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Best Practices for Developing a Solar Home Lighting System Market

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Access to electricity and home lighting are considered essential for a higher quality of life. Approximately 1.4 billion people rely on fuel-based lighting for home illumination. Thus, it has been argued, a substantial market exists for affordable home lighting products. Solid state lighting is a technology that can be employed for sustainable home lighting. In this article the authors present experiences and lessons learned from projects that "Light Up The World" has supported to deliver solid state home lighting products to rural households in developing countries. Best practices for business developments to serve the home lighting market in Africa are also proposed.

KEYWORDS best practices, home lighting, solar, solid state lighting

INTRODUCTION

Energy is the hallmark of modern society, with artificial home lighting being one of the most widespread applications (Smil, 2003). Until the advent of the electric incandescent light bulb in the late nineteenth century, home lighting was predominantly obtained using fuel-based sources such as oil lamps, gas lamps, and candles. Since the commercialization of the electric bulb, modern societies have rapidly shifted to electric lighting, which has been made possible due to the parallel expansion of large-scale electricity generation plants and distribution grids. There are, however, great inequalities in access to

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artificial home lighting throughout the world. The International Energy Agency projects that as many as 1.4 billion people remain without access to electricity (IEA, 2010). In nonelectrified communities, households rely mainly on fuel-based sources for home lighting such as kerosene wick lamps, candles, and biomass burning (Bhusal, Zahnd, Eloholma, & Halonen, 2007; IEA, 2010; Mills, 2005). Recent technological advancements in solid state lighting (SSL) have the potential to significantly alter the electricity landscape, in particular for home lighting. SSL utilizes white light emitting diodes (WLED) as the light source. The rapid advancements in WLED technology since the late 1990s have made it possible to develop small-scale home lighting systems at a cost that, when amortized, can be significantly lower than what many low-income households currently spend on home lighting. Combined with the lowering costs for solar photovoltaic technology, rural electrification practitioners have more effective technological options to expand access to home lighting (Andrews & Crain, 2009; Lighting Africa, 2010b; Mills, 2005; Peon, Doluweera, Platonova, Irvine-Halliday, & Irvine-Halliday, 2005; Pode, 2010).

If a technology that can provide adequate lighting services with fewer resource inputs is available, how can it be delivered to households that would benefit from its use? Prahalad and Hart (2002) point to the vast population without access to products and services as a lucrative market opportunity for the private sector.[1] This position has been challenged, however, on the basis that market development involves a complex process of product adoption (Simanis, 2009). As Martinot, Chaurey, Lew, Moreira, and Wamukonya (2002) reported, many home lighting programs designed in part to stimulate economic activity and growth in the renewable industry have failed to anchor the technology. Instead, programs resulted in a one-time purchase of equipment instead of establishing a market that would sustain a long-term supply network.[2] Thus, it is argued, satiating the demand for improved home lighting options is not likely to be achieved through simplistic approaches nor as a venture incurred by an individual entity.

This article explores business approaches to serving the off-grid home lighting market from the perspective of Light Up The World (LUTW)[3], a nonprofit organization dedicated to bringing renewable energy–based lighting systems to off-grid communities. Since its inception in 1997, LUTW has worked to expand access to solid state solar home lighting systems in rural communities as a method of promoting socioeconomic objectives such as literacy, education, and human development. LUTW has partnered with international solar and SSL industry leaders and supported more than 220 nonprofit organizations working on solar lighting projects in over 50 countries (Craine, Lawrance, & Irvine-Halliday, 2002; Irvine-Halliday, Craine, Upadhyaya, & Irvine-Halliday, 2000; Robertson, Craine, Irvine-Halliday, & Stone, 2002; Schultz, Platonova, Doluweera, & Irvine-Halliday, 2008). LUTW's experience is diverse and covers many aspects of market

development from hardware development to maintenance services for solar home system users.

