would have seen continued advocacy support (**F7**) and further entrepreneurial activity (**F1**), had the genocide not so deeply disrupted the country. Instead, this nascent – albeit donor driven – industry, is almost totally dislocated, along with the majority of Rwandan infrastructure.

6.2. 1994 and its Aftermath: 1995-2004

The violence during the genocide not only destroys hundreds of thousands of lives, but of much of Rwanda's infrastructure and economy. Solar PV installations built in health centres, schools, and homes cease functioning due to material destruction, battery failure and inability to afford new ones, and lack of maintenance knowledge.

The humanitarian crisis that follows the genocide spurs international relief efforts, but it is the growth of Rwanda's economy and its reputation for efficiency and lack of corruption that leads to sustained involvement by development partners and other foreign donors. Under the RPF's stewardship, increased tax collection, privatization programs and rehabilitation of cash crops all lead to significant increases in GDP (CIA World Factbook 2011).

Population and economic growth give rise to an urgent need to increase energy supply. A severe drought in 2003-5 affects hydropower-based electricity and requires the rental of extremely expensive diesel generators (GEF 2009). This increases government interest in promoting domestic supplies of energy, and its interest is both spurred and supported by European development partners (**F6**). This support, as well as the regional growth of the solar industry, leads Kenyan businesses like Davis & Shirtliff to open in Kigali (**F1**).

This time period also sees support of Rwandan knowledge capacity (**F2**, **F3**). KIST is founded by UNDP in 1998, laying important groundwork for future domestic knowledge infrastructure and knowledge development (**F3**). Later, it will offer courses of study in renewable energies, and host students from other technical colleges interested in receiving renewable energy training.

Also important in building internal knowledge and advocacy capacity is the 1999 creation of the Rwandan Private Sector Federation (**F6, F7**), and its 2004 partnership with the World Bank. PSF will continue to be an important source of advocacy support and entrepreneurial activity.

6.3. Rays of Hope: 2005-2008

This period sees a significant increase in entrepreneurial activity, knowledge development, and resource mobilization for solar PV (**F1, F2, F6**), affected in part by its neighbours' increasing focus on solar technology, and by the perception of the international community of Rwanda as an attractive site for foreign aid.

Development partners increase their presence and their financial assistance (**F6**). The Belgian Technical Corporation (BTC) becomes involved in energy access, which will lead (in 2010) to a project to electrify 50 health centres. GIZ partners with DGIS to form EnDev to study renewable energy options in Rwanda (**F2**) (Energizing Development 2010).

The government publishes several long-term strategies, including the Economic Poverty Reduction Strategy in 2007 and National Energy Policy in 2008, both of which discuss the role for solar PV in off-grid electrification (**F4**) (EPDRS 2007, NEP 2008). As the population grows rapidly, increasing energy efficiency, access, and ensuring environmental preservation become more important. The Rwandan Electricity Corporation (RECO) and Rwanda Environmental Management Agency (REMA) are formed (**F4**). President Kagame also actively supports an increased role for domestic and renewable energy sources, although documents indicate a belief that solar PV's role should be limited to electrification of health centres, schools, and administrative centres **(F4**) (MININFRA Action Plan 2009, EPDRS 2008). The role of solar home systems and solar lanterns is not really outlined. The market for solar lanterns grows somewhat despite the lack, likely influenced by regional growth.

Several new businesses are established, both Rwandan and outposts of Kenyan-based companies, to service the large donor PV projects (**F1**). Because of the fluctuating nature of the large projects and the high costs associated with transport of materials, PV generally makes up a minority of their income stream.

In 2007, Rwanda joins the East African Community, which requires harmonization of Rwandan tariffs with the EAC, including a removal of import duties on energy saving lighting and PV panels, and removal of VAT on energy saving lighting (**F5**) (EAC 2007). This has the effect of reducing prices for solar PV products, though prices remain expensive in comparison with products in neighbouring states.

Solar PV in Rwanda gets much international and domestic publicity, due in no small part to the construction of Kigali Solaire in 2007, Sub-Saharan Africa's largest solar PV power plant until 2011 (**F7**). Built through a German-Rwandan partnership, it reflects Rwanda's ambitions to develop its electricity capacity and transform itself into a middle-income country, but also its limitations: Kigali Solaire remains at 25% of its planned capacity due to an inability to arrive at a feed-in tariff rate (**F4**).

Domestic educational and infrastructural capacity continues to grow, with the establishment of the Technology Business Incubation Facility (TBIF) at KIST and the establishment of renewable energy programs at smaller technical colleges (**F3**).

Overall, the period 2005-2008 sees a growing interest in solar PV and renewable energy from all sectors, but the persistence of significant challenges, including high material costs and a belief by many that solar PV's role will be confined to large donor-driven projects.

6.4. Forecast: Sunshine with a Mix of Clouds 2009-2012

From 2009 until the present, we see a diversification in solar PV applications, and significant but still limited growth in solar lantern sales, suggesting challenges present in the 2005-2008 period remain unresolved.

The need for energy continues to rise, as does the population, and despite highly ambitious goals by the Rwandan government, only ten percent have access to electricity in 2011 (MININFRA 2011). The government continues to promote solar PV applications for service centres, including schools and hospitals (**F4**). It also encourages private sector growth and development of energy access generally, but the solar market remains a lower-ranked priority. Priorities are instead invested in putting large hydropower plants online, expanding the national biogas program, and exploring methane and geothermal extraction possibilities.

Still, development partners remain active, and diversify their involvement in solar projects to include solar some systems and SPL's (**F6**). The six development partners sitting on the Energy Sector Working Group (ESWG) set energy goals and develop many projects in conjunction with MININFRA. Notably, in 2009 the GEF joins with several development partners in the SEDP, a $71 million three-year project. The solar component of the project receives $12 million (**F6**), in part to establish labelling requirements and improve credit access for imported PV products (**F2**) (GEF 2009).

This period is also influenced by increased involvement in the off-grid lighting market by Rwanda's East African neighbours. Companies like D-Light, K-Light, and Barefoot are very involved in the Kenyan and Ugandan markets, and attempt to expand in Rwanda (**F1**) (REF 2011). Their activity is encouraged by the World Bank's Lighting Africa project, which seeks to increase off-grid lighting solutions for rural Africa (**F7**). However, expansion is hampered by low awareness of solar products, high transport costs, and low credit access.

