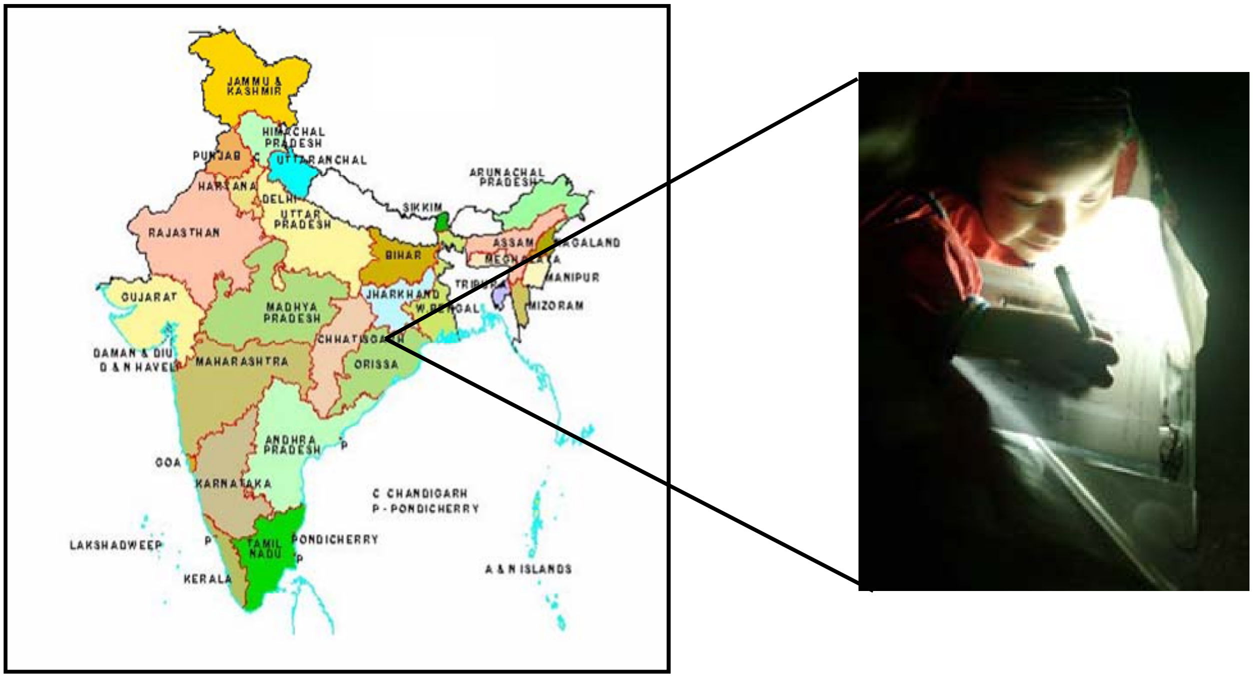
Sustainable Energy for Rural India

Bhudapada Village, a Case Study



Team Members

Angela Flood-Uppuluri
Rupal Shroff
Devon Treece
Marc Weatherill

Faculty Advisor

Professor Thomas P. Lyon

Client

Mrs. Joyasree Mahanti

Bharat Integrated Social Welfare Agency

A project submitted in
partial fulfillment of the requirements
for the degree of
Master of Science,
School of Natural Resources and Environment
at the
University of Michigan
April 2008

Acknowledgements

The authors of this report would like to give our sincere thanks for the support that we have received in the course of completing this project.

First, we would like to thank the people of Bhudapada for allowing us into their homes and for granting us access to their lives, aspirations and daily challenges. Ultimately it is our goal that this work will in some way help them, and other rural people who live at the "Base of the Pyramid"[1] without a reliable source of daily energy. We have been deeply humbled by this experience.

We would like thank our project client, Mrs. Joyasree Ranu Mahanti and the Bharat Integrated Social Welfare Agency. The work that they are undertaking is extremely important for the development of rural India, the development of women and human rights. Their openness about the internal working of the organization and their time and attention are appreciated.

Our advisors Professor Thomas P. Lyon and Professor Gautam Kaul of the University o f Michigan were instrumental in guiding us along the right path.

We would also like to thank the International Institute and the School of Natural Resources and the Environment at the University of Michigan. Without their generous financial support we would not have been able to travel to India to perform our primary research. We would also like to thank the Erb Institute for Global Sustainable Enterprise whose continuing financial assistance enables programs like these.

Abstract

Access to light is a serious development issue for those living at the Base of the Pyramid (.i.e., those who live on less than $5 per day), especially for individuals living in rural areas. The aim of this project is to develop a scalable, financially sustainable business model that a microfinance institution can implement in extremely poor rural areas. When implemented, this model will not only allow households to obtain light, but also create a new, viable business in the form of a micro-utility.

In order to generate our recommendation, we decided to focus our research on a specific village in India—Bhudapada Village near Sambalpur, Orissa. Bhudapada was chosen due to its relationship with the Baharat Integrated Social Welfare Agency, a microfinance institution. Bhudapada represents the "worst case scenario" in rural villages across India. Most of the residents earn their living as daily agricultural laborers, surviving on an average per capita income of USD$1 per day. However, the village also has some points of development, namely the existence of a self-help group, a self-organized group of local entrepreneurs that support each other in financial savings and risk diversification, and runs a small soap business and grocery store. BISWA has an established network of almost 15,000 self-help groups, which this project's recommendations were designed to leverage, maximizing the speed at which it could be scaled up following a pilot implementation.

This strategy also enables a rapid expansion of the income generating and development activities this model will create within the self-help groups themselves and the villages they operate in. With greater availability of light, the self-help groups will be able to expand their business activities into the evenings and also to generate income from a new enterprise, the provision of light to their neighbors. With light, villagers will be able to expand their own participation in cottage industries such as craft making, benefiting from the additional income opportunities this presents, as well as the opportunities for non-income generating activities such as education and safety this light will provide.

Our recommended business plan involves three partners: the Baharat Integrated Social Welfare Agency, product manufacturers, and the villagers. The Baharat Integrated Social Welfare Agency will lend money to the self-help groups that will start and manage the micro-enterprise, which is consistent with their current operations. Self-help groups will purchase LED lights and solar battery chargers with rechargeable batteries of different sizes. The self-help group will then function as a micro-utility and will provide the light to villagers using financing options suitable to their level of income.

Table of Contents

I. Introduction

While many private companies and non-governmental organizations (NGOs) are willing to develop pilot projects and subsidize energy in the developing world, these efforts often do not go far enough to solve the problem of the lack of rural energy. The goal of this project is to introduce a scalable business model that makes electric light sustainable, as well as, profitable in the economic, environmental, and social conditions that exist in India's poorest rural villages. The business model we developed is one that a microfinance institution can implement in extremely poor, rural areas. When implemented, this model will not only allow households to obtain light, but also create a new, viable business in the form of a micro-utility.

In order to generate our recommendation, we focused our research on a specific village—Bhudapada Village near Sambalpur, Orissa—as a case study in business plan development for the poorest of the very poor. Bhudapada Village provides a microcosm in which to in which to conduct field research regarding the villagers' preferences, needs, and challenges. Bhudapada was chosen due to its relationship with the Baharat Integrated Social Welfare Agency (BISWA), a microfinance institution. Bhudapada represents the "worst case scenario" in rural villages across India. Most of the residents earn their living as daily agricultural laborers, living on an average per capita income of $1 per day. However, the village also has some points of development, namely the existence of a self-help group (SHG), a self-organized group of local entrepreneurs that support one another through financial savings and risk diversification and run a small soap business and grocery store. BISWA advises their established network of almost 15,000 SHGs and the project's recommendations were designed to leverage this network of SHGs so as to maximize the speed at which our specific technological and financial recommendations could be scaled up following a pilot implementation program. In order to make sure that this plan could be implemented by the residents of Bhudapada, and villages like them, our research team traveled to India and performed field research to assess the villagers' energy needs and preferences.

Our project seeks to fill the gap between the desire for development by the rural poor, commercial interests and NGOs and the considerable barriers to entry regarding development and deployment of scalable local business models that incorporate the appropriate market and technical considerations. Our research led to the creation of a scalable, renewable energy production plan that incorporates the microcredit method of lending to SHGs in rural underdeveloped areas. Ultimately, our aim is for the business plan to inform the BISWA when it undertakes projects that provide power to villages via SHGs. The project's goal of making electricity broadly available in rural areas of India is really one of providing these communities with a basic service that can increase their economic, environmental, and social well-being by creating opportunities that were previously unavailable on a large scale in these rural areas.

II. Project Methodology

All of the methods that we employed throughout the project sought to incorporate the Base of the Pyramid (BoP) Protocol in conjunction with sound academic research. In order to provide a context for our case study in Bhudapada we researched cases studies that focused on renewable energy strategies in the developing world. Our research highlighted gaps and barriers to energy development in rural markets in the developing world as well as best practices for business development and technology choice. A summary of cases that highlight the prevalent models for technology and financial models will be presented later in the report. Next, we engaged in primary research in Orissa, India with our client organization, the Bharat Integrated Social Welfare Agency. During this time, we had the opportunity to visit rural villages and administer a market research survey that assessed villagers' energy preferences and needs. Several of the survey questions provided information on types of labor and corresponding wages available in the village as well as what villagers would do if they had electric light in their homes. The data and information collected by the survey were then used to inform our technological and financial analyses. Finally, we developed recommendations for how the village could obtain light sustainably, both environmentally and economically, thereby furthering their economic and social development.

Generating solutions for the BoP requires a new way of thinking that approaches each development constraint as an opportunity. BoP theory is predicated on the principle that business has a unique opportunity to contribute to poverty alleviation at the poorest levels of a society by offering sustainable solutions that leverage the triple-bottom line: economy, environment, and people.[2] The BoP is defined in several different manners, the most general of which, refers to individuals living on less than five dollars per day. The BoP stresses the need to involve local people in the development of small businesses. Business strategies for the BoP involve six main principles: external participation, co-creation, connecting the local and non-local, patient innovation, self-financed growth, and a focus on what is working within a society. Both our primary and secondary research and indicate that people living at the BoP can assist in their own community's economic development by performing various roles such as consumers, producers, and participants. Successful BoP ventures utilize local knowledge and work to integrate the people they are trying to help. Our business solution for BISWA, and its client villages, presented in the remainder of the article, draws upon these BoP principles. The cornerstone of our recommendation is that rural people who receive light will also be able to profit from its distribution, in turn solving their own development needs and those of their neighbors.

One of the reasons that business models for rural renewable energy production are not more common is that producing a business plan for the BoP is challenging due to research and communication barriers as well as the need for a project team with a multi-disciplinary skill-set. Conditions among the rural poor can vary widely and include demographic, development, and legal issues. However, some conditions among the rural poor remain constant such as low socio-economic development and a desire for increased development and access to education. Therefore, we have been careful that the recommendations resulting from this research are in line with BoP principles, are applicable to our client organization, and address gaps and pitfalls found in similar cases.

III. Bharat Integrated Social Welfare Agency

Bharat Integrated Social Welfare Agency (BISWA) is a nonprofit microfinance institution (MFI) based in Sambalpur, Orissa, India, that was incorporated in 1995 and began lending in 1997. BISWA loans money through its network of SHGs, which use these borrowed funds as start-up capital for microenterprises. As of September 2006, BISWA had relationships with 14,590 SHGs representing 220,840 individuals, 98% of whom were women. In 2006, the average loan to a SHG was Rs. 3,187 (USD$79) and total outstanding loans equaled Rs. 696 million (USD $17.4 million).[3]

BISWA is currently organized into two programmatic areas: development and lending. BISWA's developmental activities fall under the Basic Needs Program. The Basic Needs Program is organized as an NGO that helps to provide four basic needs: drinking water, food, education, and health care.[4] BISWA's philosophy is that basic physical needs must be met before any further development can take place. However, it is important to note that BISWA believes that help should not be given for free. In fact, villagers are asked to contribute financially for the provision of these services so that the services are properly valued, enhancing the villagers' feelings of ownership and dignity. For example, BISWA established a school in Bhudapada Village because the government school did not remain open consistently. For this educational service, villagers pay approximately Rs. 1 to 3 (USD$0.02 to $0.07 cents) per month. These small payments do not cover the full cost of the development expenditure.

Lending to Self-Help Groups

Our recommendation for a business model based on the provision of light through a micro-utility is not without precedent. BISWA has financed two microcredit enterprises in the village of Bhudapada already. These small businesses include a soap making unit and a small grocery store. Although these enterprises provide substantial income for the women of the SHG, who run them and took out loans to finance them, the businesses can only operate during daylight hours, which significantly hinders the village's development. The provision of light would not only allow existing businesses to function beyond daylight hours, thereby enhancing profitability and production, but could also provide income through the development of a new business, such as a micro-utility company while also providing other villagers with light at a reasonable rate.

BISWA's lending activities are extremely labor intensive due primarily to the rural nature of the population that they serve, the development issues associated with this population, and the sheer size of the number of SHGs that they serve. BISWA must, therefore, develop prepackaged business ideas that their clients can implement and that can be scaled across the entire organization. The micro-utility business plan is one that BISWA can implement across the 14,590 SHGs that it deals with, providing needed businesses as well as simultaneously improving lives through the provision of light, thus fulfilling both of BISWA's dual missions.

Organizational burdens are heavy because in addition to serving a multitude of small loans for a rural population, BISWA must concentrate on developing the social capital of the SHGs and their microenterprises in order to ensure reliable repayment. One of BISWA's challenges in lending to a rural population is that they are not as well-educated as their urban counterparts on what types of businesses they can start. This gap in knowledge is due primarily to the rural population's isolation.[5] Urban women see opportunities more easily because they are surrounded by several classes of people. Rural women, on the other hand, are not generally exposed to many different business ideas; therefore, it is difficult for them to imagine how they could use money to start their own business.[6] The administrative burden of this organizational structure, among other factors, has precipitated a change to a "federation" model whereby BISWA will only loan to federations of SHGs, and any direct loan servicing, including payment collection and business development, will be handled by this intermediary federation structure (Appendix B).

IV. Macro-Environment – Energy Profile of India and Orissa

In order to understand the energy environment that rural villages such as Bhudapada face, it is important to understand the energy profile of India and that of Orissa. India is often held up as a rapidly-developing country that has benefited considerably from globalization. The reality, however, is that these benefits have only extended to a small percentage of the Indian population, predominately those living in urban areas. The gap between rich and poor is especially vast between those living in urban areas and those living in rural areas. Table 1 shows the percentage of people living below the poverty line as a comparison of rural and urban India.

Table 1: Percentage of people living below poverty line (BoP) in rural and urban areas by occupation, India 1993-94 and 1999-2000.[7]

Rural	**1993-94**	**1999-00**
Self-employed in non-agriculture	32.31%	22.59%
Agricultural labor	56.75%	42.13%
Other labor	36.69%	26.27%
Self-employed in agriculture	29.19%	20.07%
Others	17.57%	13.86%
Total Rural	37.20%	27.10%
Urban	**1993-94**	**1999-00**
Self-employed	36.91%	26.47%
Regular wage and salary earners	20.93%	12.21%
Casual laborers	62.64%	50.61%
Others	26.48%	16.81%
Total Urban	32.40%	23.60%

Recognizing that poverty and development are linked, the Indian government has set a long-term goal of providing electric power to all citizens by 2012. This goal includes adding 100,000 megawatts (MW) of capacity to the 2005 installed base of 118,419 MW, an almost 100% increase in capacity. The additional transmission and distribution systems needed to support this capacity are also part of the 2012 goal.[8] Renewable energy makes up a total of 5,700 MW of India's installed capacity (4.8%). Of this, 3,000 MW is wind power, 50% of which is located in the state of Rajasthan. Orissa has only 1.1 MW of installed wind power. There are 1,693 MW installed of small hydropower (7.3 MW in Orissa) with 40.97 MW under construction, and additional potential capacity of 156 MW.

The transmission and distribution of electric power in Orissa were owned by the Indian government until 1991, at which time, several crises in the sector occurred including financial mismanagement, performance issues, and loss of credibility. There was some entry into the sector by private generators of power; however, they were unable to transmit the power effectively. Therefore, the government decided that growth in the entire utility sector would be best achieved through privatization. Therefore, the government developed a model by which they unbundled transmission, generation, and distribution to separate companies. The pilot was launched in Orissa.[9]

Rural areas were to benefit from the privatization and unbundling of the electricity grid, however, projected gains have not been realized due to the lack of fit between the costs of large scale development and the capacity of the rural poor to pay for the services this infrastructure provides.[10] Those villages that are largest in size and closest to the grid are first in line to benefit from the limited funds for the expansion of rural electrification. These funds are given as high interest loans to the private owners of the distribution network. In turn, the owners are responsible for managing the villagers' service contracts. This type of scheme, however, requires the villages to have a steady cash-flow income. Decentralized solutions, such as solar energy, may be more preferable for areas that are far from the grid because they don't know when, or if, a grid connection will ever materialize. This is a circular dilemma, as the ability to pay for services is dependent on the level of development and the level of development is dependent on the ability to access fundamental services for the basic needs of the community.

When the Orissa State Electricity Board (OSEB) was restructured, OSEB's rural development wing was disbanded, effectively leaving rural electrification to the newly formed, private power companies. Since rural electrification projects do not present a highly profitable opportunity for the privatized electricity agencies, there has been little movement on that front nor is there any reason to believe that there will be in the future. However, the introduction of the free-market into the electrification of Orissa is not completely to blame for the state of the system. After privatization, the governments of India and Orissa have done little to provide planning or funds for rural energy development. The few projects undertaken by the private companies have yet to be paid for by the government.[11]

In a heavily agrarian and mountainous state such as Orissa, many villages remain inaccessible and are not connected to the electricity grid. In Orissa, it is estimated that there are 9,682 rural villages and over 6.6 million households, rural and urban, which need to be electrified. It is also estimated that 80.6% of all households in Orissa lack electricity.[12]

V. Case Studies: Identifying Trends and the Project Gap

In order to understand the potential pitfalls of implementing a project in Bhudapada, it was imperative to understand the projects that had preceded our research; therefore, we specifically selected applicable cases that illustrated key challenges and best practices for sustainable electrification and lighting projects in rural areas. The following analysis helped us better understand the rural lighting issue in developing countries. Although cases from India were preferred, we did not limit ourselves to this country primarily because rural people in the developing world often have similar development issues. Rural communities use similar sources of fuel (kerosene and wood) and have similar energy use patterns (i.e. women are disproportionately responsible for gathering fuel and for large energy use activities such as cooking). Additionally, from a development perspective, the rural conditions in Indian states vary widely from one region to another; literacy, homogeneity of the population, and availability of development assistance are some of the parameters that vary from state to state. Therefore, it is appropriate that the cases studied also display similar variety as a basis for this project's analysis, its recommendations and implementation. We found applicable cases in India, the Caribbean, Latin American, and Africa. The following points outline the lessons learned from our case summaries.

- The chosen technology must be appropriate, provide adequate and reliable light, and be obtainable rural areas. One of the challenges with rural distribution is that replacement parts are difficult to obtain.
- The villagers must take responsibility for maintaining the technology. Maintenance systems need to exist along with the technology. In the Enersol and SELCO cases, the maintenance of the technology provides for the longevity of the project as well as consistent revenue streams and employment.
- The villagers must have a monetary stake in the project. In all of the cases examined, it has been illustrated that when the population has a financial stake in a project, they will maintain the equipment and the project will have a better chance of being financially sustainable.
- There are insufficient financial services for lighting products acquisition in rural areas because these projects are typically perceived to be too risky for large financial institutions to engage in. This gap between need and service availability produces a market opportunity for MFIs or others who have a lending relationship with this high risk rural population.
- People are willing to pay more for equal amounts (time) of electric light than they are for kerosene, candles, and batteries because light allows them to perform additional activities at night.
- Many of these benefits are particularly significant for women, who often spend more time in the home and therefore appreciate the improved light, clean environment, and additional

working hours. Furthermore, many women take responsibility for payment which reinforces their participation in the economic life of the village.

- Villagers use light to extend working hours, to increase educational opportunities, and for entertainment. Enterprise and educational aspects are the most important advantages of light. Electricity enables users to listen to music and watch videos, helping them feel more connected to the world.
- The demand for the product must come from the users. If the population being served does not desire energy and do not have activities that can benefit from energy, the project will not succeed.

Technology Choice

The cases considered show a variety of technology choices, however, the most successful technologies have been those dealing with light. A project in Indian village of Dhanawas provided valuable insight into how technology choices impact project success. Dhanawas is a village in rural Haryana, which has worked with the Tata Energy Research Institute (TERI) since 1984 carrying out field trials of various renewable energy technologies with the express purpose of improving the lives of rural Indians.[13] The case is relevant to our study of Bhudapada as TERI used the village as a testing site for many sustainable energy technologies including different types of solar, biogas, and other resources, illustrating both the technical and social successes and failures of rural villagers in adopting different technologies. This case also provides applicable lessons learned and implementation structures.

Dhanawas is dissimilar to Bhudapada in many ways, most importantly in that the village has strong urban linkages and has the help of TERI to find and implement technology that its residents would normally not be able to search out or afford on their own. The solar solutions implemented on a trial basis in Dhanawas include solar lanterns, solar street lights, solar hot water heaters, and solar cookers. Of all the solar solutions, only the lanterns were successfully deployed. The solar water heaters did not provide hot water when needed and the solar cookers necessitated changes in cooking habits and tastes. The cookers took a very long time to use and were not usable for cooking certain staple foods. The solar lanterns, however, extended work hours and allowed villagers to care for animals at night. In addition, women found cooking easier, savings in kerosene were reported, and children were able to study at night. Problems faced by the villagers included finding maintenance parts and skilled technicians. The lanterns worked for two years before extensive maintenance was needed. Villagers were trained in order to deal with some of the problems with maintenance and part replacement.

Another example of successful photovoltaic light implementation was found in Zambia in the Photovoltaic Energy Service Company (PV-ESCO) project.[14] The Zambian case illustrates a pilot project that went a step beyond the Dhanawas project by piloting a business model as well as a technology. The PV-ESCO project was initiated by the Zambian energy minister in 1996 and was developed in cooperation with researchers from the Stockholm Environment Institute and funded by the Swedish International Development Agency (Sida). The operating area for the PV-ESCO project, Nyiamba, had a district population of 63,000 whose main occupation was small scale farming. The area was not electrified and there was no telephone connection and no television broadcast available. The PV-ESCO provided electricity using solar home systems (50 watt power) with four lights and one socket. All of the solar home systems (SHS) were donated to the PV-ESCOs.

Distribution Models

The distribution model refers to the method of getting power to users. The products used in the aforementioned cases were not sourced through the same organizations that provided financial and set-up assistance. The following cases highlight two organizations whose business models are unique in combining distribution of energy products with financing and maintenance services.

An India organization, the Solar-Electric Lighting Corporation (SELCO), provides sustainable energy services to underserved households and businesses. The company's primary mission is to enhance the quality of life and create opportunities for increased income generation for people living in poverty. Since 1995, SELCO has provided affordable and reliable solar electricity systems to more than 75,000 homes in southern India. SELCO achieves its mission by employing small-scale, modular, distributed technologies such as solar photovoltaic (PV). The firm targets individual homes and businesses that are disconnected from the electricity grid. SELCO delivers PV products directly to their customer's doorstep. With its expansive network of service agents, it is able to provide at-home design consultation, installation, and after-sales service on all products sold. SELCO helps its customers finance their purchases by partnering with rural banks that offer microfinance products and services.[15] SELCO systems utilize PV modules that harness solar energy to provide electricity for lighting, water pumping, communications, computing, entertainment, and small business appliances. The most common product is their SHS, a solar electric lighting system designed for households and small businesses lacking a reliable and safe electricity option.

SELCO customizes each of its systems, incorporating need and affordability. All installations and user training are carried out by SELCO technicians. SELCO's door-to-door service has boosted consumer confidence in the organization as well as the technology. Service is free during the first year, during which SELCO staff visit each system every three months to make sure that it is working correctly. Service centers are located in such a manner that all customers are within three hours of help. PV modules supplied by SELCO come with a 10-year guarantee and batteries have a 3-year guarantee; any product failures are reported to the SELCO head office, which maintains records for all systems so that problems with suppliers can be tracked down quickly. All SELCO service centers are fully stocked with spare parts, ensuring that replacements can be made quickly if there is a problem.

Like SELCO, Enersol has also seen success in the provision of energy services to rural communities. A nonprofit founded in 1984 to serve the rural populations of the Dominican Republic and Honduras through electrifying off-grid communities, Enersol, was developed by the Solar Based Rural Electrification Concept (SO-BASEC). There are two components that make Enersol noteworthy: local technicians and NGO financing. First, Enersol trains local technicians and system providers on how PV technologies work, how to locate suppliers, and how to appropriately price services. Second, Enersol recruits NGOs to finance the projects. One of Enersol's often discussed projects involved providing solar PV systems (panel + battery + pump) that are used to draw water for agricultural purposes. Local solar companies are hired to provide service for the systems. Aquasol, as the product is known, was initially produced in 1994 after PV became more heavily commercialized throughout the country in an attempt to affect broader social impact. In more than half of these communities, women play a fundamental role in keeping the system running and collecting monthly payments. In spite of their social success, at the time of the case writing, projects using NGO support (NGO buying and managing the systems) have not been able to recover the capital costs for any of the projects.