The objectives of this article are to (a) review the home lighting market in developing countries, (b) review the various dimensions of a private sector response to demand for home lighting from households outside the electrical grid, and (c) share the lessons from LUTW's experiences that can be translated into business approaches to delivering solar home lighting services to the low-income households in Africa. The first section of this article examines the current state home lighting market in developing countries.[4] The second section deconstructs the market creation experiences of LUTW, with insight into a project being implemented in Costa Rica. The final section attempts to translate the experience and lessons learned into practical recommendations for private sector agents that have an interest in serving the home lighting market.

THE STATE OF THE HOME LIGHTING MARKET

Fuel-Based Lighting

Of the 1.4 billion people in the world without access to electricity, the IEA (2010) estimates that 589 million of them live in Africa.[5] The type of fuel-based lighting used by those who do not have access to electricity depends on the level of income and access to lighting fuels. Kerosene lamps are by far the most commonly used fuel-based lighting source (IEA, 2010; Mills, 2005; Pode, 2010). The types of kerosene lamps that are being used include simple wick lamps, improved wick lamps with chimneys, hurricane lanterns, and pressurized kerosene lamps with candoluminescence mantels. Of these lamps, the most widely used type by users in rural households with low-incomes is the simple wick lamp.

Fuel-based lighting sources produce toxic gases and volatile organic compounds which can lead to severe health problems such as respiratory infections (Peon et al., 2005; Pode, 2010; Schwebel, Swart, Hui, Simpson, & Hobe, 2009; Smith, Samet, Romieu, & Bruce, 2000). Risk of injury, death, or property destruction due to burn accidents is another adverse affect of fuel-based lighting. Surveys conducted by LUTW in Nepal and Sri Lanka reported burn accidents of some degree once in every month due to kerosene lamps (Irvine-Halliday, 1999; Leon & Graham, 2005).

Despite the poor performance and risks, in LUTW's experience, the popularity of kerosene and fuel-based lighting in general is partially due to the lack of need for upfront capital expenditure. Furthermore, due to the high reliance of rural communities on kerosene, it is frequently heavily subsidized in order to insulate the users from rising fossil fuel prices, and the level of subsidies can be high as 40% or more (Bacon & Kojima, 2006). Kerosene, as a fluid compound, is easily divisible, which means it can be

purchased in small units. This feature of kerosene creates the perception of affordability and has contributed to kerosene use becoming deeply entrenched in the consumption structure of villages. The supply chain is well established and extensive. The annual global market for kerosene as a source of light is estimated to be worth between US$30 and $40 billion per year (IFC, 2007; Mills, 2005), of which approximately US$17 billion is spent in Sub-Saharan African countries.[6] The amount that is spent on lighting fuels largely depends on household income. Average expenditures on lighting fuels can be as high as 10% to 20% of the monthly household income (Peon et al., 2005). A survey conducted by LUTW in Rwanda, Uganda, and the Democratic Republic of Congo in 2006 found that low-income households spend up to US$40 per month on kerosene (Schultz et al., 2008).

Solar Home System Market

A primary barrier for rural electrification is the substantial capital investment required to build electricity generation and distribution infrastructure. The current electricity demand in rural regions, which is dominated by home lighting loads, is typically insufficient to justify the infrastructure investment. Solar photovoltaic (PV) home systems (henceforth referred to as "solar home systems [SHS]") are considered a cost-effective and robust decentralized option for rural electrification. A typical SHS consists of a 15- to 100-Wp PV module, battery, charge-controller, and end use appliances (Martinot et al., 2002; Pode, 2010; Terrado, Cabraal, & Mukherjee, 2008). The number of devices, such as lights and radios, which may be used, depends on the size of the SHS and energy consumption of the appliance, while home lighting is an energy service provided by all SHS. Smaller systems provide home and portable lighting. The choice of light bulbs in typical SHS is direct current (DC) linear fluorescent lamps (LFL) or/and compact fluorescent lamps (CFL). The World Bank estimates that more than 2.5 million SHS are installed worldwide and over 850,000 units are installed in Africa (Lighting Africa, 2010b).

