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Power for the people

A case for a renewable energy technological innovation system

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Power for the People: A case for a Renewable Energy Technological Innovation System

By Ronke Luke and Chukwu-Emeka Chikezie (Up!-Africa Ltd)

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Glossary

DFID	Department for International Development
EDSA	Electricity Distribution and Supply Authority
GoSL	Government of Sierra Leone
GST	Goods and sales tax
IP	Investment plans
IRP	Integrated Resource Planning
IS	Innovation systems
MDA	Ministries, departments, and agencies
MoE	Ministry of Energy
NERC	Nigerian Electricity Regulatory Commission
ODA	official development assistance
REASL	Renewable Energy Association of Sierra Leone
SE4All	Sustainable Energy for All
SLAMFI	Sierra Leone Association for Microfinance Institutions
SREP	Scaling-Up Renewable Energy Program in Low Income Countries
TIS	Technological Innovation Systems
USAID	U.S. Agency for International Development

Executive Summary

This document argues that a Technological Innovation Systems offers a framework to unlock, guide, and strengthen Sierra Leone's domestic renewable energy private sector. Sierra Leone, like many developing countries, increasingly sees on- and off-grid renewable energy as a viable solution for providing electricity to its citizens. As such, there has been a marked increase in both government- and private-sector-led activity. In 2016, Government of Sierra Leone (GoSL) released the **Renewable Energy Policy of Sierra Leone**. The Ministry of Energy (MoE) launched the Energy Revolution to deliver 50,000 solar home kits in rural areas in 2016 and another 200,000 in 2017. During the 10 May 2016 Energy Revolution launch event, Sierra Leone and the United Kingdom (UK) signed the first Energy Africa compact to support and go beyond the Energy Revolution and provide "power for all by 2025." The small, yet enthusiastic, private sector has been at the forefront of early adoption of off-grid solar solutions. It took an important step in 2016 when several firms organized themselves into The Renewable Energy Association of Sierra Leone (REASL) to raise the sector's profile and more effectively lobby GoSL and MoE on issues of shared/common interest to members and the industry.

These individual initiatives are positive but are they sufficient to catalyze a vibrant renewable energy sector able to meet the country's urgent needs? Governments in developing countries often tap their energy ministries, with deep experience in running grid-tied power plants, to lead the rollout of renewable energy. Their grid-tied-central-power-plant experience may lead to renewable energy deployment being viewed in narrow technical and engineering terms. While deploying robust technical solutions is critical, the rollout of renewable energy is more complex. It is in reality an innovation challenge.

Innovation seeks to: 1) displace incumbent solutions with superior options and/or 2) provide a solution (for known and/or unknown needs) where one does not currently exist. Renewable energy is seeking to do both things. Guiding and assessing the successful deployment of innovation therefore requires additional tools and a different approach to the problem than has typically been used in Africa's power sector.

We offer Technological Innovation Systems (TIS) as a suitable framework for this purpose. Innovation Systems (IS) articulate how diverse agents, institutions and subsystems interact, willfully or unintentionally, to create and utilize new knowledge that underpins economic development. The concept is able to integrate a wide range of issues, e.g. politics, policy, economics, engineering, social issues etc., that all play a role in development. TISs refine the innovation systems concept by technology and offers a method for examining "the problem of adoption and utilization of technology" **(Carlson and Stankiewicz, 1991).** TIS has been widely used to examine how new energy technologies emerge. We show how the TIS framework can be useful to GoSL and other stakeholders as they determine where to deploy resources to nurture self-reinforcing conditions necessary for a vibrant renewable energy sector.

1.0 Introduction

The Government of Sierra Leone (GoSL) is keen to increase the share of renewable energy in the country's electricity mix. There has been a marked uptick in off-grid renewables-related activity in 2016. The Ministry of Energy (MoE) finalized the **Renewable Energy Policy of Sierra Leone** (2015) to harness the nation's solar, wind, biofuels, and hydropower resources. In 2016, Sierra Leone was invited to submit its investment plans (IP) for a national pilot under Scaling-Up Renewable Energy Program in Low Income Countries (SREP). Power for All – the global campaign to accelerate universal energy access using decentralized renewable energy – ramped up its Sierra Leone operations. In May 2016, President Ernest Bai Koroma was the keynote speaker at Sierra Leone's first ever conference on decentralized renewables. The MoE-sponsored conference launched the country's Energy Revolution - an initiative aimed at engaging the private sector in delivering solar lights and solar home kits to rural areas. In his remarks, the President announced targets of 50,000 solar home kits and lights installed in 2016 and another 200,000 in 2017. During the Energy Revolution launch event, Sierra Leone and the United Kingdom (UK) signed the first Energy Africa compact with an African government. The Energy Africa Compact will provide technical and financial support for the Energy Revolution. The Compact sets bold off-grid goals to provide "power for all by 2025" and "modern power to 1 million people by 2020." A private sector members' organization – The Renewable Energy Association of Sierra Leone (REASL) – also launched during the Energy Revolution kick-off event.

This seemingly sudden burst of renewable activity in 2016 was preceded by at least a decade of organic growth during which early adopters (solar providers and customers willing to pay) emerged at a range of domestic and commercial facilities. The providers consist of small and medium NGOs, and domestic firms, alone or partnered with foreign firms. They offer a range of solar solutions including solar lamps, solar home kits, and roof-top systems and, in recent years, grid-tied solar systems.

Recognizing this nascent activity in the solar sector, GoSL and its development partners are keen to attract foreign investors who are expected to be well capitalized and bring expertise and experience that could quickly ramp up Sierra Leone's solar market. As there are currently few and mostly small and medium domestic solar firms, this is understandable given the government's ambitious targets and urgency to rapidly increase electricity supply. But it would be a mistake for MoE to focus singularly on attracting foreign investors to the exclusion of building domestic capacity. Both are necessary.

Kenya provides evidence of the power of learning by doing in its energy sector. The country has created a vibrant, innovative solar technology community in which firms are experimenting. Firms in Kenya pioneered the innovative application of mobile payment to solar technology, which has reduced, and in some cases eliminated, the capital cost hurdle that had constrained solar energy's expansion. These technological and financial breakthroughs enabled new business models (e.g. leasing, pay-as-you-go, social impact investing) that have further accelerated solar's expansion in Kenya and made the country a leader in Africa's solar know-how. Knowledge accrues to those pioneering countries and firms that learn by doing. These firms have taken their new knowledge to open new markets across East Africa and now West Africa. Kenya's private-sector-led solar micro-grid model – financed by VC-backed social investors - is growing rapidly across rural communities **(Pearce, 2015a)**. Anecdotal evidence from a comparison

with traditional development-aid-funded solar micro-grid projects in India suggests Kenya's approach has to-date been much more successful **(Pearce, 2015b)**. Creating and sustaining this vibrant solar market requires all stakeholders in Kenya (i.e. government, private sector, NGOs, development finance partners etc.) to work through the range of policy, governance, technical, socio-economic and financial issues (e.g. power purchase agreements, tariffs, bill/usage payments etc.) that yield solutions and know-how.

Solar technology is unique amongst energy options. It is the only energy technology that today offers solutions across the entire spectrum of users: rural, urban, commercial and industrial. The technology can be deployed as both on- and off-grid installations. In Kenya we see solar applications in all these user groups. Further, we see how innovation (mobile payment) first applied to solar home kits quickly spread to solutions in all other user categories.

