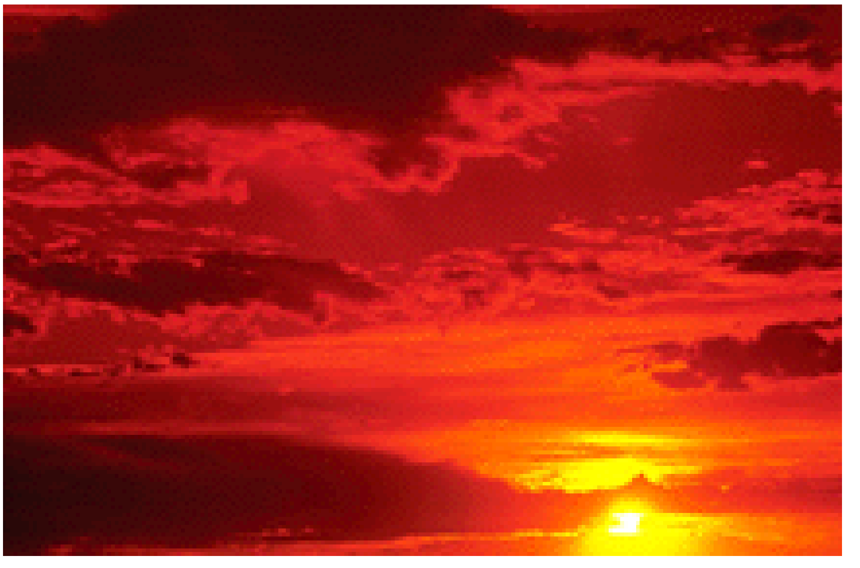

SOLAR ENERGY IN THE INFORMAL SETTLEMENTS OF OKAHANDJA

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Solar Energy in the Informal Settlements of Okahandja

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by

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ABSTRACT

There is little or no electricity available in the informal settlements, which contributes to a poor quality of life. The goal of our project was to provide information on solar energy options to the Township of Okahandja that would meet the needs of the residents of the informally settled areas. Several options were researched, but national grid electricity was found to be the best option. In addition, we provided recommendations concerning any future energy projects in the settlements.

AUTHORSHIP PAGE

The project team contributed equally to the entire project unless otherwise noted.

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EXECUTIVE SUMMARY

In the many informal settlements of Namibia, the quality of life is poor. Such necessities as running water, electricity, and waste management systems are absent or inadequate, creating harsh living conditions within the communities. Two informal settlements located in Okahandja, Five Rand and Oshetu One, are no exception. One of the major problems in both settlements is the limited availability of electricity to the residents, which has led to several problems including health and safety hazards caused by the use of traditional methods of cooking and lighting, as well as the increased labor required for gathering firewood. Some of the residents crave electricity to such an extent that they have engineered illegal electrical connections to the grid. The town government is interested in providing these communities with a legal and safe source of electricity because of its desire to improve the standard of living of its residents.

In order to assist the Township of Okahandja in finding a solution to provide electricity to the residents in the informal settlements, our team developed solar-based options to meet the energy needs of these residents. In order to obtain a complete understanding of the energy requirements of the community, the team first studied the energy needs of the people in these two settlements. The primary method used to assess these energy needs was to conduct a survey using opportunistic sampling. We determined that a survey was the best method due to the large amount of data that can be collected from many individual households in a short period of time. Overall, 260 households were surveyed in the two settlements, providing a respectable representation of the estimated 800-1200 households. Completion of the energy needs assessment allowed the team to begin researching solar energy options that would meet the demands of the residents. Interviews with solar energy company

representatives provided us with data on the equipment available that could provide the needed amount of electricity, the possible configuration options, and the estimated costs of each option. The next step was to assemble the collected information into several complete energy systems while making sure that each option would be able to satisfy the residents' needs. This two-part methodology took into account the needs of the residents to determine a variety of solar energy options that could provide electricity to Okahandja's informal settlements.

Completion of the needs assessment provided data on which to base the energy requirements of the residents. From the most popular appliances identified in our survey, we calculated that 18 kWh per household/shebeen per day would satisfy the needs of nearly all of the residents. The most important electrical applications in the majority of the homes were lighting, cooking, refrigeration, and entertainment (TV and/or radio). These appliances have a wide range of electrical requirements, with an electric stove being the single most energy consuming item. The indication that electric stoves were very important to the residents had many implications in the project. In addition to stoves requiring a large amount of electricity, refrigeration has a high consumption because it operates nearly twenty-four hours a day. Lighting can also require a significant amount of electricity depending on the wattage of the light bulb and the amount of time each light is used. Radios and TVs are generally not large burdens on an electrical system, but this is dependent on the amount of time that they are used each day.

A second value of estimated daily usage was calculated directly from the predicted future electrical usage section of the survey. In this part of the survey people reported the appliances that they would buy if they had access to adequate electricity. Based on the results from the survey, the homes in the settlements of

Okahandja would require approximately 13.4 kWh per day of electricity. This estimate is low because nine percent of the people reported not being able to afford electricity, which made the average usage estimate lower. This percentage, however, could change dramatically in the future depending on the economy in Okahandja. In addition, only twenty-nine percent of the people reported they would buy lights, but in actuality, most people would purchase lights if they had electricity. Therefore, when 13.4 kWh per day was calculated, a large amount of the households were considered not to have lights, again, lowering this estimate. Because this estimate was not a realistic consideration of the basic wants of the households, the 18 kWh value was used to develop the solar power recommendations.

Following several meetings with representatives of solar energy technology companies, the team assembled preliminary cost estimates for different solar options. Many of the solar energy experts felt that the requirements of the residents were too great for a solar energy system. In addition, when the solar experts learned that some of the residents had illegal connections to the grid, the experts stated that because of the settlements' relatively close proximity to the grid, the costs of solar energy could not compete with the low costs of grid-based power. If cooking were to be excluded from the requirements, the solar energy system would be somewhat more economically feasible, but several of the experts felt that with the exception of using very energy efficient refrigerators, it would also be better to pursue other means of refrigeration if using a solar-based energy system. With these suggestions in mind, the team calculated approximate costs for several solar energy-based systems that would have smaller than 18 kWh power outputs. If the team included these lower-powered options, other methods of cooking (such as using gas or paraffin) and other means of refrigeration (such as centralized refrigeration or energy efficient refrigerators) would be necessary in the recommendations. Each solar option was evaluated based on cost, ability to meet the electricity needs of the residents, and social acceptance. All of the solar options were also compared to grid electricity on these same factors.

We found that despite the high levels of available sunlight in Namibia, solar power is not the best option for Okahandja at this time due to several reasons. The primary reason solar energy is not adequate is because of the high initial costs compared to the low grid infrastructure (startup) costs, seen in Table A. Taking into consideration trends within the Southern African energy markets, and considering the current interest rates, solar remains a noncompetitive option. Over approximately sixty years, the costs of a large solar setup energy will break even with the cost of grid electricity. However, the solar equipment does not have the longevity to achieve this break even point. Another reason the national grid is a better option than solar energy relates to ninety percent of the people stating that they would purchase and utilize an electric stove, an option that most solar power setups cannot reasonably support. In addition, many of the residents stated that they wanted grid electricity to increase their social status. Having grid electricity rather than electricity from renewable technologies is seen as an improvement in quality of life. Because of these societal factors, the team concluded that a solar project would have a low success rate in the two settlements. Therefore, solar power would be too costly and would not satisfy the needs of the people or the Town Council.

Table A. Solar Setup Options

Setup Options	kWh/day	Initial Setup Cost for 1000 Households	Support Stove?	Support Refrigerator?
Mini-grid 15 amp	18	N$231,670,000	Yes	Yes
Mini-grid 5 amp	12	N$144,800,000	No	Yes
Individual Setup	12	N$114,900,000	No	Low energy/small
Individual Setup	12	N$114,900,000	No	Low energy/small
Thermal Solar Electricity	18	N/A	Yes	Yes
Grid Electricity	18	N$5,800,000	Yes	Yes

Although solar energy is not the best option, the team made several recommendations to the Town Council with regards to installing electrical power in the settlements based on the needs assessment, informal interviews with the residents, and direct observational data. Creation of an educational program that would introduce the concepts of energy safety, efficiency, and conservation was also suggested. These are all important issues that need to be considered in order to provide a satisfying and safe source of energy, especially in an area with limited resources at the present time.

In addition to an educational program, group discussions with members of the community would be very appropriate in order to address any concerns or questions that the residents have. For example, several of the residents stated that they felt that prepaid electricity was the best option for the settlements. They justified this opinion by stating that since many of the residents had low, unstable incomes, prepayment was the safest investment for the town and would encourage energy conservation by the users. It is important to consider that the residents in these areas may have other suggestions that should be taken into account.

Above and beyond group discussions, there are several other participatory exercises and tools for effective communication that can be used with the community in order to ensure that the residents are directly involved in the decision making process. Another option to address the concerns of the residents could be to have a drop box in the informal settlements in which people could write their questions, and then the town could reply to each of the concerns. Another suggestion is to post the Town Council meeting times and other important information in the settlements to increase awareness of the happenings in the town. These suggestions would make the process of developing the town more accessible to the citizens.

In short, the team recommends that the Township of Okahandja pursue access to the national grid as a power source for the informal settlement areas. The team would also like to suggest further discussion with community members before a final decision is reached. Topics that should be addressed include the economic situation in the settlements, particularly determining if the residents can afford to pay for whatever electricity is provided. Several residents indicated an interest in commercial use of electricity, which would require additional consideration from the town. When a final decision is reached, we suggest an educational opportunity be provided for the residents that would instruct on basic electrical safety considerations, energy efficiency, and energy conservation. With this information, the team hopes that the Township of Okahandja can successfully implement access to electricity for all of the residents of the informal settlements.

Chapter 1. **INTRODUCTION**

In the many informal settlement areas (ISAs) of Namibia, the living conditions are harsh; such necessities as running water, electricity, and waste management systems are scarce or inadequate. Although all of these aspects of infrastructure are important, one of the top priorities of the residents is access to a satisfactory electricity supply. Electricity is important to the residents because a reliable and safe supply greatly increases the standard of living of the user in a number of ways. First, it can alleviate the problems associated with gathering and using traditional forms of energy such as firewood. Further, electricity facilitates everyday household tasks ranging from cooking and refrigeration to nighttime studying, tasks that might be impossible without electricity. Moreover, safety, a key issue in the informal settlements, can be increased with the use of outdoor illumination. Access to electricity will help eliminate several problems within the ISAs and improve general living conditions.

On the outskirts of the Township of Okahandja in central Namibia, Oshetu One and Five Rand, two informal settlements totaling about 1200 households, share in the problems of ISAs. The residents of these two ISAs have little or no electricity; therefore, they have identified electricity as a major need due to the current underdeveloped setup in their communities. Only one-third of the houses and the shebeens (informal bars) in Five Rand have electrical hookups (mostly illegal), which are unsafe due to the use of undersized wires, such as phone wires, that only provide a small amount of electricity. In most cases, there is only enough electricity to run a few lights and a refrigerator, but some residents try to run additional appliances off their connections. Since deadly accidents occur but go unreported due to the fear of being fined N$2000 and losing the connection, it is clear that a desire for electricity has become more important than safety and legal considerations.

Taking a step to improve the standard of living in these ISAs, the Town Council of Okahandja was looking for the best means for electrifying Oshetu One and Five Rand. One option was a connection to the national electrical grid, but the costs of connecting these outlying settlements to main gridlines are significant. Other options based on a solar power system, possibly supplemented by alternative cooking methods or a small grid connection was considered. A general lack of definitive information about the residential electricity needs in Okahandja's ISAs raised concerns about any estimates of power requirements. The Town Council has limited resources and did not have the capacity to research these options or to determine the needs of the people.

The goal of our project was to provide solar energy options to the Town Council that would meet the needs of the people living in the ISAs and to assemble recommendations about steps required for any electricity development project in these areas. In order to provide useful results, we assessed the electrical needs and desires of the residents. These data were analyzed to determine the requirements needed to provide electricity through solar technology and to determine necessary steps for the Town Council to proceed in an electrification project. This project is the first step to determining a sustainable energy solution for the ISAs in Okahandja. The Town Council can use the information and recommendations we have provided as they consider electrical connection options for the current and future informal settlements in Okahandja.

Chapter 2. **BACKGROUND**

In two informally settled areas, Five Rand and Oshetu One, located in Okahandja, Namibia, living conditions are unacceptable. An informally settled area (ISA) is an extremely low-income, mainly residential area, containing very little infrastructure. These areas, such as Five Rand and Oshetu One, face many challenges. One of the major problems, lack of a safe and reliable source of electricity, contributes to the poor quality of life within the settlements. The Township of Okahandja decided to sponsor a study of the feasibility of using solar power as a first step to developing an electrical setup in these low-income areas. In order to understand this project, information about the ISAs in Okahandja, about the characteristics of a successful solar energy project, and about solar energy technologies is necessary.

2.1 Okahandja

Okahandja, a township of 18,000 people, lies about seventy kilometers to the north of the modern Namibian capital, Windhoek (Swaney, 2002, p.133). Within the township, the two ISAs, Five Rand and Oshetu One, are the research focus of our project. For appropriate recommendations about solar energy options to be made, it is necessary to thoroughly understand the situation in the ISAs. This task is accomplished in two ways: a characterization of the ISAs and a description of the challenges the residents face.

2.1.1 Characterization of the Informally Settled Areas of Okahandja

Although the ISA residents may seem to be a homogenous group of people, at a closer look, there is much diversity within the two settlements. There are a variety of cultures, income-levels, and neighborhoods. To properly assess the electricity needs of Five Rand and Oshetu One, it is important to understand these socio-economic conditions as well as information on the formation and governance of the two ISAs.

There are two main factors contributing to the formation of the ISAs in Okahandja: the search for jobs and the availability of land. Since the abolition of apartheid in Namibia in 1990, there have been mass migrations of people looking for work in the area of Okahandja and other urban centers (Winterfeldt et al., 2002, p. 39) (for more information on Namibian history see Appendix A.) Unfortunately, many people have been unable to find adequate employment due to the lack of industry in the area. This influx of migrants is a major contributor to the formation of the two informal settlements. The second factor leading to the creation of informal settlements is that the town government set up an area where people could reside free of charge (Van der Westhuizen, personal communication, March 12, 2003). The newly available plots of land attracted a number of people who moved to the area from all over Namibia; the residents in the settlements then invited their friends and relatives to join them. In order to accommodate the incursion of people, two new settlement areas are being built (Ramakhutla, personal communication, March 25, 2003). Saamstaan, meaning “United” in Afrikaans, and Oshetu Two will absorb some of the excess population.

The two ISAs of Okahandja are not homogenous groups of people, but instead have several subgroups located within each larger community. Within the community of Five Rand and Oshetu One, there are clearly different neighborhoods with different ethnic groups (field observation). One indicator of the diversity is that approximately ten languages are spoken within the two areas. Specific areas where each group live are also known within each settlement as well. For example, there is a large Owambo population living in Oshetu One, and part of Five Rand is known for its large Damara population (for more information on the peoples of Namibia see Appendix A). The different ethnic groups have specific neighborhoods where many people from their ethnic group reside.

In addition to having several different groups of people, the ISAs are also divided into separate areas for housing and for businesses (field observation). For example, in Five Rand, there is a 'main street' area in the middle of the settlement where there are several kiosks (convenience stores) and shebeens (informal bars). Surrounding this centralized area there are several streets with many households. In Oshetu One, there are also specific 'main street' areas in which bars and kiosks are located. Although in Oshetu One, it appears that these centralized business areas exist for each 'neighborhood' within the settlement. In addition, Oshetu One has clearly defined plots, whether business or household, and demarcated roads, and overall it is more organized than Five Rand.