Solar home systems also see a growth in interest and activity. The EU partners with Philips to install 1300 such systems in 2012, and additional SEDP funding is allotted for building commercial markets for SHS (**F1, F6**).

Knowledge institutes report increased student interest in renewable energy programs, leading the TBIF to seek financing for a renewable energy-based entrepreneurial program (**F3**) (KIST Interview May 19, 2011). International institutional partnerships also increase.

6.5. 2012 and Onwards: Climate Change?

The future of the Rwandan solar TIS is not certain. Its outcome is dependent on larger external factors like the rate in rise of oil prices and development of other domestic sources of energy, and internal factors like policy opinion and levels of awareness, among others. It is possible that solar PV continues to fill only a small subsection of the off-grid market. It is also possible that it addresses challenges and barriers and becomes a viable competitor to fossil fuels, and a workable addition to on-grid electricity projects.

The next Section considers the mechanisms blocking future functional development, and offers policy recommendations to address them.

7. Putting it Together

This Section takes the foregoing analyses to determine the system's most important 'blocking mechanisms' – the circumstances and actions that are preventing the solar TIS from reaching its adoption and diffusion potential: competing against kerosene, providing viable off-grid electrification, and developing solar PV plant potential. It then offers policy recommendations for the development of the Rwandan Solar PV Technological Innovation System.

7.1. Solar TIS Blocking Mechanisms

Blocking mechanisms can refer to factors both internal and external to the TIS. They may be structural: weak government enforcement mechanisms or low regional energy prices, or functional: low political support for the technology (Bergek 2008). Figure 24 gives an overview of the factors blocking further development of solar PV in Rwanda, and Section 7.2. considers each in more detail.

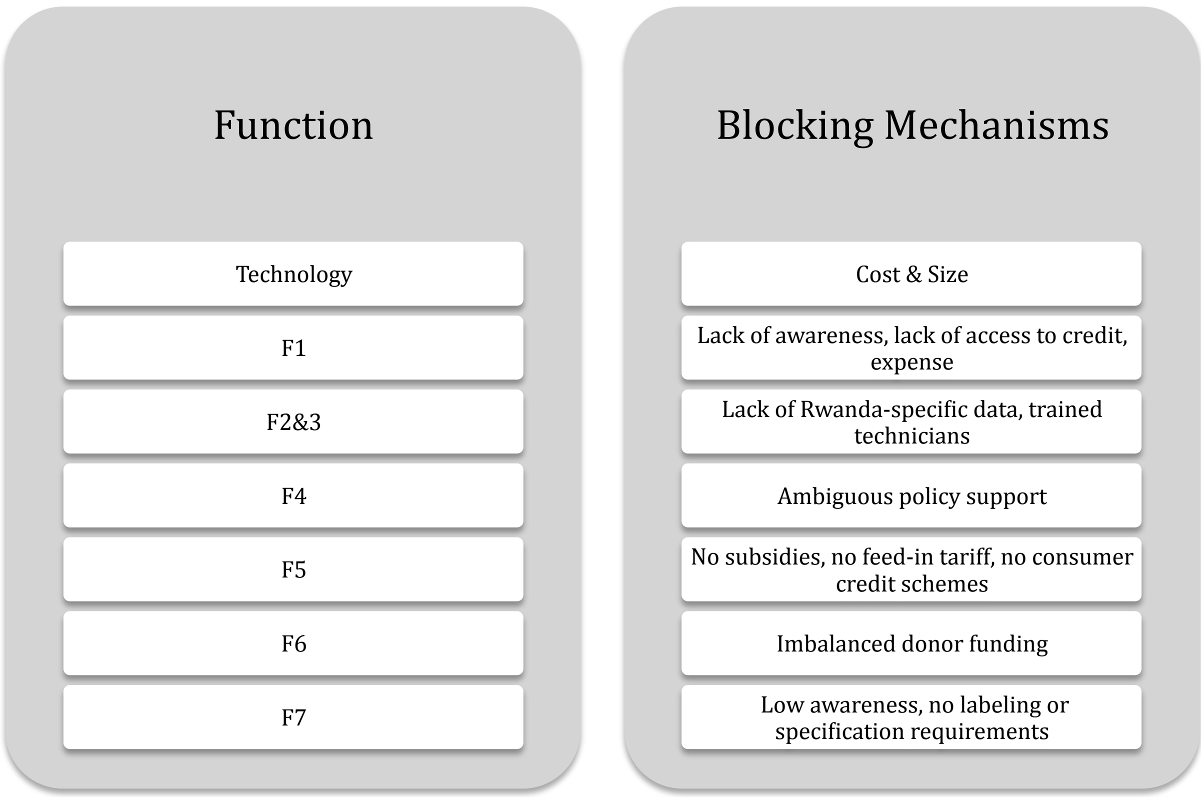


Figure 24: Blocking Mechanisms

7.2. Policy Recommendations

Once blocking mechanisms have been identified, policy recommendations may be formed to counteract them. The Report's recommendations for solar PV in Rwanda follow the TIS framework, and are thus broken down by function (with the addition of technology-specific suggestions).

Solar PV in Rwanda: Technology Recommendations

A TIS analysis should consider whether the technology is appropriate for the region. If it is, then suggestions should be offered for its improvement. In the case of the Rwanda solar TIS, one must also ask if all applications all of equal relevance and importance.

This Report's conclusion is that while institutional PV has been a necessary focus of development partner funding, now that goals for the sector have been largely met, it is time to increase focus on solar home systems and solar lanterns instead. This Report believes that SHS in particular hold great potential for domestic consumers who will likely continue to remain off-grid in the near-term. Solar lanterns can be a decent substitute for those who cannot afford SHS or want more portability. Grid-based PV, because of its low maintenance requirements after initial upfront costs, is also a viable consideration as an on-grid electricity provider.

Each aspect of solar PV technology has its advantages and disadvantages, most of which can be compensated for.

Solar PV Disadvantages:
1) Grid-based PV: requires a lot of space;
2) Institutional PV: susceptible to lightning;
3) Solar Home Systems: can be too large and too expensive for moderate energy needs and lower-income consumers;
4) Solar Lanterns: can be too heavy for easy portability, require exact positioning to get maximum charge.