User Category	**Rural Residential**	**Rural/Urban Community[1]**	**Urban Residential**	**Light Commercial[2]**	**Commercial**	**Industrial**
Solar Solutions*	Solar home kits	Micro-/Mini-grids	Roof top installations	Roof top installations Micro-/Mini-grids	Mini-grids Solar farms	Solar farms

1 Examples are health clinics, places of worship, community halls
2 Examples are shops (small kiosks to stores), commercial buildings (e.g. offices, banks), farming, light manufacturing
*These examples listed above do not show all the ways that a solar solution can be used. For example, solar home kits can be used in urban residential settings. Micro- and mini-grids can be used in rural settings. Further, solar technology can be used for water heaters.

What Kenya has been able to do is create a TIS in mobile phone technology that has spilled over into the solar space; breaking down a long-standing barrier to solar uptake i.e. high capital costs, to spur a technological innovation system in solar energy that is now driving experimentation, knowledge acquisition, and rapid diffusion of solar solutions and having tangible socio-economic impact.

The rest of this paper:

- introduces TIS
- presents recommendations on how Sierra Leone can use the TIS framework to develop, support and eventually sustain a responsive renewables energy sector. These recommendations include initiatives that expand on the Energy Revolution and make "actionable" measures presented in the **Renewable Energy Policy of Sierra Leone** (2015).

2.0 Technological Innovation Systems

Evolutionary economists and social scientists developed the concept of innovation systems (IS) to articulate how diverse agents, institutions and subsystems interact, willfully or unintentionally, to create and utilize new knowledge that underpins economic development. The concept is able to integrate a

wide range of issues, e.g. politics, policy, economics, engineering, social issues etc., that all play a role in development. Innovation systems can be refined by geography into national or regional innovation systems; by industry into sectoral innovation systems; and by technology into technological innovation systems**.**

TISs cut through the boundaries of national or sectoral innovation systems as "the technological progress, price, and diffusion" of any technology is influenced "by . . . various national and "sectoral innovation systems" **(Hekkert et al., 2007, p.416)**. Information flows between and within national, sectoral and technological innovation systems creating trickle-down, bubble-up and sideways effects between them. Success has feedback loops that result in responses to meet new or unfulfilled market demands. Kenya's mobile and solar TIS are both local (in-country) and tied to global TIS. Learning and knowledge sharing, underpinned by "good" policy and governance, are driving business opportunities that both Kenyan and international entrepreneurs and financiers are responding to.

Renewable Energy Uptake is an Innovation Challenge

An innovation is a commercially successful offering that:

- Displaces an incumbent solution (i.e. service or product) with one that is superior; and/or
- Provides a new capability (e.g. service or product) that had not existed before.

Renewable energy fits these two conditions for innovation. It is:

- Displacing inferior lighting and power solutions (e.g. kerosene- and battery powered lamps or diesel generators)
- Providing electricity services to users who previously never had power.

TIS also offers a method for examining "the problem of adoption and utilization of technology" **(Carlson and Stankiewicz, 1991)** and has been widely used to examine how new energy technologies emerge. It is an appropriate framework as deployment of new energy technologies is not singularly an engineering or technical challenge. Rather it is an innovation challenge that touches on a wide range of engineering, technical, financial, policy, marketing, social issues. Innovation theory, in general, and technological innovation systems, in particular, provides a framework for incorporating and applying systems analysis to assess and influence, in a holistic way, the emergence and uptake of new energy technology.

A TIS is "a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure . . . and involved in the generation, diffusion and utilization of technology" **(Carlson and Stankiewicz, 1991).** There are four primary structures (or building blocks) of a TIS: the actors in the supply chain; the networks; the institutions (regulations, norms, rules), and technological

factors (e.g. standards). These TIS structures are mainly static; i.e. their existence and/or composition changes slowly, sometimes over a year or longer **(Suurs, et. al, 2009)**.

Technological change, however, is very dynamic. Seemingly deliberate or disparate, uncoordinated, direct or indirect, planned or "accidental" interactions between the building blocks can eventually give rise to or modify a TIS when, in a reinforcing manner:

- Actors (e.g. entrepreneurs, government, universities or other organizations) in the supply chain undertake activities to promote a specific technology;
- Social, political or learning networks emerge to influence the technology's uptake;
- Institutions start to align to influence "rules of game;" and
- Technological factors such as the costs, performance, safety, standards etc. of a technology are increasingly clarified.

The dynamic processes causing the interactions are called functions. TIS functions change more quickly than structures, hence the importance of studying functions to understand change at a micro-level. Hekkert et. al **(2007)** identify seven functions acting within a TIS:

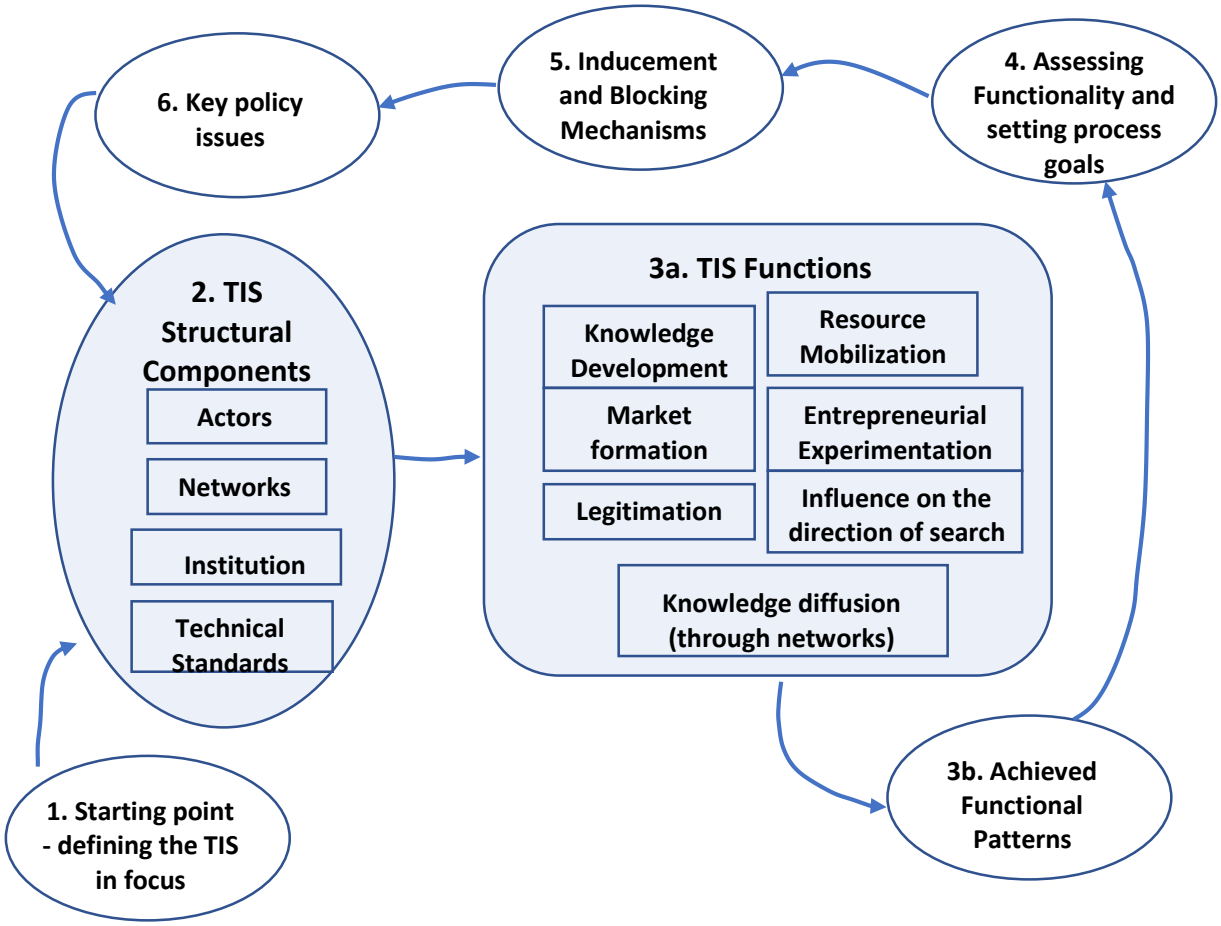
- **Function 1**: entrepreneurial activities – "Entrepreneurs are essential for a well-functioning innovation system" **(Hekkert et al. ,2007, p.421)**
- **Function 2**: knowledge development – Learning is at the heart of an innovation
- **Function 3**: knowledge diffusion through networks – Networks facilitate exchange of information
- **Function 4**: guidance of the search – Resources are limited so they should be focused for maximum effect
- **Function 5**: market formation – Creating a space so that niche markets for innovations can take hold and ultimately challenge incumbent markets
- **Function 6**: resource mobilization – Financial and human resources are necessary to secure the inputs for an innovation system
- **Function 7**: creation of legitimacy to counteract resistance to change – Creating social credibility for a new technology so it becomes a part of or dislodges the incumbent system.

