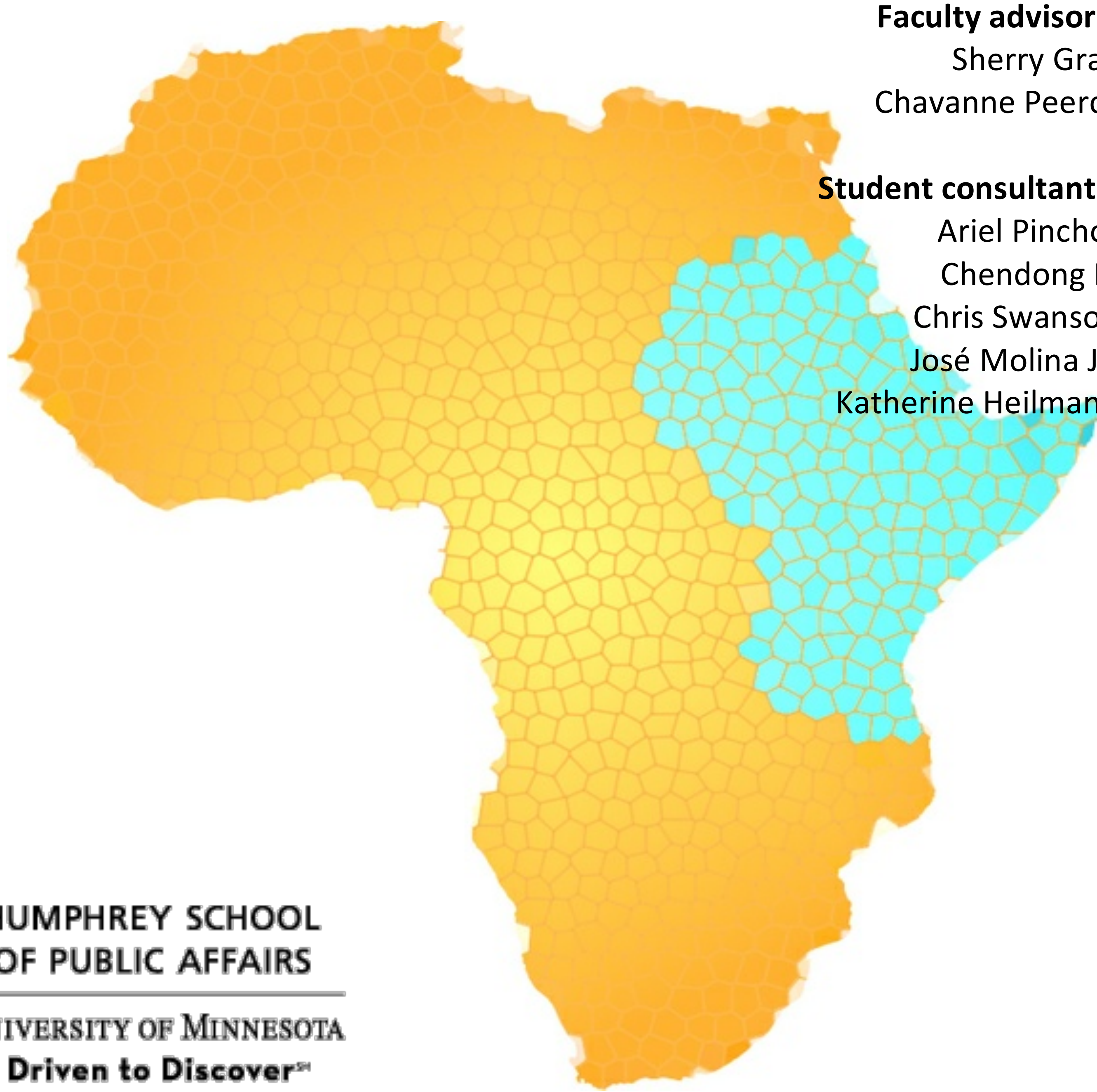
Solar Lighting Pilot Program for Shegerab Refugee Camp, Sudan

A Program Design Proposal for the
American Relief Agency for the Horn of Africa

8 May 2013



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Executive Summary

The ARAHA Solar Lighting Pilot Program (SLPP) is intended to provide affordable, effective, and safe lighting for those in need in the Shegerab refugee camp. SLPP is inspired by ARAHA's mission to provide both immediate assistance and long-term opportunities for people in the Horn of Africa. Reliable, effective lighting is a necessary component of quality of life. Lighting enhances productivity for work and education, increases family and community recreation time, and improves safety and security. In the Shegerab refugee camp of eastern Sudan, all of these are pressing needs. Many households in Shegerab are without lighting, and most that have lighting use kerosene lanterns, an inefficient, ineffective, and relatively high-cost light source. SLPP is designed to remedy this problem in a way that is compatible with the needs and means of the people in the camp, and is institutionally sustainable for ARAHA.

The program is designed as a pilot that will introduce lanterns to an initial group of 100 households. It also includes methods and criteria for scaling up in order to provide more lanterns in the camp via the marketplace. The lamps selected for the program are sourced from an American firm, d.light, but can be shipped from nearby Mombasa, Kenya. D.light's products are cost effective and designed for use in developing countries. The lanterns are small, portable, and include individual solar charging panels. They have a proven track record of reliability and ease of use in previous development projects.

The pilot will see the distribution of up to 100 individual solar powered lanterns to households affiliated with the Shegerab Secondary School for Girls. While we researched and considered several financing strategies for the program, we recommend that the lamps be provided free of charge to households, relieving them of any financial burden. We also recommend that ARAHA should provide households with guidance on the proper use and care of the units, and also assume responsibility for maintenance and repair of the lanterns for a period of two years in order to facilitate positive experiences of the new technology for the users.

We anticipate that households that replace kerosene lanterns with solar units will save USD 165 over three years, and USD 510 over ten years. This represents significant savings for households, many of which have limited opportunities to produce income while in the camp. We project the net savings of the program (total savings minus total costs) over ten years to be approximately USD 25,000.

These lamps will provide immediate help for the girls' schoolwork and their households' general lighting needs, allowing students and their relatives to enjoy more productive lives in and around their homes. A targeted monitoring and evaluation plan will provide ARAHA with information on the effectiveness and efficiency of the lights and the service delivery, with an eye toward expanding the number of lights in the camp, as well as replicating the solar program in other needy communities.

The scale-up of the project is contingent on the results of the monitoring and evaluation of the program confirming household satisfaction and quality of life improvement, as well as the product's reliability and affordability. If these are satisfied, and ARAHA is confident of the effectiveness of the pilot, ARAHA may move toward a self-sustaining market for solar lanterns in Shegerab. This stage would see ARAHA facilitating sales of the lanterns by private sellers in the community. ARAHA could assist this transition by providing guidance on the procurement of the lanterns, as well as short-term financing to encourage shop owners to carry them. Within a few years, ARAHA will be able to step away from the market that it has helped to develop. In this time, ARAHA will have directly brightened the lives of many and, through market facilitation, created a truly sustainable solution to this pressing need in Shegerab.

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Terms Defined and List of Abbreviations

Terms Defined

Lux - unit of luminous emittance, equivalent to one lumen per square meter
Lumen - measure of the quantity of visible light emitted from a given source
Photovoltaic - method for converting solar radiation into direct current electricity
Pico PV - PV system or lantern with a power output between 1 and 10 watts
Solar Home System - small to mid-sized installed modules with multiple components
Watt - unit of power equal to one joule per second, measures the rate of energy transfer
Lumen Hours - quantity of light radiated for a period of one hour by a flux of one lumen

Abbreviations

ARAHA - American Relief Agency for the Horn of Africa
CFL - Compact florescent light
CBR - Cost benefit ratio
CSA - Cost savings analysis
GHG - Greenhouse gases
HH - Household
IFC - International Finance Corporation
Kg - Kilogram
LED – Light emitting diode
Li-Ion – Lithium ion battery
Lm - Lumen
NGO – Non-governmental organization
NPV - Net present value
PV – Photovoltaic
SDG - Sudanese Pound
SHS – Solar home system
SLPP - ARAHA Pilot Solar Lighting Program for Shegerab
SPL – Solar portable light
W - Watt
WB - World Bank
WHO - World Health Organization
Wp – Watt peak
UNDP - United Nations Development Program
UNHCR - United Nations High Commissioner for Refugees
USA - United States of America
USD - United States Dollar

30 students set to graduate from Shegerab high school for girls in Sudan. They will be the first women to graduate with a diploma from the Shegerab refugee camp in 25 years *(araha.org).*

I. INTRODUCTION

The ARAHA Solar Lighting Pilot Program for Shegerab (SLPP) is a pilot program designed to provide affordable, effective, and sustainable sources of lighting to households in the Shegerab refugee camp of eastern Sudan. Household lighting is a crucial component of quality of life, improved productivity for work and education, and safety and security. Many households in the camp are without lighting and most that do have lighting use inefficient and substandard light sources. This pilot program proposal addresses the need for efficient and adequate lighting by outlining an institutionally sustainable plan for distributing solar powered household lighting units at a cost that is compatible with the means of the client population.

II. CONTEXTUAL OVERVIEW

a. Shegerab

Shegerab is a refugee camp in eastern Sudan, adjacent to the borders of Eritrea and Ethiopia. Shegerab is divided into three camps, Shegerab I, II, and III. The total population of the camps, henceforth referred to collectively as Shegerab, is approximately 30,000. The majority of Shegerab's inhabitants are Eritrean. Sudan has hosted Eritrean refugees for over forty years.

Shegerab is one of a cluster of refugee camps (see Figure 1) on the border of Sudan, Ethiopia and Eritrea. The density of camps in this area attests to the persistent political and environmental humanitarian crises in the region. The eastern Sudanese cluster of camps is collectively home to hundreds of thousands of internally displaced persons and refugees from neighboring countries. The vast majority of refugees are Eritrean. The circumstances, ethnicities, socio-economic backgrounds, and expected stays of the refugee population has changed over decades (IRIN, 2011), but the existence of a refugee population that numbers in the tens of thousands has not. The United Nations High Commissioner for Refugees (UNHCR), which is very active in the region, estimates that eastern Sudan sees 1,800 new refugees each month in most braving dangerous and violent conditions to arrive in camps like Shegerab (UNHCR, 2013).

Shegerab, like its neighbor camps, is critically underserved by essential services that meet the basic needs of its population in the present as well as opportunities to facilitate post-refugee life. UNHCR has identified several needs to be addressed in 2013 in eastern Sudan, including increased access to basic services, education, and livelihood opportunities (UNHCR, 2013).

b. Community Need for Solar Lighting

The International Energy Agency says that 1.3 billion people around the world still live without access to electricity. In most cases, kerosene lamps are used to meet lighting needs (cnn.com).

Indoor lighting can help facilitate ARAHA's goals by enabling conditions in which beneficiaries can continue work, study, and community life after sundown. Further, it may contribute to personal security, a pressing concern in the camp. Currently, access to indoor lighting is limited, as there is no power infrastructure in the camp. Hospitals and other crucial resources have some access to generators, but within individual households, lighting is generally limited to kerosene and battery powered lanterns and flashlights. Indoor lighting options for individual households have been, and continue to be, limited by cost, availability, and maintenance.

Most indoor lighting in Shegerab households is provided by kerosene lanterns. There are two models commonly utilized. The more expensive unit, which is used in most households, costs ~10 USD with a monthly operating cost of ~4 USD (email correspondence with ARAHA field staff, 2013). Battery powered house torches and generator-powered lamps are also used, but are less common. The upfront cost of a house torch is roughly half of the more expensive kerosene lantern with similar monthly upkeep costs. Generator-powered lamps are much more expensive than these other options (personal communication with ARAHA field staff).

III. METHODOLOGY

The design of the ARAHA Solar Lighting Pilot Program in Shegerab is informed by the analysis of four distinct aspects of solar lighting:

- **Best practices;**
- **NGO landscape;**
- **Product selection;**
- **Cost and savings.**

The methods of each of these analyses are described below.

a. Best Practices Analysis

For the best practices research, the team conducted a literature review of published journal articles, white papers, and industry reports. The initial literature list was generated through Google and Google Scholar keywords searches. One of the initial papers identified was a literature review that summarizes lessons learned from decentralized rural solar lighting projects around the world (Chaurey and Kandpal, 2010). The team used this existing literature review to expand the initial list of literature. The team then reviewed this list of literature and summarized key points from each piece. During the review, the team organized the lessons on best practices into the following categories: attention to local perspectives, product characteristics, financing mechanisms, product maintenance, and education and training. Altogether the team reviewed around 40 pieces of articles, which have been synthesized into a final best practices report. To augment this literature research, the team has also reached out to a selection of the organizations identified in the NGO landscape to solicit additional information and insights about their experiences with their respective programs. The best practices report was used to inform the product selection and pilot project design.

b. NGO Landscape Analysis

The team gathered data on existing organizations that are implementing off-grid solar energy programs in east Africa via internet research and email correspondences with organizations. To conduct the NGO landscape analysis the team identified eleven organizations that distribute household solar lighting products in the target region in a similar capacity to the ARAHA's intended project. For each of these organizations, information on the following key program components was gathered: name, website, contact, organizational type, headquarter location, project locations, program description, mission, solar product used, product type, product source, partners, and funding sources. This information is presented in tables displaying the program components of each of the organizations reviewed. All information presented in the tables was obtained directly from the organizational website (as listed) or from personal correspondence where noted.

c. Product Selection Analysis

The team conducted preliminary research to identify as many available solar lighting products as possible. These products were then analyzed using criteria identified in our best practices research, including affordability, quality of light output (measured in lumens), duration of runtime, durability and risk of theft. Of the dozens of solar lighting products we researched, many were too expensive, did not meet the design criteria identified in our best practices research, or were simply not suited to meet the specific objectives of the SLPP. For example, many lanterns were small desktop units that would not provide adequate lighting, while others were large wired systems with multiple lights intended to be installed in several rooms.

d. Costs and Savings Analysis

A comprehensive financial analysis was undertaken to estimate both the program costs to ARAHA and to project a variety of household repayment options for program participants. The cost analysis includes estimates of the capital and operating costs for each product. Operating costs project-wide are standardized between the three products. ARAHA's experience in the region guided assumptions regarding shipping. The household savings projections are divided into three potential payment scenarios for each of the three selected units, resulting in a total of nine distinct scenarios. Each scenario reflects a different proportion of household savings and repayment to ARAHA. The analysis section below details the results of the financial analyses.

IV. INSTITUTIONAL LANDSCAPE

a. Solar Lighting Best Practices

This section offers an overview of best practices for off-grid solar household lighting programs in the Horn of Africa and surrounding regions. The goal is to present valuable insights from the experiences of existing programs so that these lessons may be used to inform the design of ARAHA's pilot solar lighting program.

The section provides a synthesis of relevant "lessons-learned" gathered from a wide range of sources, including published journal articles, white papers, technical reports, field studies, market trials, and industry reports. From this research, five key topic areas emerged as critical considerations to household solar light programs: attention to local perspectives/preferences, product characteristics, distribution mechanisms, product maintenance, and education and training. Each of these topics is discussed in detail in Appendix A.

Attention to local perspectives/preferences

Product characteristics

Distribution mechanisms

Product maintenance

Education and Training

b. NGOs Implementing Solar Projects

This section presents common data on various organizations implementing off-grid solar energy programs in East Africa. The data offers a baseline for the program scope and design within the specific space that ARAHA's future program would exist and also catalogues a range of feasible strategies to delivering household solar lighting. This information is presented in the tables found in Appendix B.

There are several notable patterns revealed through this data. The majority of the organizations that distribute the solar products use some type of microfinance mechanism or pay-as-you-go distribution scheme (Dungo Energy Solutions, Solar Light for Africa, M-KOPA Solar, One Child One Solar, Mobisol, Azuri). Only a small number of these programs are donating products to selected participants (50 Lanterns International). Although it is also notable that these program that use microfinance mechanisms do not serve populations in refugee camps. Another interesting trend revealed that nearly all of the specific products distributed through these programs meet quality and performance standards established by the global off-grid lighting association. Additionally, the institutional research has shown that there is greater presence of organizations delivering off-grid solar lighting in Kenya, Uganda, and Ethiopia (to a lesser extent), than in other countries in the Horn of Africa region (e.g. Sudan).