Since the 1980s, governments and donor agencies have promoted and supported the diffusion of SHS in developing countries through grants, subsidies, loans, and capacity building. A prominent initiative is the program initiated by the World Bank Group in 1990s to remove barriers and to accelerate the diffusion of SHS in developing countries (Martinot, Cabraal, & Mathur, 2001). While a main objective of these initiatives was to enhance markets for SHS and remove barriers for their dissemination, the results have been mixed (Martinot et al., 2001; Martinot et al., 2002; Wamukonya, 2001).

As Martinot et al. (2002) describe, many government and donor led home lighting programs were ineffective as they failed to "demonstrate institutional and commercial viability and lacked mechanisms for equipment maintenance, sustainable sources of credit and expertise, and incentive structures for sustained operating performance." Program budgets were skewed

largely toward upfront investments in equipment, based on the misconception that solar systems required little maintenance in the short term and could be maintained with minimal training. Pressure on donors to meet certain installation targets also had an adverse influence on project development and was another source of failure. In the case of renewable energy programs that were not well established and subsequently did not continue, conditions for private sector are arguably in a worse position than before the government led initiatives. Although many of the government and donor initiatives mentioned above did stimulate demand for hardware, they did not sufficiently promote technical knowledge in the area of solar systems. This role may be filled by nonprofit actors.[7]

In Wamukonya's (2007) assessment of the effectiveness of the use of SHS for rural electrification in Africa, the higher cost of SHS compared to conventional generation is still a major barrier for the diffusion of SHS. The same study argues that the users' misconceptions about the service SHS are capable of providing in market survey stage and the difference between users' willingness and ability to pay as primary reasons for the disparity between the forecasted demand for SHS and real uptake.

Some general lessons can be drawn from SHS initiatives and incorporated into business approaches to provide lighting services to developing countries. Although SHS that provide home lighting services do not directly increase incomes, the health and education benefits of replacing kerosene and other fuel-based lighting sources are significant and critical for human development. Furthermore, they may lower lighting expenses contributing to higher disposable income (Cabraal et al., 2005; Irvine-Halliday, Doluweera, Platonova, & Irvine-Halliday, 2008; Martinot et al., 2002; Schwebel et al., 2009). In LUTW's experience, the educational benefits, lower indoor air pollution levels, reduced threat of house fires, and cost savings are some of the most frequently cited benefits of acquiring an SHS to replace kerosene as a lighting fuel. Therefore, a substantial market may exist for home lighting systems if they are affordable to low-income users who have limited access to capital. Although SHS are a costly method of providing full electricity services, they are one of the most technically feasible options to provide clean and robust lighting services to off-grid rural users in developing countries.

Solid State Home Lighting Systems

Solid state home lighting systems (SSHLS) are a subgroup of SHS. They are mainly home lighting systems where WLED-based lamps are utilized instead of LFLs or CFLs. There are some distinct advantages of SSHLS over conventional SHS. WLEDs have gone through rapid technological developments. The luminous efficiency of WLED lamps is already comparable to CFLs and on a trajectory to surpass that of LFLs. The efficiency gains lead to lower

energy requirements, reducing the overall cost per system. An advantage of the SHS is their modularity, where the system size can be increased as the demand, and possibly the affordability, rises. SSHLS have an even higher modularity advantage. WLEDs are available from sizes as small as 0.1 W and therefore they can be modularized to make lamps with different power consumption rates and light outputs, providing more design options for SSHLS.[8] This allows the end user to start with a smaller basic system, which emits a greater quantity of light output than a kerosene wick lamp. The technology advancements, therefore, are increasing the number of opportunities for the private sector to supply affordable small-scale home lighting products to the low-income households.

LUTW, along with its partners, has conducted both technical and market experiments with SSHLS of varying magnitudes since 2000 (Doluweera & Irvine-Halliday, 2007; Irvine-Halliday et al., 2000; Irvine-Halliday et al., 2008; Peon et al., 2004; Robertson et al., 2002). The World Bank Group has undertaken a major initiative titled "Lighting Africa" to provide home lighting for Africa using WLED based products through market driven approaches (Lighting Africa, 2010a).

