Creating a Solar Light Distribution Plan for Students in the Informal Settlements of Windhoek, Namibia

A Student Receiving her Solar Home System—photographed by Saadet Nur Yilmaz

By:

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SOLAR AGE NAMIBIA (PTY) LTD

DRFN

WPI

Creating a Solar Light Distribution Plan for Students in the Informal Settlements of Windhoek, Namibia

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Solar Age Namibia

Submitted to:
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Abstract

This project, sponsored by the Desert Research Foundation of Namibia, aimed to create a pilot program to provide Pico Solar Home Systems to students without sufficient access to light in the informal settlements of Windhoek, Namibia. Working with various organizations and the Immanuel Shifidi Secondary School we created a selection process, installation and monitoring procedures, and a way in which to evaluate the impacts the systems have on students.

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Authorship

ErinMari Konicki, Alexander Korpacz, Westley Russell, and Saadet Yilmaz all contributed to the research, writing, and execution of this project. The following is a summary of how the report was divided and compiled:

ErinMari Konicki was responsible for the overall formatting, organization, and editing of each version of the written report. She took the initiative of being responsible for the master copy of each draft and compiled each team members' corrections in a comprehensive manner. She also contributed by writing parts of the Introduction, Executive Summary, Background, Methodology, Findings, and Conclusions and Recommendations chapters and compiling the appendices.

Alexander Korpacz contributed to all parts of the report by writing parts of the Introduction, Executive Summary, Background, Methodology, Findings, and Conclusions and Recommendations chapters. He also compiled the results from the questionnaires and created the student consent form and the lighting price comparison table.

Westley Russell contributed to all parts of the report by writing portions of the Introduction, Executive Summary, Background, Methodology, Findings, and Conclusions and Recommendations chapters. He also documented our selection process and created graphs to represent the questionnaire results and a way to evaluate the impact the systems had on the students.

Saadet Nur Yilmaz contributed to the written report by devising parts of the Executive Summary, Background, Methodology, and Findings chapters. She created the operations manual, student contract, and took the pictures used in this report. She also took the lead during interviews and organizing the presentations.

All group members worked collaboratively to determine the project objectives, the selection criteria.

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Executive Summary

A large portion of students in Namibia struggles with continuing their education beyond the tenth grade. Attendance drops by about 37% from primary to secondary school, mostly due to the low passing rate of the Junior Secondary Certificate exams at the end of their tenth grade. One of the main contributors to this problem is the lack of accessibility to electricity for studying at night. Most students from the informal settlements of Namibia walk on average of two hours each way to attend school and once they return home, most must assist their family with household chores. By the time students can settle down to start their work, the sun has already set making it exceedingly difficult to complete their schoolwork due to the lack of light. Since only 38% of Namibians have access to electricity, students in the informal settlements must use candles or kerosene lamps to study in the evenings, which can lead to significant safety concerns, such as fire within shacks and health issues such as respiratory and vision problems. Lack of a proper lighting source also affects the academic success of the students, making it harder for them to further their education. In a country where solar energy is a prime sustainable asset, it could be the solution for students to further their education, as well as accelerating the process of electrification in informal settlements of Namibia.

The goal of our project was to assist the Desert Research Foundation of Namibia (DRFN) to select Immanuel Shifidi Secondary School students from the informal settlements of Windhoek, Namibia to participate in the Pico Solar Home Systems pilot program. Through this project, we sought to improve opportunities for students to study at night in the hopes that it will improve academic performance. To achieve this goal we needed to accomplish the following four objectives:

1. Build and Develop relations within the school community in order to assess the demand for the Pico Solar Home System
2. Generate a process to equitably distribute a select number of Pico Solar Home Systems to students within the school district
3. Ensure that students who receive the systems have support if any problems arise during installation or usage
4. Establish methods for Immanuel Shifidi and DRFN to evaluate the impact of the systems on the students

We interviewed teachers at Immaneul Shifid to gain a better understanding of life in informal settlements and the appropriate criteria to prioritize for selection. The staff assisted greatly in introducing us to students, distributing our questionnaires, and setting up interviews with individual students. Questionnaires helped us gain background knowledge about the students before we interviewed them at school and then at select homes. Challenges arose in determining actual access to electricity since many families intermittently splice into city power or occasionally save up for generator use. However, through this process we were able to select ten deserving tenth grade students who have no access to electricity, are willing to participate in an environmental club, and are passionate about their education. We later visited their homes to install the systems and distribute an operations manual that we created which explains how to use and take care of the systems.