Additionally, higher-than-usual transport costs in Rwanda make ordering PV materials more problematic, as does the diffuse population spread and expense of grid-expansion. Targeted technology suggestions include:

Recommendations:
1) Consider the Eastern Province for more grid-based PV, as it is flatter, there is more open space, and it is less lightning-prone;
2) Enforce maintenance funds for institutional PV (to replace batteries and for

lightning protection insurance);
3) Make SHS as basic as possible, but always include cell-phone charging capacity;
4) Make SPL's as small and lightweight as possible, and include cell-phone charging capacity. If possible, include PV panel on lantern itself to minimize moving parts.

F1: Entrepreneurial Activity

Entrepreneurs form the core of a sustainable TIS. They invest in and develop ways to market and promote the technology. They are its public face for early consumers. However, in developing countries, including Rwanda, the private sector is often less robust. There may be more state involvement. Due to less developed avenues of communication, entrepreneurs may have fewer ways to learn about new technologies or have access to initial finance.

Blocking Mechanisms:
1) Cost of ordering PV materials piecemeal;
2) Focus on large PV installations crowds out smaller businesses;
3) Access to funding for both business and consumers is very limited.

Rwanda is addressing these challenges by promoting the private sector, both financially and politically. Additional ways that solar PV entrepreneurs – those that sell larger-scale PV, SHS, and solar lanterns – may be supported are:

Recommendations:
1) Use the Private Sector Federation (PSF) Business Centers as sources of information for interested entrepreneurs who do not have internet access;
2) Encourage development partners to financially support domestic markets for SHS and solar lanterns, instead of only PV for government/donor projects;
3) Support plans by the Technology Business Incubation Facility (TBIF) to open their renewable energy focused entrepreneurial program;
4) Create centralized ordering facility to allow for wholesale purchases.

Because entrepreneurial activity is such an important function, the issues it faces are echoed in the blocking mechanisms of other functions. If blocking mechanisms are addressed for entrepreneurs, it is possible for the function to stimulate a positive feedback loop, stimulating growth in the others.

F2 and F3: Knowledge Development & Diffusion

Developing countries usually have access to technology-specific knowledge, but often, this is outside knowledge, brought in by international organizations or development partners. Solar PV installation specifications developed in Germany, for example, may not adequately address lightning, a potential problem in Rwanda. Sufficient knowledge of how to maintain and replace systems is another concern; several PV installations have become defunct because there is no one to fix an easily fixable problem. It is much easier said than done, but it is crucial to develop country-specific knowledge and a level of comfort with the technology by local companies.

Blocking Mechanisms:
1) Lack of proper maintenance knowledge;
2) Lack of knowledge of kinds/amount of existing PV installations and sales numbers.

In Rwanda, potential ways to improve internal knowledge development and diffusion include:

Recommendations:
1) Create government sponsored "Solar Clearinghouse:" have solar PV information packets on government ministry websites like MININFRA, and create low-bandwidth informational database for renewable energy practitioners;
2) In Clearinghouse, have contact person who can field questions, direct interested funders/entrepreneurs, and direct installers of PV systems to technicians;
3) Centralize PV tendering process, or at least mandate that any government ministry installing a PV system of 1KW or greater must report this to MININFRA, which will improve knowledge of installed capacity;
4) Develop specification guidelines for PV installation systems (**Note**: 2011 tenders have gone out for consultants);
5) Financially support existing technical colleges (like Tumba Technical College and Kicukiro College) to continue to develop their RE courses/program exchange with KIST, as well as open small technical colleges in other urban hubs like Butare, Gisenyi, and Ruhengeri.

Organizing data on existing solar PV installations in Rwanda will be very helpful for the government to assess the numbers and people reached, and can help in developing future energy targets. The more information that is publicly available also increases public awareness, and is helpful for national and regional entrepreneurs wishing to enter the market.

F4: Guidance of the Search ("Policy Support")

In developing countries, just as with developed ones, the government plays a strategic role in the success – or failure – of a new technology. In both, the government can set tax exemptions, subsidies, favorable environmental policies, or simply express its public support. Conversely, it can decide against placing the technology on the policy agenda. In Rwanda, the government, especially the Presidential office, plays a decisive role in priority-setting. Up to now it has supported PV for institutional use, offering less support for solar lanterns, SHS, and future feed-in power plants.

Blocking Mechanisms:
1) Mixed messages by government officials on solar PV potential;
2) Some confusion as to what departments oversee energy access issues

While recognizing limited resources, there are still steps that can be taken to promote the STIS.

Recommendations:
1) Set goals for installation of solar home systems, and sales of solar lanterns. This can send a positive message to entrepreneurs, and may encourage more regional business to expand into Rwanda;
2) Encourage the New Times to publish (domestic or internationally sourced) articles on renewable energy;
3) Have one *Umuganda* day devoted to raising awareness of RE issues especially;
4) Encourage teachers to educate students on renewable energy issues; offer demonstration solar lanterns to teachers Saccos.

None of these steps require much in the way of financial assistance, but they can affect people's perception of solar PV by placing renewable energy on the public agenda and by bringing discussions of energy to the public fore.

F5 and F6: Market Formation & Resource Mobilization

While resource mobilization by international organizations in the solar PV sector has been significant, relatively few steps have been taken to develop a domestic niche market for solar PV. The main exception has been removal of import duties on PV materials, through Rwanda's entrance into the EAC.

Blocking Mechanisms:
1) No formal feed-in tariff for independent power producers;
2) VAT on PV materials;
3) Imbalanced funding from donors;
4) Access to credit for interested consumers is very limited.

Because Rwanda's especially high transport costs make all incoming products more expensive, more can be done to lower the cost of PV products and increase domestic production capacity:

Recommendations:
1) Develop formal feed-in tariff;
2) Install graduated solar VAT moratorium until development of planned railway reduces transport costs (**Note**: the government has already removed the VAT on LPG);
3) Allot development funding to building local business capacity and networks for development of SHS and solar lantern market; coordinate through bi-annual ESWG meetings (**Note**: GVEP, PSF, and MININFRA are partnering to build local entrepreneurial capacity; funded by the SEDP project);
4) Encourage banks to consider individual energy loans, explore Sacco financing or group loans for off-grid businesses: have a training for financial officials on renewable energy;
4) Issue tax incentives for solar manufacturers to set up in Rwanda.

In line with Rwanda's ambitions to become the 'Singapore of East Africa,' it may be helpful to offer tax incentives to draw in and build up its industrial base. Rwanda could further brand itself as a forward-looking nation and attract foreign investment by applying these tax credits to renewable energy technologies.

