Solar Electric Light Fund
Benin Solar Irrigation Project

1. Project Summary

The Solar Electric Light Fund (SELF), in cooperation with the Association pour le Développement Economique, Social et Culturel de Kalalé (ADESCKA) and other local partners, will facilitate a two-village pilot solar electrification project in the Kalalé District, Borgou Department. This project addresses the Benin government development priority area of agricultural support while strongly supporting health, education, general economic development and community infrastructure. The pilot project will serve approximately 10,000 people distributed in two villages. The goal is to develop a scalable model that can be used to expand this program to 44 villages, ultimately impacting 100,000 people in the Kalalé.

The Solar Electric Light Fund (SELF) will implement an innovative agricultural program which combines solar water pumping with low-cost micro-irrigation—a replicable model which will profoundly address poverty, malnutrition and energy deficiencies in the region. Concurrently, SELF will provide the two pilot project communities with solar electricity for schools, homes, clinics, streetlights, micro-enterprise centers and wireless communications.

The agricultural portion of the project will establish the best practice in matching solar pumping technology with proven methods of small-scale irrigation (SSI) for assisting smallholders in growing market-garden crops. Other income-generating and community support applications powered by solar energy will also be investigated and demonstrated.

2. Project Description

This project will demonstrate a reliable and economical means of irrigation, enabling families in the Kalalé District of Benin to grow crops during the annual six-month dry season for significant improvements in family income and nutrition. Results from this two-village pilot project will inform the scale-up of a District-wide (44 villages) second phase of this project.

Subsistence farming is the primary means of survival for 95% of Kalalé District’s population of 104,000. For most, farming is limited to the rainy season by the lack of accessible water for irrigation. During the dry season people suffer from poor diets, little income, and the necessity of buying expensive food from the tropical areas of the country. For half the year, a lack of farm work causes community dislocation as many families migrate to squalid, overcrowded urban areas in search of work.
Solar water pumping and low-cost micro-irrigation techniques are technologies that have both been used effectively in developing countries, but seldom have they been used together in an effective way. By optimizing how these systems work together, a model will be developed that can be replicated in many parts of Benin, the rest of Africa and the world at large. A significant part of the model will be developing the financial and organizational means of sustaining the project.

In recognition that the sectors of health, education, communications, security and village commerce all work together with agriculture to improve life in a farming community, our solar electrification project will be used to provide general support to the villages in the following ways:

- **Community Infrastructure and Support:** The project will provide energy to address the public needs of health, education, water supply, security and communications.
- **Economic Growth:** The project will support general micro-enterprise development and the formation of a local solar industry to support the project and to place future solar electrification in the private sector.
- **Family Support for Health, Education and Home Industry:** A demonstration program will enable a small number of individual families to affordably purchase solar home lighting systems. A demonstration of this technology will build interest, confidence and demand for a future phase of solar home electrification.
- **Sustainability and Capacity Building:** In addition to the installation of solar equipment, the project focuses on creating the infrastructure and local capacity for sustaining the project. Local partners will be trained in photovoltaic (PV) design, installation and maintenance, and in the creation of the financial and organizational systems needed for sustainability.
- **Commercial Support:** Activities such as micro-finance and business development training will support and sustain the agricultural and economic growth components of the project.
- **Women’s Empowerment:** As primary growers of high-value vegetables, women will manage the co-ops that grow and market crops. Women will assume leadership roles in the management of micro-finance projects, as well as through training in solar technology installation and maintenance. Access to clean water within the village will enable women and girls to divert attention from water collection to other important endeavors such as home businesses and education.

3. **Problem Definition**

Northern Benin, and specifically Kalalé District, experiences an annual period of little or no rain from November through April. During this time, crops are only grown in the very limited areas that have a source of surface water such as a river or lake. In these more fortunate villages, water is typically moved through the laborious and time-consuming method of filling containers by hand and slowly watering individual plants. These time and labor constraints severely limit the amount of land that can be cultivated during the
dry season. Typically, only an acre or two is under cultivation, and it is often worked by women’s groups who grow high-value vegetables.