"Functions influence each other" **(Hekkert et al., 2007, p.425).** Fulfillment of one affects others. For example, government policy to provide power beyond the grid (F4-Guidance of search), influences research for and development of off-grid renewable initiatives (F2-knowledge development and F6-resource mobilization) and spurs businesses to offer solutions (F1-entrepreneurial activity). Greater entrepreneurial activity in roof-top solar creates interest for technicians to train, for example, in solar systems maintenance (F2-knowledge development and F6-resource mobilization) that increases customers' confidence to invest in solar systems (F7-creation of legitimacy). These examples show how the systems approach gives holistic guidance on policy decisions. If, for example, government action does not spur businesses as expected, the government can re-examine its actions (including policies) to understand why not. For example, MoE released its renewable energy policy (F4-Guidance of search) in early 2016 but first discussions with industry immediately identified customs duties as one immediate barrier to the policy's goals to spur private sector. Customs duties affect F1-entrepreneurial activity, and F6-resource mobilization (investment), for renewable technologies.

There are multiple, linear or non-linear interactions that may positively or negatively affect the system's performance. Self-reinforcing positive interactions can lead to virtuous cycles of processes of change (positive feedback loops) that build "momentum to create a process of creative destruction within the incumbent system" **(Hekkert et al., 2007, p.426).** Likewise, self-reinforcing negative interactions can lead to a vicious downward cycle stalling the uptake of new technology.
Three reasons support analyzing emergence of new (energy) technologies using the functions approach. First, it makes it possible to compare innovation systems regardless of their institutional set-up. Second, it provides a means to map the internal and external "determinants of innovation" over time; identifying any "cumulative and circular" causes, if present. Thirdly, a functions approach can identify "a clear set of policy targets as well as instruments to meet these targets" **(Hekkert et. al., 2007, p.420).**

Figure 1 shows a methodology for analyzing the underlying functional dynamics of a TIS and hence the success of the diffusion of new technology (innovation) to users **(Bergek, et. al, 2008)**. A vibrant TIS will have activities influencing every function in a manner that is positively reinforcing.

Figure 1 – A Methodology for Evaluating the Effectiveness of the Underlying Functions in a TIS



Source: Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A. "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis"
Elsevier, Research Policy 37 (2008) 407–429

3.0 Technological Innovation Systems offers a Method to continuously evaluate Sierra Leone Renewable Energy Policy's Success

The **Renewable Energy Policy of Sierra Leone** (2015) identifies 17 guiding principles each with multiple objectives and measures for achieving outcomes in hydropower, bio-energy, solar energy, wind energy and private sector participation. There are currently several GoSL-sponsored renewable energy initiatives underway.

The policy authors recommend "that a Committee, under the Chairmanship of the Minister of Energy, will review this document at least once every three years, and result of such review will be used to update or replace this policy or its existing replacement subject to approval by the Strategy and Policy Unit (SPU)" (p. 17).

Further, the policy recommends that the Ministry of Energy develops and implements "the necessary machinery for constant monitoring of the implementation of the approved renewable energy and energy efficiency policy and compliance with the guidelines and regulations on various energy matters by all sectors of the economy" (p. 48).

We propose the TIS framework and the methodology shown in Figure 1 for this constant "monitoring machinery" (see Figure 2). TIS offers a method for conducting ongoing analyses of the policy's effectiveness from the perspective of any stakeholder. TIS outputs can identify what is workings and, critically, where gaps exist in the sector-related efforts. Such results will provide inputs to the tri-annual review led by the Minister of Energy.

4.0 Sierra Leone Private Sector's Role

The **Renewable Energy Policy of Sierra Leone** (2015) expects to *"drive the creation of market incentives for the deployment of efficient private sector-driven renewable energy solutions, for remote and off-grid areas"* **(p. ix)** and envisions that *"renewable energy power supply for rural areas will be driven by Sierra Leone private sector"* **(p. ix)**.

While the policy is silent on the role of the private sector in non-rural areas, we infer that there is no prohibition on Sierra Leone's private sector engaging in any part of the country.

Based on the policy's expectations for a domestic private sector, we propose the following vision to define the policy's meaning of "efficient private-sector driven renewable energy solutions:"

A domestic renewable energy industry able to:

- innovate, drive technological and user experience advances;
- develop innovative business models; and
- usher in new generations of renewable energy applications suitable for a wide range of customers including government, businesses, households, and community actors.