The conditions in any market place are dynamic. This means the incentives to supply products or services in a market evolve as the competitive, technological, regulatory, demographic, and infrastructural conditions shift over time. Uptake on SSHLS would be minimal, though, if there were not the improvements in solar technology efficiency and manufacturing processes, which have resulted in greater affordability.[9] Furthermore, we know that technology is the primary factor to expanded solar home system use because, in many cases, household incomes are not changing significantly enough to warrant significantly higher rates of acquisition. Technology advancements alone, however, are not sufficient for market creation. The process of market creation for SSHLS is discussed in more detail below.

Solar Home Lighting Project Case Study

Rural home lighting projects carried out by LUTW and its partners range from strictly donor-based SSHLS delivery to quasi-business approaches where the end users pay a fractional cost of the equipment. In this section we present the project details and the lessons learned from an ongoing home lighting project that takes a market-based approach in Talamanca, Costa Rica, where LUTW provides equipment and technical support. While appreciating the diversity of the socioeconomic conditions between Costa Rica and African countries, we are confident that the lessons learned from this project are useful for any home lighting system business development.

The Talamanca solar home lighting project aims to replace the use of kerosene wick lamps and candles with SSHLS. This Costa Rican–based nongovernmental organization, ACEM (Asociación para la Ciencia y la Educación

Moral), which is the lead implementing partner in the project, has been actively working in Talamanca since 2005. The focus of ACEM's work in the region has been to address community development challenges through youth-focused education programs.[10]

The solar home lighting project has proceeded in two distinct phases: a 9-month pilot project implemented in 2008 and a scaled-up implementation phase that began in 2009. ACEM has been responsible for promoting the project in communities and identifying project beneficiaries. Community consultations and household baseline assessments were undertaken prior to the pilot phase of the project to determine the energy and lighting needs of households. Following the prefeasibility assessment, SSHLS were installed in various communities in the region where education programs were being implemented. In the pilot phase, SSHLS consisting of a 5-W solar panel, two LED lights, and 12 V/7 Ah sealed lead acid (SLA) battery were installed in 67 homes. The intention of the pilot project was to test the performance and appropriateness of the solar home lighting system. An internal evaluation of the pilot project conducted by ACEM revealed that the SSHLS were marginally meeting the lighting needs of households. As a consequence, the solar home lighting system was modified so that it would have the capacity to provide additional light hours for households and increase system autonomy, making the system more useful for end users during the rainy seasons. The revised SSHLS consists of an 11-W solar panel, two LED lights, and a 12 V/12 Ah SLA battery. A 6-amp charge controller was also added to protect the system as a whole and provide end users with information about the battery's state of charge. Households have also been given the option of adding a cell phone charger and additional LED lights to their SSHLS at an additional charge.[11]

Creating awareness of the benefits of solar technology and education about how it can be applied to the local context has been a core objective of the project implemented by ACEM in Costa Rica. A group of carefully chosen individuals who are recognized as leaders in their community and live in the project areas have been the focus of training workshops. These individuals have been trained to become solar technicians, understanding electricity basics and possessing the skills necessary to install a solar home lighting system, perform basic troubleshooting, and replace damaged components. Follow-up training courses have exposed these technicians to solar system design concepts as well as core solar and electricity concepts. Households that have received solar home lighting systems are also provided with basic training on how to operate the solar home lighting system and perform very basic troubleshooting. The Talamanca project is overcoming the barrier to acquisition through a financed purchase approach, which is facilitated by ACEM. The project concept involves households diverting the amount that they used to spend on a monthly basis on kerosene and candles to repaying the cost of the SSHLS. The cost of the basic system to project participants is US$220. Repayments are collected on a monthly basis and are structured

according to a household's economic situation. The intent behind basing repayments on existing expenditure patterns is so that the improved lighting system can be put in place without burdening households beyond their economic means. It is interesting to note, however, that although it was recommended that payments reflect a household's preexisting expenditure pattern for home lighting, most households involved in the project have chosen a monthly payment amount that exceeds their typical monthly lighting expenditures. This may suggest that some households in this community prefer to pay off the loan earlier rather than carry debt. The majority of households pay approximately US$20 per month and will have paid for the system in full within a 12-month period.[12]

Establishing supply networks for products and services is critical to the long-term success of the project. Thus far, equipment procurement has been managed by LUTW and ACEM. The majority of the system's components are still imported due to quality and affordability factors. Thus far, importing components such as solar panels, charge controllers and LED lights has not posed a significant challenge. That being said, attempts are being made to maximize the involvement of local businesses and their supply networks. Although the majority of components that make up the solar home lighting system are not yet available in the commercial centre of Talamanca, some entrepreneurs in the area have expressed an interest in selling batteries in inventory that will be sold as replacements. Linkages to other component suppliers will continue to be explored as the project expands so as to ensure the long-term sustainability of the solar home lighting market in Talamanca.