Self-Help Group Distribution

Regarding solar PV technology, we found that SHGs have not been effectively used as a part of the supply chain as we are recommending in the BISWA plan. There are other examples, however, of SHG participation in the distribution of other energy technologies. In India, SHGs form the distribution channel for highly efficient *chulas* (cook-stoves) that do not use as much energy as traditional stoves, via the Shell Breathing Space program.[16] There are three distribution models used in this program: the SHG finances purchases of the cook-stoves by its members, the SHG manufactures the cook-stoves, or the SHG finances other entrepreneurs who then manufacture and sell the cook-stoves.[17]

SHGs have proven important in other capacities besides acting as a direct distributor of technology. In the SELCO case for example, SHGs met to support members in domestic and farming matters. The groups made sure that member's more basic needs (like wells or farming equipment) were covered before they invested in a solar home system.[18]

Financing Models

In the case studies considered, two broad methods of financing were used for obtaining energy systems: donations or self-financing. However, cases of donated systems are very common in the literature. It is important to note that heavy reliance on NGOs and donor support does not create a sustainable approach for providing electricity to rural communities. In many cases, technology is implemented on a pilot basis, necessitating outside donation of technology, which precludes any investment on the part of the recipients. Some of Enersol's programs are reliant upon grants and donor support even as they operate at a loss, relying heavily upon NGO support including USAID, World Bank, Peace Corps., INDENOR, Winrock, and the Skoll Foundation as well as individual donor support. The program has also received private grants from companies such as

Citibank which helped provide funds for launching the Aquasol program. Although all of Enersol's programs are not financially sustainable, they have helped to alleviate some poverty by training local technicians to support the systems.

In some cases, the donation of technology simultaneously creates problems even as it solves them, demonstrating another weakness of the charity procurement model. In the Dhanawas case, the U.S. Secretary of Energy donated sixty-two solar lanterns to the village; however, deciding how to distribute the solar lanterns proved problematic as there were one hundred and ninety households in the village. Since the lanterns were a gift, there was no market mechanism for distribution. In the end, the village chief decided who was to receive the lanterns and all the families receiving them had some connection to him, a biased process to say the least.

The best case of self-financed systems is the SELCO model. A typical 4-light SELCO solar home system is sold for approximately Rs. 18,000 ($450), a figure far greater than the annual salary of many of SELCO's customers. This includes design, installation and a one-year service contract. It took SELCO three years to convince banks that solar electricity would empower borrowers economically and help them repay their loans. In some instances SELCO installs demonstration systems in banks to instill confidence in the product.

SELCO's efforts have given finance organizations the confidence to provide credit for PV systems, and an understanding of the payment terms that different owners may require. Some users are financed on an individual basis, while others are financed as a member of a SHG, and over 90% of SELCO's customers take advantage of the micro-credit options available. Interest rates are based on the credit source and range from 5% to 14%. Customers typically pay 10-25% of the total cost of the system immediately, paying off the balance over three to five years. In one case, installment amounts were Rs. 300-400 per month ($8-$10) over five years.[19] By extensively researching its rural customers, the SELCO team determined that this level of payment was affordable based on the extra earnings which the light system enables. SELCO also effectively tapped the existing local farmers' societies for refinancing solar systems to the end-users. The company is now a channel for the World Bank line of credit to these farmers' societies, thus creating a sustainable link from an international financial institution to the remote village level.[20]

Service and Support Ensures Success

Service and support for solar PV technology is essential for utilization, adoption, and financial success as well as for increasing employment and development opportunities. The SELCO case study demonstrated that systems will lie in neglect if something breaks and a technician is not readily accessible. Similar projects have also revealed the increased level and speed of adoption of these technologies when a village resident is able to demonstrate and educate the other villagers about the technology. Training a local technician also has the added benefit of creating employment and maintaining some of the money exchanged for ongoing costs in the community.[21]

A company that manufactures and sells SHS to rural parts of Sri Lanka enjoyed considerable success after it began training local youth to serve as sales agents and maintenance technicians for their systems.[22] The company conducted training sessions for youth who were seeking employment in their villages and the youth, in turn, serve as on-site sales agents promoting the technology among their fellow villagers. The trained youth are also capable of maintaining the systems. Before the training program began, the company had encountered difficulty in selling SHS in markets that lacked local technical support. The rural people were apprehensive to buy a complicated piece of technology without a person readily available to help them troubleshoot any problems that might arise.

Tilonia Barefoot College established a similar program in India, educating rural women on the advantages of SHS units so that these women can serve as liaisons for the technology. The women are trained in order to conduct educational sessions about SHS technologies in their villages and to service systems that require maintenance. This allows the women to gain supplemental income as salespeople and as technicians. It also exposes rural populations to SHS technologies and increases adoption rates.

Another advantage of providing local technicians is that their service can help prevent loan default. SELCO has identified a correlation between system operation and continuance of payment.[23] Customers are more likely to make consistent payments if their systems are in good working condition. Doorstep service assures the consumer as well as the financial provider that these systems will remain in good operating condition.[24]

Economic and Social Impacts

Light has the power to change lives on an economic and social level. Through light, businesses are able to stay open longer and people who previously have not had the opportunity to do much beyond their daily labor are able to extend productive activities, including education, into the evening hours. For example, in Bhudapada, the existing businesses must close when the sun sets, and all productive activity in the village, including cooking, reading, and handicraft production ends. The list below summarizes the benefits of light that resonate strongly with rural users:

a. Longer business hours in rural areas, translating to higher monthly incomes.
b. Cleaner, healthier environments, both at work and at home, as compared to those provided by kerosene lamps.
c. Increased safety for mobility and protection from animals.
d. Reduced dependence on kerosene/LPG, thus reducing monthly energy costs.
e. More time for children to study after sunset.
f. More quality time spent with families (television, dinner).
g. Increased possibility of use of televisions, computers, and cellular phones.

The greatest environmental impact, measured by solar light, is the reduction of more than five tons of CO_2 and other greenhouse gases per installed system.[25] However, SELCO indicated that when its BoP consumers were made aware of this fact, they were apathetic.[26] Regardless, environmental considerations are important for India as it continues to develop and affect its natural habitat.

A SELCO story that illustrates the economic impact of light is related here:

> Kumarasiri, a highly skilled carpenter, had a tiny un-electrified workshop in his house. Without electric light, he often could not complete the orders in time since he was limited by his daylight working hours. A SELCO representative introduced him to a solar lighting system. Through the payment scheme, Kumarasiri invested in a new solar lighting system. He now carries out carpentry work from his home under electric light. With more time to produce higher quality items, his earnings have increased and he has a more sustainable livelihood.[27]

The same effect was seen in the Zambian ESCO case study in which the system boosted an already established commercial operation's business. Although the economic impacts of light are quantifiable, the non-economic impacts of energy in general and of light in particular cannot be overemphasized. In the Zambian ESCO case, children spent more time reading and studying using the PV light as it was caused less strain on the eyes than kerosene. The light also provided for the possibility of night classes after farming work had been completed. One of the Enersol programs, Edusol, uses solar PV systems to provide access to computers in rural schools. The program began in 2000 and by 2003, sixteen projects had been implemented. Edusol partners with educational institutes wherever possible due to their relative inexperience with best educational best (Enersol is an energy provider and not an education provider).

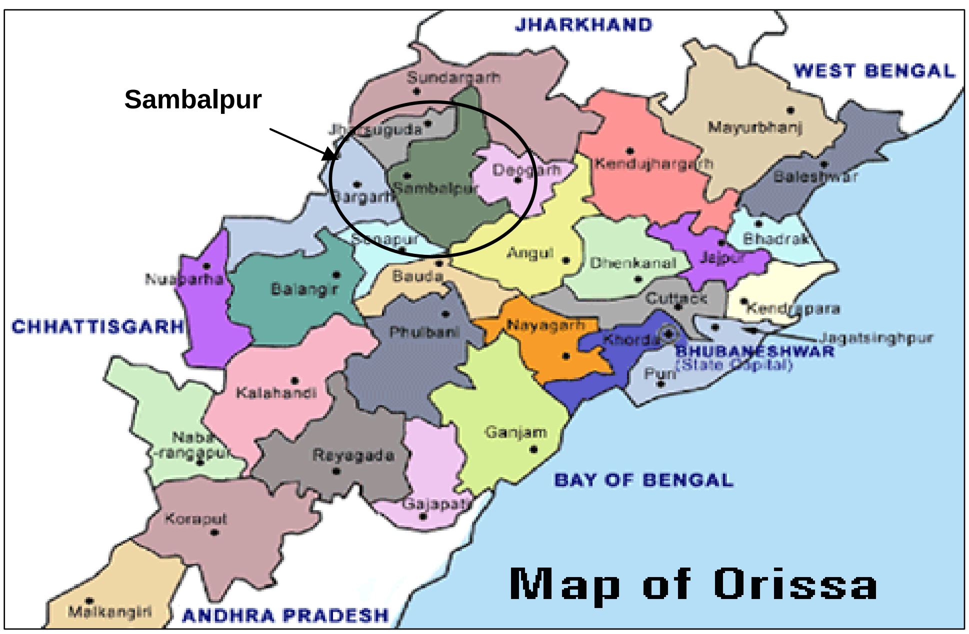
The conclusions that we can draw from the cases recounted in this section are that solar light is beneficial on a societal and economical level, there is a market for these systems, villagers can be trained in the maintenance and use of the systems, and that with appropriate financing mechanisms these systems can be financially sustainable. Important considerations for implementation are that training regarding the upkeep of these solutions should ideally be provided by local technicians, both in order to increase the economic benefits of the light and to ensure timely repair, and that the systems selected must serve the immediate and identified needs of the people being served.

VI. Bhudapada Village

In order to develop a scalable business model for BISWA, a model village was chosen so that we could understand the specific energy needs and preferences of the potential light consumers. Our team visited three villages with varying home structures, accessibility, and levels of wealth to understand the different levels of development. Bhudapada Village was selected for this project for several reasons including the village's lack of electricity (need), good accessibility from the main road, and most importantly, its strong working relationship with BISWA. Bhudapada will serve as a worst-case scenario for BISWA. Lessons learned from this case study directly informed the creation of a business plan for BISWA to scale out across its 14,590 SHGs.

Bhudapada is a small, rural village located in central Orissa. One hundred and fifty residents, comprising forty households, live within its borders (as of 2007). The village was established approximately twelve years ago by migrant travelers.[28] Sambalpur, the nearest large city, is nearly twenty-seven kilometers away. It takes BISWA employees forty-five minutes to reach Bhudapada from Sambalpur by car. The most difficult stretch is driving the last seven kilometers through the rural landscape on a dirt road that was built in 2006 and is already in need of repair. See Figure 1 for a map of Orissa and the location of Sambalpur.

Figure 1: Map of Orissa.



History

People originally came to this village for economic opportunity and an isolated setting. In the early 1990s, the primary source of income was the production and selling of rice beer, an illegal business in Orissa.[29] Rice beer provided the villagers with a livelihood, but manufacturing an addictive product such as alcohol can have negative side effects. Some of the people living in Bhudapada were experiencing domestic abuse and alcohol addiction.[30] In addition, the villagers admittedly drank the rice beer to suppress hunger cravings. This anti-hunger tactic was also used on children. The rice beer industry is a difficult industry and the strain of intense competition in the market also pitted villagers against one another as families were constantly struggling to survive.

As members of the Bhudapada community, villagers have the opportunity to collaborate for resources. However, this was difficult because many of the villagers speak different dialects of Oriya. Our research found evidence of collaboration between families, but not separate village members. This lack of social cohesion is further reflected in the positioning of homes, which are separated into clusters. BISWA has been working to eradicate rice beer from Bhudapada and help the villagers develop a sense of community. The organization has built strong working relationships with many of the villagers and continues to help the village today. This trust BISWA has established has enabled the organization to understand the Bhudapadans' problems and work toward solutions. Identifying a sustainable lighting solution for Bhudapada (and other villages in India) is one of BISWA's many important projects. It falls within BISWA's Basic Needs Program that is part of its development arm.

The Basic Needs Program, which focuses on development, especially of women, is currently successful in thirty-two villages, including Bhudapada. Building strong working relationships takes an immense amount of time and effort. BISWA's role as a partner and liaison was critical to our project's success. BISWA has worked with Bhudapada Village since 1994 and during the survey process villagers were open and willing to answer questions freely because our research team was associated with BISWA. This was critical in obtaining fair and objective data as well as overcoming cultural barriers.

Geography

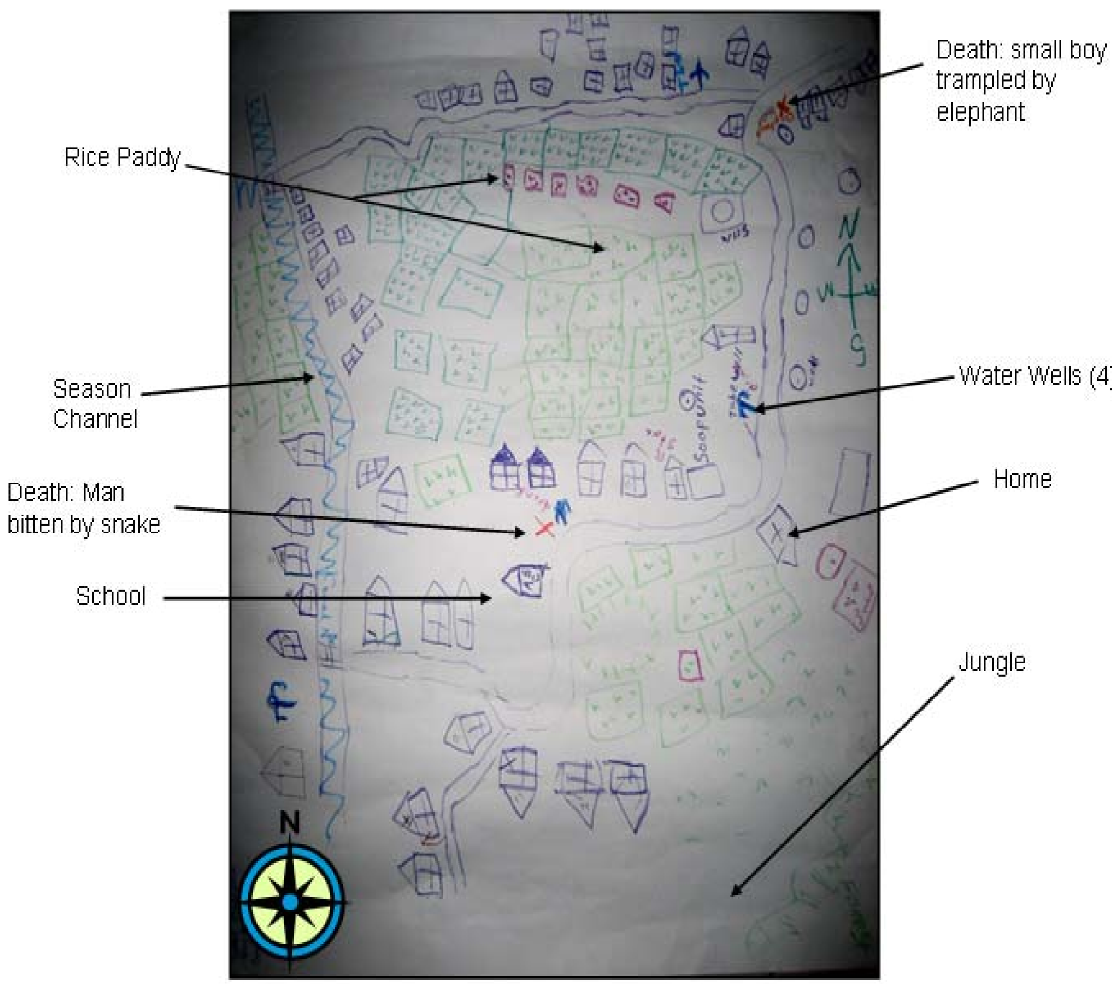
Our research team visited Bhudapada Village in May of 2007. During this visit we conducted an extensive survey as well as facilitated a participatory mapping exercise to learn more about the community from the villagers' perspective (

Figure ***2***). The mapping activity involved local women in the development of a visual representation of their homes, food growing plots, struggles, and opportunities. For example, the women were able to communicate safety issues by showing the location of two fatal animal attacks. Through this exercise the research team was able to learn about the village from the perspective of the people who live there. It should also be noted that this exercise fostered trust building between the research team and the villagers.

As shown in

Figure 2, Bhudapadan homes are surrounded by rice paddy fields. These crops are in the middle of the village and are denoted by the green and pink squares. Season Channel, a government-owned canal, is located on the west side of the village. It provides water for basic needs such as bathing and cleaning, however villagers are only permitted to withdraw water by manual methods. There is one school for all seventy children (under age of fourteen). It is located in the center of the village. There are four water wells denoted in dark blue. The nearby forest provides vegetation for home structures, cooking, and handicrafts. However, being near the jungle also has disadvantages as wild animals enter the village and jeopardize the safety of its people. The two red crosses represent locations where people were killed by animals, one by an elephant and another by a snake attack. The village is one kilometer in length and approximately two kilometers in width.[31]

Figure 2: Map of Bhudapada Village created with villagers (2007).



Housing Structures

Village homes are sparse and clustered in groups of three or four. The two furthest houses are one kilometer apart. Dirt roads are available for vehicle transport through the village, though only a few households have bicycles. Figure 3 shows an example of three homes grouped together. They face inward, creating a central space in the middle. This is the typical home configuration in

Bhudapada. The average household has two rooms and houses five people. Extended families often live close to one another. Bhudapada has one SHG with two successful businesses: a soap-making unit and general store. The general store is located inside one home. Homes are sometimes used for business purposes as this saves building costs and offers additional protection of goods because the business/home-owner can protect inventory at night.

Figure 3: Traditional home in Bhudapada.

The land in the village is arid and dusty, providing the villagers with limited resources for building their homes. Homes are made with available supplies such as straw, mud, cow dung, bamboo, and sometimes brick. The walls of the house are generally made with woven straw or bamboo. Very poor families have straw or stick walls while wealthier families may have mud and dung walls and only wealthy families can build their homes with brick. The walls do not seal at the wall intersections and this not only weakens the structure of the home, but also fails to provide adequate protection against small, wild animals entering the premises. In addition, the materials used are flammable. The villagers use kerosene for cooking and lighting and improper use and spillage of this fuel can cause burns and fires.[32] The roofs are made with grain and rarely withstand the monsoon season. The villagers often have to rebuild and improve the structural capability of their homes, a timely and costly endeavor.[33]

Village Survey[34]

A survey was administered to thirty-three households in the village (83% of the village's total households) to understand the village's needs, preferences, constraints, and opportunities regarding energy.[35] The questions covered a variety of topics including demographics, income, cooking practices, and energy sources used for light. The team interviewed women of the household because they were most aware of the challenges facing their families.[36] In some cases, we were also able to speak with the men of the household as well. The survey was conducted by two teams over a series of five days. Each team had two students (one male and one female) and a BISWA interpreter.

Figure *4* shows a member of the team interviewing (with an interpreter) a woman while many of the villagers watch and listen.

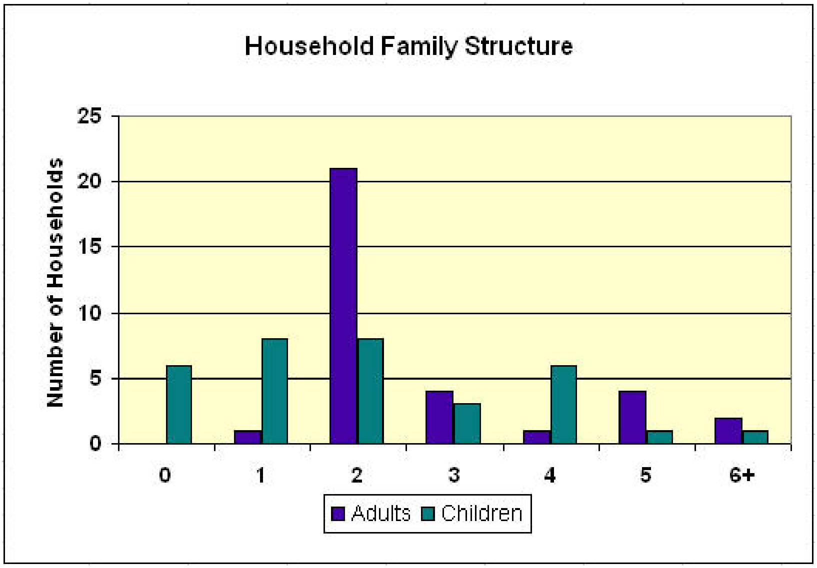
Figure 4: Team conducting survey interviews.

Figure 5: Typical Bhudapadan Family.

Survey results show the village to be very diverse. Households differ by family structure, income source, and income amount. Figure 5 shows a typical Bhudapada family during an interview. In this picture, a mother sits on her front step holding her baby, while her second child sits behind her with the grandmother. The other two children in the picture are neighborhood children. Most households consist of two adults and two children (see Figure 6). The average age of an adult in

Bhudapada is forty-five years. None of the adults can read or write beyond signing their own name. Most of the children are attending the village school and learning the local dialect of Oriya. School age children can read and write basic words in Oriya. However, they cannot read, speak, or write Hindi or English, both of which are more widely used languages in India. With our limited knowledge on their educational benchmarks, it was difficult to gauge their true level of literacy.

Figure 6: Households with the same number of adults and children.



Bhudapadan household incomes vary widely by amount earned and occupation. Families live day to day, most without a steady source of income. Irregular pay makes it very difficult to save and plan for emergencies. In addition, their options for loans were few and far between. Before BISWA started working with the villagers, the people of Bhudapada borrowed money from private money lenders for medical emergencies at extremely high interest rates. This lending practice further exacerbated many Bhudapadans' desperate economic situations. In Bhudapada, incomes range from Rs.110 to Rs.4800 (USD$2.75 to $120) per month. The majority 36% (12 households) earn between Rs.500 and Rs.1,000 (USD$12.50 to $25) per month. The average income is Rs. 1200 (USD $30) per month. Bhudapadans' income per capita is Rs. 436 (USD$10.90) per month. See Figure 7 for additional details regarding monthly household incomes in Bhudapada.

Figure 8 shows the various sources of income. The primary income source for people living in Bhudapada is agriculture labor. Seventy-three percent of the villagers rely on some form of labor to survive. While agricultural labor pays roughly Rs. 40 (USD$1) per day, it does not provide consistent work.[37] Regardless, the people of Bhudapada made it clear that agricultural labor was their first choice for work when they can get it. Their non-labor time is supplemented with other income-generating activities such as making leaf plates, weaving bamboo mats, and collecting leaves for the *bidi* cigarette industry. These activities are sporadic and often seasonal. No combination of any of the aforementioned income sources results in a steady livelihood for the Bhudapada villagers, making it difficult for them to budget and plan for their needs.

Figure 7: Monthly household income.

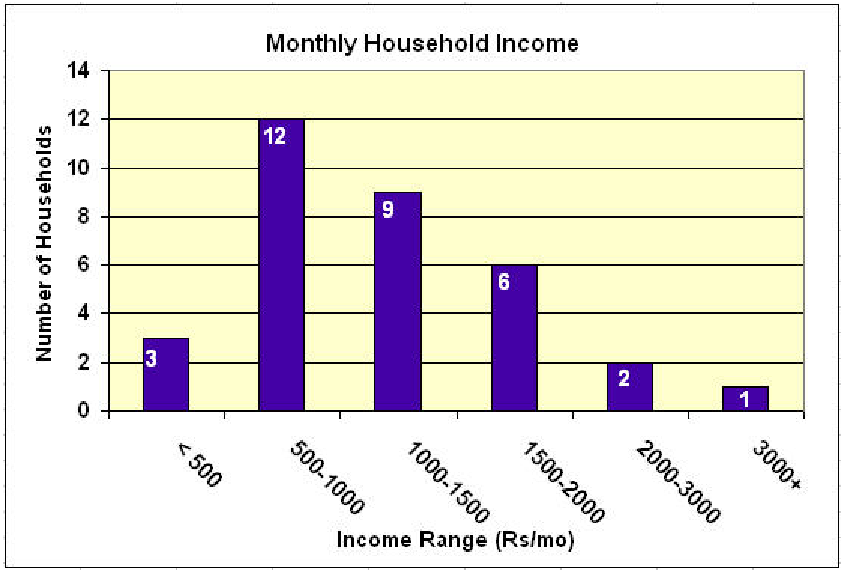
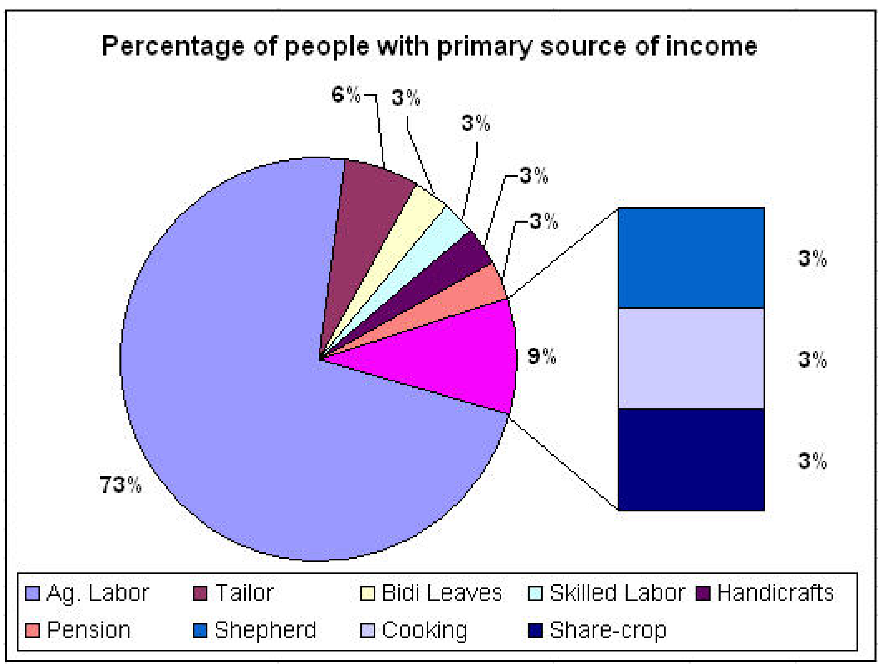


Figure 8: Primary income sources for villagers of Bhudapada.