The tables in Appendix B present the key program components of the eleven organizations reviewed. All information presented in the tables was obtained directly from the organizational website (as listed) or from personal correspondence where noted.

V. OVERVIEW OF SELECTED UNITS

The team conducted preliminary research to identify as many available solar lighting products as possible. These products were then analyzed using criteria identified in our best practices research, including affordability, quality of light output (measured in lumens), duration of runtime, durability and risk of theft. Of the dozens of solar lighting products we researched, many were too expensive, did not meet the design criteria identified in our best practices research, or were simply not suited to meet the specific objectives of the SLPP. For example, many lanterns were small desktop units that would not provide adequate lighting, while others were large wired systems with multiple lights were intended to be installed in several rooms.

Three products emerged from this product review process as best meeting the needs of the Shegerab population, the decentralized recipient population spread throughout the three Shegerab camps, and the particular objectives of the SLPP. These are the d.light S300 lantern, the Philips 6W CFL lantern, and the Tata 300W central-charging system.

Both d.light S300 and Philips 6W have portable lanterns and solar panels, while the Tata product is a multi-user system with portable lanterns and a central charging station. Implementing SLPP with a multi-user solar lantern system would have implications for how the program is structured and managed, but the team felt it was beneficial to include at least one such system in our final analysis. Each of the three products selected are seen as viable options to meet ARAHA’s program goals in its Shegerab pilot program and has been successfully utilized in previous development projects.

a. Product Comparison

d.light

d.light S300 is a 1.3 watt pico PV unit. It produces a maximum of 85 lumens of light, and has four settings, which provide between four and sixteen hours of light. The lantern is connected to the PV unit by a long cord, which allows the lantern to be charged from inside the home, decreasing the risk of theft. The PV panel may be used to charge mobile phones as well, providing an additional benefit to the user. The unit cost of the S300 model is 24 USD, with an estimated five-year ownership cost of 41 USD. This ownership cost incorporates re-investment in both the light and battery, both of which are anticipated to need replacing every four years. D.light is based in the USA, but has a regional distribution center in Mombasa from where products could be shipped to Sudan.

Philips 6W CFL

The Philips 6W CFL is a 240 lumen pico PV unit. The lantern charges from flat in ten hours and runs for half that time from a single charge. The PV solar panel connects to the lantern via cord, allowing for easy charging from indoors, which also decreases the risk of theft. The unit price is estimated at 90 USD. Its projected five-year ownership cost is 125 USD, which includes a single replacement for both battery and lamp. The unit can be shipped from the Netherlands.

Tata 300W

The Tata 300W system is a multiuser system. It has been used in the large Light a Billion Lives (LABL) initiative in India. The unit consists of a centralized battery charging station and 50 portable 7 watt CFL lanterns for 50 households, thus requiring two central charging systems to accommodate 100 households. These lanterns generate 315 lumens, and run for up to eight hours per charge. Charging a lantern's battery from flat takes seven hours. The unit's projected per household cost over five years is 126 USD, which takes into account replacement of individual lamps as well as batteries for the two central chargers. While the central-charging system eliminates the need for households to keep and maintain solar panels, it creates the need for organizational management of the central charger. It would also require recipients to transport the lanterns to the central charger on a regular basis; presumably this would mean the students would have to bring them to the school for charging. This approach would result in more complex program management and make recipient ownership more difficult. Tata is an Indian firm, and the product ships from India.

b. A summary of costs, performance specifications, and features is summarized in table 5.1 below.

Table 5.1 – Comparison of Selected Products

Model	**d.Light S300 lantern**	**Philips 6W CFL lantern**	**Tata 300W CFL system**
Photo			
Type	Pico PV unit	Pico PV unit	Central charging multiuser system
Portable	Yes	Yes	Yes
Hangable	Yes	Yes	Yes
Lumens	85	240	315
Runtime (single charge)	4-8 hours	5 hours	8 hours
Charge Time (single charge)	8 hours	10 hours	7 hours
Ships from	Mombasa	Netherlands	India
Price	24 USD per lantern	90 USD per lantern	5000 USD per system (100 USD per lantern)
5-year costs	41 USD	125 USD	126 USD

VI. FINDINGS OF COST AND SAVINGS ANALYSIS

To estimate the costs of the program to ARAHA, as well as the savings that would be expected for the recipients, the team developed a comprehensive analysis tool (see Appendix C) This tool utilizes the best cost information available to forecast both upfront capital costs and ongoing operating costs, as well as future savings for the solar lantern users. The tool analyzes these costs and savings for each of the three solar lighting models chosen based on the criteria discussed earlier. The analysis also includes three potential various financing 'scenarios' for each model. These scenarios are discussed in greater detail in a later section, but can be summarized as follows:

- ***Scenario A*** – No payback will be required from program beneficiaries.
- ***Scenario B*** – Recipients would be required to make 24 monthly payments equal to 50% of the average household kerosene use for lighting.
- ***Scenario C*** – Recipients would have a one-year trial period of the solar lantern, after which they can choose to purchase the lantern at a subsidized cost.

A program timeline of three years was chosen for the primary cost estimates, with program staff and replacement parts budgeted for these three years. This short timeline was chosen for several reasons. First, as a pilot program, the intent of the program is to assess the potential for the program to be scaled up or replicated to reach more beneficiaries. Second, shorter-term cost and savings forecasts will maximize the marketability of the program for potential donors by allowing ARAHA to provide them with estimates of short-term financial impacts in encouraging them to support the program. An extended program timeline of ten years or longer would likely not have as effective an impact on potential donors.

The program is intended to be sustainable in the long term, with a goal of enabling continued use of solar lighting by beneficiaries while eliminating the need for continued external financial assistance. Accumulated savings should allow beneficiaries to support the minimal required maintenance and replacement of the solar lighting units after the program's end.

Costs and savings estimates were calculated using the best information available from ARAHA field staff in Shegerab and from our own research. The team used the following information to calculate the analyses (these can all be easily changed within the analysis tool to recalculate costs and savings):

- Solar lantern and replacement part pricing was ascertained from various sources, including product comparison websites, company websites, and company sales representatives.
- Estimated lifetimes of lamps and batteries were ascertained from product reviews and correspondence with company representatives.
- Shipping costs were rough estimates based on known costs from past shipping of items into the region by ARAHA.
- Staff wages - vary depending on length and type of work required. These were determined from discussion with ARAHA staff.
- Kerosene lantern – 60 SDG (Sudanese pounds) for the typical kerosene lantern used in households.
- Kerosene – 4 SDG per liter.
- Monthly kerosene use – 5 liters per household.
- Currency exchange rate – 4.41 SDG per 1 USD. Inversely, this calculates to 0.23 USD per 1 SDG (retrieved from www.xe.com).

a. Costs

Estimated costs for ARAHA were calculated from upfront costs of procuring the various solar products and replacement parts and training staff and beneficiaries on how to install and maintain them, as well as the ongoing costs required for staff to maintain and repair the products and oversee the program. While replacement parts should not be necessary for the first couple years, for simplicity these parts are included in the initial product shipment, as it will reduce both complexity and shipping costs.

Initial *Capital Costs* will include the solar product units (including additional lamps to replace faulty units), replacement batteries and lamps, estimated shipping costs of all products and parts to Shegerab, training/reference materials, and solar panel and lantern hanging kits. These costs are allocated to Year 0, since they will be required prior to the start of the program. *Operating Costs* include the wages of program staff and their administrative supplies, and are allocated on a yearly basis from Years 1-3. The capital and operating costs together will result in *Total Costs* for each project year.

Program revenues collected from recipient payments (for Scenarios B and C only) will be subtracted from the *Total Costs* for Years 1 and 2. The resulting figures will be the *Program Net Cost Flow* for each year of the program, which will vary depending on the scenario (A, B, or C). These future costs flows will then be calculated into a Net Present Value (NPV), which estimates the present value of costs that will be incurred in the future, taking into account things such as inflation and interest rates with what is known as a *discount rate*. For these analyses, we chose a discount rate of 7% to account for the significant value of cash-in-hand, particularly in a low-income setting of a developing country such as Sudan. The resulting 3-year cost NPVs of Scenarios A, B, and C for each solar model is summarized in Table 6.1:

Table 6.1 – 3-Year Cost NPV

3-Year Cost NPV		
Model 1 d.Light S300	**Model 2 Philips 6W CFL**	**Model 3 Tata 300W System**
Scenario A	***Scenario A***	***Scenario A***
$11,024.77	$18,865.52	$22,270.52
Scenario B	***Scenario B***	***Scenario B***
$6,588.65	$14,429.40	$18,088.71
Scenario C	***Scenario C***	***Scenario C***
$9,059.53	$16,900.28	$20,305.28

The costs for each model understandably vary depending on the payback scenario chosen. Model 1 (d.Light S300) results in the lowest cost NPV of all three models for each potential scenario. The NPV of all estimated program costs Model 1 ranged from 6,589 USD under Scenario B (payback revenues based on kerosene savings) to 11,025 USD under Scenario A (no payback revenues). Model 2 cost NPVs ranged from 14,429 USD under Scenario B to 18,866 USD under Scenario A. Model 3 is the most expensive, resulting in cost NPVs ranging from 18,089 USD under Scenario B to 22,271 USD under Scenario A. Scenario C (one-year trial period) costs came in between Scenarios A and C for each model, but were much lower for Model 1 at 9,060 USD than Model 3 at 20,305 USD. This is understandable given that monthly payments by the recipient under Scenario B would be consistent across models, while they would vary depending on the purchase price for Scenario C. Net cost flow under Scenario C approximately breaks even in Year 1 and even results in a net income in Year 2 for Models 2 and 3.

b. Savings

Beneficiary savings were calculated and analyzed separately from costs, and include savings gained from not having to purchase a kerosene lantern, as well as the continued purchase of kerosene fuel needed to operate the lantern. From Year 1 on, recipients would realize an estimated annual fuel savings of 54.42 USD. If Scenario A were implemented, recipients would realize the full amount of fuel savings minus the costs of future lamp and battery replacement. Based on our research, we estimate that these would need replacement on average every four years. This would result in a total 3-year savings of 163 USD and 10-year savings of 512 USD per household.

For Scenario B, for the first two years of the program, half of the fuel savings amount would then be paid back in monthly installments to the ARAHA solar program. Of course, the actual savings would vary depending on the local price of kerosene throughout the year, which is impossible to estimate with any certainty. Given current fuel prices, we estimate this system to result in an annual net savings of 27.21 USD per recipient household for the first two years, and the full 54.42 USD from Year 3 on. Taking into account part replacement costs, this would result in a total 3-year savings of 109 USD and 10-year savings of 458 USD per household.

Scenario C would give recipients the option to purchase the product for a subsidized price at the end of the 1-year trial period. For those who choose to purchase the lantern, they would incur this cost in Year 2 of the program, resulting in a lower net savings for that year. In all other years recipients would realize the full fuel savings of 54.21 USD, minus the costs of replacement parts. The estimated cumulative savings for all scenarios are summarized in Table 6.2:

Table 6.2a – Cumulative Recipient Savings – 3-year

Total Savings - 3 years	per HH	Project total
Scenario A	$163.27	$16,326.53
Scenario B	$108.84	$10,884.35
Scenario C	$138.27	$13,826.53

Table 6.2b – Cumulative Recipient Savings – 10-year

Total Savings – 10 years	per HH	Project total
Scenario A	$512.22	$51,221.77
Scenario B	$457.80	$45,779.59
Scenario C	$487.22	$48,721.77

In addition to the financial savings outlined here, the solar program would also result in considerable health, social, and environmental benefits for the recipient households and the community. These non-monetary impacts are discussed in more detail in the Program Benefits section of this report.

c. Net Program Savings

From the costs and savings estimated above, we calculated Net Program Savings - the NPV of total recipient savings minus the NPV of total program costs - for each model and each potential scenario. Since the solar lanterns are expected to last beyond the 3-year duration of the program, savings will continue to be realized by households even after costs born by ARAHA end after the fifth year of the program. Therefore, we calculated 10-year Net Program Savings for the program in addition to the 3-year figures. Table 6.3 summarizes the findings of our analyses:

Table 6.3 – Comparison of Net Program Savings

Net Program Savings					
Model 1 d.Light S300		**Model 2 Philips 6W CFL**		**Model 3 Tata 300W System**	
Scenario A		***Scenario A***		***Scenario A***	
3-year	$3,257.22	3-year	$(4,583.53)	3-year	$(7,988.53)
10-year	$25,046.96	10-year	$17,206.21	10-year	$13,801.21
Scenario B		***Scenario B***		***Scenario B***	
3-year	$2,773.56	3-year	$(5,067.19)	3-year	$(8,726.49)
10-year	$24,563.30	10-year	$16,722.55	10-year	$13,063.24
Scenario C		***Scenario C***		***Scenario C***	
3-year	$3,038.86	3-year	$(4,801.89)	3-year	$(8,206.89)
10-year	$24,828.60	10-year	$16,987.85	10-year	$13,582.85

The Net Program Savings from our analyses clearly indicate that, of the three models analyzed, Model 1, the d.light S300 is the most cost-effective model. The S300 has the desired features and design criteria identified in our research. Additionally, our research found that this product has won numerous awards and shown to perform well in various cultural settings. Therefore, we recommend that the program be implemented with the d.light S300 solar lantern.

VII. PROGRAM BENEFITS

a. Overcoming the burdens of kerosene lighting

Throughout sub-Saharan Africa, about 580 million people lack access to electricity (UNDP, 2009), where more than half of households rely on kerosene lamps as their primary source of light (Lighting Africa, 2010b). The use of "traditional" lighting fuels like kerosene are not only expensive for poor households, but they are also dangerous, provide poor quality light, and are harmful to the environment (Kornbluth, 2012; Mills, 2012; Lighting Africa, 2011; Lighting Africa, 2010b; Reiche et al, 2010; WHO, 2010).

The social, economic, and environmental benefits of providing safe and clean lighting are well documented (Lighting Africa, 2010b). Solar PV technology has been widely promoted as a cost-effective means to provide lighting services for rural areas where it is too expensive to extend the electricity grid. Solar PV lights can be used anywhere there is sunlight and its operation creates no soot, emissions, or direct fire risks (Kornbluth, 2012). As a region that receives substantial year-round solar radiation, off-grid solar PV lighting systems are an ideal alternative to fuel-based lighting in the Horn of Africa. The specific burdens of kerosene-based lighting are further described below, with the corresponding benefits of implementing a program for off-grid solar lighting alternatives. (It is noted that the information included in the section speaks to the general burdens of kerosene use in the context of poor household's throughout sub-Saharan Africa, but not specifically in the Shegerab refugee camp due to limitation in available data).

b. Financial costs of kerosene lighting

The cost burden of paying for expensive kerosene-based light is an important concern with fuel-based lighting. Research estimates that kerosene or other fuel sources accounts for between 10-25% of monthly household spending among the poorest households throughout Africa (Lighting Africa, 2010b). In a refugee camp context, where the opportunity to generate income is severely limited, the cost burden of kerosene may be intensified. The average household in the Shegerab camp, for instance, consumes 5 liters of kerosene per month at the current cost of 4 SDG per liter (ARAHA field staff, 2013).

> **Program benefits of cost savings:** The fuel source for solar lights is free. After covering initial investments in the d.light solar product and basic maintenance expenses, monthly costs of lighting are drastically reduced when households switch to solar lighting. The exact cost savings have already been discussed in detail in the Costs & Savings Analyses in Section 5 of this report.

c. Health risks of kerosene lighting

The use of kerosene for lighting is associated with a number of significant health risks. The most well documented risks include poisonings, fire, and explosion (WHO, 2010), while the risks associated with the exposure to the combustion outputs of kerosene (indoor air pollution) are slightly less studied (Lam et al, 2012b). While there is limited data on national-level health impacts associated with kerosene based lighting in the Horn of Africa, the health risks are documented throughout broader regions.