After debate on whether the systems should be owned by the student or temporary placed with them, we determined that the students should keep the systems [as their own]. Not only would it be better for the family if the system was owned, but the students are more likely to take the best care of the equipment if it is theirs. To instill ownership, we discussed a service program model

with DRFN and they decided to help establish an environmental club at the school to encourage environmental education among the students, with the student recipients taking on leadership roles in the club.

The impact of the lighting system on the students' performance, both academically and personally, will be evaluated through grade reviews as well as quarterly writing assignments to help the students' reflect on the impact the lighting system has had on them. This will be coordinated by DRFN and the key contact at the school.

After completing the project, we compiled a list of recommendations for DRFN, Solar Age Namibia the provider of the Pico Solar Home Systems, and Immanuel Shifidi Secondary School. These recommendations include the following:

We Recommend for the Desert Research Foundation of Namibia:

Expand the Pico Solar Home System Project to more rural areas in Namibia

From the results of our questionnaires, we found that many students at Immanuel Shifidi already had access to electricity. We also found that many areas in the informal settlements had access to electricity by means of illegally plugging into the grid and making branching connections or using gas generators. Expanding the project to more rural areas will give a greater pool of students whose lives can be affected by this program.

Check in on a monthly or bi-monthly basis with the students who received the systems during the pilot program.

Conducting random checks will allow DRFN to ensure that the systems are being used properly. In other projects similar to this one, many people would abuse systems by trying to

power additional accessories from them. If the students know that someone will be checking in on their use of the systems, it will deter them from misusing the system.

We Recommend Immanuel Shifidi Secondary School:

Monitor the impacts of the system on the students by distributing a quarterly writing prompt and select an interested teacher to be in charge of contacting Solar Age Namibia if a problem should arise.

Through the quarterly writing assignment, the students will be able to detail the experiences they have had with the systems, both positive and negative. It will also allow them to report any problems that they are having with the systems that they have not wanted to bring the attention of to the designated teacher. Also, by selecting an interested teacher to be in contact with Solar Age, the students will feel more comfortable approaching the teacher with problems and the teacher will be able to more easily interact with Solar Age.

We Recommend for Solar Age Namibia:

Work with Immanuel Shifidi to educate a teacher about the systems and how to solve malfunctions that may occur with the systems.

In order for the teacher to be able to assist the students with any problems they face, they need to be familiar with the system and its components. By having Solar Age familiarize the teacher with the system, the teacher will be able to fix any minor malfunctions with the system. If a major problem arises, the teacher can contact Solar Age and get the appropriate pieces repaired.

By providing the selected students with the Solar Home Systems, we hope that their academic performance and overall quality of life will be greatly improved. With the creation of a selection criteria and a process to evaluate the impacts on the students, DRFN has the ability to expand the project. Through the recommendations provided, DRFN will have the option to improve upon the

pilot program and expand to rural areas in the future. By expanding the project to rural and un-electrified areas, more students will be given the opportunity to further their education.

1. Introduction

Namibian students from the informal settlements face many daily challenges such as: walking more than half an hour to get to school; not being able to afford school books, and some have to provide for themselves because their families cannot or they live on their own. Most importantly, they lack one of the basic modern day amenities that many people often take for granted—electricity**.** In Namibia, only 38% of the total population has access to electric lighting (Miranda, Amadhila, Dengeinge, & Shikongo, 2011). This low percentage can be attributed to numerous factors including the vast distances, the small and dispersed population and the growth of informal settlements around Windhoek and other cities in which service provision is limited.

To study in the evenings, students use candles or paraffin/kerosene lamps for light because by the time they return home from school it is usually too dark for them to complete their school work without a light source. The use of open flames such as candles and lamps can lead to significant safety concerns such as fire within shacks and health risks such as eye and respiratory problems. Due to these problems and risks, the need for an alternative and sustainable source of light arises.

The Desert Research Foundation of Namibia (DRFN) is a non-governmental organization that focuses on enhancing capacity and decision making for sustainable development on all levels of society in Namibia. Since the establishment of the foundation in 1990, the DRFN has conducted numerous projects and implemented various programs with a strong emphasis on three main thematic areas: energy, land and water. With the drastic increase in demand for water and electricity, especially in growing urban environments, it has become more pertinent to harness renewable energy sources.