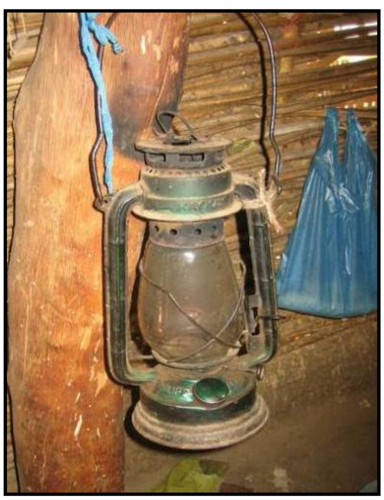
Kerosene for Light

Kerosene plays a critical role for villages like Bhudapada that are not connected to the electricity grid. It is the primary fuel source for lighting and the secondary source for cooking.

Kerosene is the most affordable fuel source available because it is offered at a subsidized rate by the government. Bhudapada villagers use kerosene to make *diwas* (small lights made with recovered metal cans or glass bottles, kerosene, and a wick inserted through a hole in the top). Diwas cost roughly Rs. 45 per unit.[38] Figure 9 shows photos of a kerosene lantern and a diwa. Households on average have 1.6 diwas and 0.9 kerosene lanterns. Only two families have battery-operated lights. One family in the village had a solar electricity system that they brought with them when they moved to Bhudapada from another state. This system was purchased at a subsidized rate from the government.[39] No solar system subsidy is currently offered for people living in Orissa.

The average household spends Rs. 50 (USD$1.25) per month on kerosene to fuel their lanterns and diwas. This represents 4% of the average monthly household income. The village members we surveyed purchase a total of one hundred and thirty-one liters of kerosene per month. Total kerosene costs equal Rs.1,633 (USD$40.83) per month, resulting in an average cost of Rs. 12 (USD$0.30) per liter of kerosene. Each liter of kerosene generally provides light for six days (depending on consumption habits). A government ration of four liters will supply the average family's energy needs for twenty-four days per month. Using four liters of kerosene monthly, the diwas allow for approximately twenty-five hours of light per month. Not only is this an insufficient duration of light (villagers indicated that they would like four hours of light each evening, or one hundred and twenty hours of light per month), but also the quality of the light is inadequate for conducting most activities.

Figure 9: Kerosene lantern and diwa candle.



While the Indian government's kerosene subsidy program is designed to help provide fuel to the poor, it is not always effective due to factors such as eligibility, accessibility, and affordability. Families must own a ration card to be eligible for the subsidy. Ninety percent of Bhudapada residents have successfully received a ration card. However, these villagers still may need to buy extra kerosene on the open market. This is sold for almost twice the price of subsidized kerosene.

Challenges with kerosene do not stop with obtaining a ration card. Families with ration cards travel by foot an average one hour to obtain kerosene from a government distribution center. Time lost traveling could be used for various income-generating activities. Furthermore, the distribution center does not always have an adequate supply of kerosene. In addition, the government can change quotas without informing the local people. As a result, families may suddenly find out they can only obtain three liters of kerosene or none at all.

Opportunities

The villagers of Bhudapada, like many rural people in India, try to complete all their work during the daylight hours. It is difficult to safely conduct activities at night with the kerosene *diwas* and lanterns. Regardless, people try to use kerosene at night for various activities such as light for cooking, housework, and protection. The low level of light provided by kerosene can make these everyday activities dangerous and sometimes fatal. Parents expressed concern that their children could fall asleep on a *diwa* candle and burn their face. Kerosene lanterns can get knocked over, spilling kerosene fuel and igniting the straw house. Villagers also expressed concern that they may injure themselves or be bitten by a snake when trying to walk at night by the light of the kerosene lamp. The conclusion of the research team and villagers is that Bhudapada is in need of a lighting solution to replace kerosene.

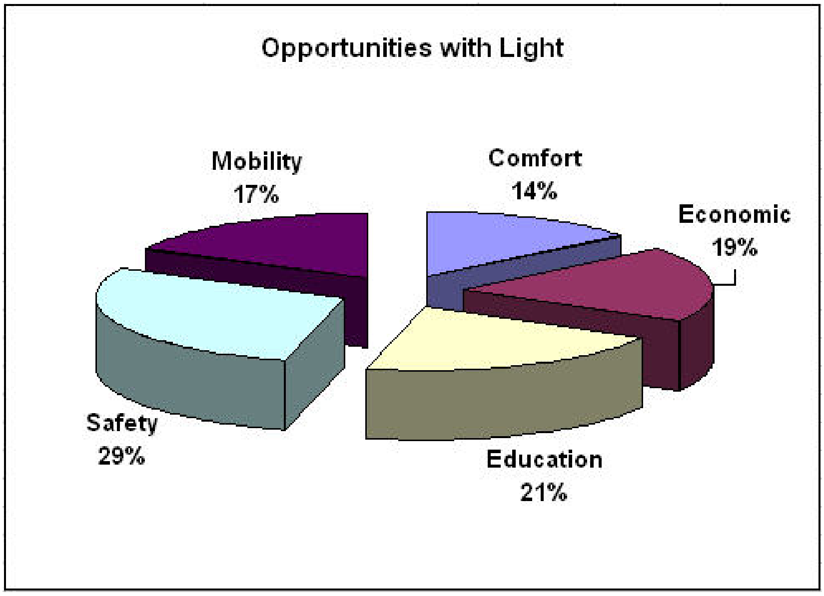
Bhudapadans have many ideas for how they would use a strong and reliable light source. The main ideas include safety, education, income generation, mobility, and comfort.

shows the percentage of villagers that mentioned various opportunities for light during the survey. It is important to note that some of the villagers mentioned one item more than twice and therefore the total does not equal 100%. Safety was the greatest opportunity that villagers saw with an improved light source. Villagers wanted to be aware of intruders (animal or human) that could pose a threat to their families. Indirectly, light can help reduce the number of health problems (illness and injury) and the resulting costly medical care and lost wages. Villagers indicated snakes and mosquitoes enter their homes at night, resulting in possible disease and death. The second most common desired application of light described by villagers was that of increased educational opportunities. Parents felt that proper reading light would allow their children to study in the evenings safely and effectively. Education is an important predicator of development and prosperity in a village.

Increased time to work was another activity described by villagers as something that they would like to do at night. Specifically, they mentioned handicraft production such as sewing leaf plates and making bamboo cots. These activities can provide additional income and improve their economic situation.

Seventeen percent of the villagers indicated mobility as an opportunity. It is difficult to move around the house, both inside and outside, in the dark. Even the light of a kerosene diwa/lantern is not enough to provide a satisfactory view of their nearby environment. Villagers also indicated interest in moving between homes to visit friends and family. In addition to mobility, comfort was identified as a need or opportunity by 14% of the villagers. Some women discussed the need for light at night to comfort a sick child and several villagers said that light made them feel safe and comfortable.

Figure 10: Opportunities for light as identified by villagers.



Bhudapada village is in strong need of a lighting solution that is reliable and of good quality. Although kerosene is offered at a reduced cost through government subsidies, the light it provides is inadequate and poses a safety threat to the villagers and their environment. Several technologies were researched that could address the villager's energy needs and preferences. A criteria matrix was used to qualitatively evaluate the products and make a recommendation. In addition, a financial model was constructed to compare the villagers' current energy costs with the estimated costs of the recommended alternative. This helped us identify solutions that incorporated the villagers' financial constraints and provide guidance on which technologies they could afford. Finally, a business model was developed describing how BISWA might implement these recommendations in their remaining villages across India.

VII. Technology

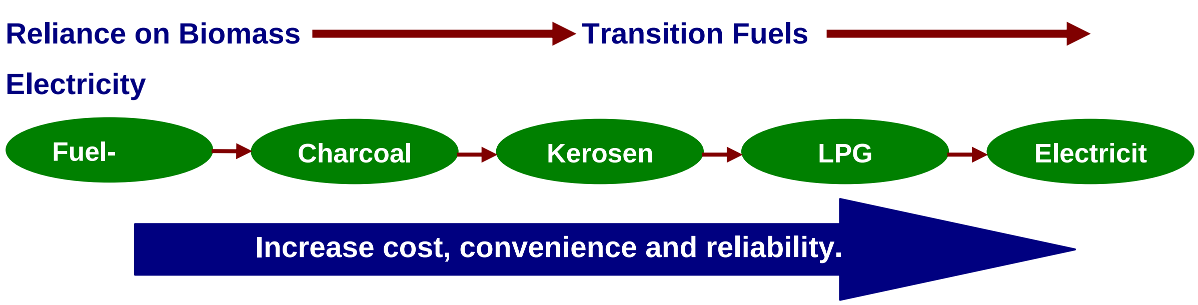
Recognizing the shortcomings of the villagers' current lighting system, and the corresponding development issues, our project sponsor requested that we explore the potential for solar PV power to serve as the primary light source. This section describes how we developed and applied a framework for evaluating different technologies for lighting and our eventual choice of solar PV systems. The section concludes with an appropriate product recommendation for implementation in Bhudapada.

Technology Choice

Figure 11 exhibits the manner in which people traditionally progress through increasingly complicated, but efficient, means of energy production. Leapfrogging takes a consumer directly from a lower rung of the ladder to a higher one without having to adopt the technologies that lie between them.

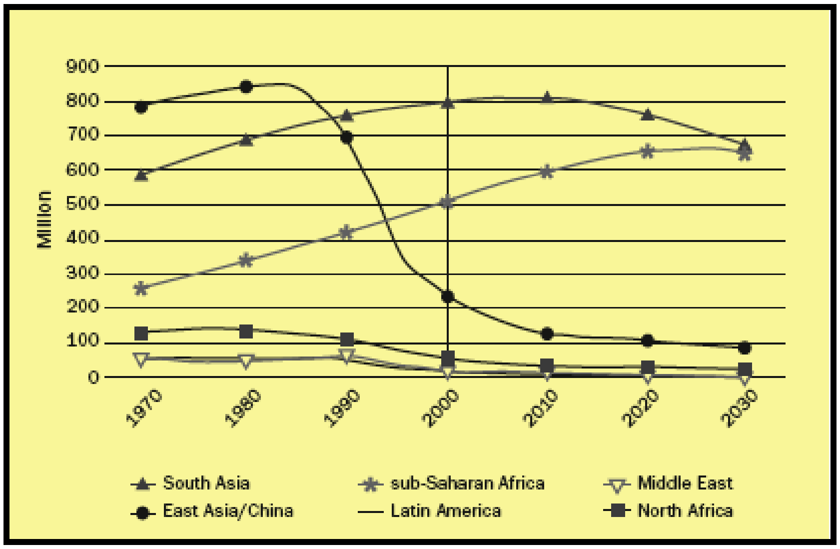
In the field of lighting technologies, leapfrogging up the energy ladder occurs when a user moves directly from a polluting and inefficient means of lighting, such as a kerosene lamp, to a cleaner, more efficient lighting solution, such as electric lighting. Jumping over less efficient technologies presents a great advantage because it allows users to avoid the social, economic, and environmental pitfalls inherent in intermediate technologies. For example, Liquid Petroleum Gas (LPG) can be difficult to obtain within some markets in India, and when it is available, the costs of procurement are high. Additionally, the burning of LPG inside the house creates the same indoor air pollution that is a concern with kerosene usage. Moving directly to electricity from kerosene allows the villagers to avoid the problems associated with LPG.

Figure 11: Energy ladder.[40]



The International Energy Agency predicts that South Asia will continue to be the region of the world with the highest number of persons who lack access to electricity. As ***Figure 12*** shows, the number of people without electricity in this region will continue to grow until 2010. Infrastructure will gradually deliver electricity to un-electrified regions, but progress will be slow. Additionally, the transition to electricity will follow the traditional trajectory exemplified in the energy ladder and years will pass as villagers employ dirtier and less efficient means of lighting. Our proposal will help villagers in Bhudapada avoid this long wait for electricity and enable them to move quickly beyond less desirable lighting solutions such as LPG.

Figure 12: Number of people (actual and projected) without electricity, 1970-2030 by region.[41]



Solar photovoltaic (SPV) technologies present an opportunity both to provide high quality light for an appropriate length of time and to enable villagers to move quickly to a clean and reliable source of energy, bypassing the intermediate energy technologies. The United Nations Millennium Development Goals recognize the potential for solar energy to achieve the UN's myriad goals aimed at raising the standard of living for those living on less than two dollars a day, stating that "PV is clean and can be scaled down to a few watts, and is thus ideal for household consumption."[42] The United Nations Development Program (UNDP) further recognizes electrical illumination as critical for achieving poverty and hunger eradication, gender equality, and environmental sustainability.[43] Finally, a survey of academics, policy makers, industrialists, and scientists revealed that they believe solar PV to be the best solution for pure illumination in remote villages in India.[44]

The desire of the world's poor to improve their lives also plays a significant role in global climate change. As the world's poor continue to grow wealthier, they tend to use the same non-renewable, non-sustainable, and carbon-intensive models as the developed world. Working with the poor to develop models based on renewable energy technologies can help break the cycle of carbon-intensive development. It will not be enough for developed countries to merely cut down on their carbon emissions as there are greater gains to be realized by leapfrogging inefficient technologies and implementing sustainable ones in developing countries. Energy production represents one of the largest areas of opportunity for this sort of improvement and is central to this project as we work at the BoP, helping communities achieve their desire for development in a sustainable manner.

Another consequence of adopting solar PV technology is the reduction in the amount of atmospheric pollution created within rural villages. In Bhudapada alone, the use of solar PV lighting would allow households to discontinue the use of kerosene for light, significantly reducing CO2, NOx, and particulates. Table 2 shows the annual avoided pollution per household and for the entire village if Bhudapadans stopped using kerosene altogether.

Table 2: Amount of pollutants avoided by discontinuing kerosene consumption.

Pollutants (CO2, NOx, Particulates)	
Net CO2 avoided per household (metric tons)	0.109
Net CO2 avoided for Budhapada (40 households)	**4.36**
Net NOx avoided per household (metric tons)	0.0002
Net CO@ avoided for Budhapada (40 households)	**0.008**
Net particulates avoided per household (metric tons)	0.0056
Net Particulates avoided for Budhapada	**0.224**

Table 2 demonstrates the significant environmental benefits achieved by using SPV technologies instead of kerosene, the current fuel used for lighting. The quantity of avoided pollutants is largely unchanged for LPG also since LPG emits about 85% of the CO2 emitted by kerosene per unit of power created,[45] and about 75% of the NOx that kerosene creates per volume consumed.[46] Thus, leap-frogging will not only decrease the villagers' environmental impact with respect to their current activities, but it will also allow them to avoid future impact with fuels that are further along the energy ladder than they currently are.

Although SPV has a higher initial cost than some other electric generation technologies such as diesel generators, the ongoing costs of SPV systems are lower due to the fact that the user does not have to continuously buy more fuel. Once a SPV system is in place, the ongoing cost for maintenance is similar to that of diesel generators, and the same cost pattern pertains to the replacement of electrical system components including wires and light bulbs. The largest difference between diesel generators and SPV is that the SPV requires a battery. Therefore the lifetime of the battery is a critical component in a system's lifetime costs. Nonetheless, SPVs are superior to other distributed generation options because of their accessibility, low environmental impact, and low ongoing costs, all of which made SPVs an extremely reasonable point of focus for the project.[47] A rigorous evaluation framework was needed to codify the relative merits of different technology options.

Framework for Evaluating Technology

The criteria by which we evaluated technology were developed through a multi-pronged approach. First, we reviewed several other cases in which SPV technology was introduced in similar settings within developing countries. These cases are recounted in the *Case Studies* section of this paper. We also conducted informal interviews with several individuals involved in deploying SPV technology throughout the developing world including: Phil LaRocco, the founder and Executive Director of E+Co, a company that finances distributed generation projects in developing countries; Dr. Peter Lilienthal, the developer of the HOMER model, which enables common users to optimize distributed power generation systems; Harish Hande, founder of SELCO India, a SPV provider; and officials within Orissa's Renewable Energy Development Administration. We also had extensive conversations with villagers and our project sponsor regarding the villagers' needs, all of which are detailed in the *Bhudapada Village* section of this paper. All of these resources provided insight into some clear trends within the common elements of success and failure when undertaking rural village electrification projects in developing countries. Ultimately, their guidance helped us to identify seven essential criteria for evaluating SPV products: capital cost, ongoing cost, productivity, mobility, safety, social acceptance, and the potential for year-round use. These criteria were then presented to our client who provided an informed perspective on how much weight each criteria should carry when considering the optimality of different products.

Capital Costs

Capital costs include all the initial costs of purchasing and setting up a solar PV unit. This included the batteries, wires, charge controllers, inverters, or lamps and light bulbs that might be required to create a working system.

Ongoing Costs

Ongoing costs are a measure of any costs associated with the maintenance or usage of the SPV unit. These costs include any parts and any labor costs required to keep a system operational. In some cases, the money transacted for these costs remain within the village as in the case of employing a local technician to maintain a system, but in other cases, the money will leave the village entirely as in the case when a battery must be purchased from a nearby city market.

Productivity

Productivity is essentially the amount of light that a given product can emit. The unit of measure for this parameter is lumens per hour. A lumen, a metric unit, is a measurement of the amount and intensity of light produced from a given source. Lumens are typically used to ascertain the level of usable light emitted, and by using this unit of measurement, we were able to assess the amount of light that various technologies make available for usage. This measurement was important because the amount of lumens produced determines how that lighting can be used. The Lighting Research Center, based at the Rensselaer Polytechnic Institute in Troy, New York, recommends that activities such as writing require 720 lumens.[48] Writing is analogous to much of the handcraft-type work villagers indicated they would perform with light in the evenings. Therefore, we adopted 720 lumens as a benchmark for how many required lumens would be required per villager activity. Thus, knowing the number of lumens a system will emit and the number of hours the light produced can last allowed us to determine the number of people who could benefit from the product and the amount of time each of those people would have to enjoy that benefit.

Mobility

This parameter is a binary measurement: either a product allows the user to move around with the light or it does not. On a more refined level, we considered the degree of ease by which a villager could move around, and also accounted for the effectiveness of lighting when on the move. Some lights have greater "productivity," and therefore, will be better designed for certain mobile applications. For example, a light that can shine further will better allow villagers to see snakes in their homes and elephants in their fields, two of the more prevalent concerns expressed by the villagers.

Safety

Many villagers indicated that they felt unsafe moving through their village at night without light. They also wished to have light within their home to be able to see snakes and other potentially dangerous animals. When considering different solar lighting technologies, we evaluated each technology's capabilities both to allow free and safe movement around the village and to enable the villagers to feel safe within their homes.

Social Acceptance

This criterion is evaluated on the expected ease of adoption for each technology. Ease of adoption is facilitated by the relative familiarity of the lighting technologies as well as by the presence of similar technologies in the village already. If technologies are simple and familiar, villagers are more likely to adopt them earlier, which will shorten the pilot project period at the same time that it quickens the successful roll-out of the program village-wide.

Year-Round Use

Year-round use is dependent upon the ability of the technology to be used multiple days between charging. It is also influenced by the extent to which the technology can be adapted to run from alternate power sources during the monsoon period when solar irradiance is lower. The alternate source could simply be a replacement of one of the inputs, such as rechargeable batteries, with a nonrenewable input such as, single-use batteries.

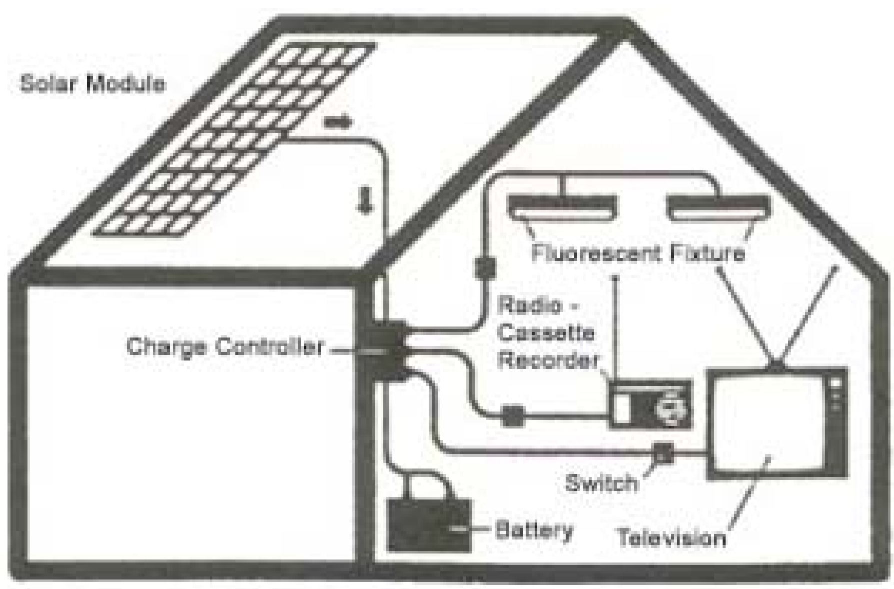
Solar Photovoltaic Technology

SPV lighting systems can be divided into two broad categories: SHS and solar lanterns. After a review of many of the products on the market, the fundamental setup and usability within categories did not exhibit significant differences. However, in a comparison between categories, there were relative advantages and disadvantages which will become apparent in the following category overviews.

Solar Home Systems

SHS are comprised of a SPV module which is connected to a battery via a charge controller unit (see Figure 13: Solar home system schematic. The battery can then be connected to an assortment of appliances. As this project is focused on lighting, we did not consider system requirements for appliances other than light bulbs. If the system is to be upgraded in order to power other items such as a fan or a television, a converter (DC-to-AC) may be required for an SHS. Some SHS are sold as kits while others must be constructed by the user after he or she has purchased the PV module, charge controller, battery, and lighting system separately. Given that the villagers of Bhudapada have little access to global markets for these SHS components and have limited transportation capabilities as well as technical experience, our project focused on examining SHS kits. The greatest advantage of an SHS is the user's ability to expand the usage of the system. Many villagers expressed interest in eventually buying fans, televisions, and other electronic appliances, and an SHS could provide the electricity for these additional items.

Figure 13: Solar home system schematic.[49]



Solar Lanterns

The other category of SPV lighting solutions is the solar lantern, as shown in Figure 14. These products are compact versions of the SHS outlined above, with the solar cells, battery, and light integrated into a single unit. The comparatively small size of solar lanterns confers advantages and disadvantages. An advantage is the portability typically featured in solar lantern products. Their portability is advantageous but it also does not preclude the usage of these lanterns in stationary situations. Many can produce sufficient lumens for writing. However, the only way to scale up the amount of light provided is to buy more lanterns. Additionally, due to the relatively smaller PV module and battery size, solar lanterns do not hold the same amount of lighting potential between recharges as an SHS would. Thus, they will require more frequent charging and a greater frequency of sunny days.