In terms of poisoning, many studies indicate that accidental ingestion of kerosene is the primary cause of child poisoning in developing countries (Mills, 2012). One national level assessment in South Africa documented about 80,000 cases of unintentional ingestion of kerosene by young children each year (Mills, 2012). The use of kerosene lamps, lanterns, and candles inside houses also carries high risks of structural fires and injuries due to burns. The same survey in South Africa reveals that over 200,000 people are injured or lose property annually due to kerosene-related fires (Mills, 2012). An UNHCR survey in refugee camp three countries in the Horn of Africa found that nearly all respondents were concerned about the fire and health hazard of kerosene lighting (UNHCR, 2012).

Kerosene based lighting also causes indoor air pollution through the emission of fine particulate matter. Burning one liter of kerosene emits 51 micrograms of PM10 (coarse dust particles 10 micrometers in diameter) per hour, which is just above the World Health Organization 24-hour mean PM10 standard of 50 micrograms per cubic meter (Lighting Africa, 2011). In the typical small households in refugee camps with poor ventilation, it is likely that these particles do not disperse easily; therefore burning a lamp indoors for just four hours may result in concentrations of toxic particles that are several times higher than the WHO standard (Lighting Africa, 2010b). Such exposure to indoor pollutants causes an increased risk of respiratory diseases including pneumonia, influenza, and chronic obstructive pulmonary disease (Reiche et al, 2010).

Program benefits of reduced health risk: The use of solar lighting products, such as the selected d.light model, is associated with zero localized emissions or soot, and no risk of fire or poisoning. Therefore, if households replace 100% of their kerosene lighting use with the new solar lighting product, the program will essentially remove all health burdens and risks associated with kerosene lighting. Even if household continue to use kerosene lighting for half of all lighting needs, replacing solar with the other half, would represent a 50% reduction in health risks associated with current kerosene lighting use.

d. Light quality of kerosene lighting

Fuel-based lighting sources like kerosene lanterns generate poor quality light at very low efficiencies (Adkins et al., 2009). A kerosene wick lamp provides about 1 lux of light (equal to one lumen per square meter), which is well below the recommended level of 150 lux for studying and 300 lux for a living area (Mills, 2005). Working or studying under these poor light conditions of kerosene lighting can lead to eyestrain and restrict the possibility of pursuing certain activities (Mills, 2005).

Program benefits of improved light quality: The d.light S300 distributed in the pilot program emits bright white light at a wide angle, illuminating an entire room. The total amount of visible light emitted by the product is 85 lumens, which far surpasses the minimum recommended illumination level of 50 lumens for room lights (Reiche et al, 2010). The amount of light emitted from the d.light represents a 466% increase from the average kerosene wick light. The greater quality of light that the d.light provides will eliminate the concern of eyestrain associated with kerosene lighting and will also expand the activities in which participants are able to engage.

e. Educational conditions with kerosene lighting

As mentioned above, the lighting conditions provided by “traditional” lighting devices, like kerosene lamps and candles, are highly insufficient. These poor lighting conditions often restrict the possible activity of households, including cooking, social gatherings, reading, and studying (Reiche et al., 2010). Field studies in selected regions of Ethiopia, Ghana, Kenya, Tanzania, and Zambia, reveal that about two thirds of respondents indicate that a lack of lighting restricts activities (Lighting Africa, 2011). By limiting student’s ability to study at home, the use of poor quality kerosene lighting can greatly reduce potential literacy and school performance (Lighting Africa, 2010b).

> **Program benefits in studying conditions:** A global study based on country-level data found that household access to electricity and modern fuels is positively correlated with educational enrollment rates (WHO, 2009). One comprehensive analysis find that the provision of access to modern energy to rural households would lead to a potential return of 80 USD–150 USD per month in improved educational opportunities and conditions (ESMAP, 2002). Providing household with d.light S300 is expected to reap similar benefits, by drastically improving lighting conditions and enabling households to engage in desired activities, especially reading and studying.

f. Environmental hazards of kerosene lighting

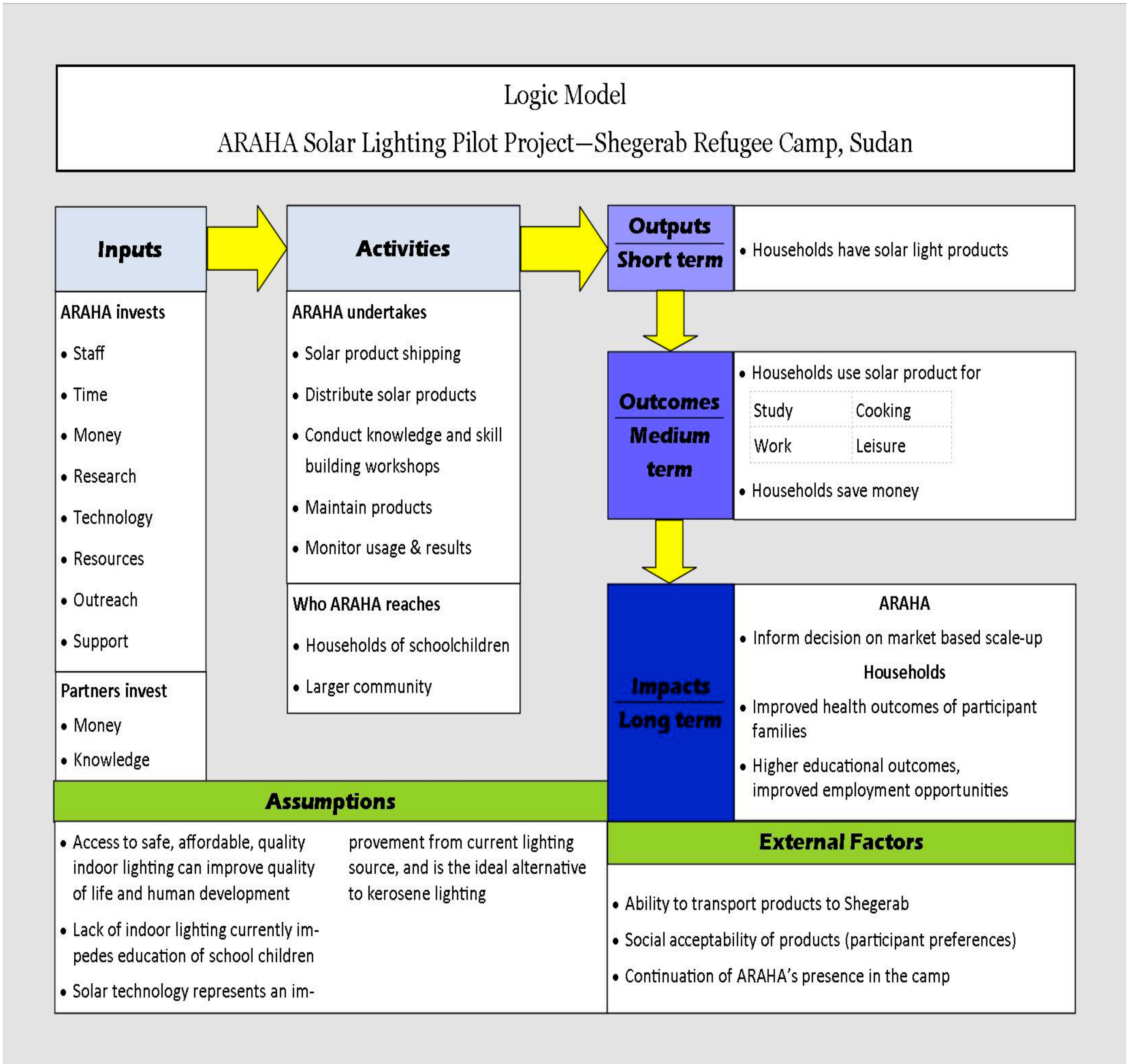
The global use of fuel based lighting devices, including kerosene lamps, oil lamps, and gas lamps, emits over 244 million tons of carbon dioxide each year (Reiche et al, 2010). Further, a recent study from researchers at UC Berkeley reveals that kerosene combustion yields higher than expected emissions of black carbon, a potent climate-forcing agent (7-9% of kerosene consumed by lamps is directly converted to black carbon) (Lam et al., 2012a). This research shows that black carbon, also known as soot, may be a major source of warming in the lower atmosphere and melting of glacial regions (Lighting Africa, 2010b). While cumulative impact of using kerosene as a light fuel on global carbon emissions and air pollutants may be substantial, it is important to acknowledge that on a per capita basis, kerosene users still remain at the very low range of CO_2 emitters (Lighting Africa, 2010b). Even so, alternative clean lighting options for off-grid areas are seen as an important entry point for reducing greenhouse gas emission (Reiche et al., 2010). Indeed, efforts to replace carbon intensive lighting in off-grid areas with clean technologies qualify as offsets for developing countries’ greenhouse gas emissions through the Clean Development Mechanism program of the Kyoto Protocol (Reiche et al., 2010).

> **Program benefits to the environment:** d.light S300 has no localized emissions and therefore no greenhouse gas or black carbon emissions. As such, the direct use of the product does not directly contribute in any way to local air pollution or climate change.

VIII. PILOT PROGRAM DESIGN

a. Logic Model

Figure 8.1 – Program Logic Model (larger version available in Appendix C)



b. Needs assessment

The majority of successful programs begin with a well-founded understanding of the local needs and of the lifestyles of the population (Schultz and Doluweera, 2001). A community needs assessment is therefore the first step for ARAHA's solar pilot program. The purpose of the assessment is to help determine the specific needs of the intended beneficiaries and to ensure that the program is shaped according to these needs. The knowledge gained from the assessment will reduce the likelihood of poor or negative program outcomes or duplication of services in the community (Watkins et al., 2012).

A successful solar lighting program requires the distribution of products that specifically match the intended users' needs while also being affordable. The assessment should involve a simple baseline survey that includes an activity and item-based energy budget (list of activities for which light is used, current light source, average expenditure on light energy, qualitative perceptions of current light sources) (Schultz and Doluweera, 2001). The needs assessment can take the form of stakeholder interviews (i.e. students and families) and interviews with key informants (e.g. high school teachers/administrators, UNHCR field workers, ARAHA field staff). The needs assessment will serve as an effective tool to tailor the program design to mitigate the risk of technology rejection due to cultural, economic, or other reasons (Schultz and Doluweera, 2001).

c. Target population

ARAHA's strong institutional relationship with the Shegerab high school for girls renders the school community an ideal target population for piloting a new program. One important factor supporting this logic is the implicit trust that ARAHA has built with this community through their continued presence at, and support of, the school. It is expected that this existing relationship with the community would increase the likelihood that potential participants opt into the program. Another important reason for selecting the school as a target population is that it represents a community that appears to be in distinct need of alternative lighting. Research shows that the current reliance on poor quality lighting like kerosene lamps greatly inhibits the performance potential of students due to challenges of studying at night (WHO, 2009). Accordingly, targeting students is prioritized as they will likely achieve greater marginal benefits from solar lighting than other demographic groups.

The pilot program will provide solar lights to all current students at the Shegerab high school whose households choose to participate. During the pilot phase, there will be a limit of one light per household, meaning that if there are more than one currently enrolled high school students in a single household, only one light will be provided during this phase.

Girls at school in Shegerab (araha.org)

d. Education and training

Existing literature stresses the importance of stakeholder participation in solar lighting projects (Chaurey and Kandpal, 2010). Program success and user satisfaction of solar products is shown to directly relate to level of understanding and expectations of the system (Nieuwenhout, 2000). In addition to an initial needs assessment, open communication forums with local community leaders, program participants, and other relevant stakeholders are an important aspect of the Shegerab pilot solar program.

In order to allow potential participants to make informed decisions about the program, it is recommended that ARAHA offer a series of comprehensive educational workshops to the students and their families prior to distribution. During these workshops, the facilitators will present an overview of the benefits of solar lighting relative to kerosene-based lighting. Specifically, facilitators will clearly explain the higher quality light output of the solar lanterns, the reduced health risks from indoor pollutants and fires, and the reduced monthly fuel costs. There will be time built in for participants to discuss their current experience with kerosene lighting and their thoughts, reactions, or questions about solar lighting alternatives.

During the workshops, the facilitators will present a product demonstration of the solar product, which will enable participants to witness the product capabilities and learn how it is operated. It is recommended that facilitators display a kerosene lamp alongside the solar lantern to provide a tangible comparison of light output and other features. Several product samples of the solar light will be passed around, allowing participants to handle the product and test it out under the guidance of the facilitators. During this product demonstration, facilitators will discuss the technical details of how to use the product, how to care for the product, and basic maintenance concerns.

Finally, the workshop session will explain in detail that ARAHA will cover the costs associated with general maintenance and replacement of broken parts (further described below) for a period of two years. These program distribution facts may also be presented visually on a chalkboard, in paper handouts, or other appropriate means to make the information most accessible to participants.

The pilot will include five community workshops held at the program initiation (following product delivery to field office). Families of the 100 students will be invited to attend one workshop, where a maximum of twenty families will be allowed to attend each session. The workshops will be held at the high school, when school is out of session (after school hours, weekend, etc.). Each session will be facilitated by two staff members who are familiar with the solar products and the general energy concerns of the camp.

It is important that the workshop content and delivery is presented in a culturally appropriate manner. Presumably, the facilitators will have extensive experience working with this specific community, helping to reduce issues arising from potential cultural insensitivity or imbalanced power dynamics. Further, it is important that the workshop does not make participants feel that their current lighting practices and decisions are “wrong.” Lastly, if deemed culturally appropriate or necessary, it may be beneficial for facilitators to discuss family members’ access to the shared device and recommendations for prioritizing use. This may help reduce the possibility of the product being dominated by certain members of the household (which may or may not be a concern).

Following the initial group workshops, students’ families will be invited to participate in program. In the following weeks, families who decided to participate in the program will have a home consultation at which an ARAHA staff member will install the solar light and cover basic use, operation and maintenance techniques, and answer any questions. It is important that both the workshops and home consultation target at principal users of light, in many cases women and children. Depending on the number of participating households, the home consultations, which will be performed by two staff members, are expected to take up to one month to complete. The maximum number of home consultations conducted per day is assumed to be five (with about two hours per consultation). Under this assumption, two dedicated implementation staff could potentially complete up to 25 household consultations in one week, completing up to 100 in one month (the maximum number of participating households).

e. Financing Strategies

There are a number of distinct institutional strategies for the distribution of off-grid solar lighting products that can be considered. The four most viable options for the Shegerab pilot program include: donations, cash sales, fee-for-service, and microfinance. There are distinct implications for each model relating to ownership, financing, maintenance, affordability, user behavior, and scale. The relative suitability of each strategy for ARAHA’s pilot program is discussed below.

i. Donations

Donation-based distributions are scenarios in which a donor organization provides the product for free (or nearly free) to the target population. The model has often failed due to lack of user commitment or lack of understanding about maintenance needs for sustained operation (Nieuwenhout, 2000). Therefore the donation model places high burdens on the donor organization, which must work to foster strong user commitment (Nieuwenhout, 2000). However in areas where the ability to pay is severely limited, as in the context of a refugee camp, this model may be more viable than other financing models. Also, donations will not disrupt ARAHA’s current relationship with the community.

ii. Cash sales

A cash sales model is the distribution of products through a one-time exchange of cash for the product at full retail or a subsidized price. This approach is not advisable for use in the Shegerab refugee camp due to the lack of stable income of the population. It is assumed that a one-time cash sale would be prohibitively expensive for the potential program participants.

iii. Fees-for-service

A fees-for-service usually entails a rental contract between users and the service provider. In case of a decentralized system, the service provider usually owns the solar products. Users pay regularly for use of the product as well as maintenance by the service provider. For a pilot project, the team thinks a fees-for-service model will create too much a burden for ARAHA (because it needs to collect payment and continues to provide service). Also like microfinance, enforcing payment could disrupt the relationship of ARAHA with the community.