The chart above illustrates the almost total lack of rain falling in much of West Africa from the months of November through April for two consecutive years. Nearly 65% of Africa experiences a tropical savannah climate where there is a pronounced dry period of 3-8 months per year. More than half of Africa receives less than 20 inches of rainfall per year.

There have been limited attempts to irrigate with pumps powered by fossil-fuel engines (gas or diesel) but these attempts have been short-lived due to the difficulty of keeping the engines maintained and running and the expense of fuel. The cost of diesel fuel is now nearly $4.00 per gallon in parts of Benin. The national electric grid has not reached Kalalé District and currently the only electrical generation is supplied by scattered, small, local generators.

Over 80% of Kalalé’s villages do not have a source of surface water and virtually nothing is grown during the 6-month dry season. During this time, families live on a combination of stored grains and expensive food brought up from the tropical southern part of the country. Prices for basic vegetables (tomatoes, onions, peppers, etc.) almost double during the year from rainy season prices to dry season prices. The lack of availability and high prices combine to severely limit diets during the dry season and malnutrition is prevalent.

In addition to a lack of water for crop production, many villages in Kalalé also suffer from a lack of clean water for drinking and domestic use. Those without clean water suffer from various water-borne illnesses while those with wells spend a great deal of time fetching water from a limited number of hand-pumps which are often not working. Because the wells and solar pumps will only be used for irrigation during the dry season, the community will benefit greatly during the rest of the year from the nearly 5,000-8,000 gallons per day of solar-pumped well water.
The pilot project supported by this proposal will serve approximately 10,000 people distributed in two villages. Phase II will serve the entire Kalalé District which consists of 104,000 people in 44 villages.

We note that the general energy poverty of the District will also be addressed in a parallel, concurrent, but separately funded project where SELF and ADESCKA (local NGO partner) will support the project communities with solar electricity for schools, homes, clinics, micro-enterprise centers and streetlights.

4. Idea and Innovation

Drip irrigation has several advantages over “flooding” irrigation techniques. Of primary importance is that it uses much less water to irrigate the same area of planting. Drip irrigation also causes much less leaching of nutrients from the soil. (A 2004 study by the International Center for Soil Fertility and Agricultural Development shows that more than 80% of the farmland in sub-Saharan Africa is plagued by severe degradation, with salinity and leaching of nitrogen and potassium being major factors.) The precise delivery of water to the crop plant reduces weed growth surrounding the crop and eliminates standing water that attracts insects, animals and pathogens. Water-soluble fertilizers are more economically applied and are easily controlled and applied through the drip system.

Numerous programs in Africa and elsewhere have shown that small family plots can be economically irrigated using inexpensive drip irrigation systems, provided there is a reliable source of water and a convenient delivery system to get it to the fields. Referring to a USAID-funded LEAD program in Zimbabwe where nearly 24,000 gardens were set up with drip irrigation kits, a local field officer states, “This is a really viable initiative, which has great potential for success, especially if creative methods of water harvesting are incorporated. As more and more kits were installed, whole communities have seen crop yields increased with less time and money invested, cutting water and labor use in half. This has meant extra time for other work, and more importantly, higher nutritional benefits.”
Solar water pumping is a well-established technology which, when compared with engine-driven pumps, has a lower life-cycle cost and a much higher reliability factor. Studies by Sandia National Laboratory, GTZ and the German Aerospace Research Institute all indicate that solar pumping is more economical for pumps up to and including 2 kilowatts (equivalent to 2 horsepower) and is of a similar life-cycle cost up to 4 kilowatts when compared to diesel pumps. (The economics are increasingly in favor of solar as all these studies were done several years ago when the cost of solar was higher and the cost of diesel fuel was considerably lower). Solar pumps used in this project will be 2 kilowatts or under. Solar pumps (typically designed without batteries), are virtually maintenance free for up to 10 years or more, with only an occasional cleaning of solar modules needed. This is in contrast to diesel-powered pumps which require an on-site operator and skilled mechanics for constant upkeep and repair.