F7: Overcoming Resistance to Change ("Advocacy Support")

Another vital piece in the TIS puzzle is advocacy support, without which even a potentially game-changing technology will not be successfully adopted. Support from entrepreneurs, government ministries, development partners, civil society, and end-consumers are all important. It may come in the form of lobbying by interested businesses, encouraging statements by political officials, development donations, positive newspaper articles, or increasing consumer awareness. This support can stimulate a positive cycle, and may help to offset system weaknesses elsewhere. Currently, however, there is not enough advocacy support for solar PV.

Blocking Mechanisms:

1) Marketing in rural areas is difficult;

2) Mixed messages from government on role of solar PV

PSF is developing an 'Energy Cluster' for its members, to allow them to more easily dialogue with each other and present coordinated lobbying demands to the government (PSF Interview June 3, 2011). Entirely donor-funded projects, including EU's planned lighting of 1300 households with solar home systems, are also shifting the focus to SHS potential. The New Times has had an increasing number of generally positive articles on solar (about twenty-five in the last five years), and this has raised awareness of solar PV.

However, consumers in rural areas may not be aware of these articles. And, when they are, they may still be skeptical. This is due in part to ambitious claims made by some solar manufacturers, but also to lack of knowledge on how to use solar PV, and the importation of mislabeled or sub-standard products by some businesses. Countering this trend is very important, and much can be accomplished with more limited financial means. Possibilities include:

Recommendations:

1) Utilizing existing promotional avenues of popular companies, like Bralirwa Brewing;

2) Advertise on radio stations;

3) Issue positive press statements;

4) Promote PSF's 'Energy Cluster' lobbying potential;

5) Develop, and enforce labeling requirements for PV panels and solar lanterns (**Note**: MININFRA has also issued a tender to consider this).

8. Conclusions

8.1. Answering the Research Question

The question posed on the title page was: can the Technological Innovation System (TIS) approach explain the adoption and diffusion of solar PV in Rwanda? The sub-question was: what can this tell us about applying the TIS framework in a developing country context?

The answer to the first question, its least complex form is: yes, the TIS framework *can* explain solar PV's adoption and diffusion in Rwanda. The structural dimension of the TIS framework helped map system structures in Rwanda and consider solar PV technology in the Rwandan context. The functional analysis made us look at *how* the players interact, first in isolation, and then with each other. This gave insights into how the various actors interacted with each other in the solar TIS and to what effect. Using the event data tool helped advance a historical narrative of the solar TIS, identify blocking mechanisms and formulate recommendations for its future development (for more detail, see Section 7). Overall, applying the TIS fashioned a clear and organized lens through which to capture the development of solar technology in Rwanda.

However, the TIS framework could be refined to more fully capture issues that may be present in a developing country context. Section 8.2. answers the sub-question by outlining suggestions.

8.2. Refining TIS for Developing Country Context

As a theoretical framework, TIS is relatively new, and has not yet been applied very often to technologies in developing countries. This Report's application of the TIS framework to solar PV in Rwanda has led to some preliminary observations and suggestions for improvement:

1) Ensure that structural analysis remains part of TIS framework and application

While the functional analysis offers insights and helps map complex interaction patterns that the structural analysis cannot, it is also true that the structural analysis provides important information that the functional analysis does not. Thus, it is important to include both. (For more information on another way to analyze a TIS, see Wieczorek 2011). Structural analysis not only maps important system players, but also larger macro-trends that a functional analysis does not address. In Rwanda for instance, a structural analysis tells us that there are physical barriers, including high transport costs and a diffuse rural population, which may hamper efforts to spread awareness of solar PV.

2) Ensure sufficient technology-specific analysis

Because of its elevated elevation, Rwanda offers a milder climate than its African neighbours. However, it is also more susceptible to lightning storms, which has struck and damaged PV installations (Davis & Shirtliff Interview May 27, 2011). The danger of lightning was not in any report I read before engaging in field research, but is extremely relevant for solar PV technology in Rwanda. Awareness can lead to additional lightning protection for example, and technicians can be trained on how to fix lightning-damaged systems.

In his book, *Motors of Sustainable Innovation*, Suurs stresses the importance of including technology in the TIS analysis because, like macro-level structures, it "enforces rules upon actors (and) it constrains and enables their actions" (Suurs 2009). This is no less the case in developing countries, even if the technology is already established elsewhere.

Ensuring proper examination of the technology itself within the structural analysis is, in this Report's opinion, crucial. By doing so, proponents might be able to address criticism that TIS theory does not allow for needed policy advice on whether the technology itself is appropriate to a system (Bergek 2008, Smith 2009).

3) Event mapping as methodological tool has limitations

When formatting the data obtained through interviews and online research, certain challenges were encountered.

a) Difficulty of getting full picture from interviews

A successful TIS analysis is predicated upon fairly complete data collection, without which the event analysis may offer a skewed picture. However, it may be difficult to obtain a full list of events in countries that do not have most of their information available online. Interviews can adequately provide information for the near-term past, but it is difficult to reconstruct a full history more than five years prior, because individuals are unlikely to remember complete details for such events. Additionally, there may be high turnover for relevant stakeholder positions, and some information may simply be lost.

The issues of high stakeholder turnover and interviewee memory capacity are universal, while limited online information tends to be more developing country-specific. If one is aware of them, most may be compensated for.

To capture information not available online, as was partially the case in Rwanda, interviews are key. The "snowball technique" can be particularly helpful, as is sufficient time in-country to meet with a good cross-section of actors (Goodman 1964). The specific number necessary will likely depend on the size of the country and the maturity of the TIS.

The difficulty of getting accurate information from interviewees for more distant events *is* problematic. If event mapping is based mostly on interviews, any functional analysis will probably be very accurate for only a short time period, and should be either limited or disclosed as a potential methodological limitation. This drawback may diminish as more information is stored and publicly available online.

b) Assigning numerical values to events does not adequately reflect subjective differences in event importance

One advantage, and disadvantage, of event mapping as a tool is that it allows for quantitative extraction of largely qualitative research. During event mapping, each event receives either a "+1" or a "-1." This allows for less-subjective conclusions of functional robustness or trends. However, this advantage comes with the drawback of removing scale: each event is a number, no matter if it is a watershed moment or merely another new enterprise in a crowded market. This is why it remains key to allow the researcher to construct a narrative and highlight particularly important events.