Figure 14: An example of a solar lantern with integrated solar panels.[50]

Solar Battery Chargers

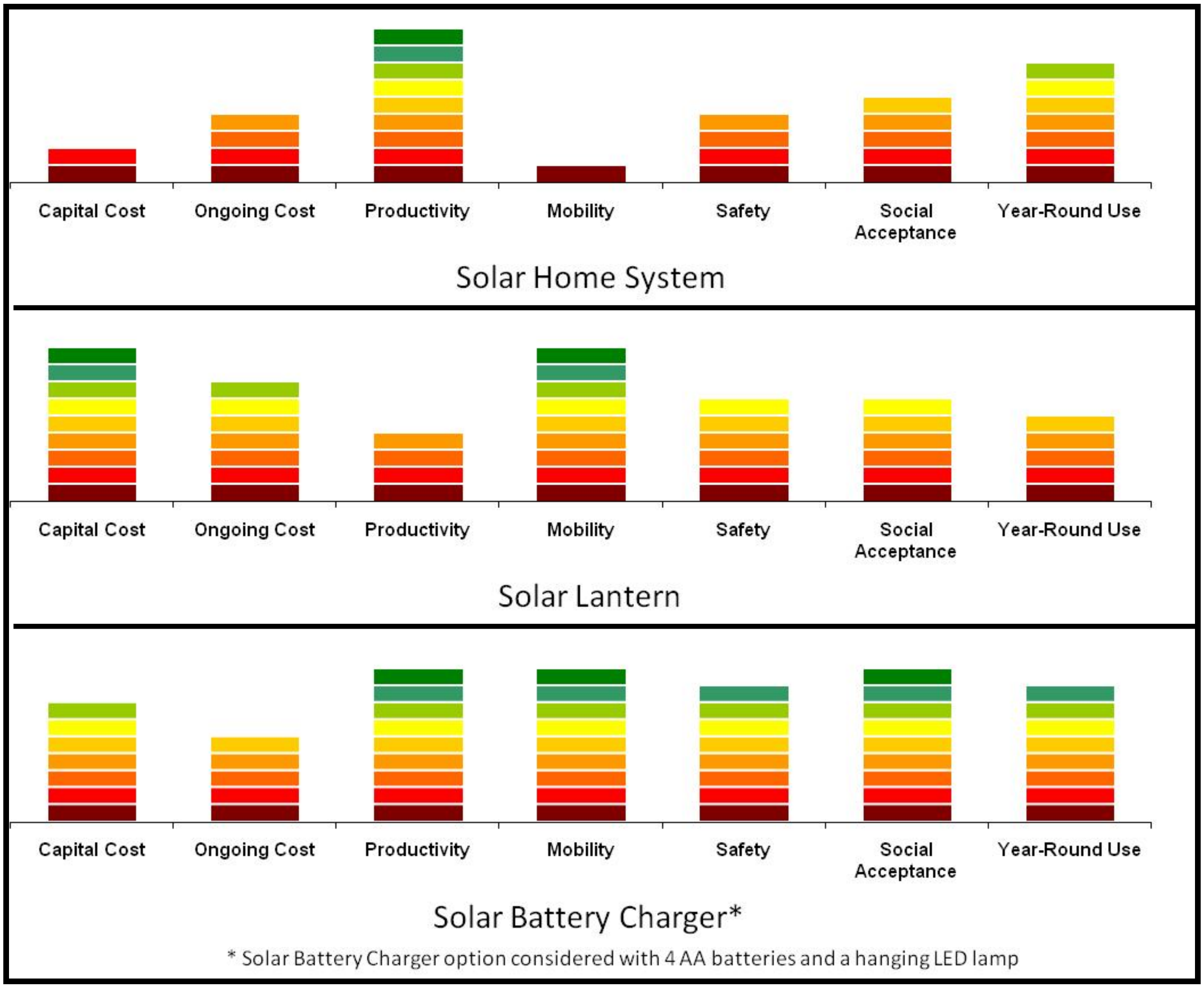
A third option we explored involved a less traditional method of converting solar energy into light than the SHS or solar lanterns. This option entails charging small batteries (AA, C, or D) via a solar charger and using these batteries in appliances or lighting systems which are readily available throughout India's commercial market. The greatest advantages that this solution provides are the low capital cost and the familiar nature and commercial availability of all of the components of a commercially available lighting system. It is also adaptable in that the batteries can be used in any other compatible appliance such as a radio or small fan. At its most basic configuration, this option requires the purchase of three components: a solar battery charger, rechargeable batteries, and a flash light or other lighting system that will use the batteries to produce light (see Figure 15 for an example of a solar charger). The drawbacks of this option are similar to those of the solar lanterns. The expected duration of light will be slightly lower than that of an SHS due to the smaller-sized batteries used and the future adaptability of this system for larger power applications is limited.

Figure 15 : An example of a solar battery charger with accompanying rechargeable batteries.[51]

Comparison of Options

After researching a number of particular products within each technology option category and gaining a deeper understanding of the strengths and weaknesses of the product options, the team evaluated each technology category relative to the other categories. These comparisons were made for all criteria discussed previously which the team identified via research and conversations with villagers as well as experts in the field. The following graphs in Figure 16 reveal how each of the SPV technology options fare with respect to each other. The intensity or height of each bar was determined by a general understanding developed through the team's research and evaluation of each SPV technology option. A higher set of tiles indicates a relative desirability of that technology for the corresponding criteria. When comparing across technologies, the technology with more tiles will be the preferred option for that criteria, and a technology option with more tiles on average for each criteria will be the overall most attractive for application in Bhudapada.

Figure 16: Comparison of solar options.



The comparisons in Figure 16 show that the SHS is superior in the *Productivity* category given its ability to power high output lighting solutions as well as its adaptability to be put to use powering other production enhancing appliances. However, this system does not fair as well under the other criteria. The solar lantern is the best option with respect to *Capital Cost* and *Ongoing Costs* because of its low component costs, but it does not have an extreme “Capital Cost” advantage and is not as capable as the Solar Battery Charger at increasing productivity, due to its inability to be used to increase light production easily without simply adding additional solar lanterns which would double or triple the “Capital Cost” of the option. The Solar Lantern option is also not capable of being used year-round easily because of its storage capacity and inability to utilize other sources of power beside the sun. This leaves the Solar Battery Charger option as the product leader given its ability to be used year-round and adapted to any of a variety of productive endeavors. Using the batteries in a flashlight or other mobile source of light also serves to address many villagers’ primary concern, safety.

Additionally, since each component of the Solar Battery Charger option can be purchased separately and do not require intensive maintenance, this option is more attractive with respect to "Ongoing Costs."

Technology Recommendation

We recommend the solar battery charger technology in combination with a battery operating lighting solution as the ideal product for Bhudapada Village given that it balances capital cost with productivity and mobility requirements. This option allows for adaptability and scalability, and the components of this system are available at appropriate prices given the Bhudapada villagers' financial situation. The components of this system are as follows: (a) solar battery charger, (b) batteries, and (c) lighting solution.

Wide spread adoption of solar lighting technologies is the ultimate goal for our project and because villagers' finances are severely restricted, we believe that the solar technology employed must create the opportunity for villagers to generate additional revenues through its use. The ability to increase income will not only allow more villagers to adopt the technology, but it will also increase the quality of life across the village beyond the mere addition of light to villagers' lives. With this in mind, the initial purchase price of a solar battery charger and accompanying lighting technology will not be cost prohibitive and the enhanced productivity possible using this option makes it more attractive than the solar lantern. Additionally, a criterion that is not measured above, but is important considering our recommended staged implementation, is the ability of solar battery chargers to be applied to multiple applications around the village. The solar battery charger is the most capable option for allowing a differentiated product offering, which will satisfy a wider spectrum of the villagers' needs that they expressed during our site visit.

In order to anticipate future demand growth, we took scalability and adaptability into consideration when evaluating the technologies. The Bhudapada villagers revealed a desire for flexibility that has been demonstrated in other case studies, including those highlighted in previous sections. The villagers wanted to be able to use fans for comfort and health (they help keep disease-carrying mosquitoes away at night) and televisions and radios for entertainment and keeping abreast of the outside world, as their income would allow. The solar battery recharging option allows for scalability to small appliances such as battery operated fans and radios. Even though the SHS provides the best option for scaling the system, it was not found to be a viable option due to the high capital costs and lack of mobility, both of which were qualities that many villagers indicated as being very important.

Solar Battery Charger

The solar battery charger should include high SPV efficiency matched with the ability of the product to charge multiple types of batteries. The purchase price will also be important, but since the owner will be enjoying significant economies of scale under our implementation recommendations, capital cost is somewhat less of a concern for this component of the system. It is also necessary to ensure that the charger will not allow discharge of the batteries in the absence of sunlight, but will also help the user avoid overcharging the batteries, simplifying its use and maximizing the lifetime of the batteries it charges.

With this mind, we chose a solar battery charger that could charge a variety of battery types in the event that the villagers purchase other technologies that employ different battery sizes. The charger we chose can charge AA, AAA, C, and D type batteries (Figure 15). The lighting technology employs AA batteries, but as villagers purchase radios, fans, and other electronic devices that necessitate different battery types, the microenterprise will be able to buy rechargeable batteries to serve the expanding villager needs. The charger also has a meter that allows the microenterprise to assess the amount of electricity reaching the batteries and the estimated number of hours until the batteries will be charged. This not only allows the user to get immediate feedback on how well the unit is positioned with respect to solar rays, but it also enables the user to use the system optimally by not leaving batteries in the charger past the time when they are fully charged. The only slight downside to the charger we selected is its capacity. The charger can recharge only two batteries at a time, which is a slight impediment to getting enough batteries charged per day. Fortunately, the Sambalpur area receives ample solar radiation for a long enough period of time to recharge roughly 6 batteries per unit per day.[52] This holds true in the monsoon season when average solar insulation reaches its lowest levels of 3.89 (July) and 3.81 (August) kWh/m2/day because both those months also contain some of the longest daylight hours throughout the year with 13.2 in July and 12.75 in August.[53]

A sample of the charger was purchased via an online distributor for $19.95 and after informal testing, we found the product claims to be accurate. At one point, the charger was left out in a slight rainfall, but the plastic casing did not allow any water to penetrate into the electronics it contained. The unit continued to work after this event as well as it had previously.

Rechargeable Batteries

Batteries require four attributes to be balanced: (1) low purchase price, (2) long product lifetime, (3) long in-use period (i.e. the battery will last for an extended period when being used in the lighting solution), and (4) high recharge efficiency. Given that battery technologies are widely diffused, we believe that this selection should be made by the MFI (in this case BISWA) since they will have immediate knowledge of the product portfolio available in the area surrounding Bhudapada. In our modeling, we assume that a rechargeable battery will cost USD$2 and will last 500 charge/recharge cycles, which is the industry standard.

Rechargeable batteries are a necessity when employed in household SPV technology, particularly for illumination purposes. This is because the hours during which the electricity is needed do not coincide with the hours during which the SPV unit is producing electricity. Quite simply, electricity for illumination is used at night and solar PV technology requires daylight. Thus, a battery is an integral part of any SPV system that the Bhudapadan villagers might use.

When locating the appropriate battery for this type of application, one needs to consider two battery traits: how many ampere-hours the battery will provide and how much autonomy it will provide. Autonomy, with respect to the batteries of solar PV systems, is the amount of cloudy days a battery can still provide energy for. In other words, autonomy is a measure of how long a battery can discharge and provide power before needing to be recharged. The autonomy is determined by first deciding how long a battery will be used for daily. Next, one should determine the duration of usage between charging a particular battery can provide. The final step is to match that battery which can provide the usage necessary to ensure the desired autonomy. For example, if a person will use a battery for three hours every day and wishes to be able to use that battery for four days between charging, the appropriate battery will need to have a capacity for twelve hours of usage (3 hours X 4 days). Twelve hours of usage will provide the person four days of autonomy.

Several tests have revealed that the optimal autonomy is about five days.[54] This will allow the villagers to light their houses for five days before needing to recharge their batteries, and the longer periods between full discharge, are essential for extending the lifetime of the battery.[55] A battery's nominal autonomy is typically higher than its measured autonomy in the field, so it is also important to understand the experience others have had with a particular battery manufacturer. In some cases, the measured autonomy is greater, and in other cases, it is less.[56]

Lighting Solution

The first lighting solution we recommend is one that is stationary and allows the SHG, who will be the pilot project participants, to extend its revenue-generating activities into the evening hours. Since rechargeable batteries have relatively little power availability (compared to the 12V car battery employed in the SHS), the efficiency of the lighting solution is of paramount concern. Light emitting diode (LED) lights are unparalleled in their ability to convert power to light with a typical LED providing roughly sixty lumens per watt. Competitively priced incandescent bulbs, on the other hand, average only fifteen lumens per watt. Since LED's can provide four times more light than incandescent and are available at nearly the same prices, we recommend that all lighting solutions employ LED lighting. An LED lamp with sufficient luminosity to work under will allow the SHG to work at night and will help prove the concept for in-house overhead lighting.

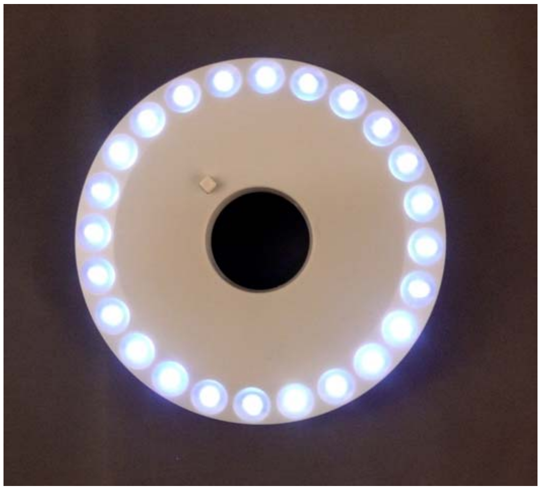
As with the battery charger, we purchased the LED product we recommend from an online distributor for USD$7.95 (*Figure 17*). We conducted informal testing in order to verify the manufacturer's claims and gain a better sense of activities that would be capable under such a light. The recommended lamp has twenty-four LEDs and employs four AA batteries. It produces light sufficient for writing and possibly even more detailed work from five feet away from the source. Thus, given the recommended lumens for these types of activities by the Illuminating Engineering Society of North America, an authority on lighting scenarios, we estimate the lumens produced by this product to be in the range of 700-1000.[57] The manufacturer claims the light can last for up to 30 hours with four fully charged AA batteries. However, our experience with the light revealed that the light's intensity declines significantly after about six hours of usage. This is due to the LED technology which is shown to lose intensity as the power source is drained of energy. Therefore, in the interest of being conservative, we believe the AA batteries will have to be recharged after six hours.

Table 3: Cost of the recommended light system.

Solar Battery Charger	$19.95	Rs. 798.00
AA Batteries (4)	$8.00	Rs. 320.00
24 LED lamp	$7.99	Rs. 319.60
TOTAL	$35.94	Rs. 1437.60

Overall, the initial costs of our lighting solution can be seen in Table 3. This recommended lighting system is available at a significantly lower cost than a SHS and is about the same cost as a solar lantern. However, given the adaptability of our solution to a wider variety of lighting products or other electronic devices we believe our recommendations to be sound. Additionally, this system will allow for one of the system components to break without having to replace the entire system, which is not a common feature of any of the solar lanterns we researched. Altogether, our recommended system will allow for high potential adaptability and productivity.

Figure 17: LED lamp with 24 LED's.



Elements that Present Challenges to Solar Photovoltaic Project Effectiveness

There are some issues with the selected technology that must be addressed in implementation. Centralized recharging stations can present problems when dealing with SPV technologies. In this model, villagers bring batteries to a station at different levels of discharge which can place strain upon the charger controller and can also have adverse effects on the lifetime of the batteries. Carrying the batteries to the centralized station poses a problem as well, and typically children take on that responsibility. These troubles were encountered in a centralized recharging project in Bangladesh.[58] The participants and evaluators of that project recommend careful consideration before proceeding with a project of this nature, and if one is to proceed with such a project, a well-implemented education program will be essential for its success.

Regardless of the project type, education is critical for successful application of SPV technologies in rural settings. The users must understand how to position the system, connect components properly, and maintain the battery cycle to insure that the system will last for an appropriate time. Instead of viewing this as an impediment to adoption, we suggest that the need for education presents an excellent opportunity to train local villagers in deploying and servicing SPV systems. By doing this, the program will promote its own sustainability at the same time that it creates local jobs for educators and technicians.

VIII. Microfinance Program Design

Successful program implementation involves considerations for financing the capital cost of purchasing energy systems, the return on investment that a financing partner can expect, and the financial gains from undertaking an energy micro-enterprise. The microfinance program, village financial evaluation model, and resulting financial recommendations for Bhudapada village described in this section are limited to the local program level. This ”bottom-up” analysis will allow for a more specific consideration of how credit programs for making solar lighting available have been designed, providing the insight necessary to make the best recommendation possible for Bhudapada, as well as other villages in the future.

Some of the assumptions adopted for this analysis are that a credit supply is available and that the interest rate charged for that credit covers the lending institution’s expenses, including its own cost of borrowing (where applicable) and all administrative expenses associated with servicing the credit. It is also assumed that the lending organization is financially viable and that there is no risk of failure which might cause it to prematurely recall loans.[59]

Program Design Process

Because not all rural villages are alike, microfinance programs will need to be customized for each village to ensure the greatest likelihood of loan repayment and program sustainability. There are three stages to this program design process. First, a village must be evaluated to understand its characteristics that are most relevant to microfinance structures. This will create a village profile that includes fundamental aspects such as population and demographics as well as more financially-oriented aspects such as the quantity and variability of its population's revenue flows.[60]

This information must then be considered against the various microfinance program features available to determine which combination best suits the village's characteristics, taking into account whether group or individual services should be offered. The combination of these features creates a best-case microfinance model for that village's program. If the microfinance model includes group (as opposed to individual) components, then a methodology for evaluating groups must also be decided upon.

Finally, this ideal "baseline" must be compared with what services are actually available to the village. For example, if a service that helps villagers manage their savings is recommended but is unavailable, an evaluation must be made as to whether it is possible to begin offering that service. If it is not possible for the feature to be provided at a reasonable cost and within a reasonable timeframe, a rationalization process must be followed to determine what alternative is available that most closely matches the baseline and the benefits that the former feature would have provided.

Village Evaluation

There are a number of criteria that can be used to evaluate villages. Not all of these criteria need to be used in each case, however, awareness of the issue addressed by each will provide practitioners the opportunity to consider for themselves what the best combination is for both the village being evaluated and their own needs, recognizing that the more information required from a village being evaluated carries a cost to the evaluator in terms of time collecting and processing the information. This decision also depends on how willing (and able) villages are to provide information, the risk being that steep information demands create a potential barrier to participation.

The following is a list of criteria that can be used to create a risk profile for a village. The information that these criteria provide can then be used to inform the design of a microfinance program for that village.[61]

Population

- **Village Population:** the number of people in the village can give insight into how likely villagers are to know each other well, with larger populations allowing a higher degree of anonymity.

- **Population Density:** how widely dispersed a population is can be used as a proxy for social cohesiveness, with more widely dispersed populations indicating a lower degree of cohesiveness.

- **Population Age Distribution:** age distribution can give insight into how transitory a population is, with a high concentration of working-age adults and few children and old-age adults suggesting a greater likelihood of transition. This criterion may also give insight into a village's income generating potential, with a higher proportion of working-age adults to children and old-age adults suggesting a greater potential for income generation. This is tenuous, however, as different cultures have different norms regarding suitable ages for labor. Less wealthy populations can also be expected to have a greater likelihood for employing children and old-age adults to earn income.

- **Population Caste Distribution:** caste distribution can be used as an indicator of social cohesiveness. It is not possible to specify, however, what distribution indicates higher cohesiveness, since an even frequency distribution across castes could be interpreted as being highly in-cohesive, while a bipolar distribution between two castes might be considered statistically more cohesive, although it may be the case that the village is socially divided between the two castes. Subjective observation and interviews should be used to provide a more nuanced understanding of this measure.

- **Population Religious Distribution:** similar to caste distribution, religious distribution can be used as an indicator of social cohesiveness. However, the difficulties of interpreting this metric are the same as for caste distribution.

Village

- **Village Longevity:** the number of years that a village has been in existence can give insight into how transitory its population is, with greater longevity indicating a lower degree of transition.

- **Number of Surnames in Village:** the number of surnames in a village can be used as an approximate indicator of how many families there are in the village and so as a proxy for social cohesiveness, with more surnames indicating a lower degree of cohesiveness. The larger the population, however, the weaker this proxy becomes.

Services

- **Travel Time Between Village and Nearest MFI Representative:** the time it takes to travel between the village and the nearest MFI representative is a proxy for how expensive monitoring the village and any clients therein will be (in regards to time, travel costs, etc.), with greater travel time indicating a greater monitoring expense, and consequently, a greater risk of default.

- **Number of Businesses per Capita:** a village's number of businesses per capita can be used as an indicator of how transitory its population is, with more businesses per capita suggesting a lower degree of transition. This can also be used as an indicator of the stability of a village's income. While some businesses that sell necessities with low demand elasticity (e.g., general stores) will almost always be present, higher numbers of businesses per capita might indicate a greater number of businesses selling non-essential goods and so greater stability in business (and village) revenue streams.

- **Nature and Availability of Other Savings and Financing Options:** a village's saving and financing options are a proxy for default risk, with more options implying a lower cost to borrowers of lost future financing opportunities in the event of default and therefore a higher risk of default.

- **Expected Time to Connection with Electric Grid[62]:** how long villagers expect to wait to be connected to the main electricity grid relative to the expected timeframe of a non-grid electrification project is a predictor of their willingness to completely honor those obligations, with longer wait time and shorter project duration predicting a lower risk of default. This measure is influenced by the perceived quality of the main electricity grid's service, with higher perceived quality increasing the risk of default in cases where a grid connection is expected soon.

The criteria that are most relevant for evaluating Bhudapada are population density, village longevity, and the number of businesses per capita. Social cohesion is important in regards to how trusting villagers feel towards each other and, consequently, the level of risk they perceive in regards to each other. This can affect villagers' willingness to share risk, potentially reducing the viability of the ROSCA and group lending microfinance models (discussed in more detail subsequently). Overall, Bhudapada's degree of social cohesion seemed quite low, though it is particularly exacerbated by a small number (2–3) of families from another tribe who are wealthier than other Bhudapadans and deliberately choose to live further away from the center of the village. Nonetheless, when surveyed, many villagers indicated a desire for portable lights that would allow them to move safely between houses. Although this will not affect population density, it indicates that social interactions between villagers can be expected to increase. In this manner, implementation of this project can be expected to improve social cohesion.

With regards to longevity, Bhudapada has only been in existence for approximately ten to fifteen years after being settled by travelers who came to the area to make and sell rice-beer (now stopped as a result of BISWA's intervention). As described previously, village longevity can be used as an indicator of how transitory the village's population is, with a shorter village lifespan suggesting a greater likelihood of mobility. This is important for two reasons: first, a greater likelihood of mobility increases the default risk associated with making loans, especially to a population with limited opportunities for "tracking" (via credit card use, cell phone use, social security numbers, etc.). Thus, shorter village longevity indicates a possible need for greater monitoring efforts. Second, for a given level of investment (whether time, capital, or otherwise) a transitory population decreases the likelihood of a microfinance or micro-enterprise program becoming sustainable due to the need to accommodate "turnover" and the expense associated with this. In the case of Bhudapada, although the village does have a relatively short lifespan, infrastructure investments have been made (e.g. water collection unit, SHG soap-making unit, etc.) that slightly mitigate this factor, though by no means entirely.

Finally, the number of businesses per capita in Bhudapada is low, with one small "convenience store" selling dried goods, candies, and basic body care products (shampoo, micro-sachets, etc.) and the soap-making micro-enterprise. This is another indicator of how transitory a population is, the logic being that a highly mobile population will make little investment in developing a business if the owners of that business intend on moving soon or if they do not feel that the business can operate without a stable customer base. This criterion is also an indicator of how stable a village's income stream is, the expectation being that beyond a small number of stores selling basic necessities, established businesses will be present only when there is a reasonably stable demand for their products and services, demand that can only be produced if the income for their client base (the village and, presumably, the surrounding area) is similarly stable. Since income stability is important when evaluating a potential borrower's default risk, the number of businesses per capita can give some additional insight into the degree to which this stability is present. As already mentioned, Bhudapada has only two businesses, one of which is of the "convenience store" variety. Given that most of the villagers' income comes from day-labor (which is inconsistently available), Bhudapada village appears extremely risky for a venture such as this.

Possible Microfinance Program Features

There is also a variety of features that can be incorporated into a microfinance program. While the ultimate objective of a microfinance program is to deliver a product or service with as little default as possible, the manner in which this is achieved is through an array of balanced incentives (i.e. rewards and penalties) for the client and a timely and accurate flow of information to the MFI about its clients and their circumstances. Overall, this flow of information is most important to successful microfinance initiatives, however, it is also very difficult to achieve As such, the majority of features included as part of microfinance programs are implemented with this objective in mind.

Individual features are described subsequently and the models into which these features have been successfully combined are described in the following section.[63]

- **Product(s) and Service(s) Offered:** depending on the needs and characteristics of the MFI's target clientele, not all microfinance products and services will be suitable.

- **Individual versus Group Services:** in typical microfinance situations where potential clients have little to no collateral, formal credit history, or access to formal financial institutions, servicing individuals is unprofitable due to the high proportion of fixed service costs (particularly due diligence of a client's willingness and ability to honor their financial obligations) relative to profits earned from that individual's account. Nonetheless, some mature MFIs with long-standing clients who have developed a history with the organization have offered services to individuals.