BEST PRACTICES FOR SUSTAINABLE SSHLS BUSINESS DEVELOPMENTS

As discussed earlier, establishing the infrastructure and supply networks to maintain a market is complex and requires analysis. Martinot et al. (2002) agreed that laying the foundations for the market is the most difficult aspect of planning any project. Therefore, before entering a market, the most important thing to consider, arguably, is the long-term viability and sustainability of the business models and institutional dimensions. Of the numerous projects that LUTW has supported, many have been successful and many others have failed to achieve long-term sustainability. The reasons for project failures are diverse. In cases where solar lighting projects are sustained, their success has largely been attributed to the careful planning and consideration of a number of critical factors. The critical success factors and a number of best practices to address the development of these vital market foundations are discussed below. These best practices have been identified from LUTW's projects, including the one described here, as well as from similar experiences reported in published literature.

Selecting Location and the Strategic Business Partner(s)

A solar home lighting business venture may begin with the proponent company selecting the location(s) and the business partner(s) that will be involved.[13] Entrepreneurs can begin to research areas of opportunity by communicating with government authorities responsible for electricity distribution to identify the locations where grid extension is not only currently unavailable, but also deemed as uneconomic. Ideally, national governments will be able to provide this information to companies. This was the case in the Philippines where there is a formal rural electrification planning process that specifies villages where grid extension is not viable (IFC, 2007). Companies can also seek areas of market potential by researching nongovernmental organization, government, or other donor activities in the country and the areas of predominance. Companies can also take advantage of expanding communication networks and locally established organizations to carry out preliminary location research.

One of the keys to entering a new market is affiliating with strategic partner(s).[14] Strategic partner(s) are public or private sector organizations that have an operating infrastructure that is used to deliver some good or service to the target community. A relationship with the organization can be leveraged to deliver SSHLS to the targeted population segment. For instance, strategic partners can facilitate initial market research activities and help to overcome the various barriers to market development through their interactions with the target population. In essence, partner organizations can help to reduce the costs of market development.[15] It is important to bear in mind that any external business will inherit the reputation of the partner with which it chooses to associate. Therefore, partnership selection is a process that should not be rushed. A successful approach is to establish partner selection criteria that specify the desired characteristics for a strategic partner. Candidate organizations can then be evaluated based on their ability to demonstrate that they fit the desired profile (Adkins, Eapen, Kaluwile, Nair, & Modi, 2010). LUTW continues to adapt its criteria for project partner selection. Generally speaking, LUTW is of the opinion that suitable project partners are organizations that share mutual objectives, have a strong commitment to the benefits of the initiative, have access to resources, and possess a useful network in the targeted area that can be used to interact with the targeted population frequently. Establishing clear roles and responsibilities for each partner involved is also critical to the success of a solar home lighting business venture.

Understanding the Needs of Targeted End Users and Appropriately Matching Solar Home Lighting Systems to User Needs