There are also a variety of income levels of the people living within the settlements (field observation). The quality of the building materials and construction of a particular household is one financial indicator. Another gauge of the income level is whether or not the house has been painted. A third indicator of 'wealth' is if the resident has the financial ability to buy new household appliances such as TV's, refrigerators, or stoves. Different income levels also exist among the shebeens and kiosks of the area. As with housing, the construction, materials, and paint used to build a shebeen can also demonstrate the status of the establishment. Shebeens can range from having no furnishings and a makeshift bar all the way up to having several tables and chairs set up with pool tables and even an arcade machine.

Within the two settlements there are needs committees that help manage the ISAs (Van der Westhuizen, personal communication, March 12, 2003). Oshetu One and Saamstaan, a future settlement area, have local leaders on the needs committee from the areas that were chosen by the ISA residents. These local leaders serve as liaisons between the Town Council and the settlement. In addition, their support and understanding of any local program is necessary because their opinions are very influential within the community. The local leaders of the settlements can also facilitate communication and mediate conflicts between the Town Council and the ISA residents. In addition, Five Rand elected Councilman Benhard to the Town Council of Okahandja for better representation in town politics (Van der Westhuizen, personal communication, March 12, 2003). The Town Council of Okahandja consists of six members and a mayor who manage and improve the town. (For more information on the Town Council see Appendix B.)

2.1.2 Challenges within the ISAs

The residents of ISAs struggle with many problems, and Five Rand and Oshetu One are no exception. Some of the main challenges that the residents in these ISAs face are overcrowding, safety, and health issues. To assemble appropriate solar recommendations it is necessary to understand these challenges as well as the many opportunities for improvement with the two areas. Although providing the ISAs with electricity recommendations is important, it must be taken into consideration with the many other development issues.

One of the main problems is overcrowding and the ISAs are now growing very quickly, compounding the issue (Van der Westhuizen, personal communication, March 12, 2003). Although the actual growth rate of the area is unknown, Namibia is growing at a rate of about three percent (McGuire, personal communication, 23 April, 2003). The overcrowded conditions create a situation where a large number of people have a limited number of resources. To illustrate these conditions, in Five Rand people wait in lines every night to obtain water from the limited number of water taps (Benhard, personal communication, March 26, 2003). In addition, in both settlements, the average household of only a few rooms has six people living in it (survey data).

Although overcrowding is a problem in both settlements, it manifests itself in different ways (field observations). In Oshetu One, several family groups have settled in plots originally designated for just one family group. Many newcomers have built shacks in the yards of friends or relatives, creating an extremely congested situation of several households on one small plot of land. The representatives of the community are unsure of the number of households in the area because of the rapid growth, but they estimate about five to seven hundred households in Oshetu One. Five Rand is less organized than Oshetu One; there are no clearly defined plots and people build their households in a haphazard manner along the roads.

In addition to overcrowding, safety is a large issue within the ISAs, and knowledge of electricity related safety is absent in both locations (field observation). Many of those who do have electricity have obtained it through illegal connections to the national grid (Benhard, personal communication, March 26, 2003). The connections are made with inadequate wires running along the ground, a very dangerous situation (Van der Westhuizen, personal communication, March 12, 2003).

Very often a large amount of current is being run through small-gauge, worn wires or telephone lines. There have been accidents in the informal settlements due to this precarious situation. One incident occurred when a wire ran between two metal shacks; a woman chased a child between the two households, touched both houses, thus completing the circuit, and was electrocuted (Ben Bois, personal communication, March 12, 2003).

Another safety hazard occurs from the methods of nighttime lighting that people use in their households (Eichas, personal communication, March 27, 2003). Several fires have occurred because of misuse of candles, and residents have reported that about four houses burn down each month. Very often, children are the victims of the fires. Paraffin is also used for nighttime lighting and residents have stated that children have become ill because they will drink paraffin, mistaking it for a beverage due to the fact that it is stored in soda bottles (Van der Westhuizen, personal communication, April 15, 2003).

Other health and safety hazards that residents face occur because of the fuels they use for cooking. Over 80% of residents reported that they cook using firewood (survey data), and although many of the fires are outside of the household it can still negatively affect the health of the residents (G8 Renewable Energy Task Force, 2000, p.21). Cooking with biomass is reported to lower life expectancy and lead to acute respiratory illness even when cooking is done outdoors. Although the residents with gas stoves are in the minority, there are also hazards associated with using this fuel (Van der Westhuizen, personal communication, March 12, 2003). Several accidents have occurred due to misuse of gas, and therefore, residents are afraid of using it. The third main cooking method used in the informal settlements is paraffin stoves, and paraffin can cause health problems with children as stated above.

2.2 Requirements for a Successful Solar Project

Throughout the world, solar energy is being more widely used in both urban and rural areas. Within these different settings, success of solar technology projects varies widely, usually based on several factors. In order to provide appropriate recommendations concerning solar options, it is necessary to understand the successes and failures of past projects. There are two key characteristics of a successful solar project: education of the users so they are empowered to operate, maintain, and repair their equipment and community participation in the development process so the needs of the residents are satisfied.

2.2.1 Importance of Educating Users about Solar Technology

Solar technologies are most often successful when users are educated on operation, maintenance, and repair of the equipment. With education about these three components, solar equipment can be properly utilized throughout its lifetime. When equipment is broken or damaged due to poor operation and/or maintenance, or takes a long time to repair, the people often reject the technology because they cannot benefit from it. Rejection of solar technologies can range from dissatisfaction with the service, to purposely sabotaging the equipment; therefore, education can be a valuable investment in any solar energy project.

Everyday users must understand the operation of solar equipment because insufficient training can result in hesitancy to use the equipment as well as damage from misuse. For example, 'Home Power!,' a program developed by the Ministry of Mines and Energy (MME) of Namibia, that provides solar and gas equipment to homes and small business on loans, had several difficulties due to insufficient training of the users (Hipangelwa, personal communication, April 17, 2003). Two to three hour demonstrations would occur in small towns to explain the operation and maintenance of the equipment. This amount of time, however, was not enough to thoroughly educate the users on the proper use of their system, which lead to the misuse and damage of the equipment. In addition, many users would try to run appliances that would draw a large amount of electricity off of a small solar setup, which would then overload and break the system. Also, people would disconnect their battery and use it at different locations, a practice that would eventually destroy it. In order to prevent more problems, the MME published brochures and pamphlets in order to educate the users about the limitations of their solar system. The brochures contained several pictures of appliances that could and could not be used with the system. The dissemination of information through these methods has had some success in educating users about the operation and limitations of their system.

Two more examples of projects that had inadequate education were in Eastern Cape, South Africa and Gibeon, Namibia. The first example, in a non-electrified school in Eastern Cape, South Africa, a project where solar powered lights were installed, the community's needs remained unsatisfied due to their inability to operate the equipment. (Leitch et al., 1997, pp. 137-138). Simple procedures such as finding the "on" switch or changing a light bulb were not taught or explained in any of the instruction manuals, and therefore, the equipment was useless to the people. To further illustrate the importance of understanding operations, in Gibeon, Namibia, a solar water pump was installed at the AME private school, where one man was responsible for the operating the equipment. (Yaron, Irving, & Jansson, S., 1994, p. 121). Due to the man's lack of education about the operation of the solar water pump, the battery overcharged causing the solar system to break. The townspeople became displeased with the performance of the solar water pump because their battery could no longer function properly.

Education on maintenance of a solar system is very important to the success of solar projects. Poor performance of solar technologies leads to an overall project failure because the technology cannot meet the needs of the community. A major aspect of maintaining solar technologies is to properly clean the equipment. For example, when photovoltaic (PV) water pumps and solar panels were installed on a farm called Khorixas, located in Mesepotemie, Namibia, the workers were not aware that the solar panels needed to be cleaned (Yaron, 1994, p. 120). Therefore, shortly after the installation, the panels were covered in dust causing a decrease in the overall efficiency of the panels. This problem hindered the people's ability to use the solar technology, consequently causing the project to be less successful than it could have been.

Solar equipment must be repaired in a reasonable amount of time by well-trained technicians or the people of the community must be trained to repair the equipment in order to have a successful project. In either case the repairs must be prompt. One example of project difficulties because of the lack of technicians and proper technician training is in the 'Home Power' project Hipangelwa, personal communication, April 17, 2003). One hundred solar technicians were trained to repair, install, and maintain the solar equipment. However, many discontinued their practice leaving only 14 technicians to cover the whole country. Consequently, the great amount of time that it takes for a solar system to be repaired has left many customers unsatisfied. In addition, there have also been complaints that the technicians were not professional, and this problem was due to their short period of training. Another example of problems caused by lack of technicians occurred in Sukatani, Indonesia, a small village located in a rural setting. When a photovoltaic system was installed, the community was faced with a disadvantage because no immediate technical support was available due to their remote location, and they were not educated on repairing the equipment themselves (Global, 2003). The community soon discontinued the use and payments for the solar system. Therefore, in a small village like Sukatani, it is vital that there is technical support in order ensure the success of a project. In another example, at Etanga Clinic, located in Koakoland, Namibia, solar energy was used for water pumping, electricity, and radios, however, technical support was not readily accessible (Yaron, 1994, p, 122). Mr. Nangolo, a clinic nurse, was overall very pleased with the system. However, the only problem was that technical support needed to be called out for the simplest problems from a very far distance because community training was not provided.

In cities where technical support is readily available and technology use is widespread, advanced technologies can be easily installed and maintained fully. Two examples of cities that have successfully utilized solar technologies are Kalil, Israel, and Kerava, Finland (Singh, 1998, p. 148, p. 160). Both cities have been extremely successful in using solar energy because many of the residents are exposed to advanced technology everyday and can easily learn how to use, understand, and maintain the equipment. Other cities understand the necessity of good technical support and are trying to develop programs to deal with these issues. A regional solar electric training and awareness workshop was completed in Nairobi, Kenya where participants discussed lack of qualified people who understand PV technologies and the importance of having adequate service and maintenance to reduce amount of broken and unused systems in the region (African, 1992, pp. 4-5).

2.2.2 Increasing Success with Participatory Approaches in ISAs

Local residents of the ISAs must be included when developing solar projects in order to have a high level of acceptance within the community, a characteristic of a successful project (Ford, personal interview, February 21, 2003). The people living in these ISAs possess a tremendous amount of knowledge about ways to effectively improve their area. The complexities that exist within the ISA often cause simple or imposed solutions to fail. By listening to the residents, several future problems can be avoided, including problems with solar projects. Methods of solving problems that involve local residents are called participatory approaches (PA). These methods have been used all over the world with promising results.

Participatory approaches are characterized by a great deal of community involvement in the planning process. In these approaches there are three main areas of data gathering: institutional, spatial, and temporal (Ford, 2001, p. 7). In order to obtain these data, there are a variety of exercises that can be used. There are procedures for everything from village sketch maps to gender calendars to institutional profiles. One part of the participatory methods includes a household survey, used to obtain detailed data from many residents (Ford, 2001, p. 78). Surveys have been used for many years to collect various types of information about less developed areas. Surveys can be used to measure wealth in informal settlements, and these data over time can demonstrate a trend that can be used to determine the effectiveness of a program. Surveys can also be used to collect other types of data, such as energy usage in an area. The most important aspect of a survey is to ensure that the questions are worded so they are understandable and not offensive to the local community. Another vital aspect to survey design is to involve local residents and allow them to come up with questions. In addition, it is important to pretest the survey to ensure the questions are worded properly and are culturally appropriate.

Sustainable development is impossible when locals are not involved, so they must be involved in every step of the process (Ford, personal communication, February 21, 2003). Participatory approaches allow for the necessary involvement of the local people. This method greatly increases the chances of project success. For example, in Swakopmund, Namibia, community members sold food from a residential building to commuters traveling from Swakopmund to a nearby town (Ramakhutla, personnel communication, March 3, 2003). There were terrible hygiene conditions and no selling standards, and in order to address this problem the Town Council worked with residents to reach an agreement about a new market area. The Town Council and the community decided to build a new market area, and also agreed on hygiene and sale standards; however, the location of the new market place was not discussed. The new market was built 200 meters away from the original location of the markets. Fearing the loss of business from the commuters, the retailers refused to move into the new market place. Therefore, the Town Council had to demolish the market and build a new one where the people wanted, costing the town a significant amount of money.

Different views occur between the government's agenda and the resident's needs. Therefore, PA is needed to ensure that leaders and residents have similar goals. In addition to the operational problems that occurred in the school in Eastern Cape, many people of the community would also have liked the money to be spent elsewhere, such as on new schools and classrooms. (Leitch et al., 1997, pp. 137-138). The community had different ideas and priorities than the decision makers on how to improve the quality of their life. By using PA, the wants and needs of the users can be understood and taken into consideration.

In the preliminary stages of a project, communities may have misconceptions of the services that they will be receiving if they are not properly informed. The communities should be made fully aware of the Town Council's plans about any sort of new technologies they might receive. This type of interaction can be accomplished through PA. Another problem in the school of Eastern Cape was that the solar electricity could only be used for low power appliances, not the appliances they wanted to use (Leitch, 1997, p. 138). Since the people were not consulted at the preliminary stages of the project, they were not satisfied with the final outcome. To further understand the importance of PA, we will discuss another example of what happens when PA is not used. In the small villages of Abu Sorra and El Mucherfeh located in Syria, solar technologies were installed to provide PV power supplies to each of the towns (Hamzeh, 1995, p. 548). Centralized and decentralized PV systems were used in these villages. Although they had never had electricity before, the users were quite pleased regarding their new electricity. However, when some of the users were switched from centralized to decentralized power, they were disappointed because they received a lower amount of power from the decentralized system. Ttherefore, PA would have contributed to the successfulness of the project.

When a new technology is being installed, it must have a certain capacity in order to satisfy and improve upon the current and projected needs of the people who will be using it, which can be done through PA. In the home of Mr. and Mrs. Andreas Nangolo in Onatsi, Namibia, candles were once used for lighting. However, since the installation of a PV system, four fluorescent lights, a color television and a portable black and white television have been in operation (Yaron, 1994, p. 127). Now, after having this system for a year and a half, "they would prefer to connect to the mains to be able to iron and cook" (Yaron, 1994, p. 128). Once the couple had received a taste of something they liked, such as electricity, they desired more. PA could have helped determine what is currently used and what people want in the future in order to determine the appropriate amount and type of technology that a community would be satisfied with.

2.3 Solar Electricity Generation

Solar energy represents one of the largest "unlimited" sources of energy available to mankind. Through several different methods sunlight can be transformed into electrical energy. Solar technology has benefited from increased concern about the negative aspects of traditional energy sources, as well as increased implementation in niche markets. Old technologies have been revised and several new ones have come to the market. In order to provide Okahandja with the best possible solar power options, it is important to know about the available technologies and how they are utilized. This knowledge will allow a solar electricity setup to be tailored to the needs of Okahandja, if it turns out to be appropriate.

2.3.1 Photovoltaic Technologies

One of the primary means of capturing solar energy is by the use of photovoltaic (PV) panels to generate electricity. Sunlight shines on PV panels, which in turn creates a direct current (DC). In an off-grid setup, the generated power is either used immediately or stored in batteries. A regulator or charge controller is used to provide the proper amount of current to the batteries, thus optimizing their lifetime and preventing overcharging (Walbaum, personal communication, April 3, 2003).