Because of its comparatively high first-cost, solar pumping is ideally suited for small to medium pumping needs, which makes it compatible with the reduced water needs inherent with micro-drip irrigation schemes.
In this project, we will be combining solar pumping with drip irrigation to determine a number of parameters that will form a model for replication. Key technical parameters to be investigated include:

- Maximum amount of land that can be irrigated using solar pumps and micro-drip.
- Optimum water application rates given the soil conditions and evapo-transpiration rates found in Kalalé.
- The most robust and reliable drip tubes and emitters.
- Optimum water storage and delivery systems.
- Optimum fertilizer delivery rates.
- The maintenance and upkeep requirements of the system.
- The average working life irrigation components under Kalalé conditions.

In addition to the technical aspects to be investigated, a set of economic variables will be researched as well and include:

- Maximum number of families that can be served by a single pump and irrigation system.
- Determining full costs of production.
- Average annual crop yields per field and market value.
- Market concerns: pricing at local markets vs. larger distant markets, etc.
- The ability and willingness of farmers to pay for their micro-drip systems and a share of the water pumping costs.

The following community/organizational concerns will also be a key component of this work:

- Determining a community-accepted means of organizing growers for sharing the water supply, collecting fees, maintaining the systems and possibly forming marketing associations.
- Working with the community, government agricultural officers and the private sector to devise a supply chain for the irrigation supplies and eventually, the solar pumps.

In all of the above aspects, SELF will be assisted by consultants that are experts in using micro-irrigation in a development context.

While both solar pumping and micro-drip irrigation schemes have had wide-spread use, they have seldom been used in combination with well-documented results. In this project we will establish the “best practices” for combining these technologies and more importantly, we will establish a “how-to” format and dissemination plan so that this technology can be used to help the millions of people in Africa and elsewhere that are limited in growing food by the absence of water. Again, the organizational and financial aspects of the model will be as important as the technical.
5. Project implementation and milestones

The first phase of this project and the subject of this proposal will involve the following implementation steps:

1. A district-wide survey/assessment will be completed by SELF and local partners to identify various water-supply and growing conditions throughout the entire district. (A preliminary needs assessment has been done).
2. Two villages representing typical growing conditions will be chosen for installation of wells, solar pumps and micro-irrigation test plots.
3. A well will be drilled and a solar pumping system installed in each village. ADESCKA personnel will be trained in solar installation before and during the installation.
4. A one-hectare test plot will be planted at each site with a drip irrigation system installed. Community members and agricultural extension officers will be involved with the process.
5. The plots will be monitored for a growing season to gauge the technical and economic performance of the solar-irrigation systems. Local agricultural agents along with consultants and villagers will be fully involved.
6. Concurrent with steps 3-5, the technical, financial and organizational aspects of sustaining the systems will be established with local partners and the communities.
7. A full agricultural, economic and organizational assessment will be performed at the end of the first growing season to determine any course corrections that need to be made in any of these three areas. Results will be disseminated to all interested parties.
8. An initial project report will be prepared that will form the basis for designing Phase II- extending the solar-micro-irrigation systems to all 44 villages in Kalalé District. Results will be disseminated to all interested parties.
9. A full report similar to step #7 will be done at the end of the second growing season to record lessons learned and recommendations stemming from that growing season.
10. A full report will also be done at the end of the third growing season.

Note: by the end of the second or third growing season we expect that the two initial project villages will be integrated into the larger district-wide project for continued monitoring and support.
A concurrent village electrification timeline will be developed once surveys have been done to assess the needs of the particular villages selected for the pilot.

6. Project Beneficiaries and Results

The general goal of this project is to develop a replicable model that will, at a minimum, impact the 100,000 people of Kalalé District. Accordingly, there will not be large numbers of people served in the pilot-demonstration phase. At least 20 families will directly benefit from the solar-irrigation project and all of the 10,000 people living in these two communities will benefit from the added supply of clean water during the rainy season.

Specific Outcomes for the solar-irrigation aspects of the project:

- Participating families will increase family monetary income in the range of 15-30% annually.
- Participating families will at least double their consumption of fresh vegetables during the dry season as a measure to reduce malnutrition.
- Project villages will at least double the harvest of fresh vegetables during the dry season.
- Project villages will gain at least an average of 6,000-8,000 gallons per day of clean water during the rainy season. (as measured by a pump meter)
- A plan will be developed to replicate the project in the remaining 42 villages of Kalalé District.