Characteristics of the products offered are a critical factor for the success of a business to provide home lighting products to rural communities. The

products should match the intended users' needs while being affordable. The majority of successful commercial ventures begin with a well-founded understanding of demand conditions and the lifestyles of the population segment that they wish to target with their product or service. The home lighting market is no exception. Many projects and business initiatives fail because the solar home lighting product is inappropriately matched to the needs of households. The World Bank argued that, "successfully tackling electrification means adapting programs to local contexts and national environments" (The World Bank, 2011). While it is widely known that households use kerosene for home lighting, companies must possess a deeper knowledge of energy and lighting needs at the household level and how they relate to the social, cultural, and economic activities of a household. This is necessary to ensuring the utility of the solar home lighting system. The IFC (2007) concurred that market segmentation embedded in economic standing and lifestyle complicated the development of the solar lighting market. Best practice is to carry out a baseline survey that involves an activity and item based energy budget. Community consultation may also serve as an effective tool to mitigate the risk of technology rejection due to cultural inappropriateness, economic, political, or other reasons. For instance, following the pilot phase of the project reported earlier, the system design was changed after consulting households about their experience with the systems. Strategic partners play a key role in developing this expanded understanding of how solar home lighting systems can be integrated into household life.[16]

The provision of a demonstration system as part of market experimentation is another best practice to learn the value perceptions about the SSHLS that may be introduced and specific product preferences. Market experimentation is a useful way of determining the potential of a product prior to a company allocating a significant quantity of resources into a marketing plan and promotion activities. Experimenting with products that fall under different typologies is particularly useful in distinguishing market preferences. Testing different types of products in parallel and in sequencing the introduction of new SSHLS products with more features is a constructive method of discerning perceptions about product value. For instance, in 2010 LUTW was involved in a phased pilot project that tested various solar lighting products.[17] After the initial pilot phase, 91% of households that received the task specific portable lighting product expressed an interest in purchasing additional units of the product. After receiving the solar home lighting system a few months later, however, all of the respondents changed their minds and abandoned their plans to purchase an additional task specific portable lighting product. It is important to note, that the another portable lighting unit, which was designed for more general lighting purposes, continued to be in demand by households even after the introduction of the solar home lighting system. This stark change in consumer response reinforces the notion that consumer value perceptions are dynamic and that the introduction of

new solar lighting technology can quickly consume the market share of other lighting systems that were once in demand. Therefore, companies should be open to supplying a range of products in order to ensure they have the flexibility to respond to the changing demands and sensitivities of clients.[18] LUTW's experience has also shown that portable solar lighting products such as lanterns can be appropriate introductory lighting systems that help to familiarize users with solar lighting technology. As was mentioned previously, the introduction of a solar lighting system that results in lower lighting expenses for a family can increase disposable income of a household. Greater savings can be used in the future to upgrade to more capital intensive solar home lighting systems in the medium-term and even systems that can be used for productive purposes in the long-term.

Financing Home Lighting System Purchases

A strong correlation exists between the level of income and access to clean and efficient energy services (IEA, 2010). In general the household's choice of fuel and appliances is constrained by the wealth and disposable income (Pachauri & Spreng, 2004). This means the likelihood that people with lower income have a large sum of discretionary financial resources available to invest in a SSHLS is low. Financing the purchase of SSHLS is arguably the primary barrier to households obtaining this technology. It has been estimated that there are between 2.5 to 2.7 billion working-age adults who lack access to formal financial services[19] (CGAP, 2004; Lafourcade, Isern, Mwangi, & Brown, 2005), a primary means of acquisition. SSHLS that are part of market experimentation exercises should consider the local economic conditions and possible payment methodologies that could potentially be employed to facilitate the ownership of systems. If the targeted population segment does not have access to formal financial services, the business should try to identify informal finance mechanisms used in the community or ensure they are working with a strategic partner that as previous experience with financial transactions in the community. For example, a partnership with a centrally located shopkeeper or a cooperative with an extended network for purchases may serve as suitable partners that can help the business address the finance gap. Leasing programs, in which solar home lighting systems are never owned outright, may also be an option to consider. The collection of a regularly scheduled payment into perpetuity, however, requires a permanent administrative infrastructure. Best practice is to consider financing options at the partner selection stage.