The electrical current is usually kept in DC form, and all devices that will run off the solar system must run off DC current. In larger setups, the power is often inverted into alternating current (AC). This conversion of the current allows for the use of common household electrical equipment, as well as allows for simple and efficient distribution of the power. Although PV can have many benefits, its high cost and other limitations must be taken into account when deciding on which appliances will be used with the system (for more information on common appliances, see Appendix C).

A major drawback to using PV is the high initial cost associated with setting up the system. While advances in PV production techniques have led to decreasing prices for PV panels, they are still very expensive (Seiferth, personal communication, April 3, 2003). When panels were first developed, more energy was required to manufacture a panel than the panel would provide over its entire lifetime, hence making them a poor choice in most situations. However, recent changes in production technique mean that this low-efficiency production is no longer the case. PV can be a cost effective solution to energy problems in many locations. Due to the high initial installation costs, only when considered over the lifetime of the installation, can PV technologies compete with other electricity options. Thus, when comparing PV to other electricity options it is important to consider costs over the lifetime of the project. Most PV cells carry a 20 to 30 year warranty and can often last longer. Therefore it is also important to consider the future of other energy technology markets over the next 20 to 30 years (see Appendix D for energy market predictions for the Southern Africa). Other components of the system, such as the batteries, may need to be replaced more often (Phillips, personal communication, April 8, 2003).

When choosing a solar panel, there are several factors to consider including brand, size, and mounting options. Several companies manufacture solar PV panels, some international companies as well as smaller companies located in Africa (for a listing of solar energy providers see Appendix E). Panels come in varying sizes, along the range of 36-150 watts/panel (Phillips, personal communication, April 8, 2003). This figure is the number of watts that the panel will generate in one hour while exposed to full sunlight. In Namibia, it is common practice to use the figure of 6 hours of full sunlight each day on a fixed panel (Seiferth, personal communication, April 3, 2003). One option that is sometimes used to increase this figure is a moving panel rack, or Sun Tracker (Walbaum, personal communication, April 3, 2003). There are currently two types available in Namibia, one which functions by gas transfer, and one that is driven by an electric motor. The gas transfer type works well in low wind situations and the power required to adjust the angle is supplied directly from the sun. The electrically driven rack has the disadvantage of requiring electricity for operation, but it is unaffected by wind (Steuber, personal communication, April 8, 2003).

2.3.2 Configuration Options

When designing a solar setup, there are several components besides PV panels that must be considered such as batteries, charge controllers and inverters. In addition, there are different options for the panel setup such as centralized or decentralized arrangements. In order to provide the best solar options to the town, it is necessary to thoroughly understand each component and the options that are available.

In any solar power system that is not connected to other power sources, it is important to have a means to store energy for use at night or in cloudy weather. Deep cycle batteries (batteries made to run over a long period of time and are not damaged when discharged completely) are by far the most common means of accomplishing this task (Walbaum, personal communication, April 3, 2003). There are two important factors in choosing a proper battery setup for a solar power system. One specification, system voltage, must be considered, since all of the components must operate at the same voltage levels. PV panels often generate power at 12 volts, 24 volts, or 36 volts, and the batteries must match this level, which is a matter of configuring the wiring of the batteries. Another important figure to consider is the storage requirements of the system. While it is possible to use the minimum number of batteries and drain them fully each day, this process is very detrimental to battery life. Most deep cycle batteries, particularly the types suitable for use with a solar power system, last for many more cycles if they are not completely discharged each time. Batteries that are discharged by as much as 50% may only last for 3 years while the same batteries would last 15 years if they are only discharged 20% each cycle. This is an important factor to take into consideration when calculating the short term and long-term costs of a solar power system.

In situations where only a small power draw is required, batteries work well, but when large quantities of electricity are required, other solutions may be required. In circumstances where batteries cannot store an ample amount of energy, having a solar energy setup that is connected to an electrical grid will ensure that power will always be available to the users. A grid connected setup means that if the amount of electricity generated by the PV cells at any point is greater than the amount being used, the excess electricity is sent into the grid. This excess is then subtracted from the amount that is later purchased during the night or other peak usage times, such as when dinner is being prepared in the evening. With a large PV array, this option might mean that more energy is produced than used, hence providing income. Smaller setups simply reduce the total electric bill for a given period of time. Kamel (1995) points out that while off-grid setups will totally eliminate bills for power from the national grid; there is always the danger of running out of power. Being grid-connected is a better way to reduce the amount of electricity to be bought off the national grid, while ensuring power availability to the consumers at all times. By being connected to the grid, if there is a sudden increase in population in a city, power will still be available to everyone. The grid will absorb the increased use until the solar array can be upgraded to handle the increased demand.

Since PV panels generate electricity in DC form, no inversion is required to store the energy in batteries. A charge controller or regulator is usually inserted in the system to optimize the charging of the batteries. While it is possible to directly charge batteries without a regulator, careful monitoring is required so as not to over charge, and therefore damage, the batteries. In systems where the final output is in DC form, it is important to have a regulator that prevents the system voltage from rising to dangerous levels and damaging any appliances attached to the system. Charge controllers and regulators can be easily purchased for small-scale applications. In the cases of larger scale solar projects, regulators and charge controllers are custom manufactured to fit specific needs and applications (Walbaum, personal communication, April 3, 2003).

For many power applications, AC power is required. Since solar power systems generate DC power, an inverter is needed to convert the power into AC. Inverters are not practical for very small setups, but for many larger setups, particularly mini-grids, inverters can be implemented successfully. For medium sized applications, such as a single house or a small group of houses it is possible to purchase small inverters. Some higher quality inverters can be setup in parallel to deal with larger loads. This technique can be used on mini-grids up to a point, however, for very large setups, other inverters must be pursued.

Whether grid connected or not, when setting up the actual components of a solar power system, they can be set in two different configurations, centralized or decentralized. Centralized systems generate and store electricity in one location, then distribute it to other buildings via transmission lines. In most cases the decentralized systems are used in individual locations, with each building having its own panels, storage devices, and inverters. Hamzeh (1995) points out that, "The overall efficiency of the centralized PV system is 20% less than the efficiency of the individual one, because of the inverter losses and greater wiring losses" (p. 548). Moreover, "The centralized system is about 24% more expensive than the individual PV systems" (p. 548). Although centralized PV systems are less efficient and more expensive, the ability to repair and maintain equipment in one location rather than at individual homes or buildings may be more convenient for a community as a whole.

2.3.3 Future Solar Options

In addition to PV technology, there are several other solar electricity generation technologies currently being developed. Two possible future options for solar electricity generation for the township are solar thermal generation and Stirling Dish technology. Although these technologies are still being developed, they could be a viable option for a mini-grid type setup in the future.

An alternative to PV electric generation is solar thermal electric generation. In a thermal system coolant is cycled through a system of pipes. These pipes run through an array of reflectors, which focus sunlight onto the pipes. As the coolant travels through the pipes it is heated to a very high temperature. The coolant then enters a converter where the heat energy is transferred into steam. This steam is used to turn a turbine, which provides the rotational force needed to run an alternator. The output from the alternator is in AC form and can be run immediately to the end users. In order to sustain output twenty-four hours a day, another fuel source is often used to create heat when the sun is not available. Natural gas and coal are two of the most commonly used fuel sources for this application.

Thermal electric generation has several benefits over PV. In most cases it is far more efficient, often in the range of 22-30% compared to 12-15% for most PV technologies (Consumer Energy Center, 2003). Due to the relative simplicity of the required components, manufacturing costs are often substantially lower and are constantly decreasing. Integration with another power source is also much simpler than with PV since all that is required is a heat source, and the same turbine and steam generator can be used. An additional benefit of using a turbine is that the generated electricity is already in AC form, thus allowing for direct distribution without inverters and other expensive power conversion equipment. One drawback to AC power comes when storage issues are raised, since batteries function in DC only. For this reason it is best to configure a thermal system to run all the time, using solar when available and another fuel source at other times. Thermal electric generation with a large solar component may be a viable option for consideration in the future.

Although there are many benefits to thermal electric generation, there are also some drawbacks that prevent its widespread use. Initial costs of thermal electric generation are lower than that of PV, but over its entire lifetime there are several 'hidden' maintenance charges because of the numerous moving parts. Also, due to the numerous moving parts, well-trained technicians must be readily available to repair the system quickly. In addition, this method of power generation is still in development, and has not yet been tested or used for peri-urban electrification.

New solar technologies such as the Stirling Dish (SD) are being developed for solar-electricity generation (SES, 2002, Section: Solar Overview). SD technology is a new, more efficient version of thermal electric generation, which involves focusing light onto a Stirling engine. The light heats the surface of the engine to a high temperature, causing the engine to rotate. The rotation is used to turn an electrical generator. This process creates a reliable AC output, which can be conditioned for use in many situations. Due to the limited number of moving parts, stirling dish systems are very reliable and are more efficient than PV systems because they have efficiency ratings near 30% (SES, 2002, Section: Solar Overview).

SD technology will most likely be used for large-scale power generation because of the reliability and overall efficiency. Another large benefit of this technology is that startup costs are less than those for PV cells for an equivalent electricity generation system. While SD technology is very promising, it is still in the development stage. Demonstration units exist in Nevada and South Africa. They have not been released commercially and there is no set date for this to occur.

Chapter 3. **METHODOLOGY**

The informal settlement areas (ISAs) of Okahandja, Oshetu One and Five Rand, currently have little or no access to electricity. The goal of our project was to provide a cost estimate to the Township of Okahandja of solar options that would meet the electricity needs of the residents in the two ISAs and to assemble recommendations about steps required for any electricity development project in the ISAs. In order to reach our goal, our methodology was divided into four main steps: assessing the electricity needs, analyzing the needs data, developing a cost estimate for solar options, and developing recommendations for further steps.

3.1 Assessment of Electrical Usage of Residents in Five Rand and Oshetu One

To assess the amount of electricity the residents of the ISAs in Okahandja use and the amount they plan on using in the future, we completed a survey. We carefully designed and administered two questionnaires and then analyzed the results. The survey was used to provide electrical usage information that would help us reach our goal of determining a cost estimate of appropriate solar equipment. The survey also allowed a number of residents to input their ideas. Community involvement was vital in order to incorporate their concerns, needs, and desires into our considerations. The survey provided us with a considerable amount of data that covered electrical usage issues.

A survey was chosen as the main method for data gathering for several reasons. Using a survey allows many individuals who might not speak up in a group format to tell us their needs. Also, a survey allowed us to gather data and address concerns in a one-on-one basis and to answer each resident's questions. The residents often answered the questionnaire as a household group, which was beneficial because the entire household would most likely make many decisions regarding electricity usage. Another aspect of surveying individual households was that we were able to use direct observation while conducting the survey. Observing the settlements, people, their cooking methods, and their use of electricity, if any, allowed us to gain data to support or sometimes refute the answers that we received.

Another reason a survey was chosen was to involve several members of the community. Community participation lays the groundwork for support of future projects. In addition, community involvement improves the chances of project success because the people expressed their needs and gained an increased understanding of the process since they were directly involved. This individual or small household group method of surveying was chosen over conducting group participatory exercises because of language barriers and problems with some hostility within the settlements. Town workers advised us not to gather the people in a large group because some people were angry with the town for cutting off their illegal electrical supply and for not providing adequate electricity. It could have been possible that the frustration over these issues could have been directed toward our group.

After the survey method was chosen, the questionnaires were carefully designed. The first step to designing a questionnaire was to decide the information that was needed in order to conduct a comprehensive electricity assessment. The group decided that current usage data and future usage data were the primary information needed when making an electricity assessment. Demographic information was also gathered so that other societal factors and trends surrounding energy usage could be examined, such as gender bias in electrical usage. One challenge of general survey design was to create easily understandable questions that could obtain data for these complex issues. The questions also had to be translated into several different languages, another reason that they had to be clear.

Two questionnaires were designed in order to cover three situations in the settlements. The three situations were households with a legal electricity connection (very rare), households with an illegal electricity connection (somewhat common, particularly in Five Rand) and households with no electricity (most of Oshetu One and much of Five Rand). The first questionnaire was designed for households with electricity and the second questionnaire was designed for households without electricity. Separate questionnaires were not created for legal versus illegal electrical connections because of validity issues. For example, people might be inclined to lie about their electricity connection due to fear that we would report an illegal connection to the town. Another reason that legal versus illegal electricity connections were not included in the survey was because it did not affect our objectives of establishing the current electricity situation and assessing the resident's knowledge of electricity, which were the purpose of asking about current usage. Having questionnaires for people who had electricity and people who did not have electricity, however, was important so we could assess the validity of answers of residents who have electricity versus answers of people who did not have electricity. For example, people without electricity may not have a realistic idea of the appliances that use electricity. The separation of the data allows us to examine the data for these issues.

The objectives of Questionnaire One (for residents with an electricity connection) were to determine the current uses of electricity in the settlement, to determine the future demand of electricity in the settlement, to assess the experience and education level of the people with electricity, and to reveal any trends between electricity and demographic information. In order to reach all of these objectives, Questionnaire One was divided into three parts. The objective of Part I was to gather demographic information and to ask questions that were easy for the residents to answer. These warm-up type questions allowed the interviewee to relax while giving us useful data. Also, gender issues could arise with respect to electricity usage, so our design took into consideration whether the participant was male or female. In order to determine which appliances the residents could currently afford and/or use off the illegal connection, Part II of the questionnaire contained questions about the current use of electricity. In this section residents were asked to list the appliances they had. Part III contained questions about the appliances that the residents would purchase in the next three years if they had an adequate electrical supply. This question was asked in order to assess the future demand for electricity in the area. Also, contained in Part III was a ranking exercise for identifying the top three appliances, and this question was asked if the resident were to purchase more than three appliances. This ranking exercise allowed us to determine the relative importance of various appliances to the people in the ISAs.

The objective of Questionnaire Two (for residents without electricity) was also to determine the future electrical demand of the settlements and to determine the relative importance of appliances. Part I of Questionnaire Two was identical to Part I of Questionnaire One, containing questions to gather demographic information. Part II of Questionnaire Two is the same as Part III of Questionnaire One; it contains questions about which appliances the people would buy. Also, to determine the relative importance of each appliance, the top three appliance ranking exercise was also included in Part II.

The next step in the process of researching the settlements was to familiarize ourselves with the local leaders and to involve the local leaders in survey design. Gaining rapport with the local leaders was paramount to the success of our survey. Without their support to prepare the residents before we arrived, translate the questionnaires into various languages, and smooth over conflicts, the survey would not have been possible. We met with the local leaders twice in order to design the process and to answer their questions. The Saamstaan group provided a list of their questions regarding electricity use and solar energy information, and from those questions we were able to identify the concerns of the residents, which helped us to later develop general electricity recommendations (for Saamstaan group questions, see Appendix F). To be able to communicate with the local people, we reviewed the questionnaire with the translators who would be traveling with us to ensure everyone understood the questions. In order to determine if any questions were difficult for the residents to answer, we pre-tested the survey on the local representatives (Final Questionnaire in Appendix G). The questionnaires were then pre-tested on local residents. After completing a small number of questionnaires, one question was deleted from the survey because when it was asked, the residents would laugh for a while and then not answer. The question asked if the resident would still use traditional ways of cooking if they had an electric stove. The answer to this question was so obvious to the residents that we did not ask any other survey participants.

We traveled to the informal settlements, Five Rand and Oshetu One, with translators who administered the survey's questions to the selected interviewees and provided us with the answers. Very often the translator was a local community leader, which helped us gain rapport with the residents. Having a respected leader was essential in order to be allowed to interview the people. In addition, the community leaders helped us identify different sections within each settlement and obtain data from each section, during the two days of questioning in each area. Opportunistic sampling was used to administer the survey. Other statistical methods of sampling were not used because of time constraints and lack of a sampling framework for the settlements. Despite the fact that a statistical random sample was not used, a significant number of interviews were completed in each settlement, 162 surveys in Five Rand and 98 in Oshetu One which we feel is representative of the entirety of both settlements.