A centralized fees-for-service (central port) system is a system with centrally located PV panels and a battery charging station, owned by an organization. Users access the station to charge the batteries of their own solar products (e.g. lanterns). The organization will charge a fee every time a person uses the station (Mukhopadhyay, Sensarma and Saha, 1993). The team decided that this model would not be optimal due to safety concerns for the schoolchildren. Presumably a central port system would require the schoolchildren to carry their lanterns to and from the central charging station, i.e. the school. The lack of security infrastructure in the camp increases the risk of robbery. Additionally, as described in our Costs and Savings Analyses Section, products utilizing this model tend to be significantly higher in cost.

iv. Savings-Based Microfinance

In case donation is not an appropriate or recommended model, credit-financing options may be the best option for the distribution of quality products to households with limited resources (Frasier, 2013). There are numerous successful examples of consumer credit programs for solar lighting including UNDP and World Bank projects, and countless small-scale projects including Dungo Energy Solutions in Ethiopia, Sudimara Solar in Indonesia, and Soluz in the Dominican Republic (Wang, 1998).

In cases where microcredit is provided by the distributor of the project, the repayment discipline is strongly related to the technical performance of the system (Nieuwenhout, 2000). That is, if the system doesn't work, people tend to stop their loan repayments (Nieuwenhout, 2000). A problem with microfinance is that it might disrupt existing relationship between a nonprofit service provider and local community if the nonprofit has never undertaken payment collection from its constituents before.

Proposed Financing Strategy

After carefully considering the various potential financing models outlined above for the SLPP, the team devised three potential financing scenarios to include in the cost analysis. These scenarios are summarized below.

- **Scenario A** – No payback would be required from program beneficiaries. In this scenario the program would follow a donation model. This approach would place no financial burden on recipients apart from potential future costs for repair or maintenance (beyond the two-year warranty period).

- **Scenario B** – Recipient households would be required to make monthly payments (or quarterly as deemed appropriate) equal to 50% of their kerosene savings (money they save from not purchasing kerosene for lighting purposes) for a duration of twenty-four months. This approach would be similar to a microfinance model, although the repayments have been calculated based on estimated savings, with the simple goal of establishing ownership rather than repaying the full product cost. One drawback of this scenario is that it is completely dependent on the local price of kerosene. As fuel prices often fluctuate significantly, estimating these savings into the future is quite difficult.

- **Scenario C** – Recipients would receive the solar lantern for a free one-year trial at no cost, after which the units could be purchased at a subsidized cost of 25 USD. Although this amount would not cover the full purchase price of the Philips and Tata models, we feel this amount would achieve the objective of conferring ownership to the recipient while not placing an unreasonable financial burden on them. Presumably by this time, the recipient household would have been able to save roughly twice this amount simply from not having to buy kerosene.

After costs-saving analyses (see Appendix C) and careful consideration of all three scenarios, the team recommends implementing Scenario A, the donation approach. Because one of the key objectives of the pilot program is to assess the viability of the chosen product, we feel that distributing the lanterns at no cost to recipient households is justified for the SLPP. If ARAHA chooses to expand or replicate the program beyond the SLPP, future solar programs could incorporate user payment approaches such as Scenarios B or C.

Although literature suggests that programs such as SLPP should require some form of payment on the part of the recipient to establish ownership and facilitate sustainability, we feel the context in which ARAHA will be implementing this program is better suited to a donation approach for the pilot program. In a refugee camp setting such as Shegerab, many households would likely struggle to make payments, despite having saved money from not purchasing kerosene. Furthermore, ARAHA's role in the community has been as a provider, not as a payment collector. Incorporating payment collection into the program would require additional management from ARAHA staff, and could impact the reputation of ARAHA in the community if ARAHA is trying to enforce repayment. Also a donation model will be most equitable because any charge on the household will likely disadvantage the poorest households.

f. Maintenance

The team recommends that ARAHA assume responsibility for product maintenance for a warranty period of two years, coinciding with the product warranty offered by d.light. This is because maintenance by users is very rarely successful (Bikam and Mulaudzi, 2006). If users are responsible for maintenance, they will be more likely to replace components and batteries with sub-quality products and therefore quickly reduce the life of the products (Chaurey and Kandpal, 2010). The team recommends that ARAHA train local ARAHA staff to be the program manager and technicians because maintenance by well-trained technicians is conducive to the sustainability of solar programs. The trained technicians will provide maintenance and replacement of parts and batteries ad hoc. It is expected that the maintenance worker will devote one day a week to providing maintenance.

Also, on a biannual basis, the technicians should visit each household to check on the status of the products and ensure proper usage and maintenance. Participation of the local community increases ownership of the program, so we recommend ARAHA involve household representatives when designing the maintenance plan, e.g. regarding household visit schedule, responsibility of households and staff, cost and case management mechanism (World Bank, 2010; Nieuwenhout, 2000). It is also important for maintenance staff to keep a log of their cases of ad hoc maintenance and replacement, complaints, whether the cases are solved or pending, and how they are solved. During biannual household visits, the staff should record condition of products, maintenance and replacement if any, as well as user satisfaction and complaints. ARAHA should also arrange for proper recycling or disposal of light bulbs and batteries.

In order for there to be clear understanding of expectations for both ARAHA and program recipients, the team recommends that a contract is signed by both parties, which outlines the requirements for the program. In the contract, ARAHA should clearly spell out the responsibility of both ARAHA and households. It is particularly important that the contract stipulates that the participants agree not to sell the product over the course of the two-year program.

Ongoing maintenance and general support of the program will require staff to be either hired or allocated from existing ARAHA field positions for the entire three year program period. The estimated maintenance staff requirement for the program is:

- 1 part-time program manager - estimated 20 hours of work per week
- 1 part-time maintenance staff - estimated 8 hours of work per week each

g. Monitoring and Evaluation

It will be important to monitor progress of the SLPP throughout the program period, as well as conduct an evaluation at the conclusion of the program. The Monitoring Plan (see Appendix E) identifies several key indicators that ARAHA should consider monitoring. While ideally ARAHA program staff would keep track of all items in the Monitoring Plan, the most important indicators have been highlighted so that ARAHA may prioritize according to their current staff capacity. This would allow the program manager and staff to notice any significant problems and address them in time. This would also provide data for a more thorough evaluation.

We highly recommend that at the end of the pilot program ARAHA hire an evaluator to frame evaluation questions, choose methods, collect data and answer the questions. The final program evaluation may considering the following issues:

- Effectiveness: Does the program achieve the intended outcomes? Why or why not? What are the unintended outcomes? Are users satisfied with the service delivery?
- Efficiency: Is the program implemented as planned? What problems are encountered? What could be done to address the problems and improve program delivery?
- Situation: Is there a need to extend, expand, or replicate the current program? Is it feasible to replicate the program in another area? Is it feasible for the private sector to provide solar lanterns and maintenance service?

In addition to evaluating the impact of the program, the evaluation should also aim to achieve institutional learning to guide ARAHA's future programs. Program staff should be required to complete reports regarding their observations about how the SLPP was designed and implemented. Implementation staff should provide feedback at the conclusion of the implementation period on the effectiveness of the community workshops and the home installation visits, while the program manager should complete annual reports with general feedback and recommendations on program structure and organization.

h. Budget

Table 8.1 shows the projected cash expenses that ARAHA should budget for each year. The team also calculated the net present value of the 3-year cash outflow of the pilot program.

Table 8.1 – 3-Year Net Cost Flow Projections for d.light S300 under Scenario A

Year 0	Year 1	Year 2	Year 3	**3-year NPV**
4,895 USD	3,170 USD	2,570 USD	1,130 USD	**11,025 USD**

Table 8.2 shows the projected savings for households. We calculated 6 numbers: 3-year savings per household, cumulative 3-year savings for all households, net present value of 3-year savings for all households (i.e. with discounted cash flows), 10-year savings per household, cumulative 10-year savings for all households, and net present value of 10-year savings for all households.

Table 8.2 – Beneficiary Savings for d.light under Scenario A

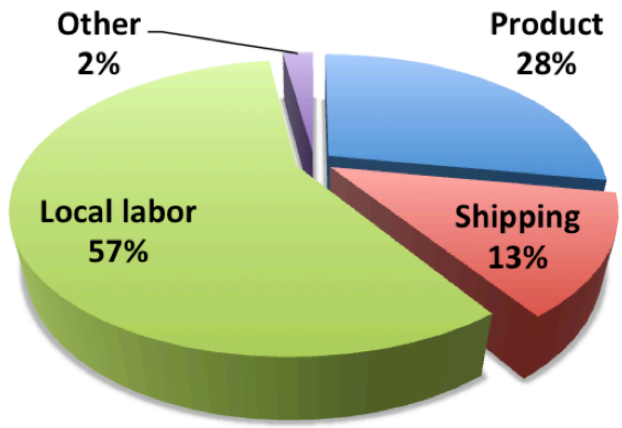
Beneficiary Savings	
3-year total per household	**163.27 USD**
Cumulative 3-year program total	**16,326.53 USD**
NPV of 3-year total	**14,281.99 USD**
10-year total per household	**512.22 USD**
Cumulative 10-year program total	**51,221.77 USD**
NPV of 10-year total	**36,071.73 USD**

Table 8.3 shows the 3-year and 10-year net program savings for the program. Net program savings is calculated by subtracting the total projected program costs for ARAHA from the total projected savings for the solar lantern recipients.

Table 8.3 – Net Program Savings for d.Light under Scenario B

Net Program Savings	
3-year	**3,257.22 USD**
10-year	**25,046.96 USD**

Table 8.4 - Program Costs by Type



IX. SCALING UP & REPLICATING

The long-term goal of SLPP is to provide a lasting improvement in the availability of household light in the Shegerab camp. It is neither desirable nor feasible for ARAHA to provide lighting for the camp directly on a large scale over a long term. However, a self-sustaining market may do so. The final phase of SLPP should aim to transition to a sustainable, independent market for solar lanterns, replacement parts and service. This transition away from the pilot program and toward sustainable, large-scale light provision will entail a change of focus from direct distribution of products to the facilitation of community-based market mechanisms.

The first step of the final stage of the program will be the final collection of monitoring and evaluation data. The data from the priority indicators (see M&E) should be used to assess the following:

1. **Financial benefit (cost savings)** – via indicator OC2.2: Monthly spending on kerosene
2. **Product reliability** – via indicator OC2.4: Description of damages to products (how product broke).
3. **Quality of life improvement** – via indicator OC3.1: Additional hours spent on schoolwork per night per student.
4. **Customer satisfaction** – via indicators OC4.3 and OC4.4: Number of participants satisfied with solar product, and Number of participants who would be willing to buy product in future (and willingness to pay).

If the relevant M&E targets for all four criteria are met or exceeded, scaling up is assumed to be feasible. If less than four criteria meet the targets, scaling up is assumed to be unfeasible.

The process of scaling up will focus on removing two "bottlenecks", in order to facilitate a self-propelling market. These are:

1. **Finance for consumers** (Demand side) and
2. **Import & distribution** (Supply side)

The demand-side bottleneck, finance, will be a crucial component of the success of the product in the marketplace. If savings reported in the pilot project compare favorably to the estimates in the CSA and meet the established M&E targets, the product will be demonstrated to be a cost effective option for households. However, its high upfront costs may prohibit many potential consumers from taking advantage of these possible savings. ARAHA should thus pursue opportunities to provide financing options to potential purchasers. This could be done in conjunction with existing lenders, either those in the community or provided by other NGOs with existing financing options. Alternatively, ARAHA itself could establish a system of credit for those who wish to buy lanterns. In the second case, interest rates, payback terms, etc. would be at the discretion of ARAHA to establish.

The supply side bottleneck would entail ARAHA facilitating connections with local entrepreneurs. Although ARAHA may be involved in financing, it is recommended that it not be directly involved in the eventual sale of lanterns. If M&E criteria 1 and 3 are satisfied, it is assumed that the product will generate enough demand to interest potential distributors. These individuals and firms may require assistance in contacting d.light and developing a supply chain. ARAHA should actively pursue interested businesspersons and share knowledge in order to establish linkages that will insure the availability of products throughout the camp. As a part of this process, ARAHA may also provide training in service and repair to distributors and/or interested entrepreneurs. ARAHA may also provide financing, or facilitate financing, for potential distributors.

Executing these two scale-up steps will conclude ARAHA's involvement with solar lighting in Shegerab. ARAHA will have proven the financial viability and appropriateness of the product for consumers during the pilot stage, and catalyzed financing opportunities and market connections to create a viable long-term market during the scale up. This approach will ensure that the products that ARAHA distributed at the school will be part of a larger "ecosystem" of products, service, and support. This community-maintained ecosystem will ensure that households' lanterns will remain useful and valuable throughout their lifetimes. Transfer of ownership of the product to the community and the market will achieve ARAHA's goal of a lasting impact in Shegerab.

Ideally, SLPP will not only provide a self-sustaining, lasting impact in Shegerab, it will also provide ARAHA with a template program that may be transferred to other locations in the region. The steps of SLPP, from beginning to end, are designed to be replicable. This replication would depend on context-based adaptations while maintaining the best practices of the Shegerab program.

APPENDIX

Appendix A - Best practices of solar lighting

This section offers an overview of best practices for off-grid solar household lighting programs in the Horn of Africa and developing countries. The goal is to present valuable insights from the experiences of existing programs so that these lessons may be used to inform the design of ARAHA's pilot solar lighting program.

The report is a synthesis of relevant "lessons-learned" gathered from a wide range of sources, including published journal articles, white papers, technical reports, field studies, market trials, and industry reports. From this research, five key topic areas emerged as critical considerations to household solar light programs: attention to local perspectives/preferences, product characteristics, distribution mechanisms, product maintenance, and education and training. Each of these topics is discussed in detail below.

1. Assessing local needs

Current and potential users of solar lighting products desire a range of component options and service levels that can be provided by different system sizes, designs, and capacities (Chaurey and Kandpal, 2010; Wang, 1998). Solar lighting products are shown to be rated differently by users across different regions, countries, and continents, and are favored or rejected for different reasons (Reiche et al., 2010). In other words, a 'one size fits all' model of a solar lighting program does not exist.

Determining local product preference through pre-distribution field tests

A successful solar lighting program requires that products specifically match the intended users' needs while also being affordable. The majority of successful programs begin with a well-founded understanding of the local needs and of the lifestyles of the population (Schultz and Doluweera, 2001). A community needs assessment is widely recommended as the first step to program planning (Watkins et al., 2012). The purpose of the assessment is to help determine the specific needs of the intended beneficiaries and to ensure that the program is shaped according to these needs. From this process, planners will come to better understand the issue from the perspective of local actors in the given context, thus reducing the likelihood of poor or negative program outcomes and avoiding potential duplication of services (Watkins et al., 2012).

For household solar lighting programs, it is recommended to carry out a baseline survey that involves an activity and item-based energy budget (Schultz and Doluweera, 2001). For example, the Lighting Africa project in Zambia surveyed kerosene/candle users in Zambia to determine perceptions about light conditions and spending on light (Kornbluth et al., 2012). 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 (Schultz and Doluweera, 2001). Provision of a demonstration system as part of market experimentation is another best practice to learn local preferences and perceptions about the solar lighting product that may be introduced. During these field tests, it may be appropriate to try products with different capacities to help distinguish user preferences (Schultz and Doluweera, 2001).

2. Product selection

Off-grid household solar lighting products fall into three categories distinguished by size and power dimensions: multiuser systems, solar home systems, and pico photovoltaic (PV) systems. Multi-user systems and solar home systems (SHS) are small to mid-sized installed modules with multiple components - including photovoltaic panels, charge controller, mounting hardware, wiring, battery pack, lights, charging outlets, etc. Solar pico PV systems, on the other hand, are simpler systems in a single unit, with less wattage and storage capacity. Pico systems are often described as "plug and play" systems, and include the popular portable LED lanterns and lights (Lighting Africa, 2010b).