- **Public vs. Private Meetings & Payments:** There are six benefits that are associated with public repayments that help strengthen the contract between the MFI and its clients[64]:
    1. Increased threat of social stigma surrounding late payments
    2. Lower transaction costs for the MFI by reducing time spent transitioning between meetings.
    3. Opportunity for the MFI to collect information about clients from other clients through cross-reporting.
    4. Facilitation of education and training of clients due to all clients being assembled together.
    5. Greater client comfort level dealing with the MFI due to support of neighbors.
    6. Reduced opportunity for fraud by the MFI employees due to greater transparency of actions with clients.

- **Meeting and Payment Location:** requiring clients to travel to the MFI increases the cost of its services to them directly through travel costs (e.g. bus fare, meals away from home) and indirectly via the opportunity cost of foregone wages. Holding meetings at a client's location also provides an opportunity for the MFI to monitor the client and their situation more directly and look for signs that may foreshadow their inability to meet their obligations.[65]

- **Meeting Frequency:** in conjunction with the location of meetings between the MFI and its clients, the frequency of meetings also has the potential to increase the effective cost of services via the opportunity cost of foregone wages. Each meeting, however, is also an opportunity for the MFI to collect information about its clients and monitor their situation.

- **Payment Frequency:** microfinance clients often have limited formal savings opportunities available to them (e.g., bank accounts, etc.) and so bear a higher risk of theft or pilfering, making more frequent repayments more desirable in spite of the added transactional cost this creates. Increased frequency also provides an opportunity for the MFI to monitor the client, reducing its exposure to both ex ante and ex post[66] moral risks.

- **Payment Method:** while financial loans will be paid in cash, services (e.g., electric lighting) can be charged on a "fee-for-service" basis or through pre-paid token systems.[67]

- **Order of Access to Funds within Groups:** if group structures are being used, the order in which group members have access to funds is an important design decision with options including sequentially, in pairs, or in random order.

- **Changes to Order of Access to Funds within Groups:** assuming multiple rounds of interaction between the MFI and the group, changing the order of access to funds may help correct perceived injustices by members who had late access to funds in an earlier round of borrowing, helping maintain a sense of equality and fairness amongst members.

- **Progressive Services:** increasing the variety of products and services available to clients who remain in good standing and/or increasing the degree to which those goods and services are available (e.g., larger loan amounts, longer payback periods, etc.) can help motivate clients to adopt a more long-term perspective on their relationship with the MFI and, consequently, their actions in that regard.

- **Subsidies:** long-term subsidies applied to offset client operating expenses are not sustainable, however, they can be used in the short-term to offset a client’s start-up costs and establish long-term, sustainable opportunities.

- **Financial Service Provider Exclusivity:** in the case of loans, maintaining relationships with multiple credit vendors and, possibly, multiple groups can reduce the effectiveness of micro-finance initiatives and the incentive structure they aim to create by removing the cost of exclusion from the MFI and the benefits it provides over other non-MFI alternatives (e.g., banks, local money-lenders, etc.).

- **Default penalties:** penalties need to be significant enough to motivate clients to meet their commitments, yet, also flexible enough to accommodate adverse circumstances that are significantly outside of a client's control.

Group Evaluation Criteria

Because microfinance often takes advantage of group dynamics to redistribute a project's risk away from lenders and on to the borrowers themselves, most microfinance programs will need to create a risk profile for groups seeking to participate. The following is a list of criteria that can be used in developing this profile:[68]

- **Group Size:** the number of people in a group is a proxy for the stability of the group's aggregate revenue stream, and thus, its ability to accommodate unexpected negative "shocks" to individual member's revenue and still meet its financial obligations over time. As such, for a given level of obligation, the larger the number of members within a group generally indicates a greater degree of revenue stability and therefore lower default risk. In extremely large groups, however, the likelihood of "free-riders" increases, which works to increase the group's default risk.

- **Group Longevity:** group longevity is a proxy for its social capital. This is a predictor of its members' willingness to support each other in times of duress which, in turn, is a proxy for a group's default risk, with shorter group lifespan indicating lower social capital and higher default risk.

- **Group Gender Distribution:** a group's gender distribution is a predictor of the positive social impact their success will have, with a higher proportion of women predicting a greater degree of positive impact. It is also a proxy for default risk, with a lower proportion of women likely to result in a higher default risk.

- **Group Caste Distribution:** caste distribution is an indicator of a group's cultural homogeneity. Caste distribution is a proxy for its social capital, a predictor of its members' willingness to support each other in times of duress. Caste distribution is, in turn, is a proxy for a group's default risk, with greater caste distribution suggesting higher default risk.

- **Group Religious Distribution:** religious distribution is an indicator of a group's cultural homogeneity. Religious distribution is a proxy for its social capital which is a predictor of its members' willingness to support each other in times of duress. Religious distribution is, in turn, is a proxy for a group's default risk, with greater religious distribution suggesting higher default risk.

- **Group Cultural Homogeneity:** cultural homogeneity is a proxy for a group's social capital. Group Cultural Homogeneity is a predictor of its members' willingness to support each other in times of duress which, in turn, is a proxy for a group's default risk, with greater homogeneity suggesting lower default risk. Examples of cultural homogeneity other than caste or religion include tribal affiliation, dialect, style of dress, or even hair style. There is a risk, however, that highly homogenous groups may collude against the MFI, indicating that extremely high levels of cultural homogeneity actually increase default risk.

- **Group Revenue Stream Diversity:** a group's revenue stream diversity is a proxy for the covariance of its members' incomes and, consequently, for how likely the group will be able to avoid defaulting in the event of circumstances that impede one or more members from earning as much as expected (e.g., crop failure would devastate a group consisting entirely of farmers), with greater diversity indicating a lower covariance and consequently a lower risk of default.

- **Group Income History:** a group's income history can give insight into trends in its ability to pay and the maximum levels of financial obligation it can support.

- **Demonstrated Ability to Save:** demonstrated savings ability indicates a group's ability to self-organize and to manage its finances. As such, it is an indicator of its members' commitment, long-term perspective, and default risk. Greater savings per capita over longer periods of time suggest greater commitment and lower default risk.

- **Group Collateral Available:** an indicator of overall risk, with higher amounts of collateral indicating lower risk to the lender in the event of default.

- **Geographic Proximity of Group Members:** distance between group members' residences is a proxy for their ability to monitor each other, with longer distances suggesting a lower ability to effectively monitor one another, and as a result, a higher degree of ex ante lending risk. [69]

The group evaluation criteria that are most relevant to Bhudapada are a demonstrated ability to save, group revenue stream diversity, and geographic proximity of group members. When surveyed, all Bhudapadans indicated that their current income is below what is necessary for "basic necessities" to be covered. If a demonstrated ability to save is weighted too heavily, however, a significant proportion of villagers might be made ineligible, even though these are the ones who probably need the greatest amount of assistance. This metric is also important because of the potential seasonality of incremental revenues created by solar lighting due to limited battery recharging ability during monsoon season (July through September). During the monsoon season, group members will need to draw on incremental revenue savings generated during non-monsoon months to maintain their repayment commitments. It is reasonable to expect that their saving ability will not decline after the project begins and thus they will be able to maintain these payments.

Seasonality of incremental revenues and the need to maintain payments is also why the diversity of Bhudapadan groups' revenue streams is important. There are a limited number of income-earning opportunities in Bhudapada. Group members will need to be from as diverse an income-earning background as possible to maximize the benefits that diversification provides and to minimize the group's default risk.

Finally, geographic proximity of group members is another important consideration for Bhudapadan groups because of the village's already low population density and lack of a true "village center." As such, self-monitoring—a key aspect to microfinance success—will already be difficult for Bhudapadans, making it especially important that group members' residences are as closely grouped as possible.

Basic Microfinance Models

Microfinance services and the models used to deliver them are not universally applicable and will achieve best results only when tailored to the characteristics of the specific situation for which they are being applied. Nonetheless, some characteristics are generally common to developing nation populations, resulting in a handful of models that can be considered fundamental to microfinance overall. These models and an understanding of their advantages, disadvantages, and why they are effective can be used as a basis for the analysis and design of the tailored models that will ultimately be implemented in specific cases such as Bhudapada village.

Savings

One definition of the verb "to save" is "to set aside, reserve, or lay by."[70] Another definition is "to keep safe, intact, or unhurt; safeguard; preserve."[71] In the case of the rural poor, both of these apply in describing their needs and the challenges they face in meeting them.[72] These challenges are many and include a lack of access to formal savings services (e.g., banks) due to the long distances between them and banking locations and/or the banks' reluctance to accept small deposits which are deemed too expensive to administer given the deposits' size. This lack of access to formal savings services introduces another challenge, that of "safety": homes without locks on doors and windows without glass do not provide a safe haven for cash or other concentrated (and so easily stolen) stocks of wealth. Nonetheless, if opportunities to save are available, there are a number of advantages and disadvantages to this form of wealth creation.

One advantage is that funds saved are owned by the household and so do not have any "liens" against them that limit what the household can apply them to. Assuming complete freedom of deposit and withdrawal, savings products also enable households to smooth their consumption profile over time.[73] Finally, outright ownership of savings also means that any returns from their use belong to the household.

A key disadvantage to saving, particularly for those essentially living at a subsistence level, is the length of time it takes to accumulate sufficient funds for an investment that will increase the household's productivity (e.g., lighting that allows work to be done at night), and consequently, its long-term income potential. This delay introduces the potential for opportunity costs that outweigh the expected value of a family's future investment opportunities (for example medical expenses that cannot go untreated barring serious detriment to the afflicted individual), causing the family to spend their savings and prolong the time until they are able to save enough to make the productivity-enhancing investment. Somewhat related, another key disadvantage to savings is that they are restricted to the family's ability to generate income. Without the opportunity to borrow money and leverage these borrowings to invest in positive net present value (NPV) projects, the family is trapped by its own limited productivity.

Rotating Savings and Credit Associations[74]

Rotating Savings and Credit Associations (ROSCAs) are one of the most fundamental microfinance models of microfinance structures. Although there are different "flavors" of ROSCAs, the basic structure involves a group of people who agree to each contribute an amount of money per period to a common "pot" for the same number of periods as there are group members. Each period's "pot" is made available to one group member to use as they wish, often for a major purchase (e.g., a sewing machine) or a large payment (e.g., school tuition fees). The result is that at the end of the last period, each member will have had access to the pot with no further obligation to any of the members or an external body.

There are three competing theories for why ROSCAs are effective. The "commitment to savings motive" theory is based on the argument that social pressure (through commitment to other members) motivates members to save more effectively than if they were to do so independently, out of fear of social reprisals by their peers, including possible exclusion from the ROSCA in future periods. The "early pot motive" theory argues that the opportunity for all participants (except the last) to gain access to the pot sooner than if they had simply saved themselves motivates participation. Lastly, the "household conflict motive" theory argues that ROSCAs are effective because they keep “saved” money outside of the household away from other family members (typically husbands) who might otherwise spend it, thus helping the saving process.

There are three main advantages to the ROSCA model. The first is the simplicity of the structure that allows it to be organized and managed relatively easily by participants. Because ROSCA members are typically well-known to each other, a second advantage is that monitoring of participants is easier and information about risk within the group is timely and well-known. A third advantage is that ROSCAs do not require physical storage of funds as the pot is collected and then immediately distributed, reducing the risk of theft or “erosion” due to numerous minor withdrawals for daily “needs.”

One limit identified with ROSCAs is that both the size of the pot and the size of contributions is fixed within the life of the ROSCA. Although not necessarily a disadvantage, this lack of flexibility nonetheless reduces the attractiveness of the ROSCA model. A genuine disadvantage of ROSCAs is that they rely entirely on the resources available to their members. As such, ROSCAs limit the size of the capital pool available to their members and, consequently, the amount of financial leverage (and subsequent returns) possible. ROSCAs are therefore more of a means of saving rather than borrowing.

Accumulated Savings and Credit Association[75]

Also referred to as “credit cooperatives” or “credit unions,” accumulated savings and credit associations (ASCAs) also rely on locally available resources. All members are shareholders and participate in decisions about how the ASCA should be managed, including setting interest rates, maximum loan sizes, etc.

Like ROSCAs, ASCAs are usually populated by members who are well-known to one another. This makes ASCAs effective in part due to the high quality and low cost of information amongst group members about one another’s risks. Loan requests from high-risk borrowers can be evaluated and awarded on the basis of that risk, minimizing the ASCA’s default costs. Borrowers who default also risk losing their assets held by the ASCA, social costs from their peers, as well as the ability to be a member of the ASCA in the future and the benefits this provides. Finally, some ASCAs also act as buying agents, coordinating the purchase of goods in bulk to lower average costs to their members.

One advantage of the ASCA model is that savers are not required to borrow funds and can simply use the ASCA as a deposit account for their own funds. This enables participation of any individual who wishes to save money. For participants who do wish to borrow money, they do not have to wait to do so, and the size of the amount they borrow can be adjusted to meet their own needs, independent of the needs of others.

A key disadvantage of ASCAs is the need to store funds, introducing the need for security and the related costs. It is also important to note that with multiple accounts and loans, ASCAs require relatively complex management systems, as well as individuals with the skills to operate these systems. Such skills may be in short supply in less educated populations and may also introduce further costs to the ASCA model.

Lending

There are two broad categories of lending within microfinance: individual lending where the MFI maintains a one to one relationship with the borrower and group lending whereby the MFI lends to a group of individuals, often with loan terms including specifications for how the loan is to be disbursed amongst the group members. Because some MFIs do have individual lending services and have met with varied success, this will be discussed below, however, this is usually applied to wealthier borrowers with greater borrowing experience. Group lending has a greater variety of models and has found more success serving less wealthy populations similar to Bhudapada and so will be covered in more detail.

As discussed already, with lending also comes risk. In general, risk associated with lending is *default risk*—the risk that the borrower does not or cannot honor their financial obligations. Underlying this, however, are two other types of risk that relate to different phases of the lending cycle: *ex ante moral risk* and *ex post moral risk*. Ex ante moral risk is the risk that the borrower does not take the actions promised, or to the level of effort necessary, to achieve the expected returns from the investment made with the borrowed funds, thereby making it difficult or impossible to repay the loan on schedule. Ex post moral risk is the risk that the borrower, after having realized a return sufficient to honor their financial obligations, either claims not to have made this return and that he/she is unable to repay the creditor, or simply makes himself/herself unavailable to the creditor so that monies cannot be collected (i.e., “take the money and run”).

Individual Lending

Advantages to individual lending accrue to the borrower, providing maximum flexibility in regards to the size and timing of the loan. However, there are no significant advantages to lenders when clients are borrowing small amounts and have little to no collateral or credit history aside from the possible distinction of having a larger client base.

The most significant disadvantage to lending to individuals with little to no collateral or credit history is the difficulty associated with collecting information about the potential client to assess the risk they pose to the MFI as well as the cost of collecting this information. For clients borrowing small amounts of money, these costs could easily outweigh any interest the lender earns on the loan.[76] As such, individual lending to the poor is not a viable strategy for most MFIs.

Group Lending

Group lending is the practice of lending money to groups of individuals as a means of overcoming barriers to their borrowing money individually (i.e.., a lack of collateral). Group lending is one of the most, if not the most, pervasive model used by microfinance programs, a perception fueled by Mohammed Yunnus' (founder of Grameen Bank) being awarded the Nobel Peace Prize in 2006 for Grameen Bank's work based on group lending. Although there is little question of how broadly group lending has been used, it is not clear whether it is financially self-sustaining, a major point of criticism leveled by those who question the accolades given to Yunnus and other microfinance proponents.[77]

It is also important to remember that group lending by itself is no panacea.[78] As noted in the list of microfinance program design features, serving clients individually or in groups is but one feature available to microfinance designers. It is, however, one of the more significant options available. The following sections describe two group lending models that have been broadly applied.

Group Lending – Joint Liability Group ("Grameen model")

As previously noted, Muhammad Yunnus founded Grameen Bank and was recently awarded the Nobel Peace Prize. This joint liability group model (colloquially referred to as "the Grameen model") is the second-most common credit delivery model employed in India and is typically structured as a group of four to five borrowers who jointly guarantee the repayment of loans to each individual borrower.[79] The availability of funds is staggered, with money initially made available to two members. If these loans (and interest) are repaid successfully, the next two members are allowed to borrow. If any borrower defaults, subsequent members are denied access to loans.

One key advantage to this model is that banks are able to lower interest rates on loans to groups. These lower interest rates are available because groups are formed by the members themselves (rather than organized by the lender). Group members have better knowledge of who in their pool of potential members they have to choose from is more reliable and who is riskier. Because it is in the borrowers' self interest to partner with the least risky members possible (so they are not responsible for supporting delinquent partners and/or so they do not lose loan privileges because of other members' risk), only relatively low risk groups will form and apply for a loan. Thus, the group structure solves the lender's problem of not having information about the borrowers.

A second advantage is that group members will self-monitor to ensure that current borrowers' actions and efforts are conducive to their being able to repay their loan. In this way, group lending eliminates the need for the lender to monitor the borrowers' actions and neutralizes ex ante moral hazard.

The Grameen lending model also neutralizes ex post moral hazard. The "joint liability" of the agreement creates social pressure between group members that will encourage borrowers to repay their loan obligations, again without the lender needing to be involved.

Finally, the Grameen lending model enables members to develop a form of credit history, both amongst themselves and, more importantly, with the lender. This can be leveraged to enable borrowing of even greater amounts of money in the future, an incentive that is often used to further motivate loan repayment.

A disadvantage of the Grameen model is that some borrowers must wait for access to funds. Depending on the nature of what they intend on using the funds for, this may create opportunity costs that might decrease the value of the loan for them. For example, if a loan is to be used to purchase seed for planting at the beginning of the harvest season, a delay of even a few weeks will essentially make the loan useless to the "second round" borrowers. Another of the Grameen model's disadvantage is that it is administratively "heavy" for the groups, requiring multiple meetings each week between the group members, the village "center," and the MFI representative.

Group lending - "village bank" (FINCA)[80]

The "village bank" model was developed in Bolivia in 1984 by the Foundation for International Community Assistance (FINCA). FINCA operates as a member-run private bank, typically serving between ten and fifty people, usually women. Banks are financed by member savings as well as seed loans provided by a supporting MFI, the size of which is determined by the bank members' collective loan requests. Members collectively guarantee the banks loan and take responsibility for managing the bank, monitoring loans, and enforcing penalties for noncompliance, meeting weekly or bi-weekly to do so. Loans from the MFI are cyclical and, on the basis of growth in the members' own savings, are progressively larger each round. Although no interest is paid on member savings, they do receive a share of the bank's profits from re-lending or investments, proportional to the amount contributed by the member to the bank's sum total.

Many of the advantages of the Grameen "joint liability group" are also shared by the village bank model, including the ability to leverage external capital to make greater investments, increased ability to save and the enhanced status of women. Because the village bank model does not employ smaller "peer groups" like the Grameen model, it is possible for individuals to borrow money independently (though still under the broader supervision of the village banks managing body). This alleviates one of the Grameen model's key disadvantages, funds being distributed sequentially amongst peer group members, forcing some members to wait until other peer group members have repaid their loans before gaining access to the loans themselves. Because village banks are managed by their own members, another advantage they have is that they are relatively autonomous and thus do not require significant amounts of input from the supporting MFI, keeping the administrative cost low.

A disadvantage of the village bank model is that to date it remains unproven with only three FINCA country programs employing the village bank model having achieved financial self-reliance: Ecuador, Uganda, and Kyrgyzstan.[81] Other attempts to employ the village bank model still rely to varying degrees on donations to supplement funds borrowed from commercial lending sources and profits from interest created by the programs themselves. However, these issues are not unique to the village bank model. The Grameen and similar models are similarly criticized for relying on external contributions to remain solvent.[82]

IX. Village Financial Evaluation Model

In order to make a business model recommendation for Bhudapada village, in addition to understanding the village's characteristics and designing an appropriate microfinance model tailored to such characteristics, it is imperative to understand both the village's current financial profile as a "base case" situation, as well as to forecast what the net impact that the "alternative case" of introducing a technology to the village will have. This will identify the village's financial constraints and, consequently, what technologies the villagers can afford.

A financial valuation model was constructed to perform this evaluation both for this project and as a tool for future projects. This section describes the model's design and the reasoning behind this design, as well as conclusions drawn from a sensitivity analysis conducted on the model. Sections of the model will be referenced directly within this paper, with a complete version of the model available separately.

Design

The model was originally designed to calculate the NPV of the solar lighting project using a structure that determines the cash-flows from an "alternative case" (in this case, an average Bhudapadan household with a solar lighting system) and subtracts from it the "base case" cash-flows (an average Bhudapadan household using the incumbent lighting technology of kerosene-fueled diwas and lanterns). The difficulty with the NPV approach in this case is that it requires a discount rate for the villagers. There is, however, a paucity of literature describing best practices for determining a discount rate for people living on the fringes of subsistence as the majority of Bhudapada residents do and, in general cannot be considered a realistic exercise given their minimal opportunities to save and consequent lack overall of revealed preferences on which such a rate could be based.

Because of these challenges, on the advice of one of this project's advisors,[83] the decision was made to diminish the importance of the discount rate (using the inflation rate only for the purpose of adjusting cash-flows to compensate for the inflation rates used) and to consider instead the net balance of a household's debt, a desirable trend being a gradual decrease in their level of debt over time, eventually arriving at a zero balance and from that point on, higher cash-flows than they would have under the base case. Although simplistic, this approach reflects the reality that households in Bhudapada are faced with.

The base for the model is the village's current situation of almost exclusively using kerosene-fueled diwas and hurricane lanterns for light and purchasing kerosene each month from government and market sources. This base case also includes its non-financial effects, including emissions from burning the kerosene and the effects these have on the villagers' health and, more broadly, the world's atmosphere (with regards to greenhouse gas emissions).

The alternative case considered is one in which the villagers purchase the recommended "stationary light" lighting technology consisting of a battery charger, four AA batteries, and a light source. The model considers how the in-house lighting can enhance productivity and thereby create the potential for additional household revenues, as well as increased cash flow from a reduction in money that was previously applied to kerosene purchases.

The timeframe adopted for the model is five years (sixty months). This was selected because it is long enough to provide insight into long term trends, while still being a timeframe that can reasonably be expected to apply to Bhudapada and other similar villages.

Finally, the model's analysis occurs at the household level because this is the level of consumption of lighting and other electrification related services. It was also assumed that households can borrow money individually. Although this is a significant simplification, as already described earlier in this report, there is a wide variety of options for how microfinance programs and their respective products are designed. Analysis on the basis of individual borrowing is a relatively "pure" and easily understood starting point for determining whether an average village household can afford a certain technology before complicating the valuation with the introduction of micro-financing administrative costs. As such, the next step for developing the model further is incorporating the ability to capture the effects that these different costs will have on the valuation and a household's ability to afford different technologies.

Assumptions

The following assumptions were made in developing the model:

- Borrowers are able to borrow the full cost of the lighting system
- Lighting units will be paid for in a single payment and will be available immediately after payment is made, i.e., there is no time delay due to installation or supply constraints
- Payment periods are monthly
- Payments are straight-line (not declining balance)
- Units will provide sufficient light[84] to allow handwork[85] to be done after dark by more than one person at a time
- Current kerosene-powered light sources (diwas and lanterns) do not provide sufficient light to allow handwork to be done after dark[86]
- Light is desired during all waking, non-daylight hours
- All households that purchase a lighting unit will do handcraft work to generate additional revenue and these handcrafts can be sold at current market prices or better[87]
- Revenues from handworks will increase at the general consumer inflation rate
- The price of kerosene increases in fixed "shocks" steps of 10% one time yearly and that these increases apply equally to both the government-subsidized "ratio card" price and black-market prices[88]

- Villagers are unable to repair the lighting units themselves, i.e., a trained service person is needed to repair the units
- Service people are employed in non-discrete units (i.e., when not working as a unit service person, the person will find other work so that the individual will not be restricted to full-time employment as service person)
- The project is replicable in the future with technology that is priced no higher than the present (prices for a given technology decrease over time) and with kerosene priced no lower than the present (price of kerosene will increase over time)
- Villagers do not have access to formal savings institutions or services, i.e., any additional cash-flows that villagers accrue and do not spend will not earn interest
- Eighty percent of kerosene is used for light and all kerosene purchased in a month is used in that month
- Recharged batteries retain 100% of charge over time, i.e., there is no "leakage" of charge if a battery is not used for a long period of time

Sensitivity Analysis

A sensitivity analysis of the financial model was conducted to better understand the robustness that could be expected of its results and recommendations coming from these. Four variables were hypothesized as being key drivers in the model and therefore to the project itself. These variables are:

System Purchase Cost

The purchase cost of the lighting system was selected because capital cost was identified by the project sponsor as the most important factor for this project,[89] and because it is expected to be the most significant factor in determining both what technology is recommended as well as the business/ownership model for any micro-enterprise based on that technology. The baseline value adopted for this parameter is Rs. 1,384 (USD$35.94), the cost for the recommended stationary light system.