3.2 Analysis of Needs Assessment

To understand the needs and the wants of the residents, the data gathered in the survey were carefully compiled and analyzed for each settlement in order to determine an average amount of electricity needed per household over the next few years. In addition to calculating the predicted amount of electricity, we established a need and desire for electricity in the two settlements to justify any electricity project. Also, the usage data was analyzed for trends in age, gender, length of time in the area, and number and age of people in household to look for any validity issues that may have affected our calculations.

The first step to analyzing the data was to establish a need for electricity. This task was accomplished through assessing the drawbacks of the current electricity setup and assessing the desire of the residents through informal interview data. Safety issues as well as convenience issues were examined to assess problems with the current situation. In order to do a qualitative assessment of safety issues, the current methods of cooking and lighting were analyzed. All data were carefully examined in order to determine the hazards posed by the current cooking methods.

After establishing a need for electricity, the future average predicted usage number was calculated directly from survey data. If the people were to gain access to a reliable source of electricity, it would be important to find out the types of appliances they would want and try to run off of their connection. The residents were asked to list the appliances that they would buy if they had electricity. The amperage required for each appliance was multiplied by the predicted usage time of the appliances and the appliance wattage specifications, thus creating an estimate of how much electricity would be used each day. The predicted usage times were determined by informal interviews, and the appliance wattage specifications were determined by looking at representative appliances available at a local store in Okahandja. This calculation provided us with an estimate of the average number of kilowatt-hours that would be required per household per day. These data were then applied to solar equipment requirements.

The next step was to produce a high-end predicted average kilowatt-hour requirement figure, taking into consideration items that may have been left out, such as lights, and the possibility that the residents would purchase all the appliances that they wanted as soon as they receive electricity. In order to do this, the survey looked at which appliances were the most important to the ISA residents, which allowed us to have some basis for determining which appliances, if any, could be eliminated from our energy estimate for each household. The frequency from the top three-preference ranking was compiled and used to determine the maximum average kilowatt-hour per household assuming each appliance was used a specific amount of time each day and each home had a standard set of appliances.

To determine if gender, age, time living in the settlement, type of building lived in (house or shebeen), or number of people living in the household affected the respondents' answers, these data were compared to current electrical usage and future demand data. A correlation would suggest that the demographic variables or type of establishment might have had some effect on the answers, although a correlation by itself does not necessarily imply a causal relationship. A correlation between the variables might play a part in the future demand analysis. Analysis of these variables is important information for the town's future planning.

After compiling all of these data, an assessment was made of the amount of electricity needed per household in each of the settlements. From this number, we were able to examine other possible options by subtracting the amount of electricity needed for large appliances to see the effect that each appliance would have on the total. For example, one solution might be to provide each household with a smaller electrical circuit and then suggest an alternative, but more energy efficient and cost effective, method of cooking.

Increased safety, decreased health risks, and decreased cooking time are three potential benefits of gaining access to electricity. In order to do a qualitative assessment of these issues, the current methods of cooking and lighting were analyzed. Also, the average number of times a household cooks food each day was determined. Another interesting piece of data is the percentage of people currently cooking with gas or paraffin stoves who would buy electric stoves if they had access to electricity. This percentage of people who prefer electric stoves could greatly affect the final recommendation as to whether or not to include enough power electric stove use. All data were carefully examined in order to determine the various possibilities of the different appliances.

3.3 Developing Solar Energy Recommendations

To determine an estimate for solar energy options that would provide the ISAs with an appropriate amount of electric power, we studied the solar energy solutions that were available and viable. The solar energy solutions were ranked and then compared on a cost basis to grid electricity and on their ability to meet the needs of the residents. The solar energy recommendations could be used by the town to eventually decide how to provide the 1200+ households in Five Rand and Oshetu One with electricity as well as provide power to the planned future ISAs of Okahandja.

Following the completion of the survey portion of our project, we determined what equipment would be needed to provide electricity to the settlements. Our first step was to identify what solar energy equipment was available that would suit Okahandja ISAs' needs. We started by contacting companies in Namibia and other areas of the world that would provide us with solar energy equipment information. From each provider we were able to get a list of equipment that was relevant to our project with sizes and costs of each component. Interviews were arranged with several Namibian companies in order to gather more data about equipment and solar energy options. Foreign companies were contacted by email and several were able to provide us with more information.

After contacting six Namibian companies, many combinations of technologies were designed to choose from, such as size of panel arrays and which power conversion hardware could be used with each type of panel. Different configuration options, such as pure solar and solar/grid mixes were also considered. Based on the ISAs' usage requirements we were able to isolate the technologies that would provide a viable solution. Once we knew what products to consider, we calculated how much of each product would be required to supply Okahandja's needs. From this information we estimated the costs that would be associated with each option. At that point, we developed a list, which we presented to our liaison for comments. He was able to make suggestions, which we considered in a revision of our list of options. Based on suggestions from solar equipment providers, a cost assessment, and the needs assessment, we were able to eliminate a number of options from the list. Then, the remaining options were evaluated based on cost and ability to satisfy the needs of the residents; a comparison was also made between grid electricity and the solar options based on the same criteria. These evaluations were included in the information that was presented to the Town Council. The final list of options of solar equipment and the analysis of each option was presented to the Town Council.

3.4 Developing Future Development Plans of Action

In order to develop further research recommendations, several aspects of the societal issues surrounding electricity usage had to be examined. Carrying out an assessment of the current level of electrical knowledge of the residents, taking steps to improve communication between the ISA residents and the Town Council, and assessing the economical situation is the ISAs, are all areas that should be looked into in order to ensure a successful electricity project

The first area that was assessed was the current level of knowledge about electricity. Two main aspects of electricity knowledge were assessed: safety issues and experience. These data were gathered from direct observation of current setups, the percentage of people who have electricity, and informal interviews with the residents while conducting the survey. Also, data were gathered from a list of questions about solar energy and electricity provided from the local Saamstaan group. The concerns about safety and usage issues that the residents had were used to help develop recommendations about educational topics that should be covered.

After the level of safety and experience of the residents was determined, educational recommendations were developed. These recommendations were centered on general electricity knowledge as well as more specific safety issues. The awareness campaign for Home Power, a Namibian solar home system program, was investigated. Several methods of disseminating information that were successfully used in the awareness campaign were analyzed to determine how they could apply to educating the residents in the ISAs about electricity issues.

The next set of recommendations that were developed centered on improving communications between the Town Council and the residents in the ISAs. The level of communication between the residents of the ISAs and the Town Council was assessed through informal interviews with the residents in the ISAs. After the necessity for improvement in communication was established, several possible ideas for improvement in communication between the Town Council and the residents in the ISAs were brainstormed. The list of possible ideas was compiled and then presented to the Town Council in order to assist them in improving communication.

The final recommendation for an economic assessment was developed because of a concern that the residents might not be able to afford any electricity project. Although an assessment of the economic level of the areas was not completed, direct observation data were gathered on the general economic level of the area.

Chapter 4. **RESULTS AND ANALYSIS**

Based on the data that we gathered from the needs assessment, our team developed several solar options and assembled recommendations concerning issues that could arise when implementing an energy project in Okahandja. The five different solar energy options were analyzed and compared in order to determine the most suitable option, from needs and economic perspectives. In addition, information extracted from field observations, such as the communities' general lack of knowledge regarding electrical technology and the need for increased communication between the Town Council and ISAs, is also discussed. Using this information, the team compiled recommendations for the Township of Okahandja, should they pursue the installation of an electrical system in the ISAs.

4.1 Electricity Needs Assessment

The main objectives for the electricity needs assessment were to first confirm the need and desire for electricity and then to quantify this need into an average electricity usage estimate. First, the need for a safe, reliable form of electricity was established. Then, in order to determine appropriate solar energy options, the predicted average electricity usage in kilowatt-hours per household or shebeen (informal bar) per day was calculated. Finally, to verify the accuracy of the estimates, it was also necessary to examine trends within the data as well as any validity issues that may have arisen.

4.1.1 Establishing the Need and Desire for Electricity

In order to determine if providing any electricity was appropriate, the need and desire for electricity within the settlements was first established. The results of the survey, combined with field observations, clearly show that the residents in the ISAs have a strong desire for access to electricity. This task was accomplished in two parts: gathering data on the current electricity situation and gathering data on the desire of the people to be supplied with electricity. The data collected provided information on the inadequate electricity situation within the settlements, which made the need for a reliable, safe, and affordable source of electrical energy very clear.

Currently, the means of obtaining most electricity in the ISAs is through dangerous and/or inadequate illegal connections to the grid, which highlights the lack of infrastructure. In addition, these connections demonstrate that the residents' desire for electricity overrides safety concerns. Also, data collected from informal interviews highlighted this desire by the residents. We found that about 1% of the households in Oshetu One reported having electricity and about 36% of the households in Five Rand have electricity (mostly illegal connections). There are currently far more electrical connections in Five Rand than Oshetu One because in Oshetu One, some of the town workers explained that the town had recently cut and removed most of the illegal electrical connections, which is why so few respondents had them. It is important to take into account that Oshetu One once had many illegal connections, showing that both ISAs have similar desires to gain access to electricity.

Not only are the electricity connections illegal, but they also provide insufficient power to support many everyday appliances. The results from Part II of Questionnaire One (for those with electricity) illustrate that most of the electricity in the ISAs is currently used for lighting and refrigeration. Both of these are relatively low draw applications and therefore can often be supported by the illegal connections. The residents stated that the illegal connections do not provide a steady and even source of power to each household or shebeen. They also reported that their lights often dimmed, indicating that there was not enough power available to go around. This occurrence is because the wiring is inadequate and distribution between the buildings is not controlled. Some of the residents, particularly in Five Rand, owned additional appliances, such as stoves, which they stated would not work, or would only occasionally work due to the limited availability of electricity.

4.1.2 Predicted Electrical Usage

Predicted electrical usage data were determined in order to understand the needs of the people so a suitable energy option could be developed. In order to have a range of usage values, two numbers were calculated for the average predicted electricity usage per household/shebeen. The first number, 18 kWh per day, was based on the assumption that everyone would buy and use the most popular appliances listed in the survey, and the second number, 13.4 kWh per day, was directly calculated from the predicted use section of the survey data. The range of predicted values is needed to assure that the solar options would accommodate the needs of the residents at the present time and into the future.

Our high-end estimate, 18 kWh per day, was calculated by first determining the most desired appliances as measured by the preference ranking exercise on the questionnaire. The top five most frequently listed appliances in both settlements were a stove (two burners), refrigerator, TV, radio, and lights, as can be clearly seen in Figures 4.1 and 4.2. These appliances represented the initial appliances a household or shebeen would be most likely to purchase once electricity was available.

Whenever an appliance was listed in the top three it was tallied, and then the five appliances that occurred the most were used for this estimate. The team realizes that the residents may not be able to afford, or choose to purchase, all of these appliances, especially not all at one time. However, since this source of electricity will be used for many years it is important to take into account the amount of energy needed at a later date when the residents can afford or save money to purchase more appliances. Including extra capacity for other appliances that may be used but did not occur in the top five appliance listing was also very important in order to account for usage increases.

Next, the consumption values for each appliance were determined based on numbers from a local appliance store in Okahandja, which can be seen on Table 4.1. This information is important because it relates to the amount of energy each appliance needs to operate. These appliances are most likely to be purchased by the ISA residents because of their availability. Energy saving appliances, although preferable for use in a solar electric system, have higher retail costs and are not as widely available making them less likely to be purchased by the average ISA household or business.