Over the past decade, DRFN, our sponsor, has sought to increase the electrification rate of Namibia through the use of solar power. Namibia experiences more than 300 days of sunshine per

year and up to 10 hours of sunlight per day, making it one of the most suitable environments in the world for implementing solar power (Leskelä, 2013). However, accessibility to solar panels and other components necessary to produce electricity in this manner are often expensive and difficult to obtain among the poor in the informal settlements of Namibia.

With the help of DRFN, we plan to provide Pico Solar Home Systems to tenth grade students from Immanuel Shifidi Secondary School. The main goal of our project is to develop a model for allocation of Pico Solar Home Systems, which will provide students in the rural areas and informal settlements surrounding the school a solar powered source of light in an effort to increase their ability to study in preparation for the upcoming JSC exam. In order to accomplish this goal, we conducted formal and informal interviews along with other methods to obtain information on the most equitable way to distribute solar light systems which we will discuss further in chapter 3. This project will provide DRFN with the necessary methods to implement a program to distribute solar home systems to deserving students and assist the selected students in achieving their dreams of continuing their education past tenth grade, attending university, and creating a brighter future for both themselves, their families, and their community.

2. Background Chapter

Our project team has been asked to create a system for equitably distributing solar home lighting units to school children in Windhoek, Namibia. The purpose of this chapter is to help gain a better understanding of the informal settlements in Namibia and the significance of solar power in Namibia. In this chapter, we discuss the importance of access to electricity through solar energy as a means to improve formal education and quality of life for students in informal settlements. We also review solar home system initiatives that have been conducted in rural areas worldwide, which demonstrate the social and economic challenges that come along with these types of projects.

2.1 Poverty and the Growth of Informal Settlements

Namibia has one of the worst wealth distributions in the world with nearly 54.7%, as compared to the United States at 20%, of the nation's income being held by the top 10% of the population. (Pasqual, 2004). This uneven distribution is caused by lack of investment and suitable jobs in the rural areas where the majority of the population resides. This gives rise to migration and growth of informal settlements in order to accommodate the country's growing urban population. Informal settlements are areas of private or government owned land that are settled without formal permission. Due to lack of proper ownership, conditions within the settlements are often worse than that of the rural areas from which people migrated. The settlements are home to nearly a quarter of Namibia's population, currently housing approximately four hundred thousand people and estimated to reach five hundred thousand by the year 2021 (Figure 1) (Government of Namibia, 2012).

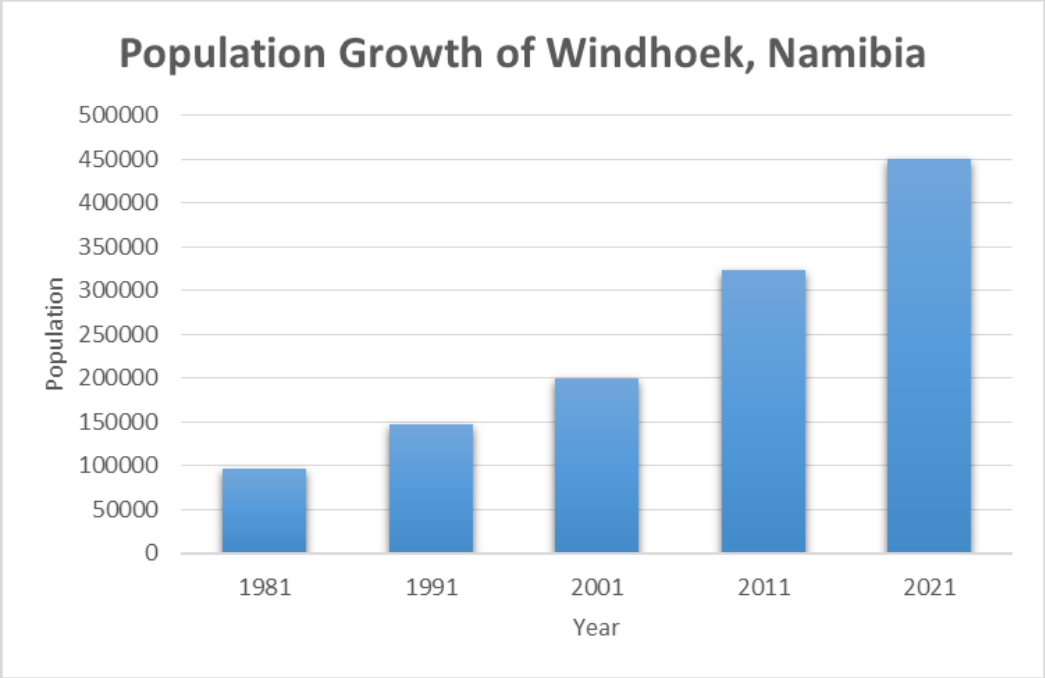

Figure 1: Population Growth of Windhoek, Namibia 1981-2021 (Government of Namibia, 2012)

One of the largest settlements is Katutura, located 5 miles north of the capital city of Windhoek. Translated into "The place where people do not want to live" in the Otjiherero language, Katutura is presently home to around 120,000 people including those who reside in its suburbs of Babylon, Havana, Soweto, etc. (Namibia Tourism Board, 2014). A map of Katutura, contained in the red dotted lines, can be seen in Figure 2.