Both multiuser systems and solar home systems have the benefit of providing more power relative to pico PV systems. However, they also typically require much higher initial investments (usually at least $200) as well as technical support both for maintenance and installation (Kornbluth et al., 2012; Adkins et al., 2009). Multiuser system has the advantage over solar home systems of offering lower cost per household and sharing maintenance costs among users. However multiuser system and process may be more complicated because it involves multiple users (Reiche et al., 2010).

In the context of developing countries, solar home systems are generally only within the financial reach of middle and upper class populations (Reiche et al., 2010; Jacobson, 2007), while the lower costs of portable pico lighting-- which typically range from $10-$70 per unit-- are more accessible to low income populations (Kornbluth et al., 2012; Adkins et al., 2009). As such, pico systems (i.e. portable lanterns) are seen as a viable substitution for households relying on traditional light sources such as inefficient and poor quality kerosene lamps (Reiche et al., 2010; Adkins et al., 2009). However, a survey in Tanzania found that consumers prefer small solar home systems, if affordable, over a portable system (Reiche et al., 2010). Table A1 below illustrates some of the key differences and trade-offs between SHS and portable lights in terms of costs, light output, range of use, and required input.

Table A1 – Comparison of solar home systems (SHS) and solar portable lights.

System	Upfront cost (USD)	Lighting service	Additional services (eg. radio)	Typical product warranty	Requires technical installation	Requires maintenance
Solar Home Systems (SHS)	200–600 USD	450–3600 lm	Potentially	3–20 years	Yes	Yes
Solar portable lights (pico)	11–65 USD	10–70 lm	Less likely	0–1 years	No	No

Kornbluth et al., 2012

Valued product qualities

A number of product trials, field surveys, and other documented feedback on the use of solar lighting products in Sub-Saharan Africa and throughout the developing world reveal specific product qualities that users prioritize. While various cross-country field surveys of solar lighting preferences have shown that a one-size-fits all model does not apply, there are many features that show relevance to consumers across regions and countries (Reich et al., 2010). A 2011 consumer market study across Ethiopia, Ghana, Kenya, Tanzania, and Zambia, for instance - which includes responses from 10,000 potential off-grid consumers - identifies the following 11 attributes as critical to an ideal lighting product: affordability, portability, sufficient light intensity, control over light intensity, safety, durability, sufficient light hours, ease of use and maintenance, theft protection, multipurpose use, familiarity (Lighting Africa, 2011). This section presents a detailed discussion of these, and other, important product features in the context of replacing kerosene based lighting.

Affordability**:** Product costs and general affordability are a commonly cited feature in selection preferences. Research shows that users want a product that not only has affordable initial costs, but also offsets existing energy costs (Tracey et al., 2010; Lambert, 2000). In other words, it is best if potential savings afforded by the product offset the cost of the initial investment. Similarly it is recommended that the product have minimal operating costs (Lighting Africa, 2011; Mills, 2007). It is important to note that the exact ability to pay is highly dependent on the site context of the project.

Portability**:** Users are found to prioritize portability in the selection of solar lighting products (Frasier, 2013; Lighting Africa, 2011; Reiche et al, 2010; Tracey et al., 2010; Lambert, 2000). A common concern in household lighting relates to the issue of having lighting needs in multiple rooms (e.g. toilet or kitchen detached from main dwelling) (Lighting Africa, 2011). If a household can only afford a limited number of lighting devices, a device that is portable can address these concerns. It is noted, however, that the criteria for portability exists within the parameters of affordability. In other words, in cases where a larger solar system is affordable, portability seems to become less of a priority, as noted in Section 3A.

For portable devices, lightweight products are more desirable (Frasier, 2013; Lighting Africa, 2011), ideally weighing 2.5 kg or less (Reiche et al., 2010). Further it is advised that the device have a decent handle or strap for convenient transport (Lighting Africa, 2011; Reiche et al., 2010).

Light quality: Light quality is commonly cited as a critical product feature for consumers (Kornbluth, 2012; Lighting Africa, 2011; Reiche et al., 2010; Tracey et al., 2010; Lambert, 2000). As most people have only one or two lighting devices, it is beneficial to have light intensity and dispersion sufficient to light one whole room (Lighting Africa, 2011). A study of solar light consumers in rural Kenya reveals a strong preference for lamps designed to provide room lighting over those providing task lighting, despite the higher price (Tracey et al., 2010).

Controllability: As lighting devices are used for a range of activities, there is value in having the ability to control light intensity. Consumers have shown preference for products that enable them to control the level of light for various uses (Lighting Africa, 2011; Adkins et al., 2009; Lambert et al., 2000). There is also value in having the ability to control the direction of light output (Adkins et al., 2009).

Safety: Safety is a commonly preferred characteristic of solar lighting products (Lighting Africa, 2011; Lambert, 2000). Lighting devices should be safe to use, especially for families with young children, e.g. no risk of electrocuting the user or starting a fire (Lighting Africa, 2011).

Durability: Users are shown to value products that are durable (Lighting Africa, 2011; Adkins et al., 2009; Nieuwenhout et al., 2000). One study revealed that users are greatly suspicious of poor quality products that have a short lifespan (Reiche et al., 2010). In fact, there is willingness to pay for quality, even among poor households, where users have less interest in cheaper products that require constant replacement (Reiche et al., 2010). Frequent failures of products cause user-dissatisfaction (Nieuwenhout et al., 2000). Users may expect the product to be protected under warranty of at least 12 months (Reiche et al., 2010). In fact, the selection of warranty guaranteed products is strongly advised, because as noted by the Lumina Project "an unwarranted product is an untrustworthy product" (The Lumina Project, 2013).

Run-time: Users value products that have an adequate duration of light use after charging. Most people want a device to provide light for a minimum of four hours a day (Lighting Africa, 2011; Reiche et al., 2010).

Ease of use and Maintenance: Ideal lighting products are those that are easy to use and maintain, and child friendly (Frasier, 2013; Lighting Africa, 2011; Reiche et al., 2010; Tracey et al., 2010; Lambert, 2000). Users may be intimidated by complex products that are difficult to operate (Lighting Africa, 2011). It can be greatly beneficial to provide educational material on installation, usage, and maintenance when distributing the light unit (Lambert et al., 2000). It is also important to have easy access to affordable replacement parts (Reiche et al., 2010; Lambert, 2000).

Minimal theft risk: Users prefer devices with a small risk of theft. A notable disadvantage of portable systems cited in the literature is the greater risk of theft relative to fixed solar home systems; portable lanterns are usually placed outside during the day to charge and are not permanently attached to rooftops (Reiche et al., 2010). Detachable solar panels and sufficiently long cords may be preferred, as some users express concern over leaving devices unattended outdoors (Lighting Africa, 2011). Permanent rooftop installations have also been shown to help reduce theft relative to portable products, as they are harder to move (Bikam, 2008).

Familiarity: Many users are shown to prefer product designs with which they are familiar (Lighting Africa, 2011; Reiche et al., 2010; Lambert, 2000). One study in Uganda reveals strong preferences for products that visually resemble the kerosene lanterns widely used in the region (Reiche et al., 2010). Further, consumer confidence in products has shown to increase if a lighting device is produced or endorsed by a known manufacturer (Lighting Africa, 2011).

Other features: Another useful feature that users identified is a warning light that indicates when the battery light is low (Reiche et al., 2010). A phone charging outlet is seen as desirable by some users (Reiche et al., 2010), but ill-advised by one practitioner for its potential to reduce equitable household use of the product because the father will likely use it for phone (Frasier, 2013). It is noted that in some cases, multipurpose lights may not serve any single purpose very well (Lumina Project, 2013).

Notable product models

There are countless solar lighting products on the market with a range of product features and of varying quality. This section presents some specific products that stand out in terms of quality and performance.

In 2010, the World Bank Group's Lighting Africa awarded five solar lighting products with the Outstanding Product Award. The award winners were selected from 24 initial products from all over the world by a panel of expert judges based on the results of rigorous product testing, evaluations by off-grid consumers in Sub Saharan Africa, and other factors including price and environmental sustainability (Lighting Africa, 2010). The winners are listed in Table A2.

Table A2, Lighting Africa's Outstanding Product Awards, 2010

Category	**Ranking**	**Product Brand**	**Product Model**
Task Lighting	*First place*	Greenlight Planet	Sun King
	Second place	Barefoot Power	Firefly 12 LED
Ambient Lighting	*First place*	Barefoot Power	Powa Pack
	Second place	d.light Design	Nova S200
Top performance	*First place*	Barefoot Power	Powa Pack
	Second place	Sun Transfer	Sun Transfer 2
Best Value	*First place*	Barefoot Power	Firefly 12 LED
	Second place	Greenlight Planet	Sun King

(Lighting Africa, 2010a)

Lighting Africa, a joint World Bank and International Finance Corporation (IFC) program, maintains two quality benchmarks for off-grid solar lighting: minimum quality standards and recommended performance targets. The Quality Standards provide a "baseline level of quality, durability, and truth-in-advertising to protect consumers" (Lighting Africa, 2012). The Performance Targets include additional benchmarks for minimum brightness (20 lumens or illuminates an area equal to 2 sheets of paper at 25 lux) and a minimum run time (8 hour full-battery run time or 4 hour PV run time) (Lighting Africa, 2012). Conformance with the Quality Standards and Performance Targets is evaluated according to results from lab testing conducted at a third party center using randomly acquired samples (Lighting Africa, 2012). The models listed Table A3 are products that meet both the Minimum Quality Standards and Performance Targets for 2012.

Table A3 – Products meeting quality verification

Product models meeting minimum quality standards and performance targets	
Azuri Indigo Duo Solar Home System	Minda LED Lantern 2W
Barefoot PowaPack 5W	Nuru Light + POWERCycle
Barefoot Firefly Mobile Lamp	One Degree Solar BrightBox 2
Barefoot PowaPack Junior Matrix	Pharos Great White Light
Barefoot PowaPack Junior 2.5W Matrix	Philips Solar Home System
Bettalights BettaOne	Schneider LED Solar Home System Mains
Bettalights BettaTwo	Schneider LED Home System 2.5W
d.light S250	Schneider Electric LED Home System 5W
Deutrex 818 Foce	Shanghai Roy Solar Lighting Kit
ECCODiva	Solux LED-50
Fosera Pico Solar Home System 7000	Solux LED-105
Fosera SCANDLE 200	SunNight Solar SN-2
Greenlight Planet Sun King Pro	SunSumSolar SunSum Lite
Greenlight Planet Sun King Solo	Sunlite Solar Light G3
Global Telelinks Arundhati Home Light	ToughStuff Desk Lamp Kit
Global Telelinks Solar Lantern 3W	ToughStuff Room Lamp Kit
Global Telelinks Home Lighting System	Trony Solar Sundial TSL 01
Lemnis Solar - Pharox Solar Kit	Trony Solar Sundial TSL 02
Marathoner Beacon MB2-090	

Lighting Africa, 2012

3. Distribution models

There are several strategies to delivering off-grid solar lighting products that could be considered. The most common strategies include donations, cash sales, credit, and fees-for-service. The ideal program strategy will depend on the specific goals of the program, the capacities of the involved organization, and the needs of the target population. As Table A4 outlines, there are distinct implications for each model relating to ownership, financing, maintenance, affordability, user behavior, and scale. This section discusses the consideration of each model.

Table A4 Comparison of different distribution models

	Donation	**Cash sales**	**Credit**	**Fee-for-service**
Ownership	user	user	user or intermediary	Energy service company (ESCO)
Financing	government or international organization	n/a	commercial bank, coop, dealer, international donor	ESCO
Maintenance and repair	generally completely dependent on user	completely dependent on user	service generally stops after loan repayment is complete	ESCO, good service generally required to maintain user payments
Affordability	high, due to low upfront cost	limited to higher income groups	limited to higher income groups	depends on what the fee covers
End user behavior	difficult to get users involved	generally good, depends on availability of parts and money	generally good, depends on availability of parts and money	users tend to be less careful, since repair and maintenance is free
Scale	Limited by budgets of org. and gov.	high potential for small system	limited	depends on fee and cost of organization

Nieuwenhout et al, 2000)

a. Donations

Donation-based distributions are program scenarios where a donor organization provides the product for free (or almost free) to the target population. Advantages of donation distributions include the low (often zero) initial costs for the user, the potential for cost reduction through economies of scale (purchase costs, transaction costs, installation costs), and rapid dissemination (Nieuwenhout, 2000). However, this type of model often is not sustainable and may fail because of lack of user commitment (Nieuwenhout, 2000). In a government program in Tunisia where the hardware was 100% subsidized, an operational fee of only 5.20 USD per participant was asked and people refuse to pay for maintenance, because of (mis)interpretations of the 'free gift' of the systems (Nieuwenhout, 2000). Similarly, in Guatemala there was a clear distinction between the maintenance efforts made by users who have invested in their solar lighting system, and those who had received a donated product. Saving for a new battery has been shown to be a lower priority for the users who have received a donated product than those who have paid (Nieuwenhout, 2000).

The user is the key to sustained operation of the system. Donations can be effective provided that the project contains provisions to create user commitment. The user should understand that they should maintain the system themselves (or pay for it) and save for replacement parts. A major consideration is that the donation model places high demands on the donor organization, which first must determine whether a target group has the appropriate social and cultural capital for the approach, and then must work to foster strong user commitment (Nieuwenhout, 2000).

b. Consumer credit

In cases where donation is not a feasible model, appropriate financing is an important consideration towards the successful distribution of solar lighting (Derrick, 1998). If financing is not accessible and users are expected to pay full cost at the outset, they are more likely to buy poorer quality systems with lower initial cost but shorter life (Derrick, 1998). Credit financing options may enable distribution of quality products to households with limited resources (Frasier, 2013). There are numerous successful examples of consumer credit programs for solar lighting including UNDP and World Bank projects, and countless small-scale projects including Dungo Energy Solutions in Ethiopia, Sudimara Solar in Indonesia, and Soluz in the Dominican Republic (Wang, 1998).

Credit cooperatives are one type of consumer credit mechanism applicable to solar lighting. In this model, borrowers are members of a cooperative that give out loans with very low interest (Nieuwenhout, 2000). These arrangements tend to lead to very low default rates because members have paid in over a period of time prior and have demonstrated their creditworthiness (Derrick, 1998). These community-based organizations that allow individuals to borrow cash and pay it back over time tend to have lending terms that are less strict than those of commercial banks (Wang, 1998).

In cases where microcredit is provided by the distributor of the project, the repayment discipline is strongly related to the technical performance of the system (Nieuwenhout, 2000). That is, if the system doesn't work, people tend to stop their loan repayments (Nieuwenhout, 2000). In a pilot study on the introduction of solar lights in a millennium village in Malawi, installment plans, as a form of microcredit, were found to have limited success (Adkins et al, 2009). In that case, product vendors/distributors experienced frustration over frequent delays in payments, with a total repayment rate of 80% (Adkins et al, 2009). In another study in Western Kenya, users had a range of feelings on the merits of cash payments versus credit payments (Mills, 2007). Some people prefered cash payments which avoided complication of future payments, but others reasoned that credit based sales were especially important for lights with relatively high initial costs (Mills, 2007).

Another type of consumer credit applicable to solar light distribution is revolving funds. In this option, a fund may borrow money from larger organizations and then lend money to consumers on a grass-roots level to purchase solar lanterns or solar home systems, where the modest interest charged to borrowers is reinvested in the fund (Derrick, 1998).

c. Fees-for-service

A fees-for-service usually entails a rental contract between users and the service provider. In case of a decentralized system, the service provider usually owns the solar products. Users pay regularly for use of the products as well as maintenance by the service provider. A centralized system is a special case of fees-for-service and is discussed separately below. A fees-for-service model has been found successful in Kiribati, Dominican Republic (Nieuwenhout, 2000; Wang, 1998), Malawi (Adkins et al., 2009) and West Bengal (Chaurey and Kandpal, 2010). Such a model allows users to enjoy the benefits of electricity without having to own a solar product (Ellegard, Arvidson, Nordstrom, Kalumiana and Mwanza, 2004) and therefore not forcing them to become experts on the solar products (Ellegard et al., 2004). It is argued that users are interested in what they could do with electricity instead of PV technology itself (Ellegard et al., 2004). A fees-for-services model increases sustainability of a solar project because maintenance is performed by trained personnel instead of users (Ellegard et al., 2004). Regular contact with technicians also allows users to provide feedback and for technicians to follow up (Lemaire, 2009; Wang, 1998). In the Kiribati project, for instance, technicians visit monthly and a senior technician visits every site twice a year (Nieuwenhout, 2000). Another advantage of a fees-for-service model is that the service deliverer can enforce payment with the threat of removing the system in case of non-compliance (Ellegard et al., 2004; Nieuwenhout, 2000). Additionally, this model is seen as more affordable for users than cash sales and thus is able to reach a larger population (Wang, 1998).