These outcomes will be measured by surveys taken before the installation to measure present day conditions and at the end of the first, second and third growing seasons to measure progress.
7. Organizational Sustainability

Applicant organization: Solar Electric Light Fund (SELF)

SELF will take the lead on all aspects of this project and together with ADESCKA, will be the implementer of the project. While coordinating all team efforts, SELF will also provide its expertise in all aspects of solar electrification and water pumping.

SELF’s projects focus on rural and remote areas not served by a utility grid, nor likely to be served in the foreseeable future. Working closely with local people and organizations, SELF implements sustainable energy solutions for essential needs including agricultural production, illumination, water pumping and purification, vaccine refrigeration, education, micro-enterprise and modern communications.

Since its founding in 1990, SELF has completed successful solar energy projects in fourteen developing country settings: Nigeria, Tanzania, Uganda, South Africa, China, India, Sri Lanka, Vietnam, Indonesia, Brazil, the Solomon Islands, Nepal, Bhutan and the Navajo Nation in the U.S.

SELF currently has projects under development with Partners in Health in Rwanda and with other Clinton Foundation HIV/AIDS Initiatives in Tanzania and Mozambique. SELF is scheduled to begin the installation phase of installing solar and un-interruptible power supply (UPS) systems at 24 hospitals and health centers in Rwanda for Columbia University’s Mailman School of Public Health during the summer of 2006.

Through its extensive experience and by studying other solar projects around the world, SELF has developed a “whole-village” model of solar development that incorporates “best practices” to effectively boost all areas of village development at the same time. Solar electrification and the introduction of productive end-use applications catalyze whole-village development in a way that single priority projects are not capable of. In a recent project completed in Jigawa State, Nigeria, SELF successfully modeled the whole-village approach in a 3-village project that benefits over 9,000 people. Plans are being made for projects that will include an additional 15-45 villages in Nigeria.

SELF is also taking a “whole-village” approach to the Kalalé project villages, but the water pumping and irrigation components stand alone and are the sole subjects of this proposal.

In addition to project design and implementation, SELF also excels in forging critical relationships between private and public sectors, donors and governments and implementers and end-users. Strong strategic partnerships are helping to increase the proliferation and size of solar-electrification projects.
SELF also puts a strong emphasis on sharing the information gained from projects. SELF disseminates and promotes projects in international journals, conferences, and through electronic media. Four of SELF’s projects have been featured on the CNN network.

Project Team:
Irrigation/agriculture consultant: International Development Enterprises (IDE)

IDE is an international NGO headquartered in Denver, Colorado, committed to improving the lives of the rural poor in developing nations through facilitating increases in income generation. In programs spanning 20 years in countries such as Bangladesh, Zambia, Zimbabwe, Cambodia, China, India, Nepal and Vietnam, IDE has specialized in addressing rural poverty with practical and affordable solutions. Working under the broad categories of providing access to water, providing small farm training, introducing affordable technologies and opening doors to marketplace opportunities, IDE primarily partners with poor rural farmers to alleviate poverty at the grass-roots level. Of special importance to this project, IDE has extensive experience and expertise in the area of small-scale irrigation systems and has developed irrigation materials and methods geared to the scale of this project. Specifically IDE will be charged with the following roles on this project:

- Collaborating with SELF on the design of water supply systems.
- Assessing and choosing test-plot sites.
- Supervising the preparation of test sites.
- Designing and supervising the installation of micro-irrigation systems.
- Working with farmers and extension agents on growing methods (planting, fertilizing, watering, etc).
- Monitoring the project and making recommendations and reports.
- Continuing follow-up through the second and third planting seasons.
- Extensive training of ADESCKA staff, farmers and agricultural officers in micro-irrigation techniques.

Note: while the final selection of the irrigation consultant has not been made, IDE has submitted a proposal, is a leading contender, and is representative of the quality partner that SELF intends to work with on this project.