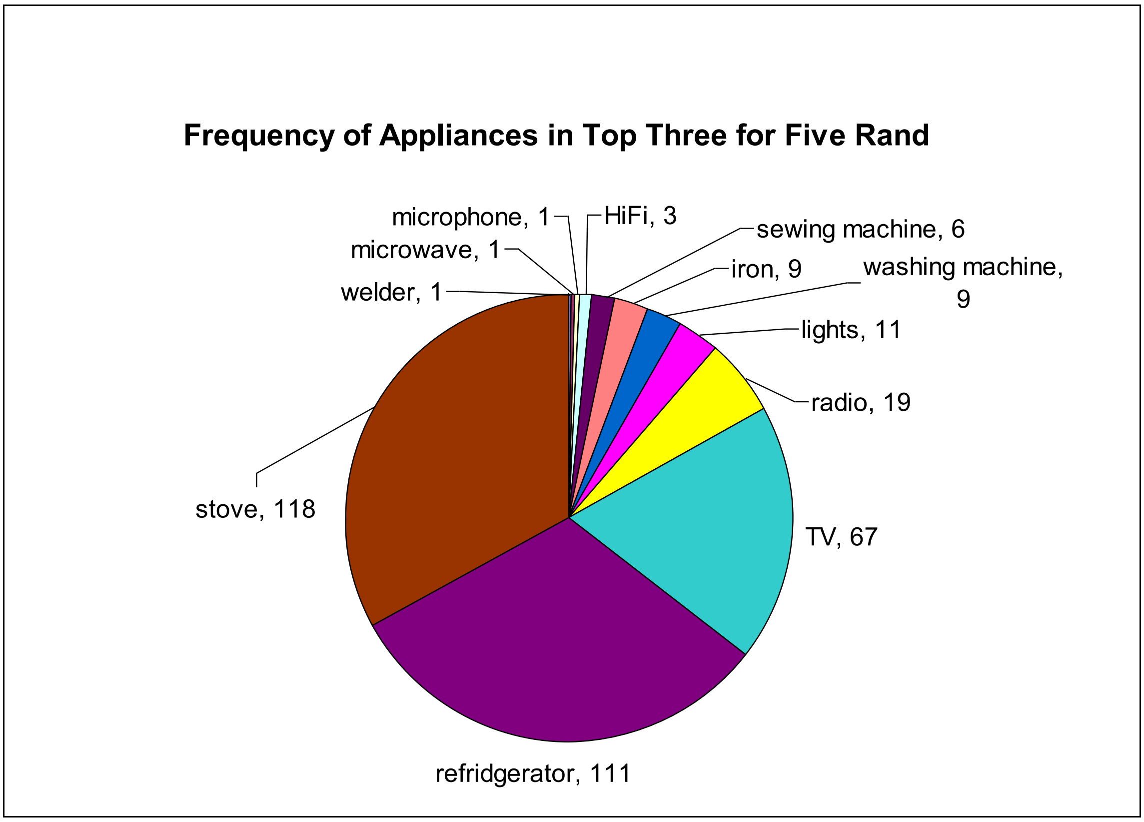

Figure 4.1 Frequency of Appliances in Top Three for Five Rand

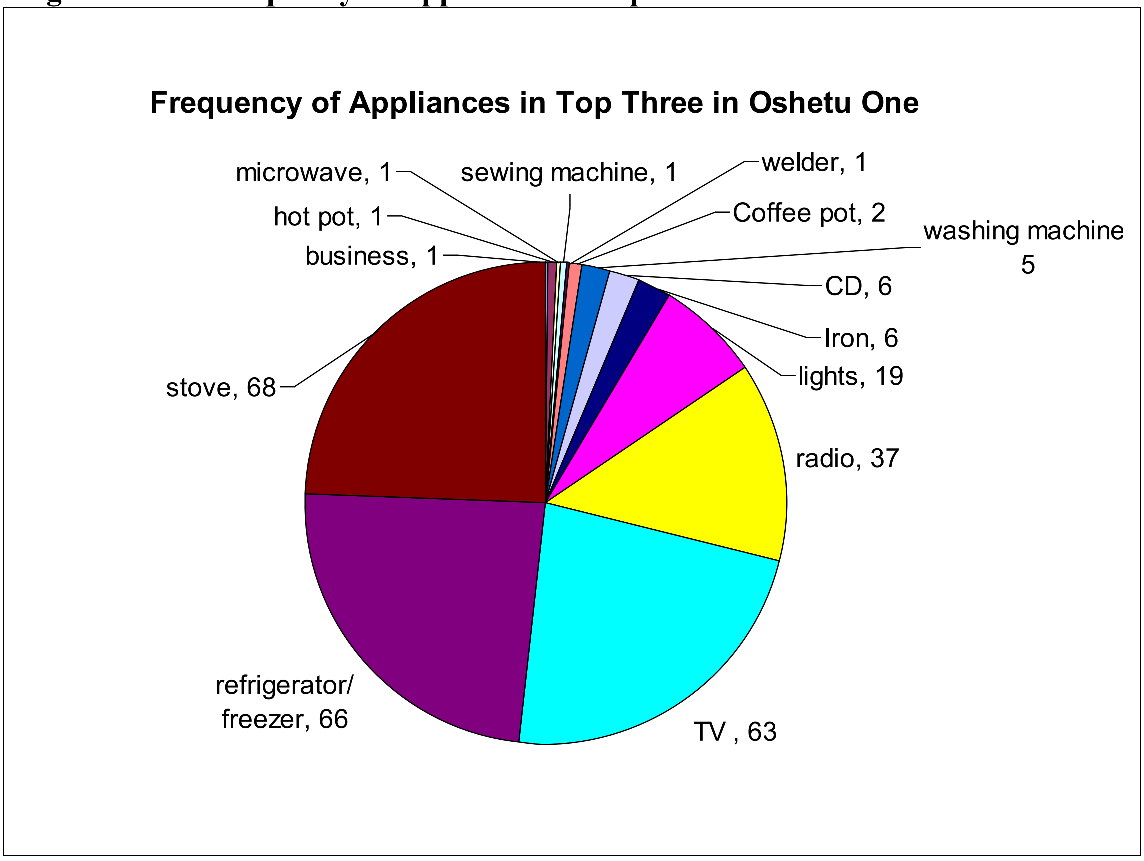

Figure 4.2 Frequency of Appliances in Top Three in Oshetu One

Table 4.1 Appliances, Wattage, and Time Used for High-End Calculation

Appliances	Info	Wattage	Time Estimate (hr/day)	Usage (Watt Hours per day)
Lights	Standard 60W	60 x 6	6	2160
Outdoor Light	Standard 100W	100 x 1	12	1200
TV	Color	85	7	595
Refrigerator	Mid-sized	220	24	5280
Radio	Small	15	7	105
Stove	2-plate	1870/plate	2	7480

In order to calculate the electricity use for each appliance (in kWh) per day, we estimated the average number of operating hours per day. This time estimate, when combined with the energy requirements of the given appliance, creates a measurable quantity that can be used to calculate system requirements. The time assumptions were extracted from survey data and observations (see Table 4.1). The estimate of six hours for lighting is derived from the assumption that lights will be on from about 18:00 to 23:00, since most people reported using nighttime lighting, as well as one hour in the morning when breakfast is being prepared. This figure was supported through discussions with community members. Provisions were also made for an outdoor light, which would be on all night. The seven hour estimate for TV and radio use is drawn from the assumption that most people will watch TV or listen to the radio in the evening hours after most people have returned from work, as well as for a few hours during the day (if a family member is at home). Stoves were assumed to be in use for two hours because the majority of participants reported cooking twice daily. The twenty-four hour estimate for a refrigerator is justified because of the high temperatures in the summer, when a refrigerator would run fulltime.

The amount of electricity each appliance draws (see Table 4.1) multiplied by the amount of time it would be used each day were added to calculate the estimated value of 16.8 kWh per day. The team decided to provide for other small appliances and variations in usage requirements by rounding this number up to *18 kWh per day*. This number is a high-end estimate used in order to ensure that the needs of the people could be met and should be an accurate prediction for usage over the next several years. This estimate contains leeway in case people decide to buy more appliances than they reported on the survey or use an appliance longer than expected each day. An allowance is also included for growth if more homes are constructed in the settlements in the next few years.

The second number, 13.4 kWh per day per household, was calculated from the future use section of the survey results, in which each household or shebeen had the opportunity to list all the appliances they would like to purchase in the future. This usage estimate was calculated by first determining the watt-hour figure for each household or shebeen. The quantity of a certain appliance a resident reported they would buy was multiplied by the number of watts required for the appliance and by the amount of time to be used per day. The number of watts and the amount of time used per day were also taken from the assumptions of Table 4.1. The watt-hour figures for each appliance were totaled in order to determine the watt-hour figure for each individual respondent (household/shebeen). Finally, all of the watt-hour figures from the questionnaires were added together and then divided by the total number of completed questionnaires, thus creating an average usage estimate. This number was then converted from watt-hours into kilowatt-hours, the standard form of electrical measurement for residential use.

The electricity usage number based on the predicted use part of the survey (13.4 kWh) is lower than the general prediction (18 kWh) for several reasons. Nine-percent of the respondents reported that they would not be able to afford electricity at all. In addition, because only twenty-nine percent of the people reported wanting lights, most likely because they assumed it was included, lighting was underreported (although it was accounted for in some questionnaires) in the survey's data, thus lowering the average kilowatt hour figure per household. The team decided not to assume any amount of lighting would be used by the seventy-one percent of people who reported no lighting since it is hard to predict the number of lights a house would buy. In addition we tried to maintain the integrity of the self-reported data. These validity issues were motivators for producing the high-end electricity usage estimate.

Finally, the electrical usage of the shebeens was compared to the usage for an average household to determine if there was a difference between the needs in each case. Many of the shebeens had more appliances than most households at the time the survey was conducted (as seen in figure 4.3). This difference may reflect the use of electricity for business purposes. The requirements of the shebeens were similar to the households as seen in Figure 4.3, but the survey was not structured to properly assess differences in energy requirements. There were insufficient data on time usage and wattage of appliances, so it is difficult to predict if shebeens would draw a disproportionably larger amount of electricity when compared to houses. Despite the lack of data, the team hypothesized that most shebeens would use more electricity than an average home because they would most likely have more refrigerators and would be cooking for more hours each day. For these reasons a shebeen could use a few times more energy than a home. However, the actual number of shebeens is unknown, and their exact usage requirements are unavailable.

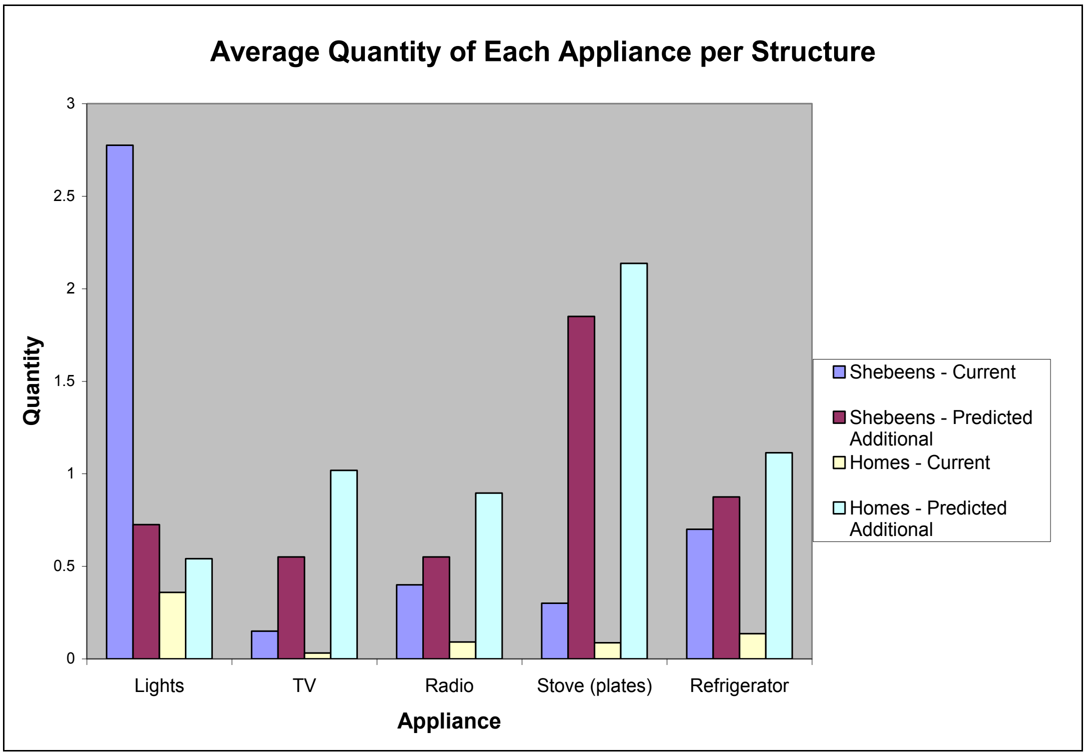

Figure 4.3 Average Current and Predicted Appliances of Households vs. Shebeens

4.1.3 Trends and Validity of Needs Assessment

Since predicting electricity use in the ISAs is a very complex process, it is important to analyze the data for trends and validity issues that arise. There could be several factors that affect a participant's answers on the survey, and therefore several different demographic variables of the data must be analyzed. Understanding how various demographic factors such as gender or age affect answers is important in order to gain a complete understanding of the strengths and weaknesses of the data, as well as identify interesting trends. However, we were unable to find any major trends or validity issues in the data analysis.

There was no gender bias found in our survey results. A bias could indicate that the electrical usage data per household was skewed due to the higher percentage of women who participated in the study (two-thirds of the participants were female and one-third male). We hypothesized that women might report wanting more electricity than men since they might have a greater desire for an electric stove, since many women walk long distances to gather firewood. However, when the data regarding the percentage of women who picked a certain appliance was calculated and compared with the percentage of men who picked the same appliance, no major differences were found in either ISA, as seen in Figure 4.4.

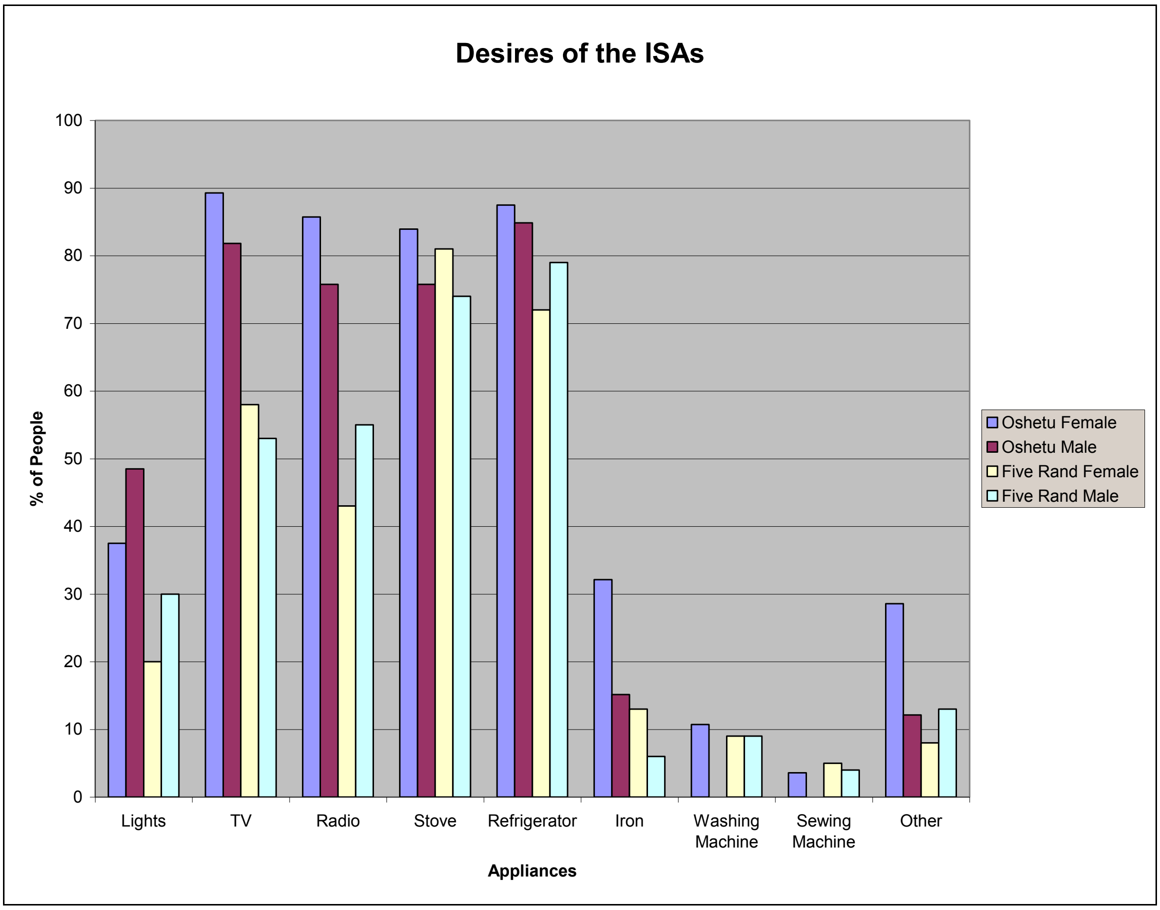

Figure 4.4 Desires of ISAs

The responses of Five Rand and Oshetu One residents were also compared, but no major differences were found. Because a limited number of buildings in Oshetu One have electricity, relative to Five Rand, there was a concern that the people of Oshetu One would have an unrealistic perception of how much electricity they would use in the future. However, when the answers of the people of Five Rand, more of whom have electricity, were compared to the answers of the residents from

Oshetu One, it was found that there was very little difference, as can be seen in Figure 4.4.

Very little correlation was found between predicted electricity usage and the number of people in each household as seen in Figure 4.5. In addition, no correlation could be found regarding the age of the respondents. The small correlation between predicted electricity usage versus the number of people in a household is not great enough to invalidate an average electrical usage number per household. Another analysis was made to determine if the age of the respondent would have an effect on the answers. A trend was looked for in this data to determine if younger members of the community were more familiar with technology or would have different needs than older members of the community. However, the age of the respondent versus predicted electricity usage could not be properly analyzed because 90% of people who answered the survey were between the ages of 21-40. Therefore, a correlation could exist, but one was not exposed by our data.