And, as TIS research continues to develop, and more empirical evidence is collected through different case studies, it should be possible to introduce more statistical complexity into the equation.

c) Not always clear where to put the *absence* of events

Another issue encountered was where to note the absence of key events, which can be equally as important. For instance, the removal of import duties on energy saving lighting was a very important event in making PV more affordable, which can be dated the year Rwanda entered the EAC. However, the absence of a fixed feed-in tariff despite the commitment to do so had just as much impact, by removing incentives for potential investors in grid-based PV. But the year was more difficult to quantify: when did this non-event become a problem?

In that instance, the event was inserted in the year after Kigali Solaire went online, when Stadtwerke Mainz officially declined to expand it to 1MW after it could not come to an agreement with the government on a feed-in tariff amount. In other cases, omissions were not included at all because their dating would be too subjective. Going forward, if it all possible, it is just as important to note what did not happen, and to outline clearer systems for noting such absences.

d) Additional relevant events

Finally, the Report recommends the addition of developing country appropriate events to allow the event-mapping tool to capture even more relevant data. Previous case studies focused on European technologies, like the Dutch biogas and hydrogen innovation systems, but less on developing country ones. Therefore, this Report proposes the following additions:

- **Resource Mobilization**: Donations of development partners/international NGO's

While donations of development partners and international NGO's are most likely irrelevant for a country like the Netherlands, they are extremely important in developing countries. I distinguish 'donations' from other 'donor funds,' because donors may either invest in a project (i.e. the Sustainable Energy Development Project), or they may simply be giving equipment, products, money, which can have both positive and negative effects.

- **Knowledge Development & Diffusion**: Creation of renewable energy-based educational programs

Creation of renewable energy-based educational programs is an event that could be listed under knowledge development. These programs often signal important investments in a country's knowledge base, and can have positive long-term effects, even if they are not exclusively focused on one technology.

- **Separate Heading:** Installed capacity; new installations)

It can also be useful to list yearly increases in installed capacity of PV, and of all known installations/major projects. This allows for a factual counterpart to event mapping and can help illustrate if positive events seem to be correlated with, or perhaps lead to, increases in project and capacity.

- **Remove/consider absence irrelevant:** Patents; Articles in domestic scientific publications

It is also important to note that some events, like 'patents' and 'scientific articles' may not be relevant, nor would there absence be significant in a developing country context. In many African countries, there may not be sufficient technological or educational infrastructure to allow for patent applications. Similarly, there may not be sufficient financial capacity to allow for scientific articles and journals to be published, and/or be put online.

Table 10: Updated Event Mapping Table

Function	Developed Country	Developing Country
1. Entrepreneurial Activity	- Number of experiments with new technology - Number of new entrants - Diversification of incumbents - Projects & Demonstrations	- Number of experiments with new technology - Number of new entrants - Diversification of incumbents - Projects & Demonstrations
2. Knowledge Development	- Feasibility studies - Standard setting - Data collection - R&D Projects and Investments - Patents - Pilot Projects	- Feasibility studies - Standard setting - Data collection - Pilot Projects
3. Knowledge Diffusion	- Workshops - Accessibility of country specific publications - Mapping network size and intensity over time	- Workshops - Accessibility of country specific publications - Mapping network size and intensity over time - Creation of RE Educational programs
4. Guidance of the Search	- Institutional formation - Explicit targets or policy statements, goal-setting - Number of articles in professional journals 'raising expectations' about that technology (Hekkert)	- Institutional formation - Explicit targets or policy statements, goal-setting
5. Market Formation	- Tax exemptions - Feed-in tariffs - Subsidies - Specific price dynamics - Environmental standards which create a more favorable environment for that technology	- Tax exemptions - Feed-in tariffs - Subsidies - Specific price dynamics - Environmental standards which create a more favorable environment for that technology

6. Resource Mobilization	- Donor funds (earmarked or no) - Technology-specific resources - Financial capability building - Access to (micro) credit	- Donor funds (earmarked or no) - Donations of Development Partners - Technology-specific resources - Financial capability building - Access to (micro) credit
7. Advocacy Support	- Individual/group lobbying - Expressed support of key opinion formers - Increased media interest/focus (# of newspaper articles, or radio programs)	- Individual/group lobbying - Increased media interest/focus (# of newspaper articles, or radio programs)
Possible Additions	- Installed Capacity - New installations/projects	- Installed Capacity - New installations/projects

4) Functions may be combined

The TIS framework is a relatively new entrant in the field of innovation systems theory, and scholars should continue to examine and refine its structure. This attention should extend to examination of the functions themselves. It is worth considering combining knowledge development and diffusion, and possibly resource mobilization and market formation. Although each possesses different elements, they are thematically similar and combining them may allow for a more concise analysis. This, in turn, may increase the use of the TIS framework by policymakers, and expand the strategic options for promoting renewable technologies.

Which after all, is the point.

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Annex A: Sample Interview Questionnaires

Date and Place:

___

Name of interviewee:

___

Position (Role of the interviewee in RET development projects):

___

Email address (optional):

___

Postal address (optional):

Interviewee's Role

- Could you please briefly explain what you do/your role?

For Businesses

General

- How did you get involved in Solar?
- Was it difficult to get started? When did you start?
- When did Solar PV start being introduced in Rwanda?

Company Specifics & Costs

- Can you describe your products?
    - Specs (voltage)
    - Cost of each equipment piece
    - Cost of on-grid electricity in Kigali? Elsewhere?
    - Maintenance system in place?
    - Where do you get them? (Uganda, Kenya, China)
- Have these costs increased/decreased in the last 10 years?
- How do you obtain your financing: purely through sales, or micro-credit, or foreign investors?
- Have your products changed? Have you added new kinds of products?
- Are new kinds of products available?
- How developed is the human resource capability, such as trained technicians, dealers, producers of solar energy, at national levels? At local levels?

Customer Awareness

- Who are your potential customers?
- How do you promote your product?
    - For example, through sharing knowledge through workshops, or raising awareness through exhibitions, promotions, etc.?
- Who usually organizes these activities?
    - Did you ever go?
    - What kinds of people were invited, and participated? (dealers, consumers, NGO's, government)
- Has there been an increase in interest or awareness by potential customers about solar?
- Is it easy to learn about solar PV and how to install it? Find someone who can do the installation?
    - Internet? Radio?
- Has media awareness increased? Are there articles written about it?

Government Involvement

- How has the government supported renewable/solar energy?
    - Is there a sense of interest by ministries/individual officials? Has it grown?
    - Are there tax benefits?
    - Are they supporting new products?
    - Offering finances for new pilots/projects?
- Has there been increased foreign investment interest?
- Have there been any observable results?
    - In cost? In awareness? In policies?