The challenge of a fees-for-service model is to organize maintenance and ensure user compliance with operational standards in a financially sustainable way. To achieve this, the organization must have the capacity of collecting fees such that user contribution covers the maintenance costs for the organization, which has not yet been demonstrated (Nieuwenhout, 2000). Because the system is not owned by users, they may be careless about using the system (Lemaire, 2009; Nieuwenhout, 2000). Also, frequent failures even of small and cheap components such as fluorescent tubes will result in dissatisfaction and will quickly reduce incentives of users to continue paying the fees (Nieuwenhout, 2000). In Zambia, even with an initial subsidy from the funding agency, only the wealthiest customers of the area who have regular incomes can be targeted (Lemaire, 2009). Despite the smaller coverage, it has been recommended that an organization should target those who can afford to avoid default (Lemaire, 2004).

A variation of fees-for-service system utilizes pre-paid cards with which users get a code to start the system (Nieuwenhout, 2000). Such a system prevents use without payment but it doesn't prevent the system from standing idle (Nieuwenhout, 2000).

Maintenance

Under a fees-for-service model, the organization installs solar equipment in households and usually charges a fee for installation. After that, the organization will charge a monthly payment for the systems to cover maintenance, replacement, and repair. In a Zambian case, a battery fund was created to replace batteries regularly (Lemaire, 2009). Because household income varies considerably during the year, payment of the debt could be made on a basis other than monthly, e.g. quarterly or annually (Lemaire, 2009). In Zambia, the organization accepts payments with interest by farmers after harvest (Lemaire, 2009). Due to the need to collect fees and check products regularly, solar systems should be installed in not too large an area (Lemaire, 2009). The criterion is that only light means of transport (bicycles and small motorcycles) are needed by technicians to accomplish their tasks (Lemaire, 2009).

A fees-for-service model is also more vulnerable to high inflation and exchange rate volatility in some African countries (Chaurey and Kandpal, 2010; Nieuwenhout, 2000). The initially agreed monthly fees are often not enough for the organization to cover repair, the cost of battery and component replacement (Chaurey and Kandpal, 2010; Nieuwenhout, 2000). To mitigate this, the battery and maintenance fund could be deposited in US dollars when possible (Lemaire, 2009). Organizations could look for alternative ways other than user payment to replenish the fund. For example, some organizations have launched a small business selling soft drinks to supplement income (Lemaire, 2009). The Sudan Community Development Fund is funded by fees for mobile phone charging, school fees, entrance and membership fees for community clubs and contributions (World Bank, 2010). For a battery and maintenance fund to function well, the administrators need to be highly trusted and frequently monitored by the committee members (Nieuwenhout, 2000).

Central port

A central port system has centrally located PV panels and a battery charging station, owned by an organization. Participants use the station to charge the batteries of their own solar products (e.g. lanterns). The organization will charge a fee every time a person uses the station (Mukhopadhyay, Sensarma and Saha, 1993). A centralized battery charging station has been used for lighting, TV, health services, and radiotelephone in Vietnam and lanterns in India (Palit and Singh, 2011; Chaurey and Kandpal, 2010). In the Indian project, lanterns are rented to households (Palit and Singh, 2011). An entrepreneur collects the rent and use fees of the charging station. S/he manages the station and is responsible for station maintenance. Part of the rent and use fee goes to maintenance and the rest is the entrepreneur's income. In a central port project, the lead organization should:

- select villages carefully based on demand for solar light;
- train entrepreneurs;
- provide maintenance and repair support for the entrepreneurs;
- partner with local microfinance organizations to provide credit to households and entrepreneurs;
- monitor performances of entrepreneurs, charging station, and microfinance partner organizations (Palit and Singh, 2011).

d. Cash sales

A cash sales model represents the distribution of products through a direct one time exchange of cash for the product at full retail price. Cash sales projects may be prone to failure because users tend to go for low quality replacement components (Nieuwenhout, 2000). To prevent this, the organization needs to effectively enforce standards for components and system designs (Nieuwenhout, 2000). Furthermore, reliable maintenance services are required to quickly remedy failures in system operation so that users will not discard the system (Nieuwenhout, 2000).

In the Kenyan Millennium Development Village project, it has been found that people prefer cash or credit sales to lay-away models. Some people believe cash arrangements are best because cash sales usually have a lower total cost compared to credit sales and users do not need to worry about subsequent payments. Others indicate the importance of having an option of credit sales when the product is expensive (Mills, 2007).

> ***Willingness to pay:*** In a Zambian project, people are found to be willing to pay more for solar electricity than they are previously paying for kerosene, candles and batteries because of the better light quality and absence of smoke (Ellegard, 2004). All clients eventually pay despite some delay (Ellegard, 2004). The payment behavior often depends on whether users perceive that there will be action taken by the organization, such as reclaiming the product in case of non-payment (Nieuwenhout, 2000). Also people are willing to pay for quality (Reiche et al., 2010).

e. Strategic partners

Strategic partnerships have been shown to be beneficial to the successful delivery of solar products (Schultz and Doluweera, 2001). Strategic partners can be public or private sector organizations that have some type of operating infrastructure that is used to deliver a good to the target community (Schultz and Doluweera, 2001). Partnerships may be beneficial to assist with household financing needs. For a microfinance model, it is recommended that the organization identify informal finance mechanisms used in the community or ensure they are working with a partner that has experience with local financial transactions. 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 (Schultz and Doluweera, 2001). When forging partnerships, it is important for organizations to have clear roles and responsibilities (Schultz and Doluweera, 2001).

4. Education/Training

a. Consumer use/awareness

Much of the existing literature stresses the importance of stakeholder participation in solar lighting projects (Chaurey and Kandpal, 2010). In order to achieve success with the program, the reasons for installing the solar system must be clear to, and accepted by, the target populations beforehand (Leitch, 1997). Therefore, on top of an initial needs assessment, sufficient communication with local community leaders, future participants, and other relevant stakeholders is highly recommended before the start of the project and throughout the planning process.

User satisfaction of solar products is shown to directly relate to their understanding and expectations of the system (Nieuwenhout, 2000). If people are accurately informed about the possibilities and limitations of a solar lighting product, they will know what to expect and can make an informed decision about whether to invest in it or not. Informed people are generally more satisfied with their system than those who are promised 'heaven on earth' (Nieuwenhout, 2000). The awareness of the existence of PV is not the same as the awareness of the functioning (Schultz and Doluweera, 2011; Nieuwenhout, 2000). Benefits of demonstration of PV systems for raising awareness and facilitation of finance for purchase have been demonstrated in Ghana (Chaurey and Kandpal, 2010).

One case study in Malawi highlights the importance and benefits of community buy-in (Adkins et al., 2009). In this project, program organizers held meetings with village chiefs before the initiation of the project to inform them about the potential lanterns and the pilot. This is followed by focus group meetings with the community members during which men and women separately discuss their specific lighting use in terms of light sources, expenditures, duration of use, the principal activities using light, and future preferences. The groups then view demonstrations of the solar lanterns, and to review charts detailing kerosene expenditures in comparison to the cost of each solar lantern model under a cash, installment, and rental plan (Adkins et al., 2009). A process similar to this may be highly beneficial both to participants as well as program designers, ensuring appropriate level of community buy-in and positive program outcomes.

b. Maintenance training

Technology–user interaction is a more critical problem for adoption of solar lighting systems as compared to cost, efficiency, or other purely technological issues (Chaurey and Kandpal, 2010). The users' attitudes determines the success or failure of the program and it is important that they understand the special characteristics of solar lighting and that they play a role in operating and maintaining the system (Chaurey and Kandpal, 2010). Great care should be taken to obtain the interest and participation of users by explaining the purpose of the installation, its limitations, and its advantages and disadvantages relative to other options, and by determining the population's exact requirements. This dialogue should continue during the implementation/construction stage. In addition, a selected number of community members should receive training in operation and maintenance of the products (Wang, 1998).

Training should be directed at the principal users: both men and women (Nieuwenhout, 2000). Research proves that user contribution improves maintenance in Guatemala and Kenya (Nieuwenhout, 2000). Training has successfully been provided through professional engineering societies, trade organizations, and universities. (Dutt and Mills, 1994).

5. General Maintenance

In India it has been found that maintenance by the user seldom works (Bikam and Mulaudzi, 2006). In Indonesia villagers are found to replace lights with cheaper alternatives (Chaurey and Kandpal, 2010). On the other hand, it has already been mentioned that user ownership contributes to better care for one's systems (Nieuwenhout, 2000; Bikam and Mulaudzi, 2006). Also, community participation (e.g. via field surveys of user preference, consultations on implementing responsibilities, maintenance-costs contributions, system ownership, locally trained technicians) may be particularly effective in helping to maintain and protect the system from theft and vandalism (World Bank, 2010; Nieuwenhout, 2000). However, the effectiveness of their involvement on maintaining the system depends to a great extent on users' level of knowledge (Nieuwenhout, 2000; Chaurey and Kandpal, 2010), the cost (Bikam and Mulaudzi, 2006) and efforts involved, willingness and ability to invest (Bikam and Mulaudzi, 2006), the availability of good quality systems and spare parts (Chaurey and Kandpal, 2010; Bikam and Mulaudzi, 2006; Nieuwenhout, 2000) and appropriate distribution mechanisms (Nieuwenhout, 2000).

In the Philippines and South Africa it is found helpful for the lead organization to spell out the responsibilities of users in a user contract (Bikam and Mulaudzi, 2006; Nieuwenhout, 2000). An organization should take action to any modification to the system without consent of a technician (Nieuwenhout, 2000). It is also important to have a reporting and tracking system to provide data to monitor (World Bank, 2010).

Donors must build cost-recovery components into renewable energy projects, even for those funded on a grant basis (Wang, 1998). User contribution is necessary for maintenance and component replacement in the long run (Wang, 1998). A cost recovery component has also been shown to increase local villagers' sense of responsibility for and involvement with installed solar system (Wang, 1998).

Battery maintenance and replacement is significant for sustainability of PV because the system tends to be overused and batteries constantly discharged as electricity loads increase (Ellegard et al., 2004). The lead organization should arrange recycling or disposal of light bulbs and batteries (World Bank, 2010).

6. Sourcing

It is important to balance the concern of equipment quality with supply chain considerations for long-term system sustainability (Schultz and Doluweera, 2011). In theory, local assembly may help shave a few percentage points off the final cost due to lower labor costs in the region. Further, local assembly will likely save on high tariffs and taxes whenever component duties are taxed at a lower rate than fully assembled products (Lighting Africa, 2010b). Other benefits of local procurement include contributions to local employment and economic development; and shorter wait times for the procurement of spare or replacement parts (Bikam and Mulaudzi, 2006). However, in reality, cost advantages of local production (relative to Asian producers) are shown to be slight or non-existent, "once the generally high costs of doing business in Africa are taken into consideration" (e.g., infrastructural and logistical issues) (Lighting Africa, 2010b).

Appendix B - NGOs Reviewed for Institutional Landscape

Program name	**Solar Sister**
Website	http://www.solarsister.org
Contact	solarsister.org@gmail.com
Organization type	Social Enterprise
Headquarters	Rhode Island, USA and Kampala, Uganda
Project locations	Rwanda, Uganda, South Sudan
Program description	Solar Sister is a social enterprise that trains local women entrepreneurs to sell solar lanterns, providing much needed household income for the women, and much needed light for their communities. Currently Solar Sister has 281 entrepreneurs and claims to benefit 31,880 people from their solar lanterns. According to their calculations, every dollar invested in a Solar Sister Entrepreneur generates over $46 in economic benefits in the first year,, through earned income for the Solar Sister Entrepreneur, and through the cash savings of the customers.
Mission	Solar Sister seeks to eradicate energy poverty by empowering women with economic opportunity. They combine the breakthrough potential of solar technology with a deliberately woman-centered direct sales network to bring light, hope and opportunity to even the most remote communities in rural Africa
Product	d.light Design, Greenlight Planet, Barefoot Power, Nokero
Product type	Lamps ($15-$50)
Source of product	"Most of the products are made in China - we would be thrilled to buy from local manufacturers, but at this time the manufacturing has not developed to that point" (email correspondence, 3/12/2013, Katherine Lucy, Founder & CEO)
Distribution model	Women establish distribution networks targeted at other women. Solar Sister has been described as the Avon model for solar power. This direct-sales network brings the solar technology to the women's doorstep and provides income generation opportunities. Solar Sister provides women with education and training to better equip them to operate and maintain the solar technology, helping them achieve success as independent business women.
Partners	Ashoka, Draper Richard Kaplan, USAID, Exxonmobil
Funding sources	Partner funded, accepts online donations

Program name	Fifty Lanterns International
Website	http://www.50lanterns.org
Contact	Linda, linda@50lanterns.org
Organization type	Nonprofit
Headquarters	St. Paul, Minnesota
Project locations	Ethiopia, Tanzania, Rwanda, (Haiti, Afghanistan, Pakistan, India, Kashmir, Honduras)
Program description	Fifty Lanterns International provides solar power lanterns and energy systems in 9 countries. Founded in 2004, the organization has completed 17 major distributions or solar installation projects. They mostly target orphans, victims of disaster, etc. They partner with established humanitarian groups to provide solar power lights and arrays. Last September, they installed solar lighting in 2 schools in Ethiopia (Ekodaga and Cololo Belala).
Mission	To help improve lives in communities torn by poverty, war, or disaster through gifts of solar-powered lanterns and energy systems.
Product type	Solar Panel Installations, solar lanterns
Product type	Undisclosed
Source of product	Undisclosed
Distribution model	Solar products are donated to individuals/schools. As a small, volunteer led organization, 50 Lanterns partners with local organizations to complete their distribution. They work closely with partners to select recipients. Representatives from 50 Lanterns make each distribution personally.
Partners	CARE International, Save the Children, HOPE Worldwide, ARC, International Health Services, and Habitat for Humanity. Ethiopian partners: Tesfa and Ethiopia Reads.
Funding sources	Donations

Program name	Dungo Energy Solutions
Website	http://www.afroenergy.gnbo.com.ng/home
Contact	afroenergyplc@gmail.com; yosephbet@gmail.com
Organization type	Social Enterprise
Headquarters	Addis Ababa, Ethiopia
Project locations	Ethiopia
Program description	Dungo Energy Solutions is a social enterprise that distributes low-cost solar lighting products to rural communities in Ethiopia to reduce reliance on kerosene.They were established in 2011 and plan to sell 200,000 lanterns by the end of 2014. The three main objectives of the organization are to distribute solar lighting products, developing certified GHG reduction credits, trade carbon credits through the clean development mechanism scheme.
Mission	To inspire Ethiopians to rise to the challenge of climate change and to create a new sense of urgency in ensuring environmental sustainability and food security. To improve the environment, health and education situation in Ethiopia through the use of solar energy solutions.
Product	Little Sun Solar Light, FireFly 12, Barefoot Power 5w, Barefoot Power 15w
Product type	They use four different models of lighting products, two of which are larger systems using panels and strip lights, the other models are solar LED lanterns with a rechargeable battery.
Source of product	Undisclosed
Distribution model	Dungo Energy Solutions employs microfinance mechanism to overcome the barrier of the initial investment costs associated with transitioning from kerosene to solar energy. Through this mechanism, villagers can buy solar lanterns and home systems and use it for three or more years without any extra costs, (where their previous spending on kerosene for lighting was about $4 per month, or $48 per year). They are also registered under the UNFCCC Clean Development Mechanism, generating carbon credits through the solar projects.
Partners	They are actively partnering with solar energy companies and social investors around the world

Program name	Solanterns
Website	http://www.solanterns.com
Contact	info@africarenwables.com
Organization type	Subsidiary of a privately held company (Renewable Energy Ventures Kenya Ltd)
Headquarters	Nairobi, Kenya and Altoona, WI, USA
Project locations	Kenya
Program description	Solanterns is an initiative of Renewable Energy Ventures Ltd., a renewable energy and energy efficiency project developer and advisor headquartered in Kenya. Solanterns uses a rental model to bring solar lanterns to low-income households while simultaneously creating primary or supplemental income through its distribution model.
Mission	To help accelerate the adoption of solar lanterns to replace kerosene lanterns in rural Kenya; and to reduce fire risk, respiratory illnesses, poor eyesight and high lighting costs of poor communities.
Product	Greenlight Planet Sun King & Greenlight Planet SunKing Pro
Product type	Solar lights
Source of product	Renewable Energy Ventures Ltd. (originally made in China)
Distribution model	The Solanterns Initiative employs micro-entrepreneurs, (recruited from youth- or women-groups) and mediates with a microfinance institution. The micro-loan enables, the micro-entrepreneur to purchase upward of 20 solar lanterns and start to either sell or rent them to local families. Daily fees for renting are adjusted to the average kerosene expenses of the households in the communities. The micro-entrepreneur repays the loan, make a living from the rental business, while more households benefit from solar lanterns. The lanterns retail about USD 25 and have a battery life of 3 years.
Partners	GVEP International, Lighting Africa, River Bank Savings and Credit, Rafiki Deposit Taking Microfinance, Humanity United. Depends on partners to assist in distribution of the solar lanterns to Peri-urban areas in Nairobi and the rest of the country.