Annual Cost of Debt

The rate of interest charged by BISWA on loans is important because it relates directly to the SHG's cost of borrowing (and consequently the price they can afford to pay for a given technology investment), as well as to whether or not a project is financially sustainable for BISWA and so the likelihood of the project's long-term survival. The baseline value for this parameter is 20%, the rate of interest BISWA currently charges its SHGs.

Price of Kerosene - Government

The price of government subsidized kerosene is the most significant expense in the model's base case and thus plays a large role in the overall valuation and the resulting decisions. The importance of this factor is enhanced due to the expected rise in accordance with the price of petroleum products in the future. The baseline value for the price of kerosene is Rs. 10 (USD$0.26) per liter of government ration card kerosene.

Handcraft Revenue Rate per Unit (bidi leaves, cots, leaf plates & cups, bamboo mats)

The additional productivity (and resulting revenue) allowed by the increased quality and quantity of light generated by the recommended technology in the alternative case is another key driver for the model product. This revenue is quantified as the average hourly rate received for each unit of bidi leaf rolling, cots, leaf plates and cups, and bamboo mats (the four most common handcraft activities identified in Bhudapada). The baseline value for this rate is Rs. 2.76 (USD$0.07) per hour.

Table 4 shows a summary of the model's outputs under these baseline values and with all other variables held constant.

Table 4: Summary of "stationary light" baseline results.

Light

Net additional light (hours)	733
Average additional hours of light per day	0 .4
Average additional hours of light per day (% change)	10%
Net additional light (lumen-hours)	5,901,928
Average additional lumen-hours per day (% change)	1569%

Pollutants (CO2, NOx, Particulates)

Net CO2 avoided per household (metric tons)	0.545
Percent decrease - CO2	100%
Net NOx avoided per household (metric tons)	0.001
Percent decrease - Nox	100%
Net particulates avoided per household (metric tons)	0.028
Percent decrease - particulates	100%

Finance

	Rs.	USD
Net Present Value of Incremental Cashflows	8,675.00	225.31
Average Monthly Net Cashflows - Alternative Case	110.12	2.90
Average Monthly Net Cashflows - Base Case	-65.88	-1.62
Average Monthly Net Cashflows during Loan Repayment	31.47	0.82

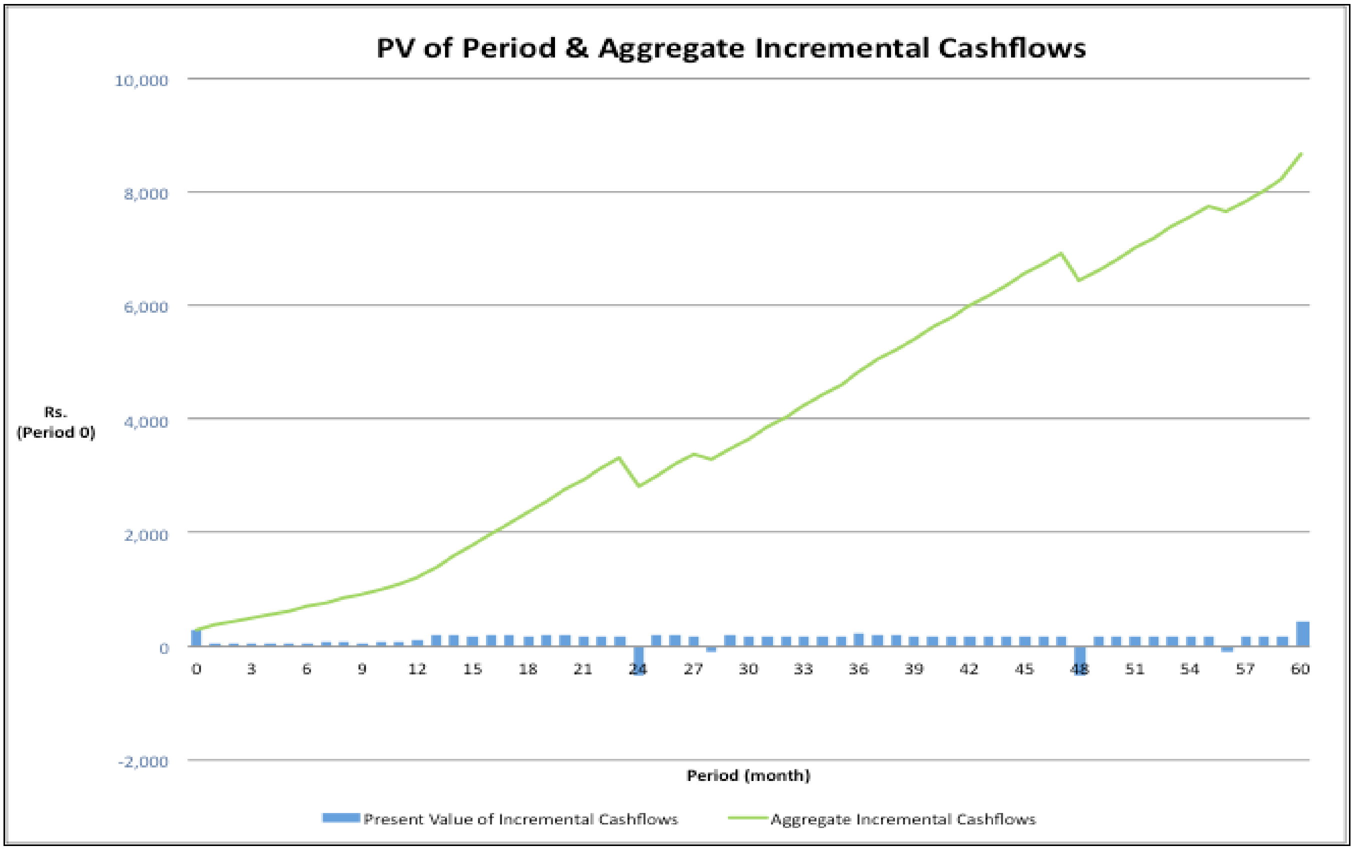
In this scenario, the average increase in hours of light per day (duration) is less than half of one hour, an increase of roughly 10%. This is considerably less than what was expected given the anecdotal information collected during interviews with villagers that indicated that current daily durations of light are far shorter than what is desired. The current durations used in the model are calculated based on kerosene burn rates for diwas and hurricane lanterns. Without further research specifically measuring the burn rates of lanterns and diwas in Bhudapada, it is impossible to say how closely these burn rates relate to the cited rates. Given the significant difference between the anecdotal and calculated, if the calculated values are, in fact, too conservative, it can be safely expected that the benefits of adopting this lighting technology will be even greater than predicted by the model.

A more significant result predicted by the model is the roughly fifteen-fold increase in the quantity of light measured in lumen-hours. This is a measure of the brightness of light available and is the factor responsible for users of this technology's ability to do handcraft work and earn additional revenues when previously they were unable to. As such, although duration of light is important to consider, as demonstrated here a much better measure also considers the quantity of light available during that time.[90]

Pollutants in this scenario are also shown to decrease 100%. This is because there is no need for kerosene to be used for light due to this particular technology's ability to recharge (on average) its energy stores faster than they are depleted. Therefore, no emissions are created. For other technologies that are not able to recharge faster than their depletion rate, kerosene will need to be used for light, resulting in pollutant emissions. Overall it is expected that this will not be significant.

Finally, under the baseline scenario, adopters of the stationary light technology can expect to have average monthly net cash-flows of Rs. 110.12 (USD$2.90), a considerable improvement over the negative cash-flows experienced under the current base case. As shown in Figure 18, incremental present value cash-flows from the stationary light scenario will total Rs. 8,657 (US $225.31) over five years for an individual household.

Figure 18: Present value of period and aggregate incremental cash-flows.



Methodology 1 – Independent Adjustment of Variables

Having established a set of baseline results for comparison, two approaches were used to conduct a sensitivity analysis of the model. The use is based on the financial impact the adoption will have on residents, on the assumption that this will be the determining factor for whether or not the project is ultimately sustained over the long-term. Each variable was changed independent of others by a fixed amount, the goal being to identify what value resulted in an average monthly cash-flow of Rs. 0 during the loan repayment period, investors in this technology will at worst be "revenue neutral" until the loan is completely repaid.

Adjusting each variable independently, *Table 5* shows the threshold value for each in order to attain an average monthly cash-flow of Rs. 0 during the loan repayment period.

Of the four variables selected for the sensitivity analysis, the revenue rate for handcrafts and the system purchase cost are the two most significant limiting factors, with threshold values representing changes of 19.6% and 24.8% respectively.

Table 5: Loan repayment period "breakeven" levels for sensitivity analysis variables.

Variable	Original Value	Threshold Value	Percent Change
System Purchase Cost	Rs. 1,384 ($35.94)	Rs. 1,727 ($44.86)	24.8%
Annual Cost of Debt	20.0%	95.20%	476.0%
Price of Kerosene (Government)	Rs. 10	N/A: under the "Stationary Light" technology scenario, there is no kerosene used for lighting and so villagers are unaffected by the change in kerosene prices	n/a
Handcraft Revenue Rate	Rs. 2.76 ($0.07) per hour	Rs. 2.22 ($0.058) per hour	-19.6%

The insulating effect from kerosene shocks identified by the model is notable. Although one variable applied in the model is that 80% of kerosene fuel is used for lighting (an estimate based on the villagers' descriptions of also using kerosene to occasionally dry wood) meaning that there is still potential for Bhudapadans to be exposed to such shocks, for the purposes of lighting (and consequently for the benefits it provides) the model shows that in the stationary light scenario, these are successfully de-coupled, a significant result given the recent rise in petrochemical costs.

Of significance to BISWA is that the model suggests there is considerable latitude for them to adjust (i.e., increase) interest rates without significantly affecting the overall opportunity for villagers to adopt the technology. For any initiative to be sustainable, especially with regards to the larger numbers of villages this could be scaled out to, BISWA will need to cover its costs. The model's relatively low sensitivity to cost of capital bodes well for the initiative's sustainability as far as BISWA is concerned.

Methodology 2 – Simultaneous Adjustment of Variables

Recognizing that changes in single inputs are not a realistic reflection of what is likely to happen, an alternative methodology was used to conduct a second sensitivity analysis, modifying the four chosen factors by 5% increments until the average monthly net cash-flows during the loan repayment period reached zero or negative. The results of this approach are documented in Table 6, which shows that all factors can change simultaneously by up to 10% while still maintaining a positive average cash-flow over the loan payback period. Although this value may initially seem low, it is worth noting that it can be reasonably assumed that the price of the stationary light scenario's technology can actually be expected to decrease over time. Furthermore, handcrafts are sold into perfectly competitive markets using widely available materials and so the average handcraft revenue rate can also be assumed to be relatively stable. As such, the stationary light scenario is actually more stable than the results of this second sensitivity analysis might indicate.

Table 6: Results of simultaneous adjustments of key variables.

Percent Change	Cost of debt (annual)	Average handicraft revenue rate	Price of kerosene (Government)	Purchase cost of system	Average monthly net cash-flows during loan repayment
Percentage	*Percentage*	*(Rs. / hour)*	*(Rs. / litre)*	*(Rs.)*	*(Rs.)*
0%	20%	2.76	10.00	1,384	31.47
5%	21%	2.63	10.50	1,453	16.55
10%	22%	2.49	11.00	1,522	1.58
15%	23%	2.35	11.50	1,591	-13.43

Analysis Conducted on Other Variables

Because many villagers stated that they would be willing to work more hours each day if they were able to (due to increased availability of light), it was estimated that the 1.5 additional working hours per adult per day used in the model (with 25 working days per month and an average of 1.5 adults per household available to work) would be a reasonable period of time and so not a potential threat to the success of a villager's adoption of the technology. Nonetheless, a break even analysis was conducted (following Methodology 1) and it was determined that under the stationary light scenario and with all other variables at their baseline level, the minimum time required for additional work was 1.21 hours (approximately one hour and twelve minutes) per day. Although the aforementioned figure represents a difference of almost 20%, this result nonetheless emphasizes the importance that the additional revenues from handcrafts have in enabling villagers to adopt the technology.

Perhaps even more significant, when the average number of adults available per household was adjusted downwards from 1.5 to 1, the average monthly net cash-flows during loan repayment became negative, at Rs. -22.05 (-USD$0.57) per month. Therefore based on this measure, single-adult households could not afford the technology by themselves unless they were willing to work even longer hours. This is not thought to be a significant concern for Bhudapada, however, as the average number of adults per household is actually 2.76.[91] With this number of working adults, each would need to work 0.66 additional hours (approximately forty minutes) per day to afford the system.

Requirements for Financial Recommendation

For this project's recommendations to be valuable to the villagers in Bhudapada as well as BISWA, they must be sustainable over the long-term. Sustainability encompasses a number of areas, however, because finances are the most significant limiting factor in this project, requirements for financial sustainability must be met if the project is to succeed.

Three such requirements have been identified. The first is that households are able to cover the costs arising from adopting the new lighting technology, i.e., it is providing a net financial benefit to them. The second requirement is that BISWA's costs (including opportunity costs) of capital and of administering the project are covered by the cash-flows it generates. Finally, on the assumption that BISWA will want to continue operating the project on a long-term basis, it must also be compatible with BISWA's long-term business strategy.

Villager Costs Covered

Although most project valuation focuses on whether or not the project delivers a positive NPV, as already discussed this methodology was deliberately avoided in favor of a more simplistic approach that considers the expected monthly cash-flows from the project and whether these are more positive than negative, as well as how evenly distributed these positive and negative occasions are. Overall, unless villagers are able to at least recoup the financial costs of paying for the technology, its maintenance, and the costs of any financing undertaken to make the initial investment, it will not be possible for them to continue using it given their already subsistence level of income. Unlike a wealthier household that may be able to "afford" certain goods or services for the non-financial utility they gain from them—for example an expensive sports car that is irrational on a purely financial basis but that provides a measure of positive consumer surplus via the non-financial benefits it provides—the opportunity cost of such "indulgences" to households living at a subsistence level are literally the things that keep them alive (e.g., food, etc.). As such, as long as this condition of subsistence is present, any recommendation must meet this requirement.

BISWA Costs Covered

BISWA's costs must also at least be covered by the project when implemented, particularly with its long-term goal of this project being disseminated across multiple villages. Although a single loss-making project may be sustainable in the long-term if its non-financial benefits compensate for the loss (like the aforementioned sports car), multiplied many times over, the financial losses will no longer be supportable by the organization.

Real costs that must be covered by BISWA include the cost of implementing and administering the projects recommendations; however more importantly for the sake of long-term sustainability is that its opportunity costs are covered, i.e. the investment in these recommendations must produce enough of a return as BISWA's next-best alternative. Financially, this means that the cost of capital charged for any loans must be high enough to provide the same return as that provided by other programs. Assuming that BISWA's efficiencies in administering projects is equivalent across all projects, this means that villagers should be charged at least BISWA's standard interest rate (currently 20% per annum).

When applied to the financial model, charging an interest rate of 20% still enables the first requirement to be met, that villagers are able to cover their own costs.

BISWA's Long-Term Strategy

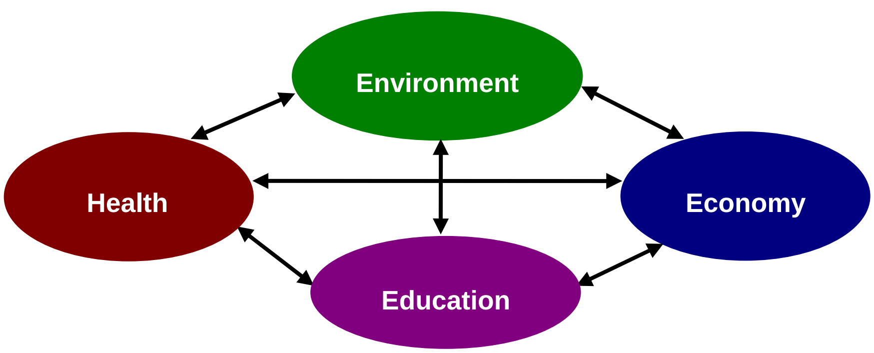
The project's recommendations must also be aligned with BISWA's long-term business strategy if it is to be viable over that period. This assumes that BISWA will want this initiative to be part of its portfolio on an ongoing basis and, consequently, will be willing to devote the resources needed in its early stages that will allow it to flourish in the long term.

From a presentation given by BISWA's CEO, the organization is working to streamline its operating and financing activities. Its long-term goal is to be 100% financially self-sustaining, with all operating expenses covered by BISWA's own micro-enterprises.[92] Stated goals for these micro-enterprises include: "converge (sic) microfinance to micro enterprise"; "ensuring sustainability of enterprises"; and "creating [an] enabling environment for cottage/rural industries." The recommendations as described meet all three of these goals and, as such, are aligned with BISWA's long-term strategic goals.[93]

X. Summary and Recommendations

BISWA is a philanthropic organization that has worked since 1994 to promote the development of rural India. Their goal is to "make a lasting social, economic, psychological and spiritual impact." This is accomplished through community empowerment and the establishment of employment opportunities. BISWA's Basic Needs Program has helped over 32 villages gain access to education, clean water, and food. BISWA helps provide these services because they are important in the overall development of rural India. More importantly, the organization understands the interaction between these services. As Figure 19 demonstrates, technological, social, environmental, political, and economic factors are part of one system and affect each other (directly or indirectly) in a web of interactions. A sustainable solution will build on these interactions and leverage their connectivity.

Figure 19: System of interactions.



BISWA has identified lighting as the next step toward development for rural people. This section outlines the specific micro-enterprise recommendations for villages with similar income, labor and social profiles as Bhudapada Village and discusses a business plan that can be implemented across all 14,590 of BISWA's SHGs.

Recommendation for Bhudapada

Based on our research over the past two years, we recommend that BISWA work with the SHG in Bhudapada to set up a micro-utility that provides electrification services to the local people. Under this model, the SHG will own and manage the solar battery chargers that are used to recharge AA batteries. These batteries will then be used in LED lamps, which households can either rent or buy from the SHG. The SHG will rent the rechargeable batteries and the lights. Revenue generated from this activity will be sufficient to repay the loan from BISWA as well as to create additional revenue for the SHG.

In Bhudapada's case, the results of the village financial evaluation model support the case for a profitable micro-utility. The village financial evaluation results showed that the average family in Bhudapada could afford to purchase their own solar lighting system and, over five years, could be expected to realize financial benefits of Rs. 8,675 (USD$225.31). This sum, together with the fact that a single solar charging unit has sufficient capacity to service approximately four households (reducing the expected cost per household of this component by 75%) indicates that there is plenty of opportunity for a micro-utility to operate profitably while still allowing households to retain some of the additional financial benefits of adopting the technology. Furthermore, even if the micro-utility does capture the entire financial benefit identified in the Bhudapada financial evaluation, villagers will still be significantly better off due to the 1,569% increase in light (in lumen-hours) that the system is expected to provide over a five-year timeframe and the additional development opportunities this will provide to them.

Technology Recommendation

In order to service the thirty households in Bhudapada, BISWA must loan Rs. 36,400 (USD$910) to the SHG so they can purchase the necessary equipment to sell light in Bhudapada. The SHG will need to purchase ten solar charging systems, thirty LED lamps, and one hundred and eighty rechargeable (AA) batteries. *Table 7* describes the equipment needed by the SGH and its approximate pricing.

Table 7: Bhudapada SHG capital investment.

Budhapada SHG: Micro-utility

Capital Investment	**Quantity**	**Costs (Rs)**	**Costs (USD)**
Solar charging system	10	Rs 10,000	$ 250
LED Lamps (4 batteries ea.)	30	Rs 12,000	$ 300
Rechargable batteries (AA)	120	Rs 9,600	$ 240
Batteries for inventory	60	Rs 4,800	$ 120
Loan to SHG		Rs 36,400	$ 910

The solar charging system is the source of economies of scale in our model and allows the SHGs to sell power in the form of rechargeable batteries. The charger can recharge up to two batteries at a time and approximately six batteries every day. The SHG will need ten solar battery chargers because they must ensure that enough batteries are recharged in order to service all thirty lamps. The recommended LED lamps are an appropriate product based on the application and affordability within the village. LED lamps provide a low-cost lighting solution, and LED's have extremely long product life spans; both qualities necessary to provide lighting to as many Bhudapadans as possible at the lowest possible cost. Other benefits of the lamps include safety and mobility since these lamps are lightweight and can easily be carried. In addition, LED lamps are extremely efficient in converting electricity to light and can provide constant light for up to thirty hours with four AA batteries. This is a vast improvement over the villagers' current light source (kerosene). The one disadvantage of LED lamps is they do not project light as far as incandescent or fluorescent lights, which can limit the number of simultaneous users, so as the villagers' incomes increase and they are able to afford other lighting technologies, LEDs may no longer be the optimal light source.

As mentioned in the case studies, training and technological support are necessary for the successful implementation of a project. In this case, it is important that the SHG accurately manage battery recharging. Batteries should be drained completely before being recharged in order to optimize the batteries' useful life. Proper battery management will lengthen the life of the battery and reduce inventory costs. Lastly, the SHG should manage a battery recycling program, so the used batteries undergo proper disposal and do not contribute to environmental waste. The design of such a program is outside the scope of this report.

Financial Recommendation

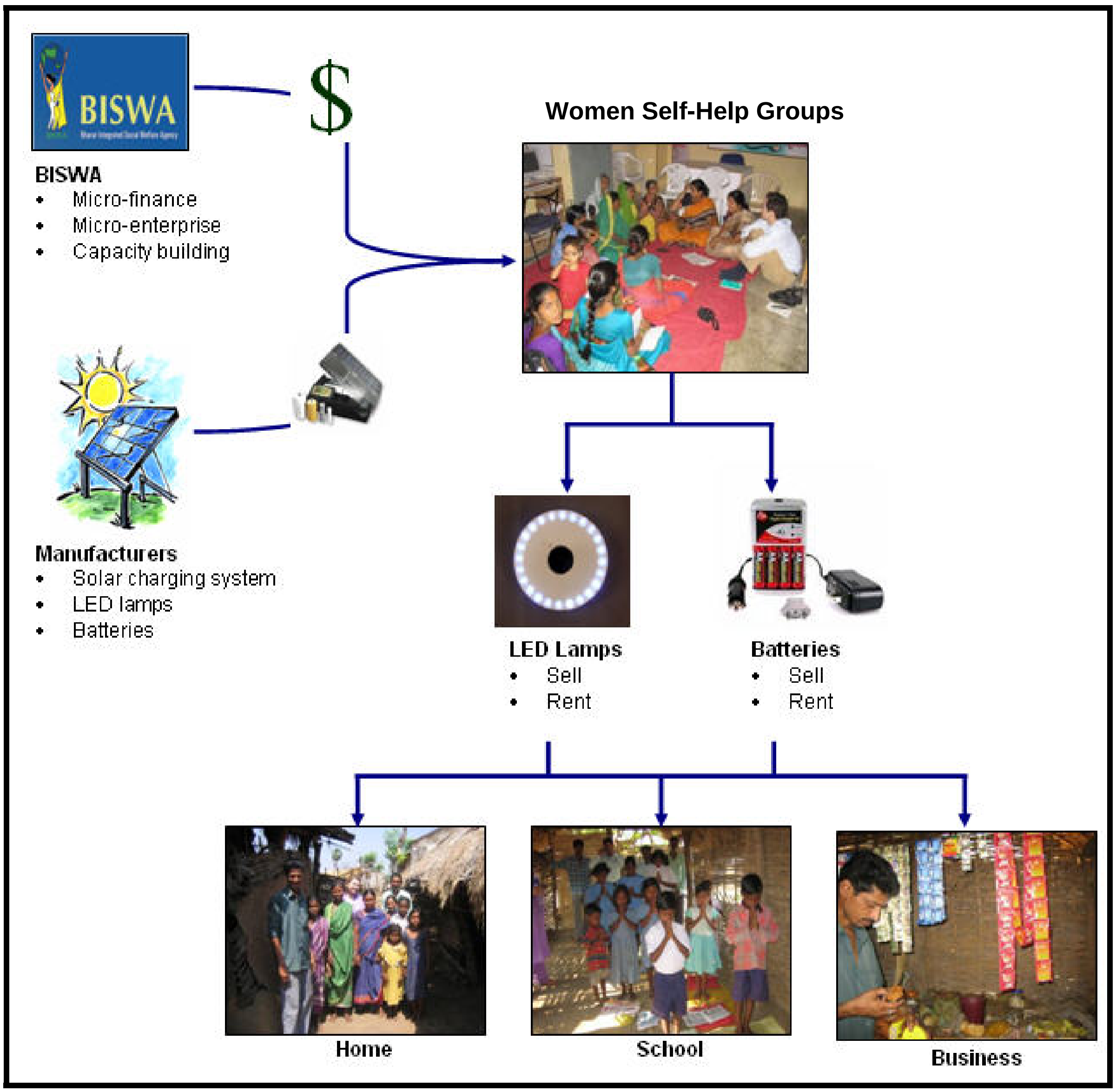
With regards to the microfinance structure recommended for Bhudapada, although the SHG structure does introduce an administrative cost, it is a cost that would have been paid for by BISWA (and ultimately the villagers) under the other microfinance structures considered. More importantly, by introducing this cost at the village level (the level at which SHGs are formed) those monies are kept within the village in the form of the salary paid to the individual(s) managing the micro-utility and therefore will contribute to the growth and development of the village overall. The human capital created by this position also stays within the village. Most significantly, BISWA already has a strong network of SHGs that it can leverage. In Bhudapada's case, village characteristics are such that we recommend that the SHG deal directly with individual households. SHGs in other villages, however, may choose to consider implementing other structures such as ROSCAs or Grameen-styled solidarity groups. These decisions will need to be made on a case-by-case basis.