Business Networks & Products

- How many other business are involved in Solar PV? Who else are you in contact with?
    - Are they mostly in SHS or connecting to the main-grid?
    - Based in Kigali, or in rural areas?
    - Are they offering new products, or re-selling?
    - Is there a network of Solar/renewable energy sellers/those interested?
- To your knowledge, what plans exist to extend the grid?
- Would that affect your product?

Main Challenges/Benefits/Follow-up

- What do you think the main challenges are in promoting solar PV?
- What are the main benefits to solar?
- Is there anyway to see a SHS installation?
- Is there anyone else you suggest I contact? Documents to read?

For Government

General

- What is your role in X?
- What are the main sources of energy in Rwanda? From where is oil/diesel imported?
- What is the cost of electricity?
    - Has it increased or decreased over the last 10 years?
    - If so, why?

Government Involvement

- How is X involved in renewable/solar energy?
    - Is there an official position on renewable energy?
    - Is there a renewable energy source the government is particularly interested in?
    - Has that changed over time – has there been more interest in solar in the last 5 years? 10 years?
- When did Solar PV start being introduced in Rwanda?
- Have there been any observable results?
    - In cost? In awareness? In policies?
- MININFRA has the target for 50% coverage of schools, administrative offices, and health centers to be covered by solar by 2012. How close is the government to meeting this goal?
- Are there specific people in government who have expressed support for renewable energy/solar?
- Has there been donor money specifically for renewable energy?
- Are there specific environmental standards/regulatory frameworks designed to promote renewable energy?
- To your knowledge, what laws exist that focus on energy, or on renewable energy?
- Have there been any workshops/are there any planned, that will focus on renewable energy?

Private Sector

- Vision 2020 and MININFRA's policy statements say they want to promote the private sector. How are they planning to do it?
- Are there financial benefits that the government gives?
    - Tax Exemptions?
    - Tariff exemptions?
    - Feed-In tariff?
    - Improving access to loans/micro-credit?
- How many other business are involved in Solar PV?
    - Are they mostly in SHS or connecting to the main-grid?
    - Based in Kigali, or in rural areas?
    - Are they offering new products, or re-selling?
    - To your knowledge, is there a network of Solar/renewable energy sellers/those interested?
- What about NGO's – do you know of NGO's involved in developing solar PV energy?

Looking Ahead

- To your knowledge, what plans exist to extend the grid? (where, how far)?
- How is Kigali Solaire going?
- Are there plans to develop more solar power plants, and use those to power grid connections?

Main Challenges/Benefits/Follow-up

- What do you think the main challenges are in promoting solar PV?
- What are the main benefits to solar?
- Is there anyway to see Kigali Solaire? How can one visit it?
- Is there anyone else you suggest I contact? Documents to read?
    - Ask about highlighted ones
    - Policies?
    - Press Releases?

For NGOS

General

- How did X get involved in Solar?
- What is your main goal?

Company Specifics & Costs

- How are you organized?
- Was it difficult to get started?
- When did Solar PV start getting introduced in Rwanda?
- Costs
    - Have these costs increased/decreased in the last 10 years?
    - How do you obtain your financing: purely through sales, or micro-credit, or foreign investors
- How developed is the human resource capability, such as trained technicians, dealers, producers of solar energy, at national levels? At local levels?
- Have your products changed? Have you added new kinds of products?
- Are new kinds of products available?
- Where do these products mostly come from?

Customer Awareness

- Who are your potential customers?
- How do you promote your product?
    - For example, through sharing knowledge through workshops, or raising awareness through exhibitions, promotions, etc.?
- Has there been an increase in interest or awareness by potential customers about solar?
- Is it easy to learn about solar PV and how to install it? Find someone who can do the installation?
    - Internet? Radio?
- Has media awareness increased? Are there articles written about it?

Government Involvement

- How has the government supported renewable/solar energy?
    - Is there a sense of interest by ministries/individual officials? Has it grown?
    - Are there tax benefits?
    - Are they supporting new products?
    - Offering finances for new pilots/projects?
- Has there been increased foreign investment interest?
    - If so, from what countries/what international organizations?
- Have there been any observable results?
    - In cost? In awareness? In policies?

Business Networks & Products

- How many other NGO's are involved in Solar PV?
    - Are they mostly in SHS?
    - Based in Kigali, or in rural areas?
    - Are they offering new products, or re-selling?
    - Is there a network of Solar/renewable energy sellers/those interested?
- To your knowledge, what plans exist to extend the grid?
- Would that affect your product? Your services?

Main Challenges/Benefits/Follow-up

- What do you think the main challenges are in promoting solar PV?
- What are the main benefits to solar?
- Is there anyway to see a SHS installation?
- Is there anyone else you suggest I contact? Documents to read?

For International Organizations

General

- What is your role in X?

Organizational Involvement

- How is X involved in renewable/solar energy?
    - What are the projects?
    - What is the focus?
        - Standard-setting
        - Capacity Building
        - Infrastructure
    - How much money has X given?
- Why did it get involved?
    - Has that changed over time – is there more interest in solar in the last 5 years? 10 years?
- Have there been any observable results?
    - In cost?
    - In access to electricity?
    - In consumer awareness?
    - In governmental policies?
- Are there specific people in government who have expressed support for renewable energy/solar?
    - Do you think this has changed over time?
- Have there been any workshops/are there any planned which will focus on renewable energy?
- When did solar PV start getting introduced in Rwanda?

Private Sector

- Vision 2020 and MININFRA's policy statements say they want to promote the private sector. Have you seen evidence of this?
    - Tax Exemptions?
    - Tariff exemptions?
    - Feed-In tariff?
    - Improving access to loans/micro-credit?
- How many other business are involved in Solar PV?
    - Are they mostly in SHS or connecting to the main-grid?
    - Based in Kigali, or in rural areas?
    - Are they offering new products, or re-selling?
    - To your knowledge, is there a network of Solar/renewable energy sellers/those interested?
- What about NGO's – do you know of NGO's involved in developing solar PV energy?

Looking Ahead

- To your knowledge, what plans exist to extend the grid? (where, how far)?
- Do you think the solar PV market will develop?

Main Challenges/Benefits/Follow-up

- What do you think the main challenges are in promoting solar PV in Rwanda?
- What are the main benefits to solar?
- Is there anyone else you suggest I contact? Documents to read?
    - Ask about highlighted ones
    - Policies?
    - Press Releases?