Program name	Solar Light for Africa
Website	http://www.solarlightforafrica.org
Contact	Charlene Turner, Executive Director, charlene@solarlightforafrica.org
Organization type	Nonprofit 501(c)3
Headquarters	Melbourne, FL, USA
Project locations	Ethiopia, Ghana, Liberia, Rwanda, Sierra Leone, Tanzania, Uganda.
Program description	Founded in 1997, Solar Lights for Africa delivers small-scale solar electrification to people throughout Africa. The organization has installed over 2500 installations in 7 countries in schools, health clinics, orphanages, churches, and villages. The solar systems are hard-wired, affixed permanently to rooftops, have locked batteries, and are customized to fit unique conditions. They work with locally trained solar contractors to ensure reliable installation and maintenance of the systems.
Mission	To transform lives and empower the people of Africa by providing light and energy using solar power. Other objectives include relieving impacts of poverty, decreasing environmental degradation by replacing kerosene lanterns, improving health, providing increased educational opportunities.
Product	Solar electrification, commercial installations, Solar LED lanterns
Product type	Solar arrays, Lanterns
Source of product	Undisclosed
Distribution model	The project plans to build up an independent sales organization which - in cooperation with local companies, micro financing organizations and schools - will enable social marketing of solar lamps.
Partners	The organization has both funding partners and program partners. Funding partners include: Aid for Africa, Apollo Solar, Galilee Episcopal Church, Sterling Planet, and St. Helenas Church. Program Partners include: Bromley Episcopal Mission School, Diocese of Atlanta, Good Samaritan Ministries, Kids Uganda, Kids Uganda.
Funding sources	Donations (EPA, USAID, Kellogg Foundation, Mustard Seed Foundation, US Department of Energy, St. John's Episcopal, Roman Catholic Diocese of Erie, Individual Donors).

Program name	M-KOPA Solar
Website	http://www.m-kopa.com/
Contact	info@m-kopa.com
Organization type	Business
Headquarters	Nairobi, Kenya
Project locations	Kenya (rural areas, initial focus on western Kenya))
Program description	Mobile technology company that provides affordable solar powered lighting and mobile charging to rural Kenyans on a pay-as-you-go basis. Established in 2011 following successful consumer trials in Kenya during 2010.
Mission	Strives to promote transformative power of affordable technology for underserved consumers.
Product	d.light solar
Product type	Solar home systems (the system consists of a base-station with a solar panel, three lamps and a charging kit for phones—an entire electrical system for a small house that would normally cost around $200)
Source of product	d.light
Distribution model	Uses a pay-as-you-go distribution model. Customers buy the solar home system on an M-KOPA payment plan, with an initial deposit ($30) followed by regular payments for up to one year. After completing payments, customers own the product outright. The systems are designed for quick and easy self-home installation. Panels can be mounted to roof and connect the lights. The solar home system is portable and can be carried during travel. M-KOPA Solar is initially available through select M-KOPA dealers in Kenya.
Partners	Safaricom (Kenya's leading mobile operator), d.light (award winning solar lighting company)
Funding sources	Program investors include: Gray Ghost Ventures, Acumen Fund, d.o.b. Foundation, LGT Venture Philanthropy, Lundin Foundation. Financial supporters include: Shell Foundation, African Enterprise Challenge Fund, DFID UK.

Program name	One Child One Solar Light
Website	http://www.one-child-one-solarlight.org/
Contact	Project Coordination, meinecke@solux.org
Organization type	Nonprofit (a project within a larger nonprofit organization: SOLUX e.V)
Headquarters	Munich, Germany
Project locations	Ghana
Program description	SOLUX e.V. is a non-profit association with the goal of introducing mobile solar lamps into southern developing countries. One Child One Solar, a project within SOLUX e.V, intends to provide portable solar lamps to school children and their families in rural areas in Ghana. Teachers at the schools serve as contact points for the participant families.
Mission	The project One Child One Solar light intends to use the existing infrastructure that schools provide to form the basis of a countrywide program to convince school children and their parents of the usefulness and cost effectiveness of solar lamps.
Product	SOLUX-LED-50, SOLUX-LED-100
Product type	Solar Lamps (provides bright light for work, reading and leisure, lasts 4-5 hours per charge from the solar module and is designed for use in rough environments)
Source of product	Solar4Ghana LTD
Distribution model	The project relies on the Christian Mothers Association (CMA) in Ghana as agents to distribute solar lanterns throughout all dioceses in which CMA operates. The project distributes solar lights at schools in Ghana by working with local companies, schools and microfinancing organizations. They have organized workshops to educate distribution partners on marketing and advertising methods, financing models, networking, solar technology training.
Partners	Christian Mothers Association, The Ghana Co-operative Credit Unions Association, Solar4ghana Ltd., Free Energy Foundation

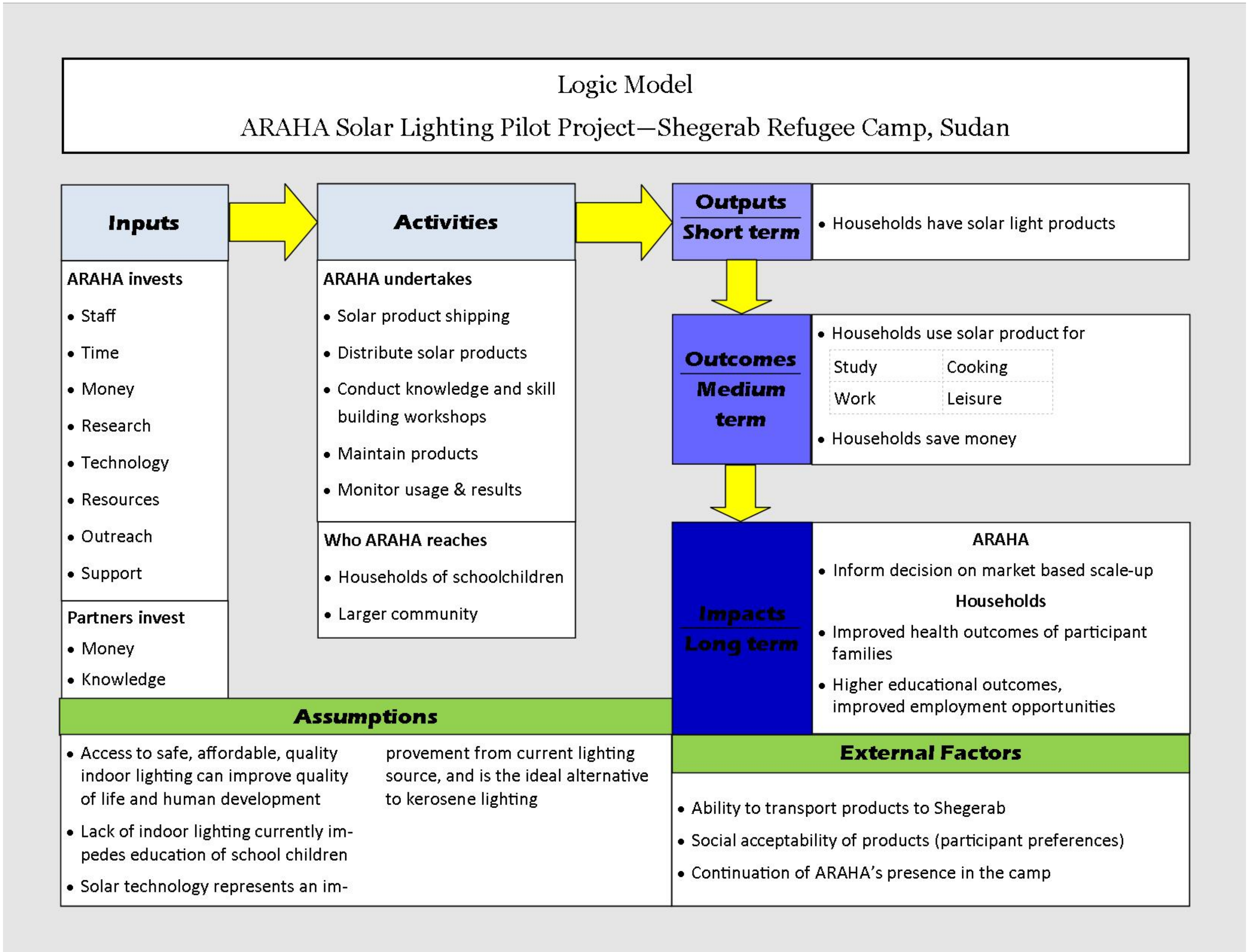
Program name	Mobisol, plug in the world
Website	http://www.plugintheworld.com
Contact	info@plugintheworld.com
Organization type	Business
Headquarters	Berlin, Germany
Project locations	East Africa (Kenya, Tanzania)
Program description	Mobisol is a young start-up founded in 2010. They provide an alternative energy source for low-income customers living without access to electricity, combining solar energy and a suitable repayment scheme with mobile banking. The program installs ready-to-use solar home systems in rural off-grid households in Kenya and Tanzania. The system will provide enough electricity for consumers to be able to operate low energy appliances including lights, radios, and mobile phones.
Mission	Mobisol aims to electrify the rural population in developing countries by combining solar energy and mobile banking.
Product	Mobisol solar home
Product type	Solar home system
Source of product	Self-produced (mobisol brand)
Distribution model	Monthly payments using mobile payment with phones, circumventing the problem of high initial investment costs of solar home systems. (Pay-as-you-go system).
Partners	Vodafone, Microenergy International, Kakute Ltd. Tanzania, Scode Ltd. Kenia

Program name	Lighting Rural Uganda with Solar
Website	http://www.lightingruraluganda.org/
Contact	lightingruraluganda@gmail.com
Organization type	Nonprofit
Headquarters	Uganda
Project locations	Uganda, Kalangala, Wakiso districts
Program description	The program model uses an entrepreneurial model of energy service delivery that was developed and successfully piloted across villages in Kalangala and Wakiso districts in Uganda. The program mobilizes village credit cooperatives for the delivery of energy services to rural villages. The model is designed to benefit both the user and the supplier of services. The program aims to reach 70,000 off-grid households over the next two years.
Mission	To be a self-sustaining and leading, pro-poor supplier of affordable and reliable household solar light in Uganda with national and international recognition.
Product	Solar Flare
Product type	LED Lanterns
Source of product	*undisclosed*
Distribution model	Initial project objectives included the testing of several marketing approaches , including distribution of solar lanterns through village credit cooperatives (VCCs), and/or retail sales. Distribution practices are aimed at promoting access, demand, and utilization of the lanterns among 3000 rural households. The organization sites three distinct benefits to their distribution model: 1) departure from the donation gives the product users a sense of ownership, 2) enabling product users to establish credit will allow them to participate in other village empowerment programs, 3) by recovering costs, the project is sustainable and scalable.
Partners	Rural Electrification Agency and Microfinance Support Center of the Uganda Ministry of Finance, Uganda Cooperatives Savings and Credit Union Limited
Funding sources	USAID, greenlight planet

Program name	Azuri
Website	http://www.azuri-technologies.com
Contact	info@azuri-technologies.com
Organization type	Business
Headquarters	Cambridge, UK
Project locations	Sub-Saharan Africa (South Sudan, Kenya, Zambia, and Malawi)
Program description	Azuri Technologies is a product and service company that delivers affordable solar power in emerging markets. By combining solar and mobile phone technology, the company's Indigo products enable users to benefit from clean renewable energy and simultaneously reduce their energy expenses. Azuri brings power at scale to off-grid customers in rural emerging markets.
Mission	Azuri's objective is to bring power at scale to off-grid customers worldwide, providing basic needs that are regarded as routine in developed countries.
Product	Indigo (product developed by Azuri team)
Product type	Home solar system
Source of product	Self-produced
Distribution model	Combines mobile phone and solar technology to allow customers to pay for their energy with scratch cards over a period of time. Consumers purchase a pay-as-you-go card that contains a code. The code and the product serial number are sent to the company via text message to obtain an access code. The access code activates the system for a week. Through this pay-as-you-go system, the consumer gradually pays off the cost of the product. After that, they can upgrade to a more powerful system. Provides light, for a cost of 0.3USD/week (compared to 2.3usd/week for kerosene)
Partners	None listed. Has received multiple awards: Nobel Sustainability supported Clean Tech Company 2012, World Economic Forum Technology Pioneer 2013, World Business and Development Award 2012, Sustainia Award.
Funding sources	On Feb 5th, 2013 Azuri secured a £1m working capital loan from Barclays to accelerate the deployment of its Indigo home solar systems.

Program name	Flexiway Solar Solutions
Website	http://flexiwaysolar.com
Contact	James Fraser (Australia), info@flexiwaysolar.com
Organization type	Social Enterprise
Headquarters	Australia (and beyond, "divided physically over the planet")
Project locations	Distributed by NGOs in Tanzania, Liberia, Rwanda (Fiji, Papua New Guinea
Program description	Flexiway Solar Solutions distributes efficient and affordable solar-powered LED lights to replace kerosene lamps.
Mission	To improve the lives of our fellow human beings and our environment by replacing dangerous and expensive kerosene lamps with affordable Solar-powered LED lights, creating a brighter future for everybody on our planet.
Product	Solar Muscle
Product type	Solar Powered LED light; (9x9x2.5cm)
Source of product	China (email correspondence, 3/10/13, James Fraser)
Distribution model	Flexiway Solar Solutions works with various NGOs for distribution. The lights are sold as cheaply as possible, (between USD $6 – $10, which covers all development, production, transportation, importation and distribution costs). The exact price will depend on local factors, such as order size, import costs, taxes etc. Local distributors can increase the prices slightly to ensure their profit, but the aim is to have the lights priced low. The lights are UN certified under the Gold Standard of the Clean Development mechanism (CDM).
Partners	Works with local parties as well as international NGO's and charities. Partners include Concern Worldwide, The Kokoda Track Foundation, Rotary International, Philadelphia Club, Awaken Mozambique, Carbonsoft
Funding sources	Generates income to fund new projects, accepts donations.