Business Plan

Our recommended business plan involves three partners: BISWA, product manufacturers, and the villagers. See Figure 20 for a diagram of where each entity engages in the model. BISWA, as a MFI will manage the micro-enterprise, which is consistent with their current operations. The organization not only provides financial support, but also training. This will be imperative to the project's success. The SHG will need to understand how the business should be run, i.e., pricing and payment collection plans. BISWA will continue to serve as the main interface to product manufacturers since they can benefit from the aggregate buying power of all the SHGs. BISWA will use its established expertise to work closely with the SHG throughout the project's initial phases, especially during market research. The SHG, as a micro-utility, will provide two products to the villagers of Bhudapada: LED lamps and batteries. Villagers will be able to choose a financing option that is appropriate for their income level. We recommend that the SHG provide four options to villagers:

1) Villagers buy LED lamps and pay the SHG to provide them with charged batteries.
2) Villagers rent LED lamps with recharged batteries included.
3) Villagers rent charged batteries for other applications.
4) Villagers buy batteries for other applications and pay the SHG for charging services.

Figure 20: BISWA business model.



Analysis of Recommendations

BISWA's primary objective is to provide the villager's with novel sources of income. In fact, most of the products produced by already established micro-enterprises are sold outside the village.

The recommendation to set up a micro-utility not only satisfies a purely economic development objective, but also addresses the need for social development because the product improves the quality of life for villagers who are not members of the SHG. Villagers can work and study at night, which increases their level of income and education. Many generations stand to benefit from this product. This business model of selling within the village reduces the administrative burden involved in setting up a distribution network (downstream) and obtaining market intelligence, which is all managed by the local SHG. Regardless, BISWA will need to work with equipment manufacturers to bring the product to the village.

BISWA Recommendation

BISWA should apply the Bhudapadan business model to villages that are similar to Bhudapada and modify it for villages that are different. While LED lights may be the optimal solution for Bhudapada, they are not necessarily the best solution for all other villages. Each village will have different needs and product offerings must be tailored accordingly. Local SHGs will help determine which products satisfy the needs of their village. For example, in some villages, the SHG may decide to offer a warranty, while in other villages, the SHG may teach the villagers how to maintain the products themselves. Strong partnerships with product manufacturers will help ensure the long-term success of the energy micro-enterprise. In addition to product offerings, the SHG will also help develop an appropriate payment plan. The aforementioned micro-enterprise works with a variety of payment schemes from purchasing power to leasing lanterns. Families with adequate and reliable incomes can afford to pay and enjoy more enhanced products. We recommend BISWA conduct initial research to segment their villages in categories based on development indicators such as income, education, and accessibility in order to find appropriate solutions for differing types of villages.

Scaling the Business Model

Some villages have higher per capita income than Bhudapada and since it can be reasonably expected that this translates into higher spending on light, will be able to pursue more expensive lighting technologies. The micro-utility model can be scaled to service the particular consumer needs of a village with greater per capita income. SHS such as those described in the SELCO case study are more expensive and complicated than the technology employed in our recommendation for Bhudapada, but these systems may be better suited to wealthier villages. Again, the SHG will be the sole owner and operator of the SHS, and gaining the economies of scale from recharging multiple twelve volt batteries (the type used in automobiles) on one system, the SHG will serve as a recharging station that can service the whole community. The villagers will need to have sufficient income to buy their own lighting technologies for within their homes, but it will not be necessary for them to cover the cost of the SPV, charge controller, or battery necessary for a SHS. The recharged twelve volt batteries will be rented from the SHG in much the same manner as the rechargeable AA batteries are rented from the SHG in Bhudapada, and given the greater power capacity of a twelve volt battery, the villagers can use their rented battery to power anything from fans to televisions. The batteries could even be used to help keep medical supplies cold. The advantage of the micro-enterprise model remains in that there will be only one point of contact with SHS manufacturers and the SHG will earn revenue from villagers who are gaining from getting a renewable power source cheaply and reliably from within their own village. The higher costs for this microenterprise will be covered by the higher incomes earned within that village and the villagers will enjoy a higher quality of life. The costs of such a proposed system can be seen in the following table.

Table 8: Example village SHG capital investment.

SHG: Micro-utility

Capital Investment	Quantity	Costs (Rs)	Costs (USD)
Solar home system	6	Rs 78,000	$ 1,950
Rechargable 12V batteries	30	Rs 84,000	$ 2,100
Loan to SHG		Rs 162,000	$ 4,050

These costs are much higher, but as previously mentioned, it is expected that they will be affordable in some of the wealthier villages in which BISWA has set up SHGs and demonstrates the flexibility of the micro-utility business model. The relative advantages of a model using twelve volt batteries and accompanying lighting technologies compared with a model using AA rechargeable batteries and LED lamps are shown in Table 9.

Table 9: Comparison of Bhudapada and proposed scaled model.

LED Lamps / AA Batteries		Solar Home System/12V Batteries	
Benefits	**Rating**	**Benefits**	**Rating**
Duration of use	Low	Duration of use	High
Increased Safety	Medium	Increased safety	High
Light source mobility	Medium	Light source mobility	Low
Light source quality	Low	Light source quality	High
System Adaptability	Medium	System Adaptability	High
Overall	**Low**	**Overall**	**High**

Scaling this micro-utility will benefit BISWA and the villages in which BISWA has established SHGs. BISWA has always worked to set up microenterprises that are market-driven. BISWA allocates considerable time and effort in determining which businesses will be successful before they are implemented. Therefore, BISWA can save on many of these administrative costs by implementing this proven business plan across all of its SHGs. This recommendation successfully incorporates the villagers as both producers and consumers. In addition, applying a proven business model will save the organization valuable human resources as well as administrative costs. With increased demand, BISWA will enjoy economies of scale (discounted prices based on a high purchase volume) and village growth. In addition, each microenterprise will yield a positive financial return for BISWA. This profit along with any savings the organization makes can be put towards new micro-enterprises. As the organization grows and continues to provide light, the rural people of India will have opportunities to develop. More importantly, BISWA will help bring people dignity, opportunity, and a greater quality of life.

[1] Throughout this report we use the phrases "Base of the Pyramid" and "Bottom of the Pyramid" interchangeably. These phrases refer to the seminal work by C.K. Prahalad and Stuart Hart to refer to people who live on less than USD$5 per day.
[2] C. K. Prahalad, *The Fortune at the Bottom of the Pyramid. Eradicating poverty Through Profits: Enabling Dignity and Choice Through Markets* (Upper Saddle River, NJ: Wharton School Pub., 2005) 401.
[3] CRISIL Limited - A Standard & Poors Company, *Bharat Social Welfare Agency (BISWA) Republic of India MFI Grading Report*, 2007.
[4] Joyasree Ranu Mahanti, "Basic Needs Program and Microfinance in Orissa, India," Presentation to Asha for Education Meeting, University of Michigan. 14 October 2006.
[5] Ibid.
[6] Joyasree Ranu Mahanti (BISWA Affiliate), personal interview, 11 November 2007.
[7] Ibid.
[8] India Core and International Publications & Information Services, *Overview of power sector in India, 2005*, Rev. ed. (New Delhi, India: India Core, International Publications & Information Services, 2005) 307.
[9] Ibid.
[10] K. Ramanathan, Shahid Hasan, and Tata Energy Research Institute, *Privatization of Electricity Distribution: The Orissa Experience* (New Delhi, India: Teri, 2003) 93.
[11] Ibid., 93.
[12] India Core and International Publications & Information Services, *Overview of power sector in India, 2005*, Rev. ed. (New Delhi, India: India Core, International Publications & Information Services, 2005) 307.
[13] Ibid.
[14] Unless otherwise noted, all notes regarding this case are from Anders Ellegård, et al., "Rural People Pay for Solar: Experiences from the Zambia PV-ESCO Project," *Renewable Energy* 29.8 (2004): 1251–1263.
[15] Ibid.
[16] Shell Foundation Website. 31 January <http://www.shellfoundation.org>.
[17] P. Karve, "A Model for Dissemination of Improved Biomass Fuels and Cooking Devices Through Rural Enterprises," *Boiling Point* 50 (2005): 26–28.
[18] The Ashden awards for sustainable energy. "SELCO India - Affordable Solar Home Systems. A case study." The Ashden awards for sustainable energy. 2005. <http://www.ashdenawards.org/winners/selco>.
[19] Hande, Harish, phone interview, 23 November 2007.
[20] Hande, Harish, and Duffy, John. "A Model for Sustainable Rural Electrification with Photovoltaics," American Solar Energy Society Annual Meeting. April 2001.
[21] S. Kaufman, "Solar Electricity for Rural Development: Experience in the Dominican Republic," *Energy for Sustainable Development* 1.1 (1994): 43–45.
[22] L. Gunaratne, "Using the Principles of Marketing for Commercial Dissemination of Solar PV in Sri Lanka," *Energy for Sustainable Development* 2.4 (1995): 41–45.
[23] Ibid.
[24] Ibid.
[25] Ibid.
[26] Hande, Harish, phone interview, 23 November 2007.
[27] Energy Wise Reports. "Series 7: Programme 1 (of 8) - 'Energy Wise'." 2004. <http://www.handsontv.info/series7/01_energy_wise_reports/report1.html>. Accessed November 10, 2007
[28] Khirod Malick (BISWA Chairman), personal interview, 9 May 2007.
[29] Ibid.
[30] Malick and Mahanti, personal interview, 27 April 2007.
[31] Mihir Kumar Nath (BISWA Representative), personal interview, 7 May 2008.

[32] Silvey Corporation, *Material Safety Data Sheet - Kerosene*, 1st ed. (United Kingdom: Silvey Oil Fuel Specialists, 2003).
[33] Angela Flood-Uppuluri, Rupal Shroff, Devon Treece, and Marc Weatherill, *India Village Energy Survey: Problems, Needs and Opportunities*, 1st ed., 10 May 2007.
[34] Ibid.
[35] Ibid.
[36] Mahanti. 14 November 2006.
[37] Nath. 9 May 2007.
[38] Ibid.
[39] Flood-Uppuluri, Shroff, Treece, and Weatherill.
[40] Jose Goldemberg, et al., "A Global Clean Cooking Fuel Initiative," *Energy for Sustainable Development* VII.3 (2004): 83.
[41] V. Modi, et al. *Energy Services for the Millennium Development Goals*, United Nations Development Programme (2006).
[42] Ibid.
[43] Ibid.
[44] S. Iniyan, L. Suganthi, and T. R. Jagadeesan, "Renewable Energy Planning for India in the 21st Century," *Renewable Energy* 14.1-4 (1998): 453–457.
[45] "2007 RFP Conversion Metrics," 2007. 6 March 2008 <http://www.climatetrust.org/solicitations_2007_Metrics.php>.
[46] *Nitrogen Oxides (NOx) Emission When Combustion Fuels*, 2005. 17 March 2008 <http://www.engineeringtoolbox.com/nox-emission-combustion-fuels-d_1086.html>.
[47] Mohanlal Kolhe, Sunita Kolhe, and J. C. Joshi, "Economic Viability of Stand-Alone Solar Photovoltaic System in Comparison with Diesel-Powered System for India," *Energy Economics* 24.2 (2002): 155–165.
[48] LRC Rensselaer presentation "Lighting Applications Guideline for LEDs," (2002) From <http://www.lrc.rpi.edu/programs/solidstate/assist/pdf/LED-lighting-apps-guide-2002.pdf > accessed on 12 February 2008.
[49] Renewable Energy (2007) Retrieved May 08, 2008 from http://www.fordwestland.com/energy.html
[50] "Solar Emergency Light / Camping Light: Model SL8000." 2005. 07 January 2008 <http://www.kyowa.com.cn/SL8000.htm>.
[51] *Solar powered battery charger.* (2008). 12 March 2008 <http://www.ccrane.com/more-categories/batteries-chargers/solar-powered-battery-charger.aspx?RefID=WS110401WSDG0100>.
[52] P. W. Stackhouse, and C. H. Whitlock, NASA Surface Meteorology and Solar Energy: SolarSizer Data (2008). 12 February 2008 <http://eosweb.larc.nasa.gov/cgi.bin/sse/sizer.cgi?email=pbandyop%40umich.edu&step=1&lat=21+17&lon=84+23&ms=1&ds=1&ys=1992&me=12&de=31&ye=1992&daily=swv_dwn&submit=Submit>.
[53] "Sunrise and Sunset in Bhubaneshwar," (2008). 12 February 2008 <http://timeanddate.com/s/rnj>.
[54] David J. Spiers and Asko A. Rasinkoski, "Limits to Battery Lifetime in Photovoltaic Applications," *Solar Energy* 58.4-6 (1996): 147–154.
[55] Jorge M. Huacuz, et al., "Field Performance of Lead-Acid Batteries in Photovoltaic Rural Electrification Kits," *Solar Energy* 55.4 (1995): 287–299.
[56] Ibid.
[57] Illuminating Engineering Society of North America and Mark Stanley Rea. *The IESNA Lighting Handbook: Reference & Application*. 9th ed. (New York, NY: Illuminating Engineering Society of North America, 2000).
[58] M. Alam, A. Rahman, and M. Eusuf, "Diffusion Potential of Renewable Energy Technology for Sustainable Development: Bangladeshi Experience," *Energy for Sustainable Development* 7.2 (2003): 88–96.
[59] It is worth noting that BISWA comfortably meets all of these assumptions.
[60] For example, as we discussed earlier, Bhudapada is very low on the development scale as measured by income, social capital, infrastructure, and education. In some way it represents a "worst case situation" as other villages that are served by BISWA are at different stages of development.

[61] This list was compiled primarily from Beatriz Armendariz de Aghion and Jonathan Morduch, *The Economics of Microfinance* (Cambridge, MA: MIT Press, 2005) and, more loosely on Joanna Ledgerwood and Sustainable Banking with the Poor, *Microfinance Handbook: An Institutional and Financial Perspective* (Washington, D.C.: World Bank, 1999). Other sources are noted where applicable.

[62] Scheutzlich, T., Pertz, K., Klinghammer, W., Scholand, M., & Wisniwski, S. (2002). *Financing mechanisms for solar home systems in developing countries* No. IEA PVPS T9-01:2002)International Energy Agency. Retrieved from http://iea-pvpsuk.org.uk/resources/documents/T9-01%202002%20financing%20shs.pdf

[63] This list was compiled from Beatriz Armendariz de Aghion and Jonathan Morduch, *The Economics of Microfinance* (Cambridge, MA: MIT Press, 2005), the BISWA Assessment of Self-Help Groups for Linkage (Gradation Sheet), and personal insight based on background reading.

[64] Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 138.

[65] S. Srinivasan, "Solar Home Systems: Offering Credit and Ensuring Recovery," *Refocus* 6.1 (2005): 38–41.

[66] Ex post moral risk is the risk that the borrower, after having realized a return sufficient to honor their financial obligations, either claims not to have made this return and is therfore unable to repay the creditor, or simply makes himself/herself unavailable to the creditor so that monies cannot be collected ("take the money and run").

[67] Srinivasan, 38–41.

[68] This list was compiled from Beatriz Armendariz de Aghion and Jonathan Morduch, *The Economics of Microfinance* (Cambridge, MA: MIT Press, 2005), the BISWA Assessment of Self-Help Groups for Linkage (Gradation Sheet), and personal insight based on background reading and site visits.

[69] Ex ante moral risk is the risk that the borrower does not take the actions promised, or to the level of effort necessary, to achieve the expected returns from the investment made with the borrowed funds, thereby making it difficult or impossible to repay the loan on schedule.

[70] Dictionary.com Unabridged (v 1.1), *save* (n.d.). 20 February 2008 <http://dictionary.reference.com/browse/save>.

[71] Ibid.

[72] In fact there has been considerable debate amongst experts as to whether or not the poor are even able to save, though it seems that overall, the tide seems to be shifting towards the belief that it is due to a lack of opportunity to save (through access to bank-provided savings products) rather than an inability to save. Anecdotally, the gold jewelry worn by women in Bhudapada also seems to support this. An insightful discussion of this phenomenon can be found in Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 147–150.

[73] Studies of BURO Tangail, a microfinance institution in Bangladesh that provides savings accounts to customers, show that customers deposited more than 62 million taka and withdrew more than 60 million in the year 2000, on a base of 27 million taka in savings, suggesting a high degree of consumption smoothing in aggregate. From, Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 148.

[74] Unless otherwise noted, information in this section is based on Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 59–68.

[75] Unless otherwise noted, information in this section is based on Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 68–73.

[76] M. Zeller and R. L. Meyer, *The Triangle of Microfinance: Financial Sustainability, Outreach, and Impact* (Baltimore, MD: Johns Hopkins University Press, 2002) 11.

[77] A. Karnani, "Microfinance Misses Its Mark," *Stanford Social Innovation Review* Summer (2007), 21 October 2007 <http://www.ssireview.org/articles/entry/microfinance_misses_its_mark/>; Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 232.

[78] Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 142.

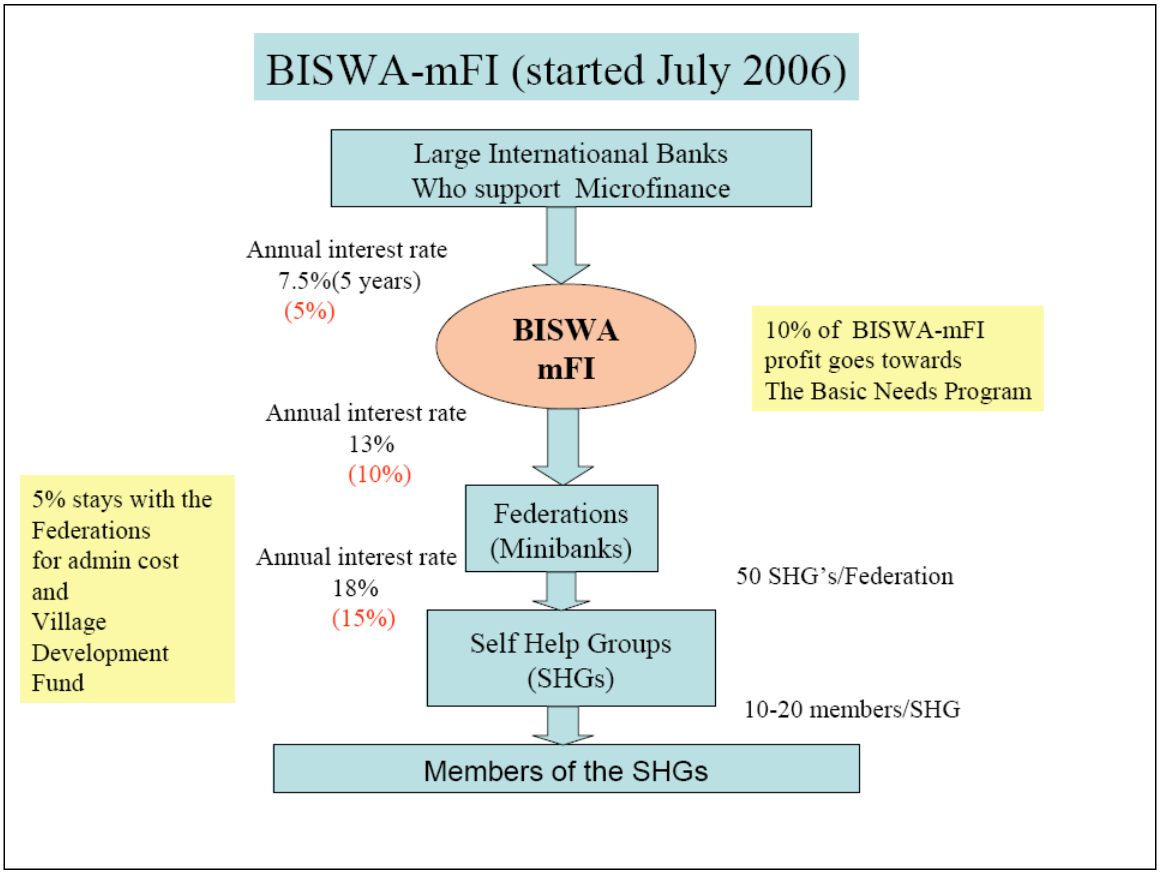
[79] Institute for Financial Management and Research, *Microfinance in India: Current Trends and Challenges* (Chennai, India: Centre for Micro Finance at Institute for Financial Management and Research, 2006).

[80] Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 86; Joanna Ledgerwood and Sustainable Banking with the Poor*, Microfinance Handbook: An Institutional and Financial Perspective*, 286; *FINCA's History: 1984, Where Village Banking Began*, 17 February 2008 <http://www.villagebanking.org/site/c.erKPI2PCIoE/b.2700247/k.A875/FINCAs_History_1984_Where_Village_Banking_Began.htm>.
[81] *FINCA's History: 1984, Where Village Banking Began*
[82] Armendariz de Aghion and Morduch, *The Economics of Microfinance*, 235 – 238; Jonathan Morduch, "The Role of Subsidies in Microfinance: Evidence from the Grameen Bank," *Journal of Development Economics* 60.1(1999): 229-248.
[83] Professor Gautam Kaul, John C. and Sally S. Morley Professor of Finance, Stephen M. Ross School of Business, University of Michigan.
[84] 250 lux is the recommended illumination for "easy office work, classes" according to *Illuminance - Recommended Light Levels*, 2005. 1 February 2008 <http://www.engineeringtoolbox.com/light-level-rooms-d_708.html>.
[85] "Handwork" refers to saleable products currently made in Bhudapada that can be made after dark provided there is sufficient light and raw materials available. In this model, "handwork" includes bidi leaf processing, cot making, leaf-plate and leaf-cup making, and the weaving of bamboo mats.
[86] G. S. Dutt, "Illumination and Sustainable Development - Part I: Technology and Economics," *Energy for Sustainable Development* 1.1 (1994): 23-35.
[87] In a survey conducted by (Monroy and Hernandez 2005), one of the best practices identified by respondents with regard to financing renewable energy projects in developing countries and ensuring their financial sustainability was the linking of electrification with "productive initiatives."
[88] This assumption is made to better model the "shocks" that can be expected to the price of government-subsidized kerosene which happen sporadically and therefore do not follow a smooth pattern or change. The latest increase in the government-controlled price of kerosene occurred in 2002, setting it at Rs. 9 per litre, while current black-market prices are approximately Rs. 25 per litre. This subsidy is an enormous cost to the Indian government, particularly in light of the significant increases in the price of oil recently. It is expected that a change in this policy resulting in a large and sudden jump in the price of kerosene would create large social unrest. On January 23, 2008, the Nepalese government reversed recent increases in the state-controlled price of kerosene, cooking gas, and diesel after wide-scale demonstrations: "Nepal rolls back fuel price hike after protests," Reuters January 23, 2008. This assumption can therefore be regarded as relatively conservative in both its frequency (price changes will likely occur less frequently) and magnitude (price changes will likely be less than 10%).
[89] Interview with Mr. Malick and Mrs. Mahanti. September 12, 2007
[90] This is consistent with findings by Wamukonya and Davis (2001) wherein they write that one of the two principal benefits of electrification was high-quality lighting, the second being access to television.
[91] Flood-Uppuluri, Shroff, Treece, and Weatherill.
[92] Currently, approximately 8% of BISWA's operating expenses are paid for with donations and/or grants, the other 92% being covered by interest earned on loans made. Marc Weatherill, personal notes, 8 May 2007.
[93] CRISIL Limited - A Standard & Poors Company, *Bharat Social Welfare Agency (BISWA) Republic of India MFI Grading Report*, 2007.

Appendix A: Acronyms

ASCAs: accumulated savings and credit associations
BISWA: Baharat Integrated Social Welfare Agency
BoP: Base of the Pyramid or Bottom of the Pyramid
ESCO: energy service company
FINCA: Foundation for International Community Assistance
LED: light emitting diodes
LPG: liquid petroleum gas
MFI: microfinance institution
MW: megawatts
NGOs: non-governmental organizations
NPV: net present value
OSEB: Orissa State Electricity Board
PV: photovoltaic
PV-ESCO: Photovoltaic Energy Service Company
ROSCAs: Rotating Savings and Credit Associations
SELCO: Solar-Electric Lighting Corporation
SHG: self-help group
SHS: solar home lighting system(s)
Sida: Swedish International Development Agency
SO-BASEC: Solar Based Rural Electrification Concept
SPV: solar photovoltaic
TERI: Tata Energy Research Institute
UNDP: United Nations Development Program

Appendix B: BISWA Business Structure



Source: Mrs. Joyasree Mahanti Presentation to Asha for Education, October, 14, 2006

Appendix C: Orissa Energy Project Survey - Village

Name of village: ________________________________

Village population: _______

Number of households in village: _______

Number of schools in village: _______

Number of businesses / commercial enterprises in village: _______

3 most common types of employment in village:

1.