For Financial Institutions

- Have there been projects focusing on renewable energy that you have financed?
- On solar energy?
- If so, can you tell me about the projects?
    - When did they start?
    - Who was involved?
    - How much?
    - Can you explain the financial specifics?
- What is your impression on governmental interest in renewable energy projects? Is there any?
    - Have there been any new rules/standards to make borrowing easier?
- Are there micro-finance institutions that have done projects involving solar energy?
- Do you feel there is an increase in consumer awareness/interest in renewable energy? In solar energy?

Annex B: Event Mapping Spreadsheet

F1: Entrepreneurial Activity is listed Below. For full list, please email author at lenagd@gmail.com.

Year	**F1: Entrepreneurial Activity**
1980-1994	**3** 1) SECAM starts in 1980's with solar PV, 2) BUFMAR starts in 1975 (Bureau de Formations Medicales Agrees du Rwanda, does solar PV, 3) 2 business (CPQ & Basimbizi) sell solar lamps
1995-2004	**2** 1) 2004 Davis & Shirtliff opens in Rwanda, 2) Solar-powered radio installed in Nyungwe National Park
2005	**3** 1) Great Lakes Energy Founded, 2) TGL founded, 3) MTS Founded
2006	**2** 1) Solar Systems Technology (SST) founded, 2) PIH becomes active in Rwanda; installs PV
2007	**3(1)** 1) Kigali Solaire built, 2) Tasha Enterprise starts selling solar PV, 3) No established Feed-In tariff prevents KC from increasing (MINUS), 4) SELF partners with PIH to install PV in HC
2008	**5(1)** 1)Manna starts PV based UV water filtration company, 2) SECAM tries and fails to introduce solar lanterns(MINUS), 3) Koinonia begins PV installations, 4) G24i wins Lighting Africa award to develop dye-sensitized PV in Rwanda, 5) Nelson Mandela school opens, 6) Equinox starts, gets funding mostly from Imperial College London
2009	**2** 1) BrazAfric starts marketing D-Light lanterns in Rwanda (2007 in Kenya) 2) E.quinox solar kiosk starts running
2010	**8(1)** 1) Entreprise La Perfection founded, does inverters and PV installations, 2) RadiantEnergy Coop selling some of its PV modules to Congo, 3) Bboxx founded,4) Mucome Ltd. founded, 5) Nuru stops w/ Solar Lanterns (MINUS), 6) NUR distributes solar lanterns w/ Cooper Union, 7) Beacon Cooperative selling solar lanterns though Konoinia Foundation, 8) K-Light Introduced 9) SolarNow(REF) introduces their line in Rwanda through Uganda sellers
2011	**8** 1) Solar Gorilla starts marketing in Rwanda, 2)Philips introducing new SHS, partnering with SACCO's and/or GLE, 3) GVEP partnering with PSF; 4) ChlorideExide starts in Rwanda, 5) TIGO/SECAM project on PV for mobile phone towers, 6) ToughStuff plans to move into Rwandan market, 7) Columbia Mailman School also begins introducing PV, 8) 2) Uganda-based Solar Sisters introduces 6 entrepreneurs to Rwanda

Annex C: Solar PV Actors

Sector	PV Type	Sector	Organization	Contact Information
Business	Solar PV Plant	Owner	Kigali Solaire / StadtWerke Mainz	https://www.facebook.com/pages/Kigali-Solaire/141643882524280
Business	PV Installations	Wholesale Distributor	African Energy	http://www.africanenergy.com/, info@africanenergy.com
Business	PV Installation	Supplier Installer	ChlorideExide	MUHIMA ROAD, P.O. BOX 4016 KIGALI, RWANDA TELEPHONE: +250280898488 EMAIL: chloridekigali@chlorideexide.com WEBSITE: www.cekl.com
Business	PV Installations Solar Home Systems	Seller	Dassy Enterprise	Francois D'Assise Nezerwa
Business	PV Installations Solar Lanterns Solar Water Heaters	Distributor Installer	Davis & Shirtliff	Muhima Road Tel: (250) 504033/9 Fax: 504033sales@dayliff.co.rw
Business	Other (inverters)	Manufacturer	Enterprise La Perfection	jcbwenge@yahoo.fr
Business	PV Installations Solar Lanterns	Installer Supplier	Great Lakes Energy	info@energyforafrica.com http://www.energyforafrica.com/
Business	PV Installations	Installer Supplier	MTS	
Business	PV Installations	Seller Installer	MUCOME Ltd	250 788 296 279
Business	PV Installation Solar Lanterns	Supplier Installer	SECAM	
Civil Society	PV Installations	Installer	Solar Electric Light Fund	info@self.org, http://www.self.org/contact1.shtml

Business	PV Installations	Installer	Solar System Technologies	
Business	PV Installation	Installer	Tasha Enterprise	tashaenterprise@gmail.com
Business	PV Installation	Supplier Installer	Tech Grand Lac (TGL)	ntezeb@yahoo.fr
Business	Solar Home Systems (Energy Kiosks)		E.quinox	http://e.quinox.org/, info@equinox.org
Business	Solar Home Systems		Bboxx	http://www.bboxx.co.uk/
Business	Solar Home Systems	Manufacturer Cooperative	Radiant Energy	Olivier Biraro mostblissful@gmail.com
Business	Solar Home Systems Solar Lanterns	Supplier Distributor	Philips	www.philips.com
Business	Solar Lanterns	Supplier Distributor	Barefoot Power	http://www.barefootpower.com/contact.html
Business	Solar Lanterns	Distributor	BrazAfric	http://www.brazafric.com/ Brazafrica-rw@brazafric.com
Business	Solar Lantern	Producer Distributor	D-Light	http://www.dlightdesign.com/contact_contact_form.php
Business	Solar Lanterns	Potential Distributor	Greenlight Planet	http://www.greenlightplanet.com/ info@greenlightplanet.com
Business	Solar Lanterns	Producer Distributor	Murika Procurement & Logistics	http://www.pisatsolar.com Murika Procurement & Logistics, LTD BP 3499 Kigali, Rwanda Phone: 250-78304667
Civil Society	Solar Lanterns	Distributor	Rural Energy Foundation	http://www.ruralenergy.nl/index.php?option=com_content&view=frontpage&Itemid=1

				http://www.ruralenergy.nl
Business	Other (LED Lights)	Producer Distributor	Nuru Lighting	http://nurulight.com/ info@nurulight.com
Business	Other (UV Irradiation)		Manna Energy	http://www.mannaenergy.org/projects.html jennifer.mccard@mannaenergy.com
Business	Other (LED Lights)	Manufacturer Supplier	Lemnis Lighting	http://www.lemnislighting.com/pdf/PRESSREL_LightingAfrica-En.pdf
Business	Other (business dev.)	ToughStuff solar seller	Karisimbi Partners	http://www.karisimbipartners.com/rwanda.html info@karisimbipartners.com P.O. Box 7164 Kigali, Rwanda +(250) (0)78 511 6198