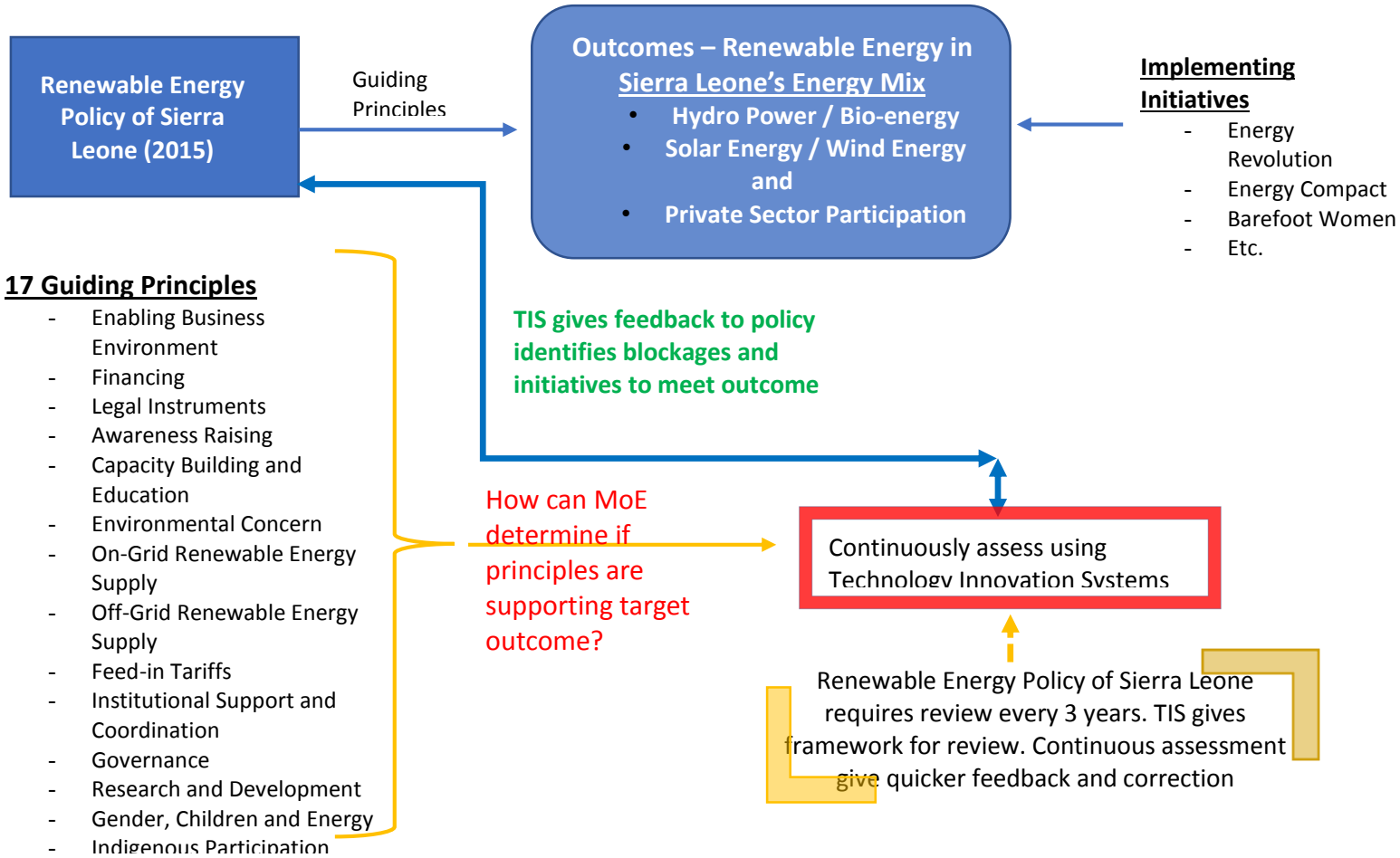


Figure 2 – Technological Innovation Systems (TIS) offers a methodology to assess effectiveness of Sierra Leone's Renewable Energy Policy

Such a vision is ambitious, but a domestic private sector with this capability is more likely to attract foreign partners and will be able to contribute in the long-term, to sustainable success of the national renewable energy policy.

The difficulty of raising finance for (renewable) energy projects in developing countries is well documented. A theme from the Financing for Development Conference in Addis Ababa in 2015 was the necessity for developing countries to mobilize domestic resources and attract innovative financing rather than depending on official development assistance (ODA) that is insufficient to meet global needs. There is a lot of discussion in development finance circles about the incentives that will attract other private funding sources such as corporate funding, venture capital or pension funds to fill the gap. However, financiers and entrepreneurs have identified unclear policy and weak governance in developing countries as an equal or more significant hurdle to investment **(Brent, 2016)**. Therefore, clarifying or making "actionable" the policy statements and measures presented in the "Renewable Energy Policy of Sierra Leone" is critical to guide both domestic firms and potential foreign investors. We make a contribution towards this goal in this paper. In the next section, we summarize work that has been conducted and work that is underway to understand Sierra Leone's domestic private sector needs. In Section 6, we provide additional practical actions that GoSL, the private sector, and other stakeholders can undertake in the short- and medium-term to expand the Energy Revolution and satisfy measures in the Sierra Leone Renewable Energy Policy.

5.0 Preliminary Steps towards understanding the Domestic Private Sector Needs

MoE has taken early steps to understand the composition of Sierra Leone's domestic solar solution providers, their services and capabilities and the current constraints they face. The insights from three 2016 consultations, one each on policy, financing and market understanding, were included in formulating the Energy Compact signed between the MoE and the U.K. government.

Policy. On 17th February 2016, MoE hosted a private sector roundtable discussion that brought together private companies involved primarily in the home and institutional solar installation markets (including solar home kits) and representatives from relevant ministries, departments, and agencies (MDAs). This meeting highlighted the need for the MDAs to rationalize the existing import tax duty waiver process that the intended beneficiaries, i.e. the private sector and ultimately their customers, have been unable to easily access. An important outcome of this meeting was the decision to found a trade association – Renewable Energy Association Sierra Leone (REASL) - to act as an industry body representing the common interests of its members, e.g. lobbying for the import duty tax waiver. On 25 February 2016, MoE convened a roundtable with MDAs spanning the relevant areas of renewable energy implementation. This meeting served to underscore the importance of a "joined-up", whole-of-government, collaborative approach to renewable policy development and implementation.

Financing Renewables. On 2nd March 2016, MoE hosted a roundtable with the financial sector and private companies to examine the financial challenges to attracting funding (both domestic and direct foreign investment) for off-grid renewables in Sierra Leone. The meeting outlined areas for further work including reducing capital/loan risk and creating accessible financing products for customers.

Market Understanding. On 2nd April 2016, MoE hosted a meeting with 149 Paramount Chiefs, District Council Chairmen, and City Mayors in Sierra Leone to understand the challenges of rural electricity and socialize available renewable energy solutions, in particular small solar home systems. MoE hopes to inspire leaders to champion renewable energy in their chiefdoms. This type of outreach is important for match-making and market formation. It cuts the time, and therefore cost, that solution providers and seekers spend in identifying opportunities. Further, MoE's involvement in presenting solar solutions to these leaders plays a role in legitimating the technology that might still be unfamiliar to many potential beneficiaries.

These areas of consultation are important to start understanding Sierra Leone's rural market potential, the sector's financing needs and to foster joined-up government between the MoE and many other government agencies that influence energy sector development (e.g. joining up the activities between MoE and the Ministry of Finance and Economic Development for the customs tax waiver). The tax waiver and enlisting the Paramount Chiefs in market definition activities are being addressed under the implementation of the Compact. Access to finance remains a challenge for which we provide short- and medium-term activities in the next section of this paper. We also propose activities guided by the TIS functions that expand on the Energy Revolution and the national renewable energy policy.

6.0 Proposed Initiatives towards building a Domestic Private Sector-focused Renewables Program

We identify several near-term (one to two years) and longer-term initiatives (two plus years) that MoE can undertake to support its private sector-focused renewables policy. These initiatives, anchored in the functions of a TIS, provide a "how" to implementing the measures in Sierra Leone's national renewable energy policy and expanding the Energy Revolution. Each of the proposed activities fits into the technology innovation system framework.

6.1 Near-term initiatives towards building a domestic private-sector

We propose five near-term activities that aim to set renewable energy targets, streamline regulatory processes, address easing obstacles to financing, and provide critical information for project developers.

6.1.1 Renewable Energy Targets

The **Renewable Energy Policy of Sierra Leone** aims for renewable energy to increase *"from 3,622 ktoe in 2013 to 9,315 ktoe by 2030"* (p. 13). MoE's 2014-2017 Energy Strategy targets adding 56MW of solar power **(Ministry of Energy, Sierra Leone, 2014)**. The Energy Revolution focuses on installing 50,000 solar home kits in 2016 and 200,000 in 2017.