2.

3.

Description of village government:

What services are provided locally by village/regional/state/national governments?

Does anybody do tasks for the whole village? Are they paid? If yes, how?

Orissa Energy Project Survey - Household

Survey to be given to mother of household.

Name of village: ______________________________

Household Characteristics

Number of people in household: _______

Number of generations in household: _______

	Gender (M/F)	Age (years)	Can read? (Y/N)	Can write? (Y/N)	Attends School? (Y/N)
Grandmother	F				
Grandfather	M				
Mother	F				
Father	M				
Child 1					
Child 2					
Child 3					
Child 4					
Other: __________________					
Other: __________________					
Other: __________________					
Other: __________________					

Household Income/Employment

Description of Income Source	Earned By	Consistency (constant / seasonal / sporadic)*	Method of Payment (cash / goods / services)**

* If seasonal or sporadic, please describe why.
** If goods or services, please describe what goods or services they are.

Estimated monthly income that would allow for the household's basic necessities to be met?:

Housing

Owner of land house located on: (circle answer)

Private (own)	Private (other)	Government	Don't Know	Other: ______________

What materials is the house made of?

Number of rooms in house: ________

Fuel

Type(s) of fuel used for cooking? (circle all that apply)

kerosene

bio-fuel (wood, etc.)

electricity – batteries

electricity – grid

dung

other: ____

other: ____

Type(s) of fuel used for light? (circle all that apply)

kerosene

bio-fuel (wood, etc.)

electricity – batteries

electricity – grid

dung

other: ____

other: ____

What are sources of fuel(s) used for cooking and light?

kerosene: ____

bio-fuel (wood, etc.) : __________________________________

electricity – batteries: __________________________________

electricity – grid: ______________________________________

dung: ____

other: ____

other: ____

	Is fuel collected / purchased / both?	If fuel is collected, how often? (daily / weekly / monthly / other) How much time (hours) for each collection?*	If fuel is purchased, how often? (daily / weekly / monthly / other) How much time (hours) for each collection?*	If fuel is purchased, how much does it cost per unit?	How consistently available is fuel? (always / usually / rarely / almost never)	Who usually collects this fuel?
kerosene						
bio-fuel (wood, etc.)						
electricity – batteries						
electricity – grid						
dung						
other: ______________						
other: ______________						

* If fuel is delivered, enter “0”.

Household activities that use the most fuel (top 3):

1.

2.

3.

Household Needs & Aspirations

What are the most significant challenges the household is facing?

How do you see these challenges being eliminated?

What would you do if you had electricity in the village? How would your life change (better and worse)?

What would you do if you had electricity at home? How would your life change (better and worse)?

Appendix D: Village Financial Evaluation Model

Appendix E: Project Team Bios

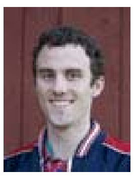
Project Advisor

Professor Tom Lyon, PhD tplyon@umich.edu
Professor Lyon's current research deals with the interplay between corporate strategy and public policy, including corporate environmentalism, electric utility investment practices, natural gas contracting, innovation in the health care sector, and the introduction of competition in regulated industries. His book Corporate Environmentalism and Public Policy was published by Cambridge University Press in November 2004. Professor Lyon serves on the editorial board of the Journal of Regulatory Economics, and his research has been published in such journals as the RAND Journal of Economics, the Journal of Law and Economics, the Journal of Public Economics, the Journal of Economics and Management Strategy, and the Journal of Law, Economics and Organization.

Project Team

Angela Flood-Uppuluri flooda@umich.edu
Angela concentrates on carbon reduction strategy in the developing world for major manufacturers. She has spent her two summers during the Erb program interning for Cummins Inc, most recently implementing a global carbon reduction strategy for the company. She has a background in urban planning, project management, and manufacturing policy. Prior to coming to Michigan, Angela was the Policy Director of the Michigan Manufacturing Technology Center. Currently, Angela is the Professional Development VP of the Ross Energy Club where her big project is the production of “Carbon 101” the first ever student symposium at the University of Michigan about the intersection between carbon and business.

Rupal Shroff rshroff@umich.edu
From engineering to business, Rupal has trekked across the automotive industry following a desire for greater social responsibility. It is this passion for change that has led her to the Erb Institute, where her ultimate goal is to create value for shareholders through the development of economic environmental solutions for corporate strategy. For the past 5+ years, Rupal has held various jobs in design, manufacturing and strategy. As a business planner for Visteon Corporation, she developed strategic alliances with competitors to ensure product viability. She currently works as a fuel systems engineer for Ford Motor Company. Her primary responsibility is engineering diesel truck applications for biodiesel compatibility. Rupal is a member of Net Impact, Women in Business and the SOL Consortium. She holds a B.S. in mechanical engineering from the University of Minnesota and is joining the GE Renewable Energy Leadership Program after graduation.



Devon Treece drtreece@umich.edu
Devon is focused on finding creative solutions to environmental and social problems which might arise in developing markets. Particularly, he would like to find ways to avoid these problems entirely by working in the nascent stages of these projects. In the past, he has conducted scientific research to assess ecological responses to environmental degradation as well as to elucidate human responses to toxicologic environments. He is now attempting to create smaller scaled yet broadly applicable development solutions that will render his previous research endeavors irrelevant. Since graduating from Oberlin College with a double major in Biology and Environmental Studies, Devon has enjoyed extensive travels within the United States and is anxious to extend those travels globally.

Marc Weatherill mweath@umich.edu
Marc is interested in applying operations management and industrial ecology best practices to increase corporate sustainability and profitability, particularly in developing nations where he sees the greatest opportunities for maximizing their long-term impact. To this end, in addition to his studies with the Erb Institute, Marc is also earning a concentration in operations management through the Tauber Institute for Global Operations. Prior to graduate school, Marc lived in Shanghai, China for three years where he re-designed the work-flow and quality-control processes of Mercer Human Resource Consulting's North Asia employee compensation survey operations. Marc has also worked in Sydney, Australia as Operations Manager of a local internet-services company, and across Canada implementing the Logistics modules of the SAP enterprise resource planning system. Marc speaks French and Mandarin Chinese and, in his free time, enjoys running, Chinese karaoke, and cooking breakfast for his wife and friends.

List of References

"Aar-em Lights Up Rural India And Bridges the Gap Between Power Demand And Supply Through Solar Energy." Net News Publisher. 2008. <http://www.netnewspublisher.com/aar-em-lights-up-rural-india-and-bridges-the-gap-between-power-demand-and-supply-through-solar-energy/>.

Ahmad, Bashir. "Users and Disusers of Box Solar Cookers in Urban India—: Implications for Solar Cooking Projects." Solar Energy 69.Supplement 6 (2001/0): 209-15.

Alam, M., A. Rahman, and M. Eusuf. "Diffusion Potential of Renewable Energy Technology for Sustainable Development: Bangladeshi Experience." Energy for Sustainable Development 7.2 (2003): 88-96.

Allderdice, A., and J. H. Rogers. "Renewable Energy for Microenterprise." (2000).

Flood-Uppuluri, Angela., Rupal Shroff,Devon Treece and Marc Weatherill. India Village Energy Survey: Problems, Needs and Opportunities. 1st ed., 2007.

Armendariz de Aghion, Beatriz, and Jonathan Morduch. The Economics of Microfinance. Cambridge, Mass.: MIT Press, 2005.

Arvidson, Anders. "From Candles to Electric Light: Can Poor People Afford Solar Electricity?" Renewable Energy for Development 8.4 (1995): ?.

Banerjee, Bani P. Handbook of Energy and the Environment in India. New Delhi ; Oxford ; New York: Oxford University Press, 2005.

Banerjee, Rangan. "Comparison of Options for Distributed Generation in India." Energy Policy, 34.1 (2006): 101-11.

Berinstein, Paula. Alternative Energy : Facts, Statistics, and Issues. Westport, CT: Oryx Press, 2001.

Berkhout, Peter H. G., Jos C. Muskens, and Jan W. Velthuijsen. "Defining the Rebound Effect." Energy Policy, 28.6-7 (2000): 425-32.

Bhagat, R. P. Rural Electrification and Development. New Delhi: Deep & Deep Publications, 1993.

Bhattacharya, S. C. "Renewable Energy Technologies in Asia: A Summary of Activities and Achievements in Nepal." (2003).

"Borneo forest protection deal signed." 2007. <http://www.radioaustralia.net.au/connectasia/stories/s1847655.htm>.

Bose, Sarmila. Money, Energy and Welfare : The State and the Household in India's Rural Electrification Policy. Delhi ; New York: Oxford University Press, 1993.

Chakrabarti, Snigdha, and Subhendu Chakrabarti. "Rural Electrification Programme with Solar Energy in Remote region–a Case Study in an Island." Energy Policy, 30.1 (2002): 33-42.

---. "Rural Electrification Programme with Solar Energy in Remote region–a Case Study in an Island." Energy Policy, 30.1 (2002): 33-42.

Chandrasekar, B., and Tara C. Kandpal. "Effect of Financial and Fiscal Incentives on the Effective Capital Cost of Solar Energy Technologies to the User." Solar Energy 78.2 (2005/2): 147-56.

Chapman, Duane, and Jon D. Erickson. "Residential Rural Solar Electricity In Developing Countries." Contemporary Economic Policy 13.2 (1995): 98-108.

Choudhury, R. C., and National Institute of Rural Development. Rural Agricultural Energisation Programme : Consumer Consultative Survey : Andhra Pradesh Energy Efficiency Project, Sponsored by the Dept. for International Development, UK. Hyderabad, India: National Instittue of Rural Development, 1999.

Crandall, Robert W. "Air Pollution, Environmentalists, and the Coal Lobby." The Political Economy of Deregulation: Interests Groups in the Regulatory Process. Washington, D.C.: American Enterprise Institute, 1983.

CRISIL Limited - A Standard & Poors Company. Bharat Social Welfare Agency (BISWA) Republic of India MFI Grading Report., 2007.

Das, Gurcharan. India Unbound. New Delhi: New York, NY : Viking, 2000.

Deo, Pramod, S. Modak, and P. R. Shukla. Decentralised Energy Planning : Methodology and Case Studies. New Delhi: Oxford & IBH Pub. Co., 1991.

Deshpande, Aruna. India, a Travel Guide. New Delhi: Crest Pub. House, 2000.

Dutt, G. "Illumination and Sustainable Development Part I: Technology and Economics." Energy for Sustainable Development 1.1: 23-35.

Ellegård, Anders, et al. "Rural People Pay for Solar: Experiences from the Zambia PV-ESCO Project." Renewable Energy, 29.8 (2004): 1251-63.

Fernando, Jude L. Microfinance : Perils and Prospects. New York: Routledge, 2006.

"FINCA's History: 1984, Where Village Banking Began." Electronic Resource: <http://www.villagebanking.org/site/c.erKPI2PCIoE/b.2700247/k.A875/FINCAs_History_1984_Where_Village_Banking_Began.htm>.

Funk. "Evaluating the International Standard Procedure for Testing Solar Cookers and Reporting Performance." Solar Energy 68.1 (2000/1): 1-7.

George, Jacob, and National Institute of Rural Development. Household Energy use Pattern with Levels of Development : Factors Affecting Adoption of Renewable Technologies. Vol. 6. Hyderabad, India: National Institute of Rural Development, 1991.

Giriappa, S. Energy use in Rural Areas : Process, Problem, and Prospects. New Delhi: Oxford & IBH Pub. Co., 1991.

Goldemberg, Jose, et al. "A Global Clean Cooking Fuel Initiative." Energy for Sustainable Development VII.3 (2004).

---. "A Global Clean Cooking Fuel Initiative." Energy for Sustainable Development VII.3 (2004).

Gomkale, S. D., and R. L. Datta. "Solar Energy Applications in India." Solar Energy 14.3 (1973/2): 321-6.

Grupp, Michael, Pierre Montagne, and Mathis Wackernagel. "A Novel Advanced Box-Type Solar Cooker." Solar Energy 47.2 (1991): 107-13.

Guidi, Daniele. "A Model of Solar Rural Electrification in the Dominican Republic." Renewable Energy, 3.2-3 (1993): 221-6.

Gunaratne, L. "Using the Principles of Marketing for Commercial Dissemination of Solar PV in Sri Lanka." Energy for Sustainable Development 2.4 (1995): 41-45.

Gupta, P. K. "Renewable Energy Sources — A Longway to Go in India." Renewable Energy, 16.1-4 (1999): 1216-9.

Gupta, V. P., and Sneh Gupta. Electricity Pricing in India. Jaipur: Printwell, 1996.

Gusain, P. P. S., and Society for Development Alternatives. Renewable Energy in India. Vol. 3. New Delhi: Har-Anand Publications in association with Vikas Pub. House, 1990.

Gustavsson, Mathias, and Anders Ellegård. "The Impact of Solar Home Systems on Rural Livelihoods. Experiences from the Nyimba Energy Service Company in Zambia." Renewable Energy, 29.7 (2004): 1059-72.

Gustavsson, Mathias. "Educational Benefits from Solar technology—Access to Solar Electric Services and Changes in Children's Study Routines, Experiences from Eastern Province Zambia." Energy Policy, 35.2 (2007): 1292-9.

Hande, H. Harish, and John Duffy. "A Model for Sustainable Rural Electrification with Photovoltaics." American Solar Energy Society Annual Meeting.

Hawas, M. M., and T. Muneer. "Study of Diffuse and Global Radiation Characteristics in India." Energy Conversion and Management, 24.2 (1984): 143-9.

Huacuz, Jorge M., et al. "Field Performance of Lead-Acid Batteries in Photovoltaic Rural Electrification Kits." Solar Energy, 55.4 (1995): 287-99.

Ibrahim, Muhammad, et al. "Demonstration of PV Micro-Utility System for Rural Electrification." Solar Energy, 72.6 (2002): 521-30.

"Illuminance - Recommended Light Levels." 2005. <http://www.engineeringtoolbox.com/light-level-rooms-d_708.html>.

Iniyan, S., and T. R. Jagadeesan. "A Comparative Study of Critical Factors Influencing the Renewable Energy Systems use in the Indian Context." Renewable Energy, 11.3 (1997): 299-317.

Iniyan, S., et al. "Reliability Based Socio Economic Optimal Renewable Energy Model for India." Renewable Energy, 19.1-2 (2000): 291-7.

Iniyan, S., L. Suganthi, and T. R. Jagadeesan. "Renewable Energy Planning for India in 21st Century." Renewable Energy, 14.1-4 (1998): 453-7.

Iniyan, S., and K. Sumathy. "An Optimal Renewable Energy Model for various End-Uses." Energy, 25.6 (2000): 563-75.

Interview with Khirod Malick, BISWA Chairman., 2007.

Interview with Mihir Kumar Nath, BISWA Representative., 2008.

Interview with Ranu Mahanti, BISWA Affiliate., 2007.

Karnani, Aneel. "Microfinance Misses its Mark." Stanford Social Innovation Review Summer (2007).

Kaufman, S. "Solar Electricity for Rural Development: Experience in the Dominican Republic." Energy for Sustainable Development 1.1 (1994): 43-45.

Kolhe, Mohanlal, Sunita Kolhe, and J. C. Joshi. "Economic Viability of Stand-Alone Solar Photovoltaic System in Comparison with Diesel-Powered System for India." Energy Economics, 24.2 (2002): 155-65.

Kumar, S., and R. Varadarajan. "Urban Market Response for Solar Photovoltaic Systems: An Economic appraisal—South Indian Case Study." Solar Energy 51.3 (1993/9): 229-32.

Ledgerwood, Joanna, and Sustainable Banking with the Poor. Microfinance Handbook : An Institutional and Financial Perspective. Washington, D.C.: World Bank, 1999.

"Lighting Malawian homes." 2008. Electronic Resource: <http://solar-aid.org/projects/health/lighting-malawian-homes.html>.

Lipp, Judith. "Micro-Financing Solar Power : The Sri Lankan SEEDS Model." Refocus, 2.8 (2001): 18-21.

Madhavi Latha, K., and K. V. S. Badarinath. "Influence of Local Waste Burning on Atmospheric Aerosol Properties in Urban Environment." Journal of Quantitative Spectroscopy and Radiative Transfer, 98.2 (2006): 180-8.

Mahanti, Joyasree Ranu. Basic Needs Program and Microfinance in Orissa, India - Presentation to Asha for Education Meeting October 14, 2006.

Malaviya, J. N., and S. P. Ranade. "Potential of Solar Home-Lighting System in Rural Western India." Solar Energy Materials and Solar Cells, 47.1-4 (1997): 79-84.

Malhotra, Preeti, and Tata Energy Research Institute. Rural Energy Matters : The Dhanawas Experience. New Delhi: Tata Energy Research Institute, 2000.

Mathur, K. N., and M. L. Khanna. "Application of Solar Energy to Small Scale Industries." Solar Energy 1.1 (1957/1): 34-6.

Microfinance in India: Current Trends and Challenges. Chennai, India: Centre for Micro Finance at Institute for Financial Management and Research, Institute for Financial Management and Research, 2006.

Miller, Damian, and Chris Hope. "Learning to Lend for Off-Grid Solar Power: Policy Lessons from World Bank Loans to India, Indonesia, and Sri Lanka." Energy Policy, 28.2 (2000): 87-105.

Modi, V., et al. Energy Services for the Millennium Development Goals., 2005.

Monroy, Carlos Rodriguez, and Antonio San Segundo Hernandez. "Main Issues Concerning the Financing and Sustainability of Electrification Projects in Rural Areas: International Survey Results." Energy for Sustainable Development 9.2 (2005): 17-25.

Morduch, Jonathan. "The Role of Subsidies in Microfinance: Evidence from the Grameen Bank." Journal of Development Economics, 60.1 (1999): 229-48.

Muñoz, F. J., et al. "A New Method Based on Charge Parameters to Analyse the Performance of Stand-Alone Photovoltaic Systems." Solar Energy Materials and Solar Cells, 90.12 (2006): 1750-63.

"Nepal Rolls Back Fuel Price Hike After Protests." Reuters January 23, 2008 2008.

Nguyen, Khanh Q. "Alternatives to Grid Extension for Rural Electrification: Decentralized Renewable Energy Technologies in Vietnam." Energy Policy, 35.4 (2007): 2579-89.

Nieuwenhout, F. D. J., et al. "Rural Lighting Services: A Comparison of Lamps for Domestic Lighting in Developing Countries.".

"Nitrogen Oxides (NOx) Emission When Combustion Fuels." 2005. <http://www.engineeringtoolbox.com/nox-emission-combustion-fuels-d_1086.html>.

Northrup, Michael F., Peter W. Riggs, and Frances A. Raymond. Selling Solar: Financing Household Solar Energy in the Developing World. Vol. POCANTICO PAPER NO 2. New York: Rockefeller Brothers Fund, Inc., 1996.

Ostrom, Elinor. Governing the Commons : The Evolution of Institutions for Collective Action. Cambridge ; New York: Cambridge University Press, 1990.

"Outputs, Prices and Jobs." The Economist January 19, 2008 2008: 109.

Parishwad, G. V., R. K. Bhardwaj, and V. K. Nema. "Estimation of Hourly Solar Radiation for India." Renewable Energy, 12.3 (1997): 303-13.

Peter, Raja, Laurence Dickie, and Vasanthi M. Peter. "Adoption of Photovoltaic Power Supply Systems: A Study of Key Determinants in India." Renewable Energy, 31.14 (2006): 2272-83.

Prahalad, C. K. The Fortune at the Bottom of the Pyramid : [Eradicating Poverty through Profits : Enabling Dignity and Choice through Markets]. Upper Saddle River, NJ: Wharton School Pub., 2005.

Rabah, Kefa V. O. "Integrated Solar Energy Systems for Rural Electrification in Kenya." Renewable Energy, 30.1 (2005): 23-42.

Rai, S. "Sustainable Dissemination of Solar Home Systems for Rural Development: Experiences in Nepal." Energy for Sustainable Development VIII.2 (2004): ?.

Raikhy, P. S., and Parminder Singh. Energy Consumption in India : Pattern and Determinants. New Delhi: Deep & Deep Publications, 1990.

Rama Rao, R., and Birla Economic Research Foundation. India's Energy Scene : Options for the Future. New Delhi: Birla Economic Research Foundation : Radiant Publishers, 1988.

Ramanathan, K., Shahid Hasan, and Tata Energy Research Institute. Privatization of Electricity Distribution : The Orissa Experience. New Delhi: Teri, 2003.

Rouse, J. "Community Participation in Household Energy Programmes: A Case-Study from India." Energy for Sustainable Development 6.2 (2002): 28-36.

Roy, Joyashree, and Soma Gupta. "Cost of Oil-Based Decentralized Power Generation in India: Scope for SPV Technology." Solar Energy 57.3 (1996/9): 231-7.

Roy, Joyashree. "The Rebound Effect: Some Empirical Evidence from India." Energy Policy, 28.6-7 (2000): 433-8.

SAARC. SAARC Regional Poverty Profile 2005, Poverty Reduction in South Asia through Productive Employement. South Asian Association for Regional Cooperation, 2005.

Saha, H., P. Basu, and S. B. Roy. "Applications of Photovoltaic systems—An Economic Appraisal with Reference to India." Solar Energy 41.6 (1988): 513-9.

Saha, H. "Design of a Photovoltaic Electric Power System for an Indian Village." Solar Energy 27.2 (1981): 103-7.

Sastry, E. V. R. "The Photovoltaic Programme in India: An Overview." Solar Energy Materials and Solar Cells, 47.1-4 (1997): 63-9.

"save (n.d.)." Dictionary.com Unabridged (v 1.1). <http://dictionary.reference.com/browse/save>.

Schare, Stuart, and Kirk R. Smith. "Particulate Emission Rates of Simple Kerosene Lamps." Energy for Sustainable Development II.2 (1995): 32-5.

Scheutzlich, T., Pertz, K., Klinghammer, W., Scholand, M., & Wisniwski, S. (2002). *Financing mechanisms for solar home systems in developing countries* No. IEA PVPS T9-01:2002)International Energy Agency. Retrieved from http://iea-pvpsuk.org.uk/resources/documents/T9-01%202002%20financing%20shs.pdf

Schwarzer, Klemens, and Vieira da Silva,Maria Eugênia. "Solar Cooking System with Or without Heat Storage for Families and Institutions." Solar Energy 75.1 (2003/7): 35-41.

Sharma, Dinesh C. "Transforming Rural Lives through Decentralized Green Power." Futures, 39.5 (2007): 583-96.

Shirodker, R. P. "Extreme Low-Maintenance, lead/acid Battery for Photovoltaic Power-Supply Systems in Remote, Tropical Areas." Journal of Power Sources, 53.2 (1995): 255-60.

Silvey Corporation. Material Safety Data Sheet - Kerosene. 1st ed. Vol. 3. United Kingdom: Silvey Oil Fuel Specialists, 2003.

Solar Electric Light Company. "SELCO.com." <http://www.selco.com>.

Spiers, David J., and Asko A. Rasinkoski. "Limits to Battery Lifetime in Photovoltaic Applications." Solar Energy, 58.4-6 (1996): 147-54.

Srinivasan, Sunderasan. "Solar Home Systems: Offering Credit and Ensuring Recovery." Refocus, 6.1 (2005): 38-41.

Subudhi, R. N. Energy, Environment, and Economy. New Delhi: Kanishka Publishers, Distributors, 1996.

The Ashden awards for sustainable energy. "SELCO India - Affordable Solar Home Systems. A case study." The Ashden awards for sustainable energy. 2005. <http://www.ashdenawards.org/winners/selco>.

Thomas, Cherian. "India Holds Key Rates as it Assesses Global Slowdown (Update 5)." Bloomberg.com2008: 1.

Vervaart, M. R., and F. D. J. Nieuwenhout. "SOLAR HOME SYSTEMS Manual for the Design and Modification of Solar Home System Components." (2000).

Wamukonya, Njeri, and Mark Davis. "Socio-Economic Impacts of Rural Electrification in Namibia: Comparisons between Grid, Solar and Unelectrified Households." Energy for Sustainable Development V.3 (2001): 5-6.

Wamukonya, Njeri. "Solar Home System Electrification as a Viable Technology Option for Africa's Development." Energy Policy, 35.1 (2007): 6-14.

Williams, Neville. "Financing Small Photovoltaic Applications." Renewable Energy, 6.5-6 (1995): 477-82.

India Core. www.IndiaCore.com, and International Publications & Information Services. Overview of Power Sector in India, 2005. Rev. ed. New Delhi: www.IndiaCore.com, International Publications & Information Services, 2005.

Zeller, Manfred, and Richard L. Meyer. The Triangle of Microfinance : Financial Sustainability, Outreach, and Impact. Baltimore: Johns Hopkins University Press, 2002.