Civil Society	**Energy Focus**	**Type**	**Organization**	**Contact Information**
Civil Society	Renewable Energy	Association	Ass. Rwandese l'Energie Durable (ARED)	
Civil Society	Renewable Energy	NGO	GVEP	Kiganjo House, Rose Avenue P O Box 76580 - 00508 Nairobi - Kenya Phone number: +254 20 2714 164 or +254 20 2714 165 E-Mail: east.africa@gvepinternational.org
Civil Society	Renewable Energy	NGO	Koinoinia Foundation (also see MPL)	http://www.kfaid.com/ info@kfaid.com
Civil Society	Misc.	Business Association	Rwanda Private Sector Federation	http://www.psf.org.rw/ Gikondo MAGERWA Kigali

				Rwanda PO Box 319 info@psf.org.rw (250)-252-570650

Finance	Focus	Type	Organization	Contact Information
Finance	Electrification	Development	Africa Development Bank	http://www.afdb.org/en/contact-us/ Immeuble BCDI 8 Avenue de la Paix BP 7329 Kigali, Rwanda
Finance		Investment	Banque Populaire du Rwanda	http://www.bpr.rw/spip.php?article11 B.P. 1348 Kigali - Rwanda **info@bpr.rw**
Finance	Lighting Product	Microfinance	Urwego Opportunity Bank	http://www.uomb.org/ Plot 1230 Nyarugenge Avenue de la Paix P.O Box 748 Kigali, Rwanda. Phone +250 0830 3957 / +250 500 160 Fax +250 57042 E-mail: mailto:info@uob.rwinfo@uob.rw
Finance		Microfinance	VisionFinance	http://www.kiva.org/partners/117

Government	Energy Focus	Projects	Organization	Contact Information
Government	All energy, water, sanitation	Oversees MININFRA solar projects	EWSA Energy, Water, Sanitation Agency	http://www.ewsa.rw/contacthead.html
Government	All energy, water, sanitation, transport	All institutional PV projects, energy access projects	MININFRA Ministry of Infrastructure	info@mininfra.gov.rw

Government		Solar PV for admin centres	MINALOC Ministry of Local Government	http://www.minaloc.gov.rw/index.php?id=37 secretariat@minaloc.gov.rw
Government		Solar PV for schools	MINEDUC Ministry of Education	http://www.mineduc.gov.rw/
Government		Solar PV for health centres	MINISANTE Ministry of Health	http://www.moh.gov.rw/
Government			MINECOFIN Ministry of Finance	Office Phone: +0250 252 596002 E-mail: mfin@minecofin.gov.rw
Government		Helps locate investors for energy Projects	RDB Rwanda Development Board	Boulevard de l'Umuganda, Gishushu, Nyarutarama Road. P.O. Box 6239 Kigali, Rwanda Fax: +250 252 580388 Email: info@rdb.rw
Government	Environment protection		REMA Rwanda Environmental Management Agency	Kigali City Rwanda B.P 7436 Kacyiru +250 252580101 + 250 252580017 http://www.rema.gov.rw
Government		Sets feed-in tariff	RURA Rwanda Utility Regulatory Agency	P.O.Box: 7289 Kigali-Rwanda Phone: (250)252 58 45 62 arms@rwanda1.com info@rura.gov.rw www.rura.gov.rw
Government			RIEPA Investment & Expert Promotion Agency	P.O.Box: 7289 Kigali-Rwanda

	Energy Focus	Projects	Organization	Contact Information

Int'l/Dev.				
Int'l Dev or IGO	Solar	Solar PV for health centres	BTC	41 avenue Député Kayuku BP 6089 Kigali + 250 252 57 02 85 prudence.uwabakurikiza@btcctb.org
Int'l Dev or IGO	Solar	EU Village Electrification Project Several other infrastructure projects	EU	Physical address: Aurore building, 1807 Boulevard de l'Umuganda, Kigali P.O. Box 515, Kigali Telephone: (+250) 252 58 57 38 / 39 / 40 / 41 Fax: (+250) 252 58 57 34 / 36 delegation-rwanda@ec.europa.eu
Int'l Dev or IGO	Hydro Biomass	Did a 2009 Solar Market Analysis	GIZ (GTZ)	Bureau de la GIZ 11, Avenue de Kiyovu B.P. 59 Kigali Rwanda Tel: +250 252 573537 Fax: +250 252 572439 Email: giz-ruanda@giz.de
Int'l Dev or IGO	Water Education		JICA	Japan International Cooperation Agency EBENEZER HOUSE, Umuganda Boulevard P.O. Box 6878 Kacyiru, Kigali-Rwanda Tel: +250 (0) 788301731/32/23/35
Int'l Dev or IGO	Biomass		SNV	Boulevard de l'Umuganda, I Kacyiru, P.O. Box 1049, Kigali Tel : +250 78 830 6220/1; 846 7210 rwanda@snvworld.org
Int'l Dev or IGO	Health Solar	Solar PV for health centres	USAID	2657 Avenue de la Gendarmerie Kigali, Rwanda kigali@usaid.gov
Int'l Dev or IGO	Solar	Solar Home System Project	UNEP	www.unep.org

Knowledge Inst.	Energy Focus	Projects	Organization	Name/Contact
Knowledge Institute	Vocational School	Renewable energy	Training Center of	William Singira, singirawilliam@yahoo.fr

		training	Modern Occupations	
Knowledge Institute	Technological Institute	Renewable energy training	KIST/KITT (Kigali Institute of Science & Technology),	http://www.kist.ac.rw/
Knowledge Institute	Business Institute	Entrepreneurial training	Technology & Business Incubation Foundation	www.kist.ac.rw/tbif dcitt@kist.ac.rw

Annex D: List of Relevant Policy Documents

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