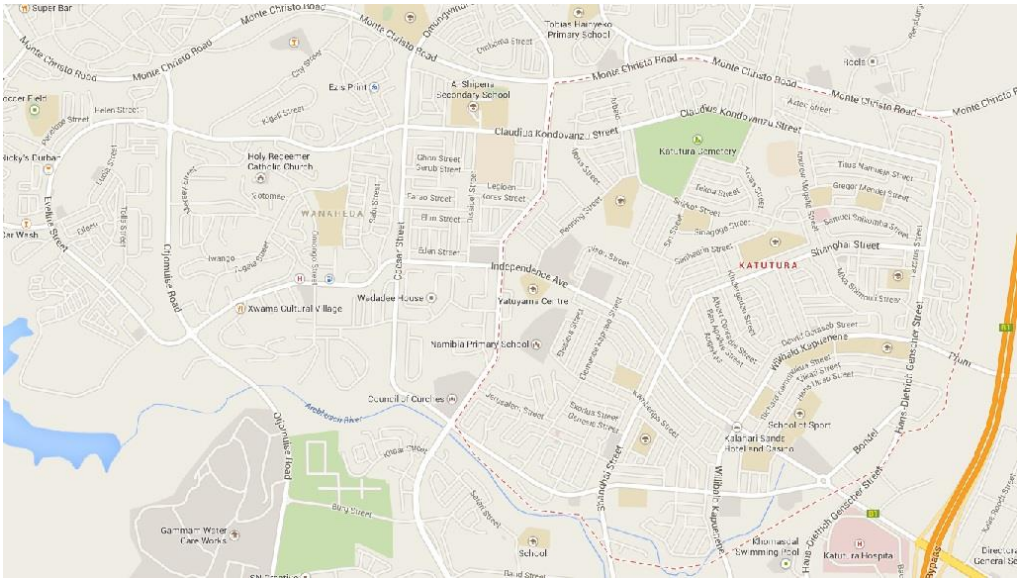

Figure 2: Map of Katutura (Google Maps, 2014)

Katutura, like the majority of informal settlements, is constructed mainly of shacks built of large pieces of sheet metal and wood. Within the settlement, there is a lack of access to electricity and proper sanitation facilities such as working toilets or running water. Because of these factors and many others, it results in overall poor living conditions in Katutura and other informal settlements around Windhoek (Figures 3 and 4).

Figure 3: Shacks in Katutura

Figure 4 A Small Child in Front of His Family's Shack

Migration to informal settlements like Katutura, is largely due to the termination of Apartheid-inspired laws that had once controlled the settlement of people (The World Bank, 2002). Under these laws, which were upheld until the late 1980s, blacks were banned from open mobility and the right to resettle legally. Even today, the majority of land is owned by town councils rather than individuals (Shack Dwellers, 2009). However, moving from rural to urban areas allows for better access to public amenities that are not available in rural villages such as primary and secondary schools, police departments, infrastructure and health clinics (Shack Dwellers, 2009). Migration to informal settlements is also driven by the search for employment and better quality of life.

2.1.1 Unemployment and the Importance of Formal Education

Through the increase in privates sector employment, the unemployment rate in Namibia has dropped from a global high of 51.2% in 2008 to 27.4% in 2013, however, the unemployment rate continues to prove a major issue for the country (NSA, 2013). Namibia has struggled to establish a formal economy since gaining its independence from South Africa in 1990, resulting in a high level of unemployment and the emergence of informal economies. A formal economy or

formal sector is the taxable part of the economy, monitored by the government and included in the gross national product. Conversely, the informal economy is defined as a system of trade or economic exchange operating outside government control (World Bank, 2014). Residents, especially in informal settlements, rely heavily on informal economies within the settlements rather than pursuing more stable employment outside of their communities (Mwinga, 2013). This economy consists largely of individuals selling in-demand products such as candles, food, and other goods often at a higher price than what customers would pay in the formal sector (Figure 5).