Technology Awareness Creation and Educating End Users

Communicating the benefits of switching from kerosene and candles to a solar home lighting system is fundamental to marketing any product that is

designed as a replacement. As Simanis (2009) outlines, a typical tactic used by companies when introducing new technologies that require a behavioral change is to launch an awareness campaign. He also points out that awareness programs can be complicated and require frequent messages that reach a broad audience. For solar home lighting systems, LUTW's experience is that an awareness of benefits must be complemented by education programs that provide a basic understanding of system functionality at the household and community level so as to avoid accidental system failures, which can lead to rejection of the technology. Customers who know how to properly use and care for their solar home lighting system will influence the life-cycle cost of the equipment as additional maintenance costs are avoided and replacement of components becomes less frequent. When technical issues do arise, households should be in contact with a service provider that can offer technical support in a reasonable amount of time and within their financial means. If technical expertise cannot be sourced within the community, it increases the likelihood of system failure or abandonment. The breadth of awareness and educational activities depends in part on the long-term plan for how systems will be maintained and service providers involved in these activities. If a community is located a significant distance from the proponent business, it is arguable that more intensive and content heavy education and training programs must be incorporated into the venture. This is necessary in order for solar home lighting systems to be serviced sufficiently frequently so that households do not lose interest in the technology. If the distance between the business and potential clients is less significant and the cost structure of long-term service provision is low, then it is arguable that less rigorous education programs are required to develop the market. Best practice is to assess the market size and long-term service factors prior to engaging the market.

Supply Chain Considerations

A dependable supply chain is pivotal to the sustainability of markets. The home lighting market requires the support of sustainable business models for equipment supply and service provision.[20] Given the nature of the components used in the solar home lighting industry, importing equipment will continue as a key activity for suppliers. Businesses should be aware of the nearest suppliers of equipment and services for the market they have identified. This is vital not only to understanding the competition forces active in the potential market location but may also serve as an option for partnership in an attempt to coordinate development of the market. Business ventures are more likely to achieve success if they can evaluate and channels for equipment and service provision and determine whether the margins necessary to sustain a business will be available in the targeted market. Best practice is for businesses to take advantage of those preexisting channels where similarities and complementarities exist.

It is equally important to balance the issue of equipment quality along with supply chain considerations for long-term system sustainability. As Prahalad and Hart (2002) point out, there are serious issues with the quality and quantity of goods and services available to low-income households. Invariably, this is the nature of the market in areas where entrepreneurs are profit maximizing and extract high rents from customers for their time and efforts in providing a product or service in an area that is more costly to serve, due to high transaction costs. If a high-quality solar home lighting system is promoted in a small market, then the price that the entrepreneur would have to charge to attain profitability may be beyond the financial means of a large segment of the population.

Ensuring the quality of the equipment is critical for the credibility and the sustainability of a business that provide SSHLS. A significant increase of WLEDs and other SSHLS suppliers was observed in the last 5 to 6 years. Through product testing and evaluations, LUTW observed an influx of inferior SSHLS products (Peon, 2006). The most common issues include rapid degradation of the light output of the WLEDs and inferior quality and undersized batteries. Inferior quality photovoltaic modules is another issue identified through field testing (Jacobson & Kammen, 2007). In the absence of widely accepted standardization and certification processes, business initiators have to be vigilant to exclude inferior products.

CONCLUSIONS

Technology advancements and lower manufacturing costs have provided the foundation upon which the solar home lighting market can expand into off-grid communities. However, LUTW's experience and additional evidence suggests that while suitable products are necessary, they are not sufficient on their own for market development to take shape. Creating and serving the solar home lighting market is an active and interventionist process. In this article, we presented the details of an off-grid home lighting project that took a business approach. The solar PV project in Talamanca, Costa Rica, has shown signs of effectively creating a new market for SSHLS for off-grid households while providing numerous lessons about approaches that can be applied by businesses seeking to provide solar home lighting services to the low-income households in Africa. We presented the key lessons learned and best practice recommendations identified from the Talamanca lighting project as well as other home lighting projects LUTW has executed over the past 10 years. We have identified that forming strategic partnerships, designing and offering a suite of home lighting products that fits the diverse needs and choices of the consumers, offering financing options, awareness created along with education, and establishing reliable supply chains are some of the most crucial best practices to develop a successful home lighting

system business. Considering these best practices should help to create models of success for businesses operating in off-grid areas in Africa.