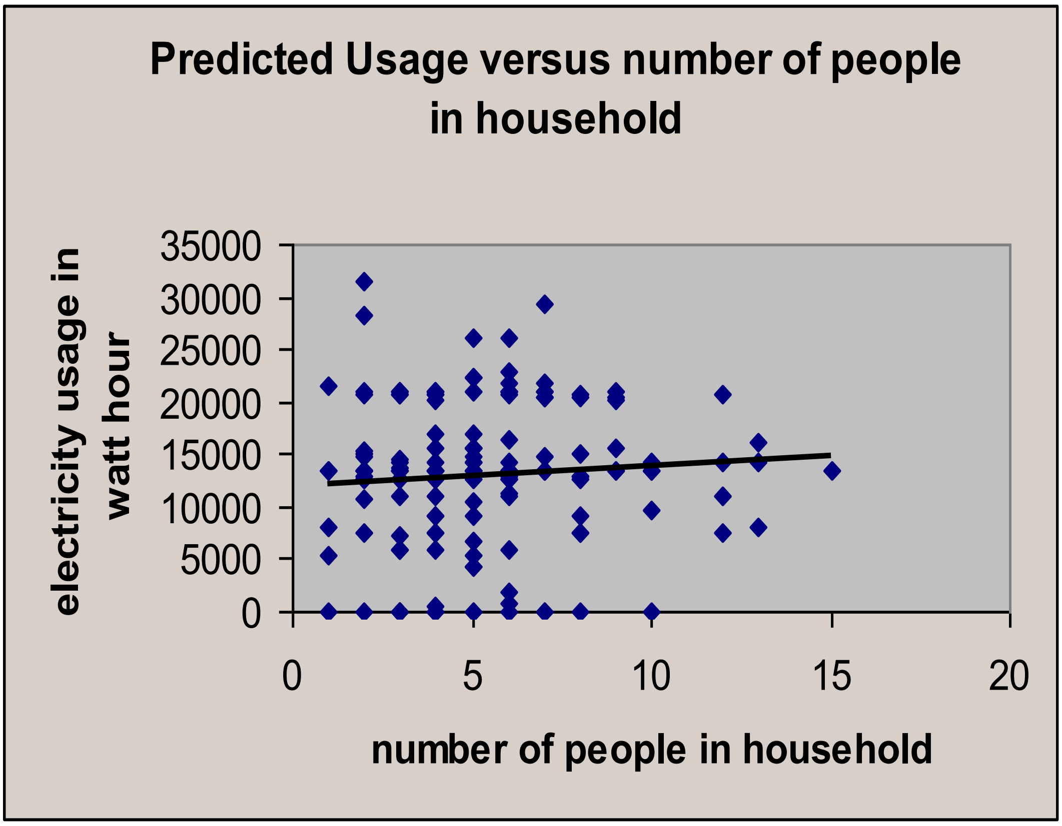

Figure 4.5 Number of People in Household vs. Current Electrical Usage for Five Rand

4.2 Solar Findings

After completing the analysis of the needs assessment, we developed five solar energy options to meet the needs of the residents of Okahandja's ISAs. The advantages and disadvantages of each option were identified for consideration and an overview of the five options is presented in Table 4.2. These options were also compared to grid electricity in order to facilitate the town's decision-making process in choosing an appropriate energy source. In this section, many aspects of each option are examined such as size, cost, acceptability to residents, supportive technologies, and other educational components.

Table 4.2 Solar Setup Options

Setup Options	kWh /day	Capital cost to supply ~1000 households	Support Stove?	Support Refrigerator?
Mini-grid 15 amp	18	N$231,790,000	Yes	Yes
Mini-grid 5 amp	12	N$147,820,000	No	Yes
Mini-grid 1 amp	5	N$60,650,000	No	Low energy/small
Individual Setup	12	N$114,900,000	No	Low energy/small
Thermal Solar Electricity	18	N/A	Yes	Yes
Grid Electricity (note: this does not include the cost of electricity)	18	N$5,800,000	Yes	Yes

The first three options all involve a solar energy setup called a mini-grid, a setup that has many benefits and drawbacks. One of the main advantages of a mini-grid setup is that it can provide a larger amount of electricity than individual setups to an area. Also, it is easy for the town to maintain all of the equipment because of the centralized location. Moreover, if the end-users understand the limitations of the system, then they should not notice a difference between grid and solar electricity. Despite the many benefits of this setup, there are also several disadvantages. The need for wiring from the generation point to each residence raises initial costs. The discrepancy in time between production (when the sun is out) and usage (evening) is one of the main drawbacks to solar technologies in this situation. As a result, a large number of batteries are needed in the system, an expensive drawback to all of the solar options, not only due to cost, but because maintenance requirements increase as well. Mini-grid setups are usually setup using AC power. Due to the ready availability of AC appliances, all of our suggestions use AC power, although this will increase the hardware costs for the system.

The first option is to supply the residences with 18 kWh per day, provided by a large mini-grid setup. With a large mini-grid option, each household could be supplied with a fifteen-amp circuit, enough to support the five primary appliances as well as other small appliances that would fulfill the needs of the residents. The two main issues with this option are that a large number of solar panels would be required to support this massive demand at the extreme capital cost of approximately N$231,790,000 for the entire setup, the details of this estimate are shown in Table 4.3. This table is a screen shot of an Excel spreadsheet. The component information and system variables can be changed and the output values are automatically updated. This spreadsheet allowed us to adjust variables to achieve different cost estimates based on the use of different components.

For these calculations we used equipment quotations provided by Siemens Namibia, with the exception of batteries. The panels are 100W units produced by Shell Renewables, with 12 volt output per panel. The regulators are Solarix Tarom units with a rated capacity of 45 amps. Although a large system would likely use custom made regulators that are much larger, we used these smaller units for an estimate. The same situation occurred with inverters in that the calculations were done with 550W Sinus units, which would not actually function properly in a system of this magnitude. The batteries for this system are manufactured and sold by Willard Batteries. We chose to set the system up to drain the batteries 20% on each cycle, which would provide the longest lifespan for the batteries, thus minimizing maintenance requirements. Even with this low usage level, the batteries would need to be replaced in the middle of the 20 year system life span. Despite the benefits of this option it is most likely too expensive for the township and the users.

Table 4.3 Solar Cost Estimator

Solar Cost Estimator

Component Information

Panel Information		
Brand:	Shell Renewables	
Model:	SM100-12	
Provider:	Siemens Namibia	
Panel Cost (per unit)	4725	N$
Panel Output (per unit)	100	watts
Panel Voltage	12	volts

Regulator Information		
Brand:	Solarix Tarom	
Model:	245	
Provider:	Siemens Namibia	
Regulator Cost (per unit)	1808	N$
Regulator Output (per unit)	45	amps

Inverter Information		
Brand:	Sinus	
Model:	550 I	
Provider:	Siemens Namibia	
Inverter Cost (per unit)	3520	N$
Inverter Output (per unit)	550	watts

Battery Information		
Brand:	Willard Batteries	
Model:		
Provider:	Willard Batteries	
Battery Cost (per unit)	1655.64	N$
Battery Capacity (per unit)	762	ah
Battery Voltage	12	volts

System Variables

System Information		
Circuit Size	15	amps
Electrical Requirements per Home per Day	18	kwh
Number of Homes	1000	
Hours of Sunlight each Day	6	
System Lifetime	20	Years
Battery Capacity Use	20.00%	
Interest Rate	5.00%	
Wiring Costs	1	Millions of N$

Output Data

Total Electrical Requirements per Day	18000	Kwh
Generation Requirements per Hour	3000	Kw
Required Number of Panels	30000	
Cost of Panels	141.75	Millions of N$
Required Number of Regulators	5556	
Cost of Regulators	10.04	Millions of N$
Required Number of Inverters	6000	
Cost of Inverters	21.12	Millions of N$
Required Number of Batteries	16296	
Number of Replacements	2	
Cost of Batteries	57.9	Millions of N$

Total System Cost w/o Interest	**231.79**	**Millions of N$**
Total System Cost w/ Fixed Interest	**243.38**	**Millions of N$**
Total System Cost w/ Compound Interest	**615.00**	**Millions of N$**

Legend
Input
Output

On a lower price scale, but still not an economical option, a five amp circuit could satisfy some of the residents' basic needs. With this setup an alternative non-electric cooking source would have to be used because an electric stove could not be operated on a five amp circuit. Although this option is more economically feasible, it does not meet the desires of 92% percent of the residents, who stated that they would buy an electric stove if it would be supported. It may be possible to increase the acceptance of alternative cooking methods through a two step process: research to determine the reasons that these methods are not as desired as electric stoves and then an educational campaign for the residents on alternative cooking methods. If this type of small circuit mini-grid option were to be pursued, it would be necessary to have full community involvement so that people would understand the limitations of such a system. In addition, measures such as enforcing energy saving practices and energy efficiency procedures would be extremely important to ensure that residents do not overload the system. Despite the lower cost when compared with the fifteen-amp solar mini-grid option, the five-amp circuit is still not a financially or socially acceptable option.

Supplying a minimal setup of a one amp with a flat rate payment plan to each household would cut costs tremendously and simplify billing greatly, but alternative cooking and refrigeration methods would be needed. This option would provide enough electricity for lighting and other low power applications. This suggestion would include a simple payment plan in which the user could pay a flat fee each month and draw as much electricity as needed from the one-amp circuit. The cost of this option is much lower than that of other options because a minimal amount of electricity would need to be produced, and no pre-payment meters would have to be purchased by the town. The users, however, would most likely be very unhappy with their limited ability to operate appliances. In order for this option to succeed, the community would have to be well informed of the limitations of the process. As with the five amp mini-grid system, measures such as enforcing energy saving practices and energy efficiency procedures would be extremely important. In addition, alternative approaches to refrigeration and cooking would need to be looked into on a large scale, such as a central refrigeration system with individual lockers for each household. The community would need to be well informed about the various options for alternative cooking and refrigeration in order for them to make an informed decision about how to proceed. Despite this option being in a more acceptable range with respect to price, it would not meet the needs of the users based on the needs assessment.

Another option is to provide each house with its own panels, batteries, and regulators. The size of each setup could be tailored to the needs of the house/shebeen, however, for our calculations we choose a single configuration. This setup would not support electric stoves because a small-scale system cannot supply the current flow required for cooking. In addition, because the size of the system would be limited to the area available at the house and the initial capital available, it may require the use of energy efficient or alternative refrigerators in addition to alternative cooking methods. One problem with this option is that high efficiency refrigerators may be too expensive for some consumers. In addition, because each household and shebeen would have its own setup, it would be very difficult to maintain all the different components of a solar energy system. Theft of equipment could also become an issue because each household would have its own setup, which would be difficult to protect. A massive education process would be necessary in order to inform each household about how to operate, protect, and maintain its equipment as well as the limitations of the equipment.

A possible future option, thermal solar electricity not only would provide the residents with their electrical needs, but the initial cost is also much lower than the previous PV-based options. However, maintenance would be higher than for a PV system because a thermal system is far more complex in its operation. Unfortunately solar thermal energy systems have not been refined to the point that costs can be accurately predicted, and preliminary estimates are still too high for use in Okahandja. In addition, solar thermal electrical generation is not widely used and only has been successful in large-scale use in California, U.S.A. Because solar thermal generation has not been studied or tested for an area like Okahandja, this technology may or may not work in this type of situation and further research is needed.

Not only do the different setup options have to meet the needs of the people, but the cost has to be economically feasible for the community. The problem might arise that the residents would be unable to pay for electricity even though they reported wanting it in our survey. There is an overall lack of economic data about the residents in the informal settlements and therefore the average income of a household is unknown. One resident of the town stated that the monthly income of the people in the settlements varies from N$500 to N$50,000 per month. Although the range of incomes is most likely not that large, it was evident that people do have different income levels. Due to the overall lack of financial data about the settlements, it is extremely hard to assess if the residents can or cannot afford electricity. From conversations with the residents it would appear that many of the residents cannot afford any appliances and would not be able to pay for the required electricity if they did have the appliances. The town should consider an economic assessment of the residents in the ISAs to determine if the project is a financially sound investment.

Each of the setups has an initial cost, displayed in Table 4.2. While this cost may seem acceptable, it is important to look at how much people would have to pay over twenty years to determine whether a project is feasible or not. In Appendix H, the cost per household can be seen for each option. Grid electricity is the cheapest and most reasonable for the community to pay off, not only for setup costs, but for long-term fees as well. Two possible scenarios are taken into consideration: one with 5% yearly compound interest and one with 14.75% yearly compound interest, the current rate for a home loan in Namibia. Also, seen in Figure 4.6, we have calculated the break-even point of approximately 65 years, where a fifteen amp solar setup would equal the cost estimate of grid electricity. The assumptions for this graph are that there is 14.75% yearly compounded interest on the total cost of the solar option and the capital for grid. Also, it is assumed that the price of grid electricity will rise at a rate of 15% per annum. After twenty years all components of the solar system would be paid off, and the only additional cost to account for is batteries.

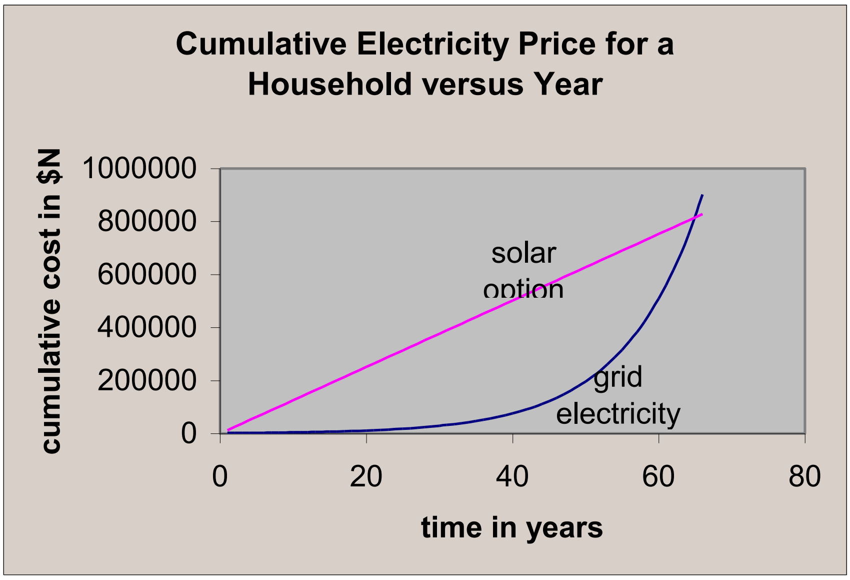

Figure 4.6 Cumulative Electricity Price for a Household versus Year

4.3 Additional Considerations

Throughout the data collection phase, many issues regarding the implementation of an energy project arose. The communities' minimal experience with technology, misconceptions about electricity, and the inadequate amount of communication between the Town Council and ISAs are all areas that could affect the success of an energy project in Okahandja. These shortcomings should be addressed if the town is seriously considering an energy project.

A general lack of knowledge about electricity among ISA residents was established based on their limited experience with electricity, direct observations, as well as interview data. Only one-third of Five Rand households and one-percent of the households Oshetu One currently have access to electricity, creating a situation in which a majority of the population has little or no experience with electricity. Although the current percentage of Oshetu residents that have electricity is low, several residents had illegal connections that were cut by the town, so the percentage was higher in the past. Most of the residents' energy consumption consists of burning candles or paraffin for nighttime lighting and burning wood during the day for cooking food. Currently 90% of the residents of Five Rand cook with wood and 86% of the residents in Oshetu One use wood as their primary cooking fuel. Some residents had small battery powered radios, but other than those there were no other forms of energy usage within the household. Due to the overall lack of experience of the residents with electricity, any sort of project to supply them with electricity must have a strong educational component.

For the residents who did have electricity, there were many safety hazards created by dangerous illegal setups. Members of the community reported that several accidents have occurred, and sometimes people have been electrocuted. To illustrate the unsafe situation, the electricity is run into the household in small, inadequate wires, often run along the ground where people are walking and children are playing. In addition, the metal-sided homes can conduct electricity, and are not waterproof. This situation creates a high degree of danger and creates many unnecessary risks for the residents.

In the ISA communities there is also an overall lack of understanding about how electricity works. During interviews, some of the residents stated that they had an electric stove, but sometimes it did not work properly. They were unsure of the reason why except that they thought it was because the electricity "was not strong enough." Residents also commented on how they thought solar energy was not as "good" as grid power, even though solar energy can produce the same amount of electricity as the grid. It is evident that the people do not have a basic understanding of how electricity works; therefore, education will be needed when an energy project is being implemented.