Appendix C – Program Logic Model



Appendix D - Costs and Savings Analyses

Model 1		**d.light S300**					
Household Use							
Years				**Year**			
	Unit Cost	*Qty.*		0	1	2	3
Capital Costs							
Solar Lighting Unit	24	110		2,640			
Spare Batteries	10	20		200			
Spare Lamps	5	20		100			
Shipping				1,500			
Training/Reference Materials				125			
Panel and Lantern mounting tools	3	110		330			
Total Capital Costs				**4,895**	**0**	**0**	**0**
Operating Costs	# of Staff	*Monthly salary*	*# of months*				
Implentation Staff	1	200	3		600.00	0.00	0.00
Project Manager - Part Time	1	160	12		1,920.00	1,920.00	480.00
Maintenance Staff - Part Time	1	50	12		600.00	600.00	0.00
Evaluation Staff	1	200	3		0.00	0.00	600.00
Staff supplies					50.00	50.00	50.00
Total Operating Costs				**0**	**3,170**	**2,570**	**1,130**
Total Costs				***4,895***	***3,170***	***2,570***	***1,130***
Revenues from Payback Schemes		*Repayment Rate*			95%	85%	
Payback revenue - Scenario B					2,585	2,313	
	Cost	*Purchase Rate*					
Payback revenue -Scenario C	25	100%			0	2,500	
Program Net Cost Flow - Scenario A				***4,895***	***3,170***	***2,570***	***1,130***
Program Net Cost Flow - Scenario B				***4,895***	***585***	***257***	***1,130***
Program Net Cost Flow - Scenario C				***4,895***	***3,170***	***70***	***1,130***

3 Year Cost NPV - Scenario A	**$ 11,025**
3 Year Cost NPV - Scenario B	**$ 6,589**
3 Year Cost NPV - Scenario C	**$ 8,841**

Appendix D - Costs and Savings Analyses

Model 2		**Philips 6W CFL Lantern**					
Household Use							
Years				**Year**			
	Unit Cost	*Qty.*		0	1	2	3
Capital Costs							
Solar Lighting Unit	90	110		9,900			
Spare Batteries	12	20		240			
Spare Lamps	4	20		80			
Shipping				1,500			
Training/Reference Materials				125			
Panel and Lantern mounting tools	3	110		330			
Total Capital Costs				**12,175**	**0**	**0**	**0**
Operating Costs	# of Staff	*Monthly salary*	*# of months*				
Implentation Staff	2	200	3		1,200.00	0.00	0.00
Project Manager - Part Time	1	160	12		1,920.00	1,920.00	480.00
Maintenance Staff - Part Time	1	50	12		600.00	600.00	0.00
Evaluation Staff	1	200	3		0.00	0.00	600.00
Staff supplies					50.00	50.00	50.00
Total Operating Costs				**-**	**3,770**	**2,570**	**1,130**
Total Costs				***12,175***	***3,770***	***2,570***	***1,130***
Revenues from Payback Schemes		*Repayment Rate*			95%	85%	
Payback revenue - Scenario B					2,585	2,313	
	Price	*Purchase Rate*					
Payback revenue -Scenario C	25	100%			0	2,500	
Program Net Cost Flow - Scenario A				***12,175***	***3,770***	***2,570***	***1,130***
Program Net Cost Flow - Scenario B				***12,175***	***1,185***	***257***	***1,130***
Program Net Cost Flow - Scenario C				***12,175***	***3,770***	***70***	***1,130***

3 Year Cost NPV - Scenario A	**$ 18,866**
3 Year Cost NPV - Scenario B	**$ 14,429**
3 Year Cost NPV - Scenario C	**$ 16,682**

Appendix D - Costs and Savings Analyses

Model 3				**Tata 300W Solar BCS CFL**			
Household Use							
Years				**Year**			
	Unit Cost	*Qty.*		0	1	2	3
Capital Costs							
Solar Lighting Unit	5000	2		10,000			
Spare Lanterns	50	10		500			
Spare Batteries	250	2		500			
Spare Lamps	5	25		125			
Shipping				4,000			
Training/Reference Materials				125			
Panel and Lantern mounting tools	3	110		330			
Total Capital Costs				**15,580**	**0**	**0**	**0**
Operating Costs	# of *Staff*	*Monthly salary*	*# of months*				
Implentation Staff	2	200	3		1,200.00	0.00	0.00
Project Manager - Part Time	1	160	12		1,920.00	1,920.00	480.00
Maintenance Staff - Part Time	1	50	12		600.00	600.00	0.00
Evaluation Staff	1	200	3		0.00	0.00	600.00
Staff supplies					50.00	50.00	50.00
Total Operating Costs				**0**	**3,770**	**2,570**	**1,130**
Total Costs				***15,580***	***3,770***	***2,570***	***1,130***
Revenues from Payback Schemes		*Repayment Rate*			85%	85%	
Payback revenue - Scenario B					2,313	2,313	
	Cost	*Purchase Rate*					
Payback revenue -Scenario C	25	100%			0	2,500	
Program Net Cost Flow - Scenario A				***15,580***	***3,770***	***2,570***	***1,130***
Program Net Cost Flow - Scenario B				***15,580***	***1,457***	***257***	***1,130***
Program Net Cost Flow - Scenario C				***15,580***	***3,770***	***70***	***1,130***

3 Year Cost NPV - Scenario A	**$ 22,271**
3 Year Cost NPV - Scenario B	**$ 18,089**
3 Year Cost NPV - Scenario C	**$ 20,087**

Appendix D - Costs and Savings Analyses

Solar Lighting Household Savings

Household Use			Year									
Years			1	2	3	4	5	6	7	8	9	10
Scenario A	*US$/ltr.*	*Ltrs/month*										
Kerosene Savings (annual)	0.91	5	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42
No Payback			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement parts			0.00	0.00	0.00	16.00	0.00	0.00	0.00	16.00	0.00	0.00
Net Savings			54.42	54.42	54.42	38.42	54.42	54.42	54.42	38.42	54.42	54.42
Scenario B	*US$/ltr.*	*Ltrs/month*										
Kerosene Savings (annual)	0.91	5	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42
Payback 50% of fuel savings			27.21	27.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement parts			0.00	0.00	0.00	16.00	0.00	0.00	0.00	16.00	0.00	0.00
Net Savings			27.21	27.21	54.42	38.42	54.42	54.42	54.42	38.42	54.42	54.42
Scenario C	*US$/ltr.*	*Ltrs/month*										
Kerosene Savings (annual)	0.91	5	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42	54.42
Purchase of unit after trial			0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement parts			0.00	0.00	0.00	16.00	0.00	0.00	0.00	16.00	0.00	0.00
Net Savings			54.42	29.42	54.42	38.42	54.42	54.42	54.42	38.42	54.42	54.42

Total Savings - 3 years	per HH	Project total
Scenario A	**$ 163.27**	**$ 16,326.53**
Scenario B	**$ 108.84**	**$ 10,884.35**
Scenario C	**$ 138.27**	**$ 12,988.10**

Total Savings NPV - 3 years	Project total
Scenario A	**$ 14,281.99**
Scenario B	**$ 9,362.21**
Scenario C	**$ 12,098.40**

Total Savings - 10 years	per HH	Project total
Scenario A	**$ 512.22**	**$ 51,221.77**
Scenario B	**$ 457.80**	**$ 45,779.59**
Scenario C	**$ 487.22**	**$ 44,393.81**

Total Savings NPV - 10 years	Project total
Scenario A	**$ 36,071.73**
Scenario B	**$ 31,151.95**
Scenario C	**$ 35,904.27**

Appendix D - Costs and Savings Analyses

Model 1		**d.light S300**
Scenario A		**No Payback**
Program Costs		
3 year NPV	$	11,024.77
Beneficiary Savings		
3 year total per HH	$	163.27
Cumulative 3 year total	$	16,326.53
NPV of 3 year total	$	14,281.99
10 year total per HH	$	512.22
Cumulative 10 year total	$	51,221.77
NPV of 10 year total	$	36,071.73
Net Program Savings		
3 year	$	3,257.22
10 year	$	25,046.96
Scenario B		**50% savings payback**
Program Costs		
3 year NPV	$	6,588.65
Beneficiary Savings		
3 year total per HH	$	108.84
Cumulative 3 year total	$	10,884.35
NPV of 3 year total	$	9,362.21
10 year total per HH	$	457.80
Cumulative 10 year total	$	45,779.59
NPV of 10 year total	$	31,151.95
Net Program Savings		
3 year	$	2,773.56
10 year	$	24,563.30
Scenario C		**One year trial period**
Program Costs		
3 year NPV	$	8,841.17
Beneficiary Savings		
3 year total per HH	$	138.27
Cumulative 3 year total	$	13,826.53
NPV of 3 year total	$	12,098.40
10 year total per HH	$	487.22
Cumulative 10 year total	$	44,393.81
NPV of 10 year total	$	35,904.27
Net Program Savings		
3 year	$	3,257.22
10 year	$	27,063.09

Model 2		**Philips 6W CFL**
Scenario A		**No Payback**
Program Costs		
3 year NPV	$	18,865.52
Beneficiary Savings		
3 year total per HH	$	163.27
Cumulative 3 year total	$	16,326.53
NPV of 3 year total	$	14,281.99
10 year total per HH	$	512.22
Cumulative 10 year total	$	51,221.77
NPV of 10 year total	$	36,071.73
Net Program Savings		
3 year	$	(4,583.53)
10 year	$	17,206.21
Scenario B		**50% savings payback**
Program Costs		
3 year NPV	$	14,429.40
Beneficiary Savings		
3 year total per HH	$	108.84
Cumulative 3 year total	$	10,884.35
NPV of 3 year total	$	9,362.21
10 year total per HH	$	457.80
Cumulative 10 year total	$	45,779.59
NPV of 10 year total	$	31,151.95
Net Program Savings		
3 year	$	(5,067.19)
10 year	$	16,722.55
Scenario C		**One year trial period**
Program Costs		
3 year NPV	$	16,681.92
Beneficiary Savings		
3 year total per HH	$	138.27
Cumulative 3 year total	$	13,826.53
NPV of 3 year total	$	12,098.40
10 year total per HH	$	487.22
Cumulative 10 year total	$	44,393.81
NPV of 10 year total	$	35,904.27
Net Program Savings		
3 year	$	(4,583.53)
10 year	$	19,222.35

Model 3		**Tata 600W System**
Scenario A		**No Payback**
Program Costs		
3 year NPV	$	22,270.52
Beneficiary Savings		
3 year total per HH	$	163.27
Cumulative 3 year total	$	16,326.53
NPV of 3 year total	$	14,281.99
10 year total per HH	$	512.22
Cumulative 10 year total	$	51,221.77
NPV of 10 year total	$	36,071.73
Net Program Savings		
3 year	$	(7,988.53)
10 year	$	13,801.21
Scenario B		**50% savings payback**
Program Costs		
3 year NPV	$	18,088.71
Beneficiary Savings		
3 year total per HH	$	108.84
Cumulative 3 year total	$	10,884.35
NPV of 3 year total	$	9,362.21
10 year total per HH	$	457.80
Cumulative 10 year total	$	45,779.59
NPV of 10 year total	$	31,151.95
Net Program Savings		
3 year	$	(8,726.49)
10 year	$	13,063.24
Scenario C		**One year trial period**
Program Costs		
3 year NPV	$	20,086.92
Beneficiary Savings		
3 year total per HH	$	138.27
Cumulative 3 year total	$	13,826.53
NPV of 3 year total	$	12,098.40
10 year total per HH	$	487.22
Cumulative 10 year total	$	44,393.81
NPV of 10 year total	$	35,904.27
Net Program Savings		
3 year	$	(7,988.53)
10 year	$	15,817.35

Overall Summary

Appendix D - Costs and Savings Analyses

Model 1	d.light S300
Model 2	Philips 6W CFL Lantern
Model 3	Tata 300W Solar BCS CFL

Scenario A	No payback by recipients
Scenario B	Monthly payback of 50% of kerosene fuel savings
Scenario C	One year trial period, after which recipient has option to purchase lantern

Discount Rate	7%
Kerosene Price	
SDG	4.00
US$	0.91
Exchange Rate	
SDG/US$	4.41
US$/SDG	0.227

Legend

Appendix E – Monitoring and Evaluation

Activity	Indicator Number	Indicator	Output/ Outcome	Baseline	Target/ Benchmark	Data Source	Frequency
Inputs: staff time							
Staff maintain detailed time sheet disaggregated by project	IP1.1	Number of hours field staff spends (Shegerab offices) to coordinate in country shipping logistics, distribution, training, maintenance and monitoring	N/A	0 hours devoted to solar program	N/A	Timesheets of field staff	Staff record daily; ARAHA monitors it annually
Output: selected households (100) in Shegerab camps have solar light products							
Ship solar products to Shegerab, Sudan	OP1.1	Number and condition of products arrived to field office	Output	0 products shipped to Shegerab	Year 1: 100+ solar light products; 20 spare batteries; 20 spare bulbs; all with good condition	Records of field staff	Once
Distribute solar products to households	**OP1.2**	**Number of households that received solar light products, and name of recipients.** **PRIORITY INDICATOR**	**Output**	**0 (baseline from pre-program survey**	**Year 1: Each household whose children go to Shegerab camp school has at least one product per child**	**Records of field staff**	**Once**

Activity	Indicator Number	Indicator	Output/ Outcome	Baseline	Target/ Benchmark	Data Source	Frequency
Outcome 1: households are more comfortable with and knowledgeable of solar products							
Conduct knowledge and skill building workshops on solar lighting with program participants	OC1.1	Number of group workshops offered	Output	0 workshops offered	Year 1: 2 workshops in the first year	Records of field staff	Following workshop
	OC1.2	Number of household consultations provided	Output	0 consultation s offered	Year 1: 1 consultation per household	Records of field staff	Following family visit
	OC1.3	Participant's level of ability to operate solar product	Outcome	Baseline from pre-program survey	Year 1: All participants able to operate solar product	Pre/post-program survey	Following workshop and family visit
Outcome 2: households use solar products							
	OC2.1	Percentage of households who are using the products	Outcome	0	Year 1-5: 90% of households use solar product daily	Records of staff family visit	Biannually
	OC2.2	**Monthly spending on kerosene** **PRIORITY INDICATOR**	**Outcome**	**$3.50 per month (Baseline from pre-program survey)**	**Year 1-5: 90% reduction from baseline**	**Records of staff family visit**	**Biannually**
	OC2.3	Number of repairs and replacement cases (parts, batteries)	Outcome	NA	NA	Records of field staff	Ad hoc
	OC2.4	**Description of damages to products (how product broke)** **PRIORITY INDICATOR**	**Outcome**	**NA**	**NA**	**Records of field staff**	**Ad hoc**

Activity	Indicator Number	Indicator	Output/ Outcome	Baseline	Target/ Benchmark	Data Source	Frequency
Outcome 3: Students are able to spend more time on school work with better quality light							
	OC3.1	**Additional hours spent on school work per night per student PRIORITY OUTCOME**	**Outcome**	**baseline from pre-program survey**	**Year 1-2: extra 2 hours**	**Pre-program and survey and staff family visits**	**Survey at the beginning of project; family visits are done quarterly**
Outcome 4: Participants have improved light source for various activities (cooking, social gatherings, security etc.)							
	OC4.1	Number of additional hours spent on work, cooking, and social gathering per night	Outcome	baseline from pre-program survey	Year 1-2: extra 2 hours	Pre-program and survey and staff family visits	Survey at the beginning of project; family visits are done quarterly
	OC4.2	Participants sense of general security	Outcome	baseline from pre-program survey	Year 1-2: increased sense of security	Pre- and post-program survey	Survey at the beginning of the project; post-program survey every year
	OC4.3	**Number of participants satisfied with solar product PRIORITY INDICATOR**	**Outcome**	**n/a**	**Year 1-2: 90% of participants are satisfied with the product**	**Post-program survey**	**Post-program survey every year**
	OC4.4	**Number of participants who would be willing to buy product in future (and willingness to pay) PRIORITY INDICATOR**	**Outcome**	**n/a**	**n/a**	**Post-program survey**	**Post-program survey every year**

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