NOTES

1. In their seminal paper, it is suggested that the market potential at the "Bottom of the Pyramid" is significant across many sectors and that it may be tapped into with innovative business approaches. The notion of considerable profit potential from serving the low-income markets has prompted many multinational corporations to explore methods of serving and profiting from a myriad of new clients in untapped markets. Many manufacturers responded to this call to action by developing solar home lighting products.

2. Martinot et al. (2002) notes that many renewable energy projects fell out of favor in the late 1980s due to the low impact of programs. The technology developed the reputation of being a "second-class technology."

3. LUTW is a Canadian-based nonprofit organization that focuses on the dissemination of efficient lighting system technologies such as the system described above. LUTW's approach is to respond to requests for technology transfer by evaluating existing energy needs and to design modular systems that are based on existing needs but have some capacity for growth.

4. This article examines opportunities and approaches for companies interested in serving the electricity market with a focus on home lighting. This article does not comment specifically on business opportunities for electricity to power larger household devices such as refrigerators, stereos, computers, televisions, etc.

5. Approximately 99.7% of those live in Sub-Saharan Africa, where electrification rates are about 28.5%. It is largely a rural issue, with 88% of households in Sub-Saharan Africa being without access to electricity located in small towns and villages.

6. Financially, the cost of kerosene represents a significant portion of household consumed goods. Expanding electricity access to eliminate the use of kerosene for lighting and to promote socioeconomic development objectives such as the Millennium Development Goals has been the focus of many government and international donor initiatives. Governments and donors spend between US$0.2 to US$1 billion globally per year on traditional rural electrification (Andrews & Crain, 2009). This equates to approximately 100 million households in spending on average of US$170 per year on fossil fuel sources of lighting (IFC, 2010).

7. This type of intervention is described as being carried out by Market Facilitating Organizations (MFOs) (Martinot et al., 2002). In essence, LUTW's mandate matches that of a market facilitating organization (MFO) although it does so independently of any particular supplier.

8. For example a typical SSHLS use by LUTW has two to three WLED lamps that are rated at approximately 1.3 W, a 5- to 10-W PV panel, a 12 V/7 Ah battery, and a dedicated charge controller. Each lamp emits approximately 100 lm of light and the system is capable of providing 4 to 5 hours of lighting (8 to 10 lamp hours in total).

9. Improvements in the product efficiency of manufacturing solar photovoltaic modules have been increasing significantly since the 1990s (Ahmed, 2004).

10. Course curricula cover a number of themes including appropriate technology (AT) and AT project implementation. Projects are implemented by a network of staff, all of whom are native to the region, who implement the education programs.

11. Cell phone towers were installed in the region in December 2009.

12. As of January 31, 2011, 33% of beneficiaries had completed their payments for the systems in full and 66% of the total balance outstanding for the SSHLS has been repaid.

13. A clear notion of the product or service that will be offered to the targeted population segment will help to frame the location and partner selection process.

14. The sequencing of identifying a strategic partner and identifying a location of market potential may be reversed and involve various steps of engagement and disengagement.

15. Partnership is seen to be a sensible option if the cost of establishing the organizational infrastructure and establishing the "goodwill" necessary to work in a community exceeds the cost of providing compensation for an already established organization to serve this role.

16. It is also important to consider annual solar insolation data and variation in lighting use by season.

17. A task specific portable light and general use portable light were tested in parallel in 25 homes for a 3-month period. A solar home lighting system was introduced in all 50 homes to assess the value perceptions of all three products and potential marketability.

18. Companies should research new products on the market and their supply network penetration. Originally, many donor programs for solar home systems began by offering large systems that often exceeded 100 W. They soon learned that large systems were too costly for rural households and lowered system sizes to more manageable sizes (20 to 50 W). Thus far, the market has responded with a focus on small systems (10 to 20 W), with households upgrading to systems with greater capacity when they are the financial position to do so (Martinot et al., 2002). The LUTW experience has been to focus on small-scale and more affordable lighting systems that meet existing energy needs.

19. Formal financial services are considered as those that are provided by a regulated financial entity.

20. Sustainability is achieved if equipment and services can be supplied to households in a manner that is both profitable to the business owner and affordable and of value to the purchaser.

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