Main Partner Organization: Association pour le Développement Economique, Social et Culturel de Kalalé (ADESCKA), is a non-government organization (NGO) formed in 1988 to promote community development throughout the entire Kalalé District. Among ADESCKA’s current projects are the recent financing and building of 3 schools as well as housing for university students. ADESCKA has also contributed to the training of 6 nurses by providing full scholarships for their three-year training programs. ADESCKA has a road renovation program that renovates approximately 20km of road each year. ADESCKA’s main source of income is contributions by the cotton growers of the district.
ADESCKA’s role in the pilot-demonstration phase is to work alongside SELF in designing and implementing the project. In the process, ADESCKA staff will receive extensive training in solar-electric installation and maintenance, pumping technology, and micro-irrigation techniques. ADESCKA’s capacity will be raised in all areas so that it will eventually be the primary implementing organization in the second District-wide phase.

ADESCKA’s roles in this project include:

- Assessment and selection of project villages.
- Assisting in the design of solar pumping and irrigation systems.
- Working alongside IDE in all agricultural aspects of the project.
- Maintaining a store of spare parts for the irrigation and solar pumping systems.
- Serving as the on-site contact for the farmers and the project villages.
- Serving as the project liaison to all levels of Government.
- Managing the micro-credit aspects of the project. (dispersing, collecting and managing fees)
- Performing the basic monitoring of the test plots and the solar/irrigation systems.

Note: while ADESCKA (with support from SELF) will be the lead implementing organization in the second phase, it is also intended that some of its roles, such as providing irrigation kits, will be taken over by an emerging private sector and that other roles such as providing micro-finance may be taken over by local lending institutions.

8. Team Leader

Jeff Lahl, SELF Project Director, will be the Team Leader and primary contact.

Jeff Lahl combines a strong and varied management background, expert solar knowledge, and training experience with international development experience to lead unique and challenging solar electrification projects as SELF’s Project Director. Prior to leading SELF projects in Nigeria, Bhutan, Benin, Tanzania, Rwanda and Mozambique, Jeff worked for a number of years in the solar industry as a system designer and specifier as well as a community college instructor in solar energy. He first became involved with solar-electrification for development as a Peace Corps volunteer from 1993-1995 when he managed the Kingdom of Tonga’s solar electrification program. Jeff’s solar career started over 20 years ago when he formed a company that designed and built solar homes.

As an example of his work with SELF, Jeff was the project manager for SELF’s Nigeria project which served 9,000 people in 3 villages. In that capacity, he was in charge of and personally involved with assessment, project design, partner/village relations, technical design, procurement, training, installation, evaluation, reporting and follow-up activities. Results of this work include the installation of 4 village water pumping systems for
drinking water, 2 solar pumps for irrigation, solar electrification of 3 micro-enterprise centers serving 20 small businesses, 3 schools, 3 mosques and 60 home lighting systems.

9. Risk Evaluation

The challenges to this project can be broken down into technical, financial and organizational challenges.

Technically, after the initial solar and irrigation system installations, the challenge will be to keep the systems maintained and operating. To this end, ADESCKA technicians will be receive extensive initial training from both SELF and the irrigation consultant and they will be get actual experience doing the installations, under supervision. Going forward, refresher training has been budgeted for the next 2 years and senior ADESCKA technicians will receive advanced training so that they can train others. ADESCKA will be issued spare parts from the initial project budget and they will be charged with collecting the fees for the continuing purchase of spares as needed.

(Note: SELF routinely invites and trains local people from outside of the immediate project who may also have interest in the technology, such as electricians, well installers, and government agricultural officers so that a broader technical base is established in the communities. This policy of inclusion also helps stimulate the private sector in adopting and promoting new technologies.)

The financially viability of the project depends on the growers making carefully calculated payments to pay for their irrigation systems, the solar installations and the ongoing operation and maintenance costs. To achieve high repayment rates, the preferred model in this project will be to use the existing cultural structure of women’s groups who traditionally organize themselves to grow and market vegetables. By utilizing existing groups and by forming new groups who self-screen their own members for financial responsibility, we intend to establish and promote peer groups of borrowers who purchase systems based on social collateral.