Residents could also be better informed about different cooking options. Most of the residents of the settlements are not using cooking fuels beyond wood. There are several alternative cooking fuels and methods that could lower health risks and be more cost effective, but they are not in use in the settlements. The residents would prefer electric stoves over paraffin or gas stoves for many reasons. Some reasons arise from the health problems that surround the use of paraffin and gas. Paraffin is known to make young children sick because they find it in their homes and drink it since they do not understand what it is. Gas has caused several injuries due to explosions and fires. In addition, gas is also quite expensive for many of the residents, and for this reason they do not use it.

Another potential concern that was observed in the ISAs was inadequate communication between the Town Council and the residents. Throughout our visit there were a few occasions in which this inadequate communication was demonstrated, and there is a large opportunity for improvement in this area. There were a few key points in which the need for improved communication between the ISA residents and the Town Council was established. Although we had been informed that the ISA residents had been briefed on our study and our purpose for being in the settlements, when we conducted our interviews, some of the respondents stated that they had not been told anything about the study and therefore, they were hesitant to comply with us. Others were aware that we were coming, but they had several misconceptions about our purpose. It is unclear at which point the message did not get properly relayed because there were a few steps between the Town Council and the residents of the ISAs. Several people thought that we were providing them with solar electricity; others thought we were providing them with grid electricity. Many people believed we were selling equipment and did not know where the information we collected was going. Overall, the people in the settlements did not appear well informed about our study and its purpose. If an energy project is going to be attempted, communication with the residents must be sufficient to avoid confusion and misunderstandings.

During our trips to the ISAs, we discovered informational issues regarding the residents' views of different electricity sources. One common misconception was that solar energy is not as "good" as grid electricity. In other words, the people felt that it would not meet their needs. Based on this information, they believed the town was trying to provide them with a "second class" service by giving them solar electricity. There also appeared to be distrust between the some of the residents and the Town

Council. For this reason they would sometimes hesitate, and would not answer our question until the purpose of the survey had been clearly explained.

Chapter 5. **SUMMARY AND RECOMMENDATIONS**

After analyzing the information gathered with the needs assessment survey and solar energy options research, we have developed several recommendations. We not only determined the best energy option for the town, but also developed additional recommendations for electricity project development tools that can be considered for future town use. We have addressed both the technical and social issues relating to our project.

5.1 Electrical Recommendations

In order to provide electricity to the residents of the ISAs, we recommend that the town setup prepaid grid electricity for the residents. In order to arrive at this recommendation, various solar energy options were first evaluated based on cost and ability to meet the needs of the residents, which then were compared to the grid option. As well as providing electricity options, various payment methods were also evaluated to determine the best arrangement for the town. The best payment option and electricity option are discussed in this section.

To summarize the results of the study, three main solar energy options were considered in order to provide the area with electricity. All three options were considerably higher in cost than the grid, and only one of the three options could completely satisfy the needs of the residents. So consequently, all options were found to be inferior to grid electricity. The first option was a large mini-grid system (fifteen amps per household) with PV panels and a backup generator, which would provide enough electricity to satisfy the residents. Despite the high cost of this option, it is the best of the three solar options because it is the only one that meets the current and future needs of the residents. The second solar energy option, a smaller capacity mini-grid, costs less, but it requires alternative cooking methods to be used because it does not support an electric stove, a highly desired item. Even though this option is less expensive than the large mini-grid setup, it is still relatively expensive when compared to the cost of grid electricity, and it does not meet the needs of the residents. The third solar energy option would be to have individual solar setups located at each home, which would save money compared to a mini-grid because wiring between homes is not required. Unfortunately, this system cannot support stoves or standard refrigerators, two of the most desired appliances as found through the needs assessment, therefore, not meeting the needs of the people. In addition, the individual setups for all of the households are still more expensive than the grid electricity. In conclusion, grid electricity is clearly the best choice from an economic and needs based perspective.

In addition to the purely economic benefits of grid electricity for the township and the residents, there are societal issues, which cause the residents in the ISAs to desire grid over solar power. Several of the residents who were interviewed stated that they felt solar power was inferior to grid electricity. In addition, some of the residents stated that having access to grid electricity was a symbol of social status and would be a considerable improvement to their quality of life. Moreover, several other respondents suggested that the township was trying to oppress them by giving them an inferior supply of electricity or none at all. In conclusion, grid electricity is highly desired in the ISAs because it is more than just a source of electricity; it is a symbol of progress. For these reasons, grid electricity is clearly a better option.

There are numerous methods to pay for electricity, whether supplied by a solar powered system or by the grid, and we found the best payment method to utilize is a form of pre-paid meter because it gives the township assurance that all the electricity that is used is paid for in advance. Although prepayment meters raise the initial price of electricity because of the cost of the meter, they ensure that the town will not go into debt if residents are delinquent in paying their bills, a cost that is then transferred to the residents. The variable income levels of the residents make any sort of electricity project a high-risk investment for the town, and the prepayment meters lower the risk considerably. One variation on the pre-payment meter is to have a split pre-payment meter where the input panel is located within a household, and the metering component is located at the top of a distribution pole. This method of payment is ideal because several input panels can be wired to one metering component, further reducing the investment in prepayment meters, as well as inhibiting tampering with the distribution device.

We suggest that PV technology be revisited in the future because technological improvements could make it a more viable option at a later time. Photovoltaic technologies have been in existence for about 30 years and are still being improved for higher efficiency and lower cost. With the constantly and sometimes unpredictably changing energy market, PV technology should be considered at another time because it may become a more cost effective electricity source for the town. (Websites for PV technology information can be seen in Appendix I.)

We recommend that the town consider solar thermal generation and Stirling Dish technologies for future projects in ten to twenty years. These alternative solar technologies are currently in development and could someday be considered in place of PV technologies. Hybrid thermal generation systems, which also use solar power during the daylight hours, are powered by gas or other fuel sources at night and are an emerging possibility for large-scale generation of electricity as well. These solar thermal systems show promising initial results, but they still need to be perfected in order to work in more remote and technologically disadvantaged areas such as the informal settlements Okahandja. Solar thermal systems have only been tested in large-scale industrial settings, and the feasibility of such systems in remote locations needs to be assessed. Further refinements of this technology are the Stirling Dish systems, which have the highest efficiency levels of all solar power generation technologies at this time. When these technologies come to market, they may be able to produce large amounts of electricity at cheaper costs than PV-based systems. In order for the town to remain updated on these emerging technologies a list of helpful websites are listed in Appendix J.

5.2 Electricity Education Campaign

In order for the people to be able to safely and effectively use electricity, it is imperative that they be educated on the proper uses of electricity. We believe that safety is the most important issue on which to provide education. In addition to safety, other topics such as energy conservation and technical support should be addressed. Although education may require a large investment in time and money, the pay-off in lower numbers of accidents and higher energy efficiency make the costs well worth it. In this section we make several suggestions for possible education programs.

There are numerous steps that can be taken to educate people on new technologies and their proper use. Disseminating pamphlets, stickers, and fliers on electricity is one suggestion that can be used to educate adults in the community on different topics such as general electricity information, safety issues surrounding electricity, the various uses of electricity, and energy conservation. Information can be displayed through visual representations so that people who speak different languages or may not be literate can understand the information easily. A well-designed pamphlet is a useful tool to give people valuable information in a clear and concise manner. An example of an electrical safety pamphlet can be seen in Appendix K. Also, slogans on stickers and fliers can help people remember different techniques to use electricity safely or conserve electricity.

Another education suggestion is that the Town Council holds demonstrations and seminars for the residents about electricity. Showing people the way electricity works, the way to safely handle it, and the ways to conserve energy can be very powerful. In the informal settlements there are currently several safety issues because of the dangerous illegal connections, and therefore, making a safety education campaign essential. Another forum for disseminating electricity information is at primary schools, when these same topics can be incorporated into classroom teaching so students will begin learning about electricity at a young age.

In order to supplement our suggestions, members of the community should be consulted for their ideas for the best way to educate the community. People within the community may have the best understanding of approaches that will succeed or will fail based on their experiences. In addition, members of the community could have creative ideas about new ways to display and publicize the necessary information. For example, members of the community might volunteer to assess households in their community for safety hazards and spread the knowledge of conservation issues.

In addition to education on safety and efficiency, educational seminars could also be held to train individuals on how to install, maintain, and repair new technologies. Education on the three components will empower the users to be able to manage the electronics within their own households. Basic training can be held for everyday users, and more in-depth trainings can be held for people interested in having jobs related to the operation, maintenance, or repair of the equipment. (For an example practice installation exercise see Appendix L.)

5.3 Economic Assessment of the Residents

One major topic that needs to be further researched is the economic feasibility of a large-scale energy project, whether it is solar, grid, or another means of power generation. This research is another important step that needs to be taken in addition to our needs assessment to appropriately provide electricity for the residents. In order for the town to receive a return on the initial setup cost of the grid, a majority of the ISA community must be able to participate. The data gained from an economic assessment combined with the data of our needs assessment will provide the town with a realistic picture of the feasibility of various electrical options.

In the electricity needs assessment, 91% of the people reported that they would buy appliances to run on electricity, and an economic assessment of the ISAs could verify that these people could afford to pay the town back for the initial setup costs. The economic needs assessment could be conducted in a survey format, where questions about income could be addressed or a participatory research method could be used. If possible, random statistical sampling would be the best way to conduct a survey in order to have an accurate assessment for the town. Unlike our survey where results from one household to the next were very similar, an economic assessment could have a tremendous amount of variation among households. In addition to survey data, direct observational data could be gathered to further assess the economic levels of the area. Direct observation data can be a useful tool for supporting other options by noting other economic indicators in the study area.

5.4 Increased Communication between the Residents and the Town Council

In order to facilitate development in the town, communication between the residents in the ISAs and the Town Council needs to be improved. Open communication provides several benefits to the Town Council and the residents. Communication will allow for increased understanding and trust, increasing the chances of future project success. There are several different ways to facilitate the process of increased communication, which are outlined in this section.

Two easily implemented suggestions for increasing communication are to place a comment drop box and bulletin board within the settlements. Community drop boxes could be made available so people would be able to give comments and concerns anonymously to the Town Council. The Town Council could respond to the questions and concerns of the people with written fliers posted on a bulletin board within the community. Also, the posting of Town Council meeting times on bulletin boards in the ISAs would allow residents to be more aware of the happenings within the town. Town Council members could post their office hours and office contact information within the informal settlements so that they are more easily accessible.

Another suggestion is to have ISA leaders and community members regularly attend Town Council meetings, and their presence at the meetings could greatly increase communication and understanding between the ISA residents and the Town Council. The Town Council meetings are open to the public, and the residents should certainly take advantage of this opportunity. The residents would better understand the limitations and capabilities of the town government, and the Town Council would better understand the needs of the residents. Finally, having the ISA leaders brief the residents of the ISAs at regular monthly meetings on happenings within the town would increase the general awareness of the community. An improvement in the communication between the Town Council and the residents of the ISAs would prevent future misunderstandings and problems as well as facilitate any sort of community development program.

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Appendix A. **NAMIBIAN HISTORY**

Namibian history begins four million years ago when it is believed that the first humans lived in southern or eastern Africa (Swaney, 2002, p.7). About 20,000 years ago organized hunter and gatherer groups had formed in the area. These hunter-gatherer groups are believed to be the early ancestors of the San people of Namibia today. The next migration into the country was between 2,300 to 2,400 years ago when Bantu-speaking farming groups began sporadically settling in Namibia. The Khoi-Khoi speaking people, mainly cattle herders, migrated to the country after the Bantu-speaking groups. It is thought that the Khoi-Khoi people, the ancestors of the modern Nama, pushed out the San people. Around the year 1600 the Herero people moved into Namibia and fought with the Khoi-Khoi over grazing land. Eventually the Herero won and they displaced some of the Khoi-Khoi and the San people. The Damara people also lived in Namibia at this time, but where they came from is unknown. The last tribe to move into the country was the Owambo people who moved into northern Namibia. These tribes all still live in Namibia today, as well as many in Okahandja.

Colonialism

Several social and cultural practices that are present today date from the colonial period. It is important that we understand the recent historical context of the area because several of the effects from this time period affect the lives and livelihood of the residents today. The overall attitude of the Germans toward the peoples of Namibia was one of oppression. The Germans viewed the Namibian people as uncivilized and looked down on them. During the time of colonialism one European missionary described the people of southern Africa as "ignorant, brutalized race of savages, little removed from their pristine barbarism" (Fleming, 1856, p.30). He warned people to not feel sorry for the African people and if one favored them then they were helping "the conservation of heathenism, to the hindrance of the spread of blessings of civilization and religion, through the means of enlightened and Christian nations" (Fleming, 1856, p.30).

Through this sort of reasoning the Europeans believed they had the right to the land in Africa. The first Germans arrived in the Okahandja in 1827 and built a mission in the town, which the Nama, a cultural group in Namibia, subsequently burnt down in protest. In 1883 Namibia was placed under German "protection." For the rest of the decade there was fighting between the Herero, another local tribe, and the Nama, so Germany sent a chancellor to Namibia in order to keep the peace. Several German forts were constructed in the area in order to control the rebels. In the year 1892 Germany made Namibia a protectorate and called it German South-West Africa (Swaney, 2002, pp.13-14). Two years later the Germans officially colonized Okahandja. The local tribes did not like the foreign presence and laws governing over their land and so, in 1905, the historically antagonistic tribes joined together against German rule. The Nama, Herero, Owambo and Basters led a rebellion against the Germans. The Germans did not do well at the beginning of the rebellion and were pushed to Windhoek, but when reinforcements arrived they annihilated the Herero troops. The Nama then lead another rebellion but were defeated by the German forces in 1910.

The colonial rule affected labor patterns in Namibia. Germans had recruited the local tribesmen to come and do unskilled jobs in the area, which took mainly men away from the traditional jobs of herding or subsistence farming. It created a dependence of the tribal workers on wage labor. In 1907 the German rule passed a decree called "Massregein zur Kontrolle dur Eingeborenen" which forced all of the

Namibian people within the central police zone to register with the German rulers (Winterfeldt et al., 2002, p.48). Every native citizen had to have papers at all times proving that they had a labor contract. Also, no new land could be bought with out the permission of the German rulers. This system greatly upset the traditional herding of the Herero and the Nama people.

South African Rule and Independence

At the end of the First World War Namibia was annexed to South Africa, who was able to hold on to it until 1990, when Namibia gained its independence (Swaney, 2002, pp.14-15). The entire period was characterized by oppression under the strict apartheid of South Africa. The separation of races caused many socioeconomic problems that Namibia is just beginning to sort out. Apartheid caused only a few Namibians to hold the wealth while the rest of the country lived well below the poverty line.

Under the rule of South Africa, the system of apartheid was put into place in Namibia, which still has lasting consequences today. Apartheid had a large impact on labor migrations (Winterfeldt, 2002, p. 50-53). The South Africans oppressed the people with several laws restricting migration and forcing them to do wage labor. The central area of the country was called a police zone and any native African without a certain number of cattle was forced to do wage labor. The control of the people was very strict, with several colonial officers who had the power to punish any of the workers. Laws were enacted that denied worker's rights such as the right to protest, form a union, or go on strike.