Declaring targets is always fraught with peril that one might fall short of the goal; however, targets provide tangible goals against which to focus efforts, measure progress and inspire achievement. As power projects are typically defined in terms of watts of capacity (e.g. megawatts), Sierra Leone should also present the megawatt-equivalents underpinning the Ktoe targets. This will make the information more quickly understood by industry practitioners (e.g. project developers, financiers etc.). For example, in 2015, Nigeria passed feed-in-tariff regulations to encourage investments in 2,000MW of renewable power by 2020 towards the national goal of 10 percent of total supply from renewables in 2020 **(NERC, 2015)**. Because Sierra Leone plans to further develop the grid-tied hydro capacity at Bumbuna, the percentage of renewable energy in its fuel mix will be quite high. Therefore, further refinement of the national policy to specify non-hydro and off-grid targets and potential locations will be very beneficial for understanding the opportunities across the country. Such clear goals are important in the development of a TIS as they influence the guidance of search, i.e. whether developers will direct limited resources to Sierra Leone's opportunities. Sierra Leone needs to make it as easy as possible for entrepreneurs and investors to understand its markets in order to commit resources.

6.1.2 Regulation – Establish Thresholds for Regulatory Exemptions

Having a simple, transparent, tailored regulatory process is vital to making Sierra Leone attractive for the private sector. One-size-fits-all regulation is not helpful. A 5 MW solar installation developer should not be subjected to the same regulatory requirements of a 150 MW diesel-fired plant. A mini-grid provider should not face the same requirements of one feeding into a national grid. Vendors of solar home kits should not be subject to mini-grid rules. Tailoring regulatory requirements is important for easing the burden on entrepreneurs and private developers. MoE should consider regulatory waivers for certain classes of off-grid renewables, e.g. small-scale installations. Solar installations for self-generation should enjoy the same freedoms as current stand-alone diesel installations. Nigeria, for example, in its Electric Power Sector Reform Act 2005 exempts installations with generating capacity not exceeding 1MW from licensing requirements and gives the Commissioner of the Nigerian Electricity Regulatory Commission (NERC) the ability to exempt other capacity from licensing. Tanzania also exempts producers below 1MW from licensing requirements. Further, its small producer policy introduces a Standard Power Purchase Agreement and Tariff Methodology to guide the developer and buyer with the intention of reducing negotiations and costs associated with and fostering the scale-up of mini-grid development. As MoE determines the rules to implement policies for renewable energy and rural electrification, threshold waivers should be included within a streamlined, transparent process. Within the context of a TIS, waivers would influence entrepreneurial activities (F1), guidance of search (F4) and resource mobilization (F6).

6.1.3 Regulation – Clarify Requirements for non-EDSA Supply and Distribution

Sierra Leone needs to clarify regulations for supply and distribution of electricity by entities other than the Electricity Distribution and Supply Authority (EDSA). The **National Electricity Act**, 2011 (Part VI, 34) reserves for EDSA the responsibility for *"the supply, distribution and retail sale of electricity for the entire country except in areas where the commission has issued a distribution licence to another appropriately qualified entity."* The lack of guidance from the Sierra Leone Electricity and Water Regulatory Commission for non-EDSA participation is already causing confusion and concern for developers of micro-and mini-grid projects. During the question and answer portion of one session during the Energy Revolution launch on May 10, 2016, an attendee voiced concern to the Minister of Energy that mini-grids currently operating in communities across Sierra Leone would be found in breach of the law. Such concern is likely dampening entrepreneurial activity (F1), critical for a TIS. While there are now two mini-grid projects funded by development partners, the absence of clear rules in compliance with existing law, stifles further investment in off-grid projects including micro- and mini-grids. MoE should make it a priority to work with the Commission to clarify the licensing rules for off-grid suppliers including waivers for installations below specified thresholds to spur interest in such projects. Such clarification would influence entrepreneurial activities (F1), guidance of search (F4) and resource mobilization (F6).

6.1.4 Finance

Remove bottlenecks in current import tax waiver process. Under the Energy Compact with the U.K government, GoSL, in response to industry requests, and in keeping with its renewable energy policy to provide "tax-free concessions on technologies" **(Renewable Energy Policy of Sierra Leone, 2015, p. 23)** is streamlining how the current import tax waiver is implemented. The current process increases cost, complexity and unpredictability by requiring businesses to seek in sequential order approvals from several government offices. Each office can hold up the process for any number of reasons, from absence of relevant officials to more arbitrary reasons. Ambiguities in the law and/or different government departments' interpretation of the law can further complicate matters because interpretation can become highly subjective, dependent on the official on duty. Resolving these bottlenecks is forcing different government agencies with jurisdiction (i.e. MoE) or influence (e.g. Finance, Customs) over the energy sector to understand greater national energy goals rather than narrow agency mandates. Better inter-government coordination of this kind is critical to removing frictions entrepreneurs are currently facing that can stifle a nascent industry. Implementing customs waivers will reduce consumer costs and be a boon to Sierra Leone's solar market. In the context of a TIS streamlining the tax waiver process facilitates learning (F2) and leads to development of networks (F3) within and diffusion of knowledge through the participating government agencies, private sector and other stakeholders (e.g. UK's Department for International Development (DFID)).

Create a multi-stakeholder committee to address the obstacles to financing identified during the 2nd March 2016 roundtable. The roundtable identified capital/loan risk and the lack of customer-focused financing products as major hurdles facing the industry. Resolving these challenges is neither quick nor easy. Financiers at the outset will, likely, be cautious, even skeptical about the viability of Sierra Leone's renewable energy potential and the credibility of the firms and customers. Traditional banks might be

the most risk-averse. Entrepreneurs, particularly those focused on the pay-as-you-go consumer sector (still unfamiliar to Sierra Leone), will need to prove business models. Those focused on rural consumers might face higher hurdles to prove that rural customers can pay per plan. A lot of education is necessary at the outset to build knowledge across the networks involved in financing. Once trust and confidence builds the participants are more likely to take experiment and take risks in pursuit of the market. We propose a standing multi-stakeholder committee that meets regularly, if necessary with a facilitator, to hash out various topics as a good forum for building trust, understanding the stakeholders' needs and diffusing knowledge. It is an example of how "networks" in a TIS (F3) that can play an important role in identifying policy needs, educating actors in the sector, removing blockages, and fostering public-private partnerships. Importantly, the committee's work can help direct the design of market-relevant financial products and requests for technical assistance from Sierra Leone's development partners targeted towards unlocking specific bottlenecks. These types of real-world outputs of such a standing multi-stakeholder consultative group will make actionable the current policy's intent to *"continuously improve the climate for enhanced funding of renewable electricity through equity, debt financing, grants and micro finance"* **(Renewable Energy Policy of Sierra Leone, p. 23**).

6.1.5 Data

Sierra Leone, according to its renewable energy policy, aims to *"increase access to electricity from 13% in 2013 to 82% by 2030, increase energy efficiency from 55% in 2013 to 91% by 2030 and double renewable energy level from 3,622 ktoe in 2013 to 9,315 ktoe by 2030"* (**Renewable Energy Policy of Sierra Leone, 2015, p. 13)**. Data collected through monitoring and evaluation is the only way to assess whether the country is on course to meet these goals.

Such data will inform learning; understanding the market opportunities; directing human and financial resources efficiently; directing search when weighing competing solutions (e.g. solar roof top versus diesel generator); communicating success and/or needs. These are fundamental TIS functions.