Organizationally, ADESCKA will be the partner with on-the-ground responsibility for maintaining and monitoring this project phase. Building on ADESCKA’s District-wide presence and reputation, SELF and the irrigation consultant will build the NGO’s capacity technically as well as its ability to administer a micro-finance program. The project budget allows for continued and close contact between the Partners for up to 3 years, including multiple follow-up trips. Additional local micro-finance expertise will be brought into the project as needed.

10. Potential for Scaling Up/Replication

This project is designed for Scale-up on the District level to serve 100,000 people. On the national level, the Ministers of Energy and Agriculture and other officials have indicated a strong interest in this project for replication on a country-wide scale and an indication
of possible Phase II funding from Benin’s Millennium Challenge account. As much of sub-Saharan West Africa suffers from the same lack of water and electricity, the opportunities for large-scale replication are enormous. SELF is currently developing village solar-electrification projects in Senegal and in several Nigerian states that can benefit from the results of this project. These projects are pilots themselves that can then be scaled-up and replicated. For all these projects, SELF is building partnerships with the private and public sectors. In Benin and in Nigeria, we are making progress in obtaining commitments from the private sector and will then seek matching funding from USAID under the Global Development Alliance Program.

For the Kalalé project specifically, SELF and ADESCKA will again co-implement the larger District-wide Phase II project, with ADESCKA gradually assuming the lead role as it gains the capacity to do so. To scale-up beyond the District Scale to regional or national scale, it is likely that governments will be involved to some degree, either in taking on major implementation roles (agricultural agencies) or in facilitating and empowering local organizations such as ADESCKA. Going beyond the District Scale, SELF would partner with and help develop a national solar energy organization such as the Solar Research Center at the University of Cotonou.

11. Economic viability

The overall financial objectives of this project are that solar/micro-irrigation systems pay for themselves over time and that they be self-sustaining. The initial donated money in Phase I purchases all material and equipment. Individual family farmers purchase their own drip system on a credit basis from the project at a projected cost of $.18/square meter. They also pay an annual fee designed to cover the initial capital costs of the pump, well and distribution system, based on the projected life of each component. For instance, the fees collected towards the solar pump are based on the assumption that an average pump life is 10 years while the life of the solar panels (the most costly part of the system) is 20+ years. The capital recovery payments will be made over 10 years for the pump and 20 years for the solar panels. The annual fee also covers any operation and maintenance costs associated with the systems, which primarily show up in the water storage and distribution systems.

A summary of cost categories accounted for in our initial economic model are as follows:

1. solar pumping system (over 10 years for pump, 20 years for PV).
2. water distribution infrastructure (over 20 year life).
3. drip irrigation materials (over 3 year life).
4. seed/bedding plants.
5. fertilizer.
6. pest control.
7. transporting crops to local markets.
8. O&M costs which are used to purchase new pumps in 10 years plus routine maintenance and replacement of water distribution equipment.
9. A service fee to ADESCKA for maintaining the pumping and distribution systems and for managing the micro-finance program.
Initial estimates indicate that if a hectare of land were divided into 10 family plots, each plot could yield a gross income of around $782 if growing high-value vegetables and after assuming that 20% of the crop will be consumed by the family. After all of the above costs and expenses are accounted for, an initial estimate is that each family could achieve a net gain to family income of $484 per growing season. While small by western standards, this amount could increase family monetary incomes by as much as 25% annually and make the difference of affording such things as school fees or medical care. (A typical cotton farming family in this region makes about $1,000 annually.)

These calculations assume that the irrigation systems are only used during the six month dry season. However, it may be that they are also used during dry periods of the rainy season to increase yield and income as well.

If current work-division patterns hold, women will be the prime beneficiaries of this project and for many, growing vegetables will be a completely new source of income for the family as well as a needed source of nutrition. It is not expected that this activity will replace other income-generating work for most of these women.

The budget for the two-village electrification is $450,874

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Beyond providing a cleaner and quieter local environment when compared to diesel pumps, solar pumping in this project models a productive end-use powered by an carbon-free and sustainable energy source. As 1.8 billion people in the world without electricity look for energy solutions to improve their lives, projects such as this show that the targeted use of solar energy can raise living standards and still preserve fragile environments already under stress from overuse and climate change.