Namibians were very unhappy with the rule of South Africa because of the forced labor and all of the Namibian resources were used by South Africa (Swaney, 2002, p. 14). There were many demonstrations in Namibia against South Africa and in 1966 Namibians began a guerilla warfare campaign. Some of the leaders of the campaign were imprisoned as terrorists by the South Africans and others like the current Namibian president, Sam Nujoma, were forced to flee. After 1966 there was great turmoil in the country. Namibia made several appeals to the UN and eventually in 1988 the UN declared South Africa's occupation of Namibia to be illegal. After that Sam Nujoma was allowed to return to Namibia from his exile and was elected as the first president of the country in 1990. He is part of the SWAPO party and is currently serving his third five year term in office.

Appendix B. **OKANHANDJA TOWN GOVERNMENT**

The town government is the main body responsible for identifying and meeting the needs of the residents and further developing the town. Therefore, an understanding of the town government is necessary to provide the framework for our project. The four major aspects of the town government are the structure, the goals of the leadership, the past projects, and challenges for the future. Knowledge of past successes and failures of projects in the town prevents the same mistakes from being repeated. In addition, understanding of the goals of the town allows our objectives to fit within their objectives.

The structure of the current government includes six Town Council members and one mayor (Hambecka, personal communication, March 26, 2003). Every third year, elections are held, and the Town Council (TC) members are elected from within their own party. The majority party receives four of the seven Town Council positions, while the other parties have the three remaining chairs divided up among them. Monthly meetings, open to the public, are held at the Town Municipal building, although, it has been noted by Hambecka that most of the public is not aware that the meetings are open. The TC governs over a variety of cultural groups in Okahandja. The majority of the population is Oshiwambo; many of these people have traveled to Okahandja from the north in search of work. In Okahandja, there are also significant Herero, Nama and Damara populations.

The TC's vision for the 21st century is that "We [the TC] are committed to establishing the town as an industrial giant, a beautiful garden town and a tourist magnet in Southern Africa" (Town Council bulletin board). The mission statement of the town also contains several other goals including "equalize the socio-economic imbalance and improve the quality of life of all people of Okahandja, promote infrastructural development for investment and sustainability" and to "promote accessible organizational structures and user-friendly management for community participation and management."

In order to begin to reach two of the goals of the TC, Aberthina Hambecka (March 26, 2003) noted that one major project is currently being implemented. The project is to train young people about computers and the Internet, and many of the youth involved in the project do not attend school. Overall, the program has been a major success and was well received by the youth of the town. This project meets the goals of "equalizing the socio-economic imbalance and improving the quality of life of all people of Okahandja" and also involves many young members of the community by educating them on a large scale. The project is accomplished through a partnership between a Finnish group and the Town Council. Forming partnerships with outside help is a major step towards improving an area (Riley, Fiori, and Ramirez, 2001, p.523). Public-private partnerships are essential to help organizations such as the municipality of Okahandja move forward.

There are still many challenges that the Town Council faces (Hambecka, personal communication, March 26, 2003). Major infrastructure improvements are still needed, especially in the informal settlements on the outskirts of town. Roads, housing, and waste management are all insufficient in certain areas of Okahandja. One of the challenges of the Town Council is to improve conditions in the informal settlements in a way that is satisfactory to the residents. For example, the TC offered to build new housing for the people of Five Rand at a new location, but many residents stated that they did not wish to move. Currently, there is no solution to the housing problem. This problem is just one of the many obstacles for the town to overcome in the future.

Appendix C. **ELECTRICAL APPLIANCE INFORMATION**

Regardless of the type of electricity that is available (grid, solar, or otherwise), it is important to consider the appliances that will be used with the systems. In situations where relatively low amounts of energy are available, such as in most solar energy setups, it is imperative to account for the amount of electricity each appliance requires. High efficiency appliances are often available, but at higher costs that may be prohibitive to some end users.

One very important appliance, especially in hot climates such as Namibia's, is a refrigerator. Most medium sized refrigerators draw between 0.75 and 1.0 amps, which translates to 165 to 220 watts per hour (field notes, March 26, 2003). While this load is not high at any given time, in warmer climates refrigerators run almost all of the time, making them one of the largest electrical consumers in a home. For this very reason, work has been done to create more energy efficient refrigerators (Sieferth, personal communication, April 3rd, 2003). By adding insulation and creating more efficient cooling units, adequate refrigeration has been achieved at much lower power levels; unfortunately this comes at an increased cost.

Another common household energy drain that has seen greatly improved efficiency in the past decade is lighting. While typical incandescent light bulbs are still the common choice in Namibia due to their low initial cost and common availability, compact fluorescent light (CFL) bulbs are beginning to gain in popularity. CFL's often use as little as five to eleven watts per hour while providing as much or more light than a sixty watt incandescent bulb (Phillips, personal communication, April 8th, 2003). CFL's typically have a lifetime that is five times longer than that of an incandescent bulb. Solar power applications commonly use CFL's since they require much less electricity, however, they do have a somewhat higher initial cost, contributing to the often high costs associated with solar technologies.

Another major consumer of power in the household is an electric stove. While a stove is only used for short periods of time each day, the current draw is very high, often in the range of five to ten amps per burner. This large energy consumption can place a large strain on the electrical system for the period of time when people are cooking. The drain is usually too high for most solar power systems, so alternative cooking methods are suggested in conjunction with solar power applications.

A common electrical draw is by various entertainment devices, radios, TVs, and Hi-Fis. Small radios draw in the ten to thirty watt range, which is in the acceptable range for solar setups. Most modern TVs are also of relatively low power consumption, usually in the range of fifty watts, larger color TVs may exceed this figure, but due to high cost they should be less of an issue. The largest energy drain in the entertainment sector is often Hi-Fis in the ISAs. These audio systems can draw as much as 500 watts. This amount is far too much for most PV setups, so Hi-Fis must be limited to other power sources.

Other appliances for consideration fall under the housekeeping category. Washing machines usually draw in the range of 300 to 500 watts, but are used only occasionally and often during the day. Sewing machines may be desirable to many homes and will work with most electrical systems. A homeowner type sewing machine only draws in the range of fifteen watts, which can be accommodated by most types of power systems. Another clothing related appliance, the iron, can cause problems for a small scale solar system. An iron contains a large heating element and requires a large electrical current to heat up. Many irons draw in the range of 800 to 1000 watts, a value much too high for a PV power system.

Appendix D. **SADC ENERGY MARKET PREDICTIONS**

SADC Energy Market Trends and Predictions

To determine accurate long-term solar option estimates, it is crucial to understand trends in the energy market. Very often solar can be used in conjunction with other energy technologies; thus trends in other technologies could greatly affect a hybrid solar option. Another reason it is important to understand trends in the energy market is that long term predictions of the energy market are necessary for cost comparison purposes to justify the relatively high initial cost of solar technology.

The price of electricity is expected to increase drastically over the next several years (Phillips, personal communication, April 8th, 2003). The electricity bought from South African energy provider, ESKOM, by NamPower, the main electricity supplier for Namibia, is artificially low (Walbaum, personal communication, April 3rd, 2003) because it is directly tied to subsidized coal prices (Moyo and Sill, 1999, p.9). Moreover, electricity demand is expected to drastically increase over the next several years due to more rural villages being electrified and the population of the SADC continuing to grow at a rate of about 6% per year (Moyo and Sill, 1999, p.4). This increased demand within Namibia is likely to surpass the excess South African supply and drive up prices considerably (Phillips, personal communication, April 8th, 2003).

Due to expected high future electricity costs, other electricity generation options are being considered. Hydropower, one possible source for electricity generation within Namibia, is estimated to have a potential capacity of 1805 MW per year (Moyo and Sill, 1999, p.9). Oil resources are also being looked into as a possible source of energy. Currently, oil is not a viable large-scale option because much of the oil consumed by the SADC region is imported, and it is expensive due to unfavorable exchange rates (Moyo and Sill, 1999, p.4). There is currently oil exploration taking place in SADC member states, but so far nothing has been found, although there is tentative optimism that oil fields will be discovered.

Currently gas is very expensive (Walbaum, personal communication, April 3, 2003), but it could become a more affordable and viable source of energy for the SADC region (Moyo and Sill, 1999, p.7). Potentially, four gas fields could be developed in the SADC including the Kudu field in Namibia. There are 134 billions of cubic meters (BCM) of natural gas discovered in the Kudu field that are currently untapped (p.8). Also, there is a license for further gas exploration off of the coast of Namibia (p.7). If more gas resources are discovered and developed, then gas may become a more affordable source of energy.

Appendix E. **SOLAR EQUIPMENT PROVIDERS**

Local Providers/Representatives in Namibia

SunTechnics
Contact Person: Rolf Seiferth
Tel: +264-61-260338
Fax: +264-61-260338
E-mail: alemdars@mweb.com.na

Siemens Namibia
Contact Person: Derek Phillips
Tel: +264-61-217720
Fax: +264-61-218420
Email: derek.phillips@siemens.com.na

Willard Batteries
Contact Person: Peter Walbaum
Tel: +264-61-234023
Cell: +264-61-1289746
pwalbaum@willard.co.za

SolTec
Contact Person: Heinrich Steuber
Tel: +264-61-235646
Fax: +264-61-250460
h.steuber@soltec.com.na

Solar Age Namibia (Pty) Ltd.
Contact Person: Mr. Bjorn Wilschke / Mr. C Roedern
Tel: +264-61-215809
Fax: +264-61-215793
E-mail: solarage@iafrica.com.na

Appendix F. **SAAMSTAAN GROUP QUESTIONS**

Solar Energy Project

Questions from SaamStaan Group

1. Will I be able to use a sewer machine?
2. If the sun is not shining, how will I be able to charge the solar panels?
3. How strong or sufficient will the energy be?
4. How many people will utilize so lar energy?
5. Will solar energy operate the same way as pre-paid electricity?
6. Is there a life-long guarantee on solar energy?
7. Will each house be equipped with a solar panel?
8. Will I be able to replace solar energy with conventional electricity, should it prove to be non-sufficient?
9. Should we purchase the generator ourselves, or will it be provided and then we will have to pay for it like conventional electricity?
10. There is a problem with electricity in the fact that children cut the wires, will they be able to cut the wires like in conventional electricity?

Appendix G. **NEEDS ASSESSMENT QUESTIONNAIRE**

Questionnaire 1

We are not supplying the area with electricity. This survey is only a study.

Part 1

1. Gender: ________male ____female
2. Age: 1-20 ____ 21-40____ 41-60____ 61+ ____
3. How long have you lived here? ___________________________
4. How many people live in your household?__________________
5. Are you answering this survey with others? Yes___ No___

Part 2

Current Use of Electricity

Appliance	How many do you have?
Light bulb	
TV	
Radio	
Stove (# of burners)	
Refrigerator (size)	
Iron	
Other:	

1. When do you cook each day and for how long? _______________________
2. What fuel do you use to cook? _____________________________________
3. What do you use for nighttime lighting and for how long? ______________
4. Do you use any daytime lighting?___________________________________

Part 3

We are interested in which appliances you would buy and how often you would use them if you did have access to adequate electricity.

Appliance	How many would you plan on buying in the next three years?
Light bulb	
TV	
Radio	
Stove (# of burners)	
Refrigerator (size)	
Iron	
Other	
Other	

Please list the three most important appliances to you, in order:

1. _________________ 2. ___________________ 3. __________________

most important second in importance third in importance

Questionnaire 2

We are not supplying the area with electricity. This survey is only a study.
Part 1

1. Gender: ________male ____female
6. Age: 1-20 ____ 21-40____ 41-60____ 61+ ____
7. How long have you lived here? ___________________________
8. How many people live in your household?__________________
9. Are you answering this survey with others? Yes___ No___

Part 2
We are interested in which appliances you would buy and how often you would use them if you did have access to adequate electricity.

Appliance	How many would you plan on buying in the next three years?
Light bulb	
TV	
Radio	
Stove (# of burners)	
Refrigerator (size)	
Iron	
Other	
Other	

5. When do you cook each day and for how long? _______________________
6. What fuel do you use to cook? _____________________________________
7. What do you use for nighttime lighting and for how long? ______________
8. Do you use any daytime lighting?___________________________________

Please list the three most important appliances to you, in order:

1. _________________ 2. ___________________ 3. __________________
most important second in importance third in importance

Appendix H. **ELECTRICAL OPTIONS COST PER HOUSEHOLD**

Option 1. 5% yearly compounded interest

option	total cost for 1000 households	individual cost per household	yearly payment for household	monthly payment with interest		tot ho ov
mini-grid-15 Amp	231,790,000.00	231,790.00	11,589.50	2,562.53		
mini-grid-5 Amp	144,800,000.00	144,800.00	7,240.00	1,600.82		
mini-grid-1 Amp	30,800,000.00	30,800.00	1,540.00	340.51		
individual household setup	114,900,000.00	114,900.00	5,745.00	1,270.27		

fixed interest on solar and grid capital 5.00%

	total connection setup cost for 1000 households	individual cost per household for connection	monthly payment for household (for connection)	monthly payment of capital with interest	total cost of electricity over 20 years with 10% yearly increase	tot ho ov
Grid Electricity	5,800,000.00	5,800.00	24.17	64.12	12,375.91	27

Option 2. 14.75% yearly compounded interest

option	total cost for 1000 households	individual cost per household	yearly payment for household	monthly payment with interest	
mini-grid-15 Amp	231,790,000.00	231,790.00	11,589.50	15,133.43	
mini-grid-5 Amp	144,800,000.00	144,800.00	7,240.00	9,453.90	
mini-grid-1 Amp	30,800,000.00	30,800.00	1,540.00	2,010.91	
individual household setup	114,900,000.00	114,900.00	5,745.00	7,501.75	

Fixed interest on solar and grid capital 14.75%

	total connection setup cost for 1000 households	individual cost per household for connection	monthly payment for household (for connection)	monthly payment of capital with interest	Electricity total cos over 20 years with 10% yearly increase
Grid Electricity	5,800,000.00	5,800.00	24.17	378.68	12,375.91

Appendix I. **WEBSITES FOR INFORMATION ON PV**

1. Advanced Energy - http://www.advancedenergy.com/
2. AstroPower - http://www.astropower.com/
3. BP Solar/Solarex - http://www.bpsolar.com/
4. Shell Solar - http://www.shell.com/solar/
5. SunPower - http://www.sunpower.com/
6. United Solar Systems Corp. - http://www.uni-solar.com/

Appendix J. **WEBSITES ON THERMAL SOLAR AND STIRLING DISH TECHNOLGY**

Stirling Energy Systems-
http://www.ses.com

Consumer Energy Center **-**
www.consumerenergycenter.org/renewable/basics/solarthermal/thermal.html

Appendix K. **ELECTRICITY SAFETY PAMPHLET**

Appendix L. **PRACTICAL INSTALLATION EXERCISE**
Adapted from the Regional Solar Electric Training and Awareness Workshop (African, 1992, p. 67)

2.7.1 Objective

The installation exercise was composed of:
• classroom sessions • site visits • at least 3 hours per day of actual installation experience
With this training the participants were expected to:
• assist in installation work • cost a system • evaluate a system (performing commissioning and regular maintenance tests) • solve simple repair problems
During the Session,
1. Each participant learnt to use a voltmeter to measure voltages and determine polarity 2. Each participant learnt to install the main switch and light wires. 3. Each participant installed switches and socket outlets. 4. Each participant learnt to install fluorescent tube light bulbs. 5. Each participant learnt to fill batteries and attach battery wires 6. Solar array, battery and controllers were installed by the participants in groups. Each participant learnt to follow a wiring diagram 7. Each participant learnt to make all final connections to the controller and main switch in the proper order. 8. Each participant learnt to check system operation and measure voltage drops. 9. Participants understood basic system operation and were able to explain the systems to a user. 10. Each participant learnt to make regular maintenance system checks and complete a logbook entry. 11. Each participant learnt to solve basic system repair problems.