There is a dearth of data in developing countries like Sierra Leone. This affects decision making. Customer misinformation can be harder to disprove without firm data. Investors who do not understand a market are less likely to invest in the absence of reliable data. Collecting data, however, can be expensive; therefore, private investors will think hard about investing limited funding in this research. If they do, the market research is often, understandably, proprietary as it is critical to business strategy. MoE might decide that its limited resources are best spent pursuing projects rather than collecting and analyzing data. However, without good data there is a limit to how far Sierra Leone can get with a project-only focus. It is also hard to correlate energy-sector achievements with national poverty-reduction goals without data. Therefore, for GoSL, good data is important, not only, for communicating and marketing investment opportunity in Sierra Leone, but also as evidence that investment has raised living standards.

Compile and publish atlas/data sets of renewable resources. There is no easy way for prospective project developers to find data on renewable energy resources in Sierra Leone. As finance is fungible and competition from other countries is fierce, the onus is on GoSL and MoE to make Sierra Leone as

attractive as possible to potential project developers and investors. Detailed data sets showing renewable energy resources e.g. daily and seasonal solar radiation and mini hydro potential across the country are important for project developers and investors in modeling potential revenue from solar and hydro projects at prospective sites.

According to the **Renewable Energy Policy of Sierra Leone (p. 20)**, a 2008 mapping of Sierra Leone's solar potential estimated average solar radiation between 1,460 and 1,800 KWh/m^2/yr. This information should be made widely available. More sophisticated data that includes information on aerosols such as dust, smoke, particulates, haze that can partially block solar irradiation is extremely valuable in modeling scenarios closer to real world conditions. Early PV adopters in Sierra Leone have experience on the effect of aerosols on their system's performance. For example, the "**SIERRA LEONE HEALTH FACILITY ASSESSMENT 2015**" found that 10% of solar refrigerators intended to store vaccines failed *"because their (mostly solar) power supply is not reliable."* The failure of solar refrigerators has direct effect on health care delivery. Knowing solar irradiation ahead of installation could have helped understand and plan for expectations. Sierra Leone's partner government agencies (e.g. National Aeronautics and Space Administration and National Renewable Energy Laboratory in the U.S) and international agencies (e.g. International Renewable Energy Agency) may have data sets on solar radiation that can be published by MoE's and other GoSL's agencies. This type of cooperation can contribute to knowledge development (F2) and diffusion (F3) if lessons learned are gleaned and applied, otherwise it affects the legitimacy of solar technology.

Solar Installations in Sierra Leone

Health facility Installations – 206

Non-health facility Installations - 37

Mini-grids – 4

Note: this is not a complete count and the numbers shown could be an undercount. Further, the count includes installations that are privately-owned

Data Sources: Sierra Leone Health Assessment, 2015/ Energy for Opportunity / UNOPS / Personal

Capture and share data from publicly-funded solar and renewable energy projects. Fortunately, there is a ready source of untapped data about solar installations and mini-grids that could be made available to all solar market participants. For example, Sierra Leone has used solar refrigerators for vaccine refrigeration since 2002 **(Government of Sierra Leone, 2015)**. Over a decade of knowledge could be shared with other networks. More recently, NGOs and development-finance partners have funded important learning and seeding initiatives throughout the country including designing and operating solar mini-grids, training skilled technicians, and socializing solar technologies across differing user communities. The learning and data these efforts generate could be very important in bridging and diffusing knowledge across Sierra Leone's domestic solar sector. MoE should work with NGOs and their development finance partners to catalog and disseminate this knowledge in easily, searchable, usable formats.

The quality not quantity of energy connections is important to meet energy access goals. On the user side, simply counting increasing energy connections is not useful. Universal access is the goal of the Sustainable Energy for All (SE4All) initiative. The Energy Revolution aims to provide lighting through solar lights and home kits to currently unserved communities. MoE needs insight into whether and how the energy connections are improving energy access. Poor connections resulting in unreliable, low grade energy may increase the number of connections across the country, but do not improve quality of life

and could undermine credibility of solar lighting solutions if they perform poorly. For example, data show that in 2015, 62% of health clinics in Sierra Leone have vaccine refrigeration **(Government of Sierra Leone, 2015)**. One may be tempted to extrapolate this to electricity supply at health clinics. This would be incorrect. Only 34% of health facilities nationally had access to electricity in 2015. Solar refrigerators provide most vaccine refrigeration explaining the difference in the numbers. Further, 64% of the facilities with electricity had constant power supply during the prior seven days; indicating that roughly one-third of the 34% of health clinics with access to electricity were without in the measurement period. Understanding the quality of power connections and the energy services provided (e.g. lighting, refrigeration etc.) is more important than simply counting the quantity of connections. Poor quality services from renewable energy will undermine the legitimacy of the technologies affecting guidance of search, resource mobilization and ultimately entrepreneurial activity. Therefore, MoE should develop insight into quality of energy connections.

The World Bank's Energy Sector Management Assistance Program has conducted detailed energy access studies in Guinea and is planning a similar assessment in Liberia. These studies provide data on the quality of connections by user groups in Guinea and Liberia. MoE should consider requesting a similar assessment in Sierra Leone. This data will provide information on how Sierra Leone is meeting its Energy Revolution and SE4All goals; thus influencing the direction of search (e.g. if solar mini grids fail to meet consumer needs they will seek other solutions), providing market information and mobilizing resources more efficiently.

Consumer Attitudes. Understanding consumers' attitudes towards private power supply and their willingness to pay will be critical in successfully integrating private participation in to Sierra Leone's energy sector. Private firms will only pursue opportunities in Sierra Leone if financial incentives are right. GoSL's regulatory obligation is to maintain a fair balance between the interests of consumers and suppliers. GoSL and private actors need to understand where the balance lies. Will consumers be indifferent about whether power is supplied by private or public entities? Will consumer attitudes towards cost be influenced by the type of provider? What type of financing programs will work for consumers? We propose that GoSL conduct consumer surveys designed to understand these issues. Data from these types of studies influence all aspects of a TIS and GoSL's efforts to meet its sector goals.

6.1.6 Communication

Communication and messaging are key to the uptake of innovations. Whether through word of mouth or planned campaigns, positive or negative messaging about new ideas can influence consumer behavior and the desired outcome. For example, in the US, the government launched the EnergySTAR program that set technical standards to: 1) drive businesses to incorporate energy efficiency into products ranging from homes to appliances and electronics (e.g. televisions, refrigerators, computers etc.) and 2) communicate to U.S. consumers the differences between products to influence their behavior towards energy efficient options. The EnergySTAR logo is central to the initiative. Businesses can only affix the logo to products that meet minimum performance standards and consumers immediately understand that products with the logo have superior energy performance than those without it. MoE should launch a communication initiative to support the Energy Revolution. Such an

initiative will communicate in all media, at events and through other initiatives the program's benefits, its successes, renewable energy products and providers, solutions to common hurdles so users remain confident in the technologies, users' stories etc. On a broader level, meeting the Energy Revolution's goals, contributes to national goals stipulated by the Renewable Energy Policy of Sierra Leone (2015). Communication initiatives can support every function in a TIS.

6.2 Long-term Activities towards building a Domestic Private-Sector

We propose two long-term (greater than two years) initiatives that connect energy investment/policy with socio-economic development and create an environment that encourages both foreign and domestic investment.

6.2.1 Integrate Renewable Targets into Sector and Social Planning

Power sector planning across Africa often only considers the technical side of planning electricity generation, and often only for large central grid-tied facilities. While the purpose of delivering reliable, affordable energy is to enable socio-economic goals, these goals are not often well integrated into energy ministries' planning efforts. Energy access, energy efficiency, social goals and increasingly climate-related goals are not often considered early in energy planning. Integrated Resource Planning (IRP) is a means to tie the supply side planning with consumption and other national goals. An IRP that considers how distributed solutions make sense for users beyond the grid should automatically be forced to consider renewables and lead towards an integrated top down (i.e. central grid-tied power plant) meets bottom-up (i.e. off-grid solutions) approach. It would clarify the range of actors beyond MoE that have a role and influence in the success of Sierra Leone's off-grid strategy. For example, the Ministry of Finance and Economic Development is a key partner in implementing the custom duty waiver that is important to MoE's strategy. Further, such an IRP would delineate that the needs of rural electrification are different from urban and commercial electricity needs.

It could also incorporate social goals more directly. For example, Sierra Leone has maternal and child wellness goals. Many factors influence when and how these goals are met, but the absence of reliable electricity at 66% of the country's health facilities **(Government of Sierra Leone, 2015)** definitely hinders the country's health aspirations. MoE could consider a (pilot) project to deliver reliable electricity to all government health clinics across the country. Such a project, designed well, to include not only installation but also operations and maintenance, could be put out for bid (one or more) with a strong encouragement for domestic and foreign investors/project developers to partner in their proposals. It would be necessary to determine an appropriate level of aggregation for the pilot to provide sufficient scale to be interesting to private sector suppliers. It would require MoE to partner with the Ministry of Health and Sanitation and a range of development partners to design and fund the project. But this is a potential example of integrating social outcomes into energy planning and rural electrification, while creating opportunities for domestic private sector/NGOs.

Other examples include integrating climate protection goals (e.g. forestry protection efforts) into energy planning. Such integrated projects would involve every function within a TIS.

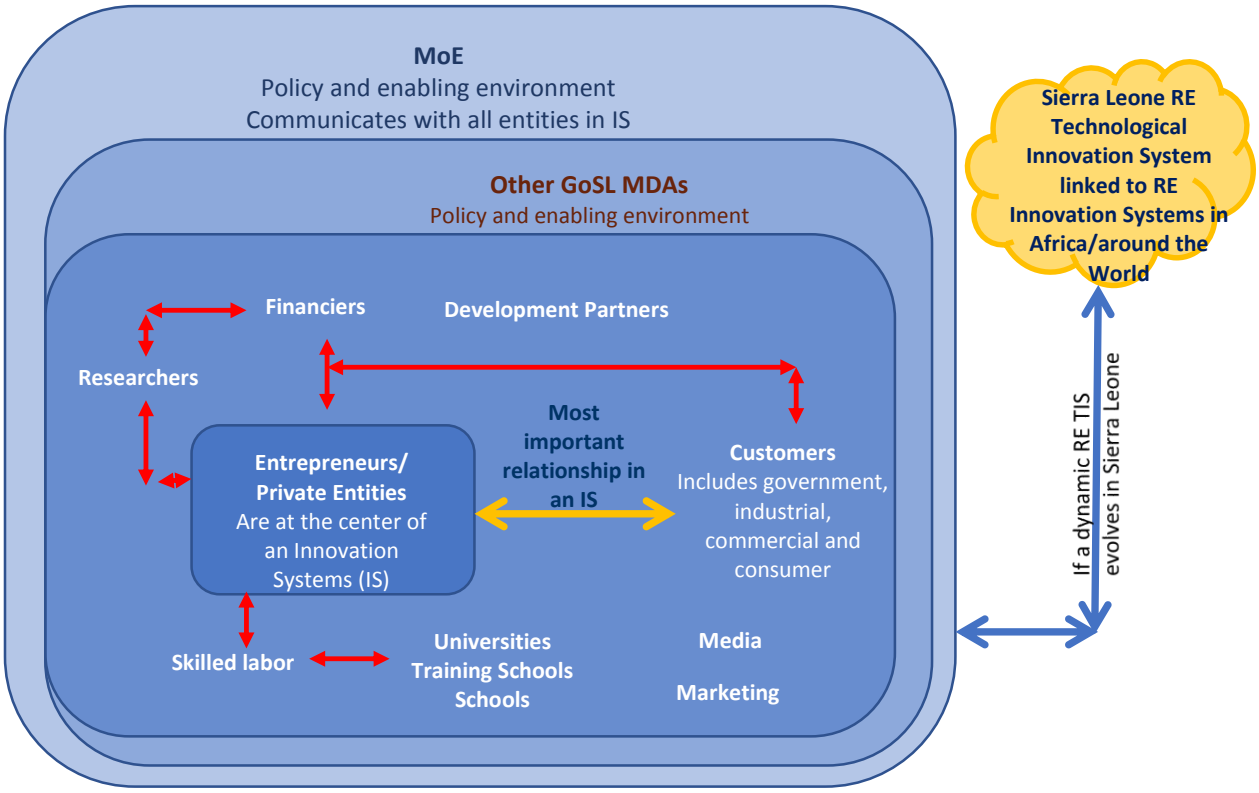
6.2.2 Improve domestic financiers/banks' capability to lend to domestic enterprises and their capability to raise financing from domestic and foreign financiers/investors

Sierra Leone, like all developing countries, will need to find other sources of financing beyond ODA to meet its development needs. The nascent domestic renewable businesses and NGOs face formidable challenges to fund potential projects. Government policy is critical to create incentives for private financing and de-risk the market. In 2013, U.S. Agency for International Development (USAID) Nigeria supported a comprehensive initiative to support the development of the renewable energy market in Nigeria. The **Promoting Renewable Energy and Energy Efficiency** project (USAID, 2013), intended to run to 2017, had three goals: 1) to develop a Development Credit Authority instrument (up to $1M) to provide partial credit guarantees to local banks (initially Ecobank and FirstBank) to increase debt financing to the clean energy sector; 2) set up the Global Development Alliance with the Private Financing Advisory Network to link investors/financiers with clean energy project developers to help produce "bankable" projects and equity financing proposals; and 3) provide technical assistance for the successful implementation of the initiative. The USAID Nigeria initiative focused on strengthening the capacity of domestic banks to lend to small and medium enterprises to provide energy solutions to a wide range of sectors in Nigeria including health and agriculture; and further to prepare these domestic businesses for foreign investors/financiers. MoE should examine whether this USAID Nigeria project could be a template for Sierra Leone. Nigeria's market is more mature than Sierra Leone's and better able to absorb such support tailored to its domestic banking and small and medium enterprises. However, understanding the prerequisites could provide a blueprint that could be tailored to Sierra Leone's particular conditions. It will make actionable Sierra Leone's renewable energy policy's intent to *"continuously improve the climate for enhanced funding of renewable electricity through equity, debt financing, grants and micro finance"* **(Renewable Energy Policy of Sierra Leone, 2015, p. 23)**.

7.0 Viewing Sierra Leone's nascent renewables energy sector through a Technology Innovation Systems framework

The pick-up in renewable energy activity in Sierra Leone is not accidental. It is occurring because Sierra Leone has connected to the global renewable energy TIS. Actors who have gained experience in or information from other countries are entering Sierra Leone's market independently and through MoE's encouragement. These early movers are forming networks and influencing the rules of the game. Not all these early entrants will survive. This is the nature of early TIS development and should not be discouraging. The key is whether Sierra Leone can create sufficient positive momentum to create an

enabling environment that not only draws in new actors but is flexible enough to respond to the actors' changing needs as the sector evolves.



- MoE leads and facilitates activities with other GoSL agencies. Sets policy and rules for enabling environment.
- Redefine role of private entities
- Knowledge development and sharing through networks
- Building customers' confidence in renewable energy solutions
- Seeding, nurturing, creating markets

Figure 3: Key actors in Sierra Leone's Renewable Energy TIS

The initiatives we recommend in this paper support MoE-sponsored initiatives currently underway in Sierra Leone e.g. renewable energy policy, Energy Revolution, Energy Compact. Our recommendations focus on areas that are currently neglected but are important foundations for a successful TIS. Each recommended initiative maps to one or more of the seven functions of a TIS (See Appendix 1). These initiatives, which are to be led by GoSL, do not preclude private-sector led initiatives or engagement. We focus on initiatives that private-sector is unlikely to fund, but are necessary and influence whether private developers enter a market. Our recommendations are intended to complement and nudge existing efforts towards a positive reinforcing effect that is necessary for forming a TIS.

The activities currently underway in the Energy Revolution, Energy Compact or the ones we recommend are by no means the final ones that GoSL or other stakeholders will undertake. These activities will yield follow-on efforts. New actors will emerge who will close existing gaps and identify emerging ones. The advantage of the TIS framework is that it can be overlaid on current or future activities to assess their

effectiveness including identifying functions that are being neglected. The aim is to have a right balance of effective activities across all seven TIS functions. This raises the number of direct and indirect interactions, planned and unplanned interactions that can give rise to a TIS. If efforts are skewed towards only a few functions the creation of a vibrant TIS might stall. Any of the actors in a TIS (e.g. entrepreneurs, government, universities or other organizations) can apply the framework from their perspective to identify and assess interventions they may undertake. We hope future research can utilize Bergek et. al's **(2008)** methodology (Figure 1) to assess the inducements and blockages presently underlying Sierra Leone's efforts to create a vibrant renewable energy sector.

New actors, networks and initiatives constantly emerge in response to gaps hindering a TIS

In December 2016, to address a financing gap hindering the Energy Revolution's goals, REASL and the Sierra Leone Association for Microfinance Institutions (SLAMFI) launched a pilot program to enable 1,000 families to purchase solar home kits. The pilot will provide the financial sector with a "better understanding of the business opportunities presented by the emerging solar market."

Source: Power for All (www.powerforall.org), "**Today the Sierra Leone Association for Microfinance Institutions (SLAMFI) and the Renewable Energy Association of Sierra Leone (REASL) launched a pioneering household solar pilot project" 2016**

Appendix 1

In this section we map current activities in Sierra Leone's renewable energy sector and the initiatives we propose in Section 6 to the building blocks and functions of a TIS.

Figure A1 summarizes the building blocks of Sierra Leone's nascent renewable energy sector. The composition of each building block will change as the TIS evolves.

Figure A1. Building Blocks of Sierra Leone's nascent renewable energy Technology Innovation System

Building Blocks	Energy Revolution
Actors (e.g. entrepreneurs, government, universities or other organizations) in the supply chain undertake activities to promote a specific technology	MoE, Other GoSL Agencies International governments and development organizations: e.g. UK Government/DFID/Sierra Leone Opportunities for Business Action/Power for All Domestic enterprises (private sector, NGOs, cooperatives etc.) Foreign private enterprises REASL SLAMFI
Institutions that align to influence "rules of game"	MoE, other GoSL MDAs International development organizations: e.g. DFID, SOBA, Power for All REASL SLAMFI
Social, political or learning networks emerge to influence the technology's uptake	Barefoot Women REASL SLAMFI Power for All
Technological factors such as the costs, performance, safety, standards etc. of a technology are increasingly clarified	Standards Bureau

Dynamic change in a TIS occurs through its functions. Figure A2 maps the Energy Revolution and the recommendations in this paper against the seven functions.

Figure A2. Mapping the Energy Revolution and recommended actions to the Technology Innovation System Functions

Technological Innovation System Functions	**Energy Revolution**	**Energy Revolution + Recommended Initiatives in this Paper**
Function 1: entrepreneurial activities – "Entrepreneurs are essential for a well-functioning innovation system	REASL members Private sector entities not within REASL	REASL members New domestic and foreign firms and NGOs
Function 2: knowledge development –Learning is at the heart of an innovation	REASL members Barefoot Women Power for All SLAMFI	REASL members Domestic financial firms (includes traditional banks and non-traditional firms such as mobile money)
Function 3: knowledge diffusion through networks – Networks facilitate exchange of information	Barefoot Women REASL Power for All SLAMFI	Energy Revolution networks plus - Finance sector workgroup - Technical standards - Communication campaigns
Function 4: guidance of the search – Resources are limited so they should be focused for maximum effect	MoE Renewable Energy policy MoE – DiFD Compact Other donor initiatives e.g. SE4ALL, SREP Customs waiver / goods and sales tax (GST) waiver /Financing initiatives	All activities under Energy Revolution, plus - Renewable energy targets - Threshold exemptions from permitting - Regulations permitting entities other than ESDA to supply and distribute power
Function 5: market formation – Creating a space so that niche markets for innovations can take hold and ultimately challenge incumbent markets	Energy Revolution Targets - Solar lights - Home kits - Customs waiver / GST waiver REASL/SLAMFI Financing Pilot	Energy Revolution targets plus - targets for all renewables; i.e. solar kits and other renewable installations) - Finance sector workgroup - Communication campaign - Data availability
Function 6: resource mobilization – Financial and human resources are necessary to secure the inputs for an innovation system	Energy Revolution Sierra Leone - UK Energy Compact	Energy Revolution activities plus - Standing finance work group - Data availability - Communication campaigns
Function 7: creation of legitimacy/counteract resistance to change – Creating social credibility for a new technology so it becomes a part of or dislodges the incumbent system	Paramount Chiefs' backing District solar ambassadors REASL-SLAMFI Finance Pilot	Energy Revolution activities plus - Technical standards - Communication campaign - Successful projects

Each of these functions can be further disaggregated. Figure A3 drills down into one function as an example: Function 4 – Guidance of Search. Each initiative can be further disaggregated to understand how it influences the guidance of search (Function 4). For example, in Figure A3, the initiatives cover policy, regulation, marketing and communication.

Figure A3 – Drilling Down on Function 4: guidance of the search – Resources are limited so they should be focused for maximum effect

Initiatives and Issues	**Energy Revolution**	**Energy Revolution + Recommended Initiatives in this Paper**
Renewable Energy policy	Published	Policy continuously evaluated using the TIS framework
Renewable energy targets	Targets for: - solar lights - home kits	Renewables goals beyond solar lights and home kits
Fiscal policy	Customs waiver GST waiver	Finance working group could identify other fiscal incentives REASL members identify new fiscal needs
Financing Accesses	REASL – SLAMFI Pilot	Finance working group identifies other initiatives to finance renewable energy products, projects, services
Regulatory gap – Guidelines for permitting entities other than EDSA to supply and distribute	No	Issue needs to be clarified for businesses and NGOs
Regulatory gap to meet policy vision - Threshold exemptions from permitting	No	Recommend setting an exemption threshold
Data availability	No	Capture and make available results of publicly- and donor-funded renewable project Refine solar irradiation data across country
Communication and messaging programs	Public service announcements by MoE	Consumer- and customer-focused initiatives Investor-focused / Business-focused Influencer-focused

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Needless to say, we take full responsibility for any and all errors and omissions.

Ronke Luke, Chukwu-Emeka Chikezie, January 2017

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