Figure 5: An Example of Namibia's Informal Sector

Although informal economies are beneficial in the short term, they are not stable nor do they provide lasting benefits. Informal workers do not pay taxes, both local or federal, resulting in lost revenue that is used to improve services such as education, sanitation, and etc. The reliance on an informal economy can be contributed to numerous factors, including the lack of proper

training, skills, and education which are needed to obtain jobs in Windhoek and other areas of Namibia.

Unemployment is especially prevalent among those who lack formal education. It is common for the young population of Namibia to enter the work force prematurely, lacking both the knowledge and skill needed, resulting in youth composing the largest percent of those who are considered unemployed (NSA, 2013). In 2008, 51% of the total population of Namibia was composed of people aged 15-39 years, as seen in Figure 6, and continues to grow due to improved health conditions and a steady decrease in infant mortality rates (Mwinga, 2013).

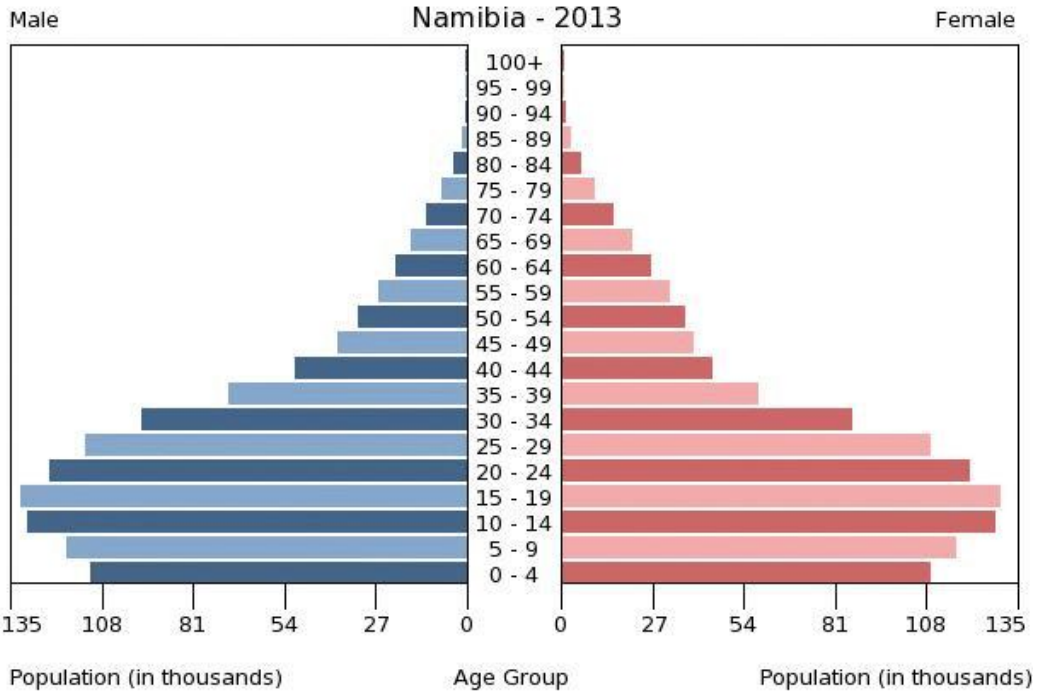

Figure 6: Population Pyramid of Namibia 2013 (CIA World Fact Book, 2013)

With an increase in youth population, there has been a massive influx of youth entering the work force within a short period of time, resulting in fewer opportunities for employment and an increase in the already high percent of residents unemployed (Mwinga, 2013) . Most of these

young adults who entered the work force between the ages of 15-19 failed out of secondary school, with roughly only 19% continuing their education past 10th grade (Minongelwa, 2014). Once students leave school, they are often unable to secure permanent employment thus stressing the importance of receiving a formal education in order to better prepare and train Namibia's youth to enter the work force.

2.2 Education in Informal Settlements

2.2.1 Education and Quality of Life

Education is one of the main factors taken into consideration when determining a country's standard of living. The United Nations Development Programme (UNDP) releases human development reports every year that examine topics such as health, education, and income to produce human development index (HDI) data for each country. The HDI ranges from zero to one and is used to view a country's potential development, relative to other countries. When examining the countries that top the list, it can be observed that each of these countries is recognized by the UNDP education index as a highly educated society. The education index is determined by the average school attendance of children and the average years of schooling completed for a 25 year old person. Countries towards the bottom of the list have much lower scores in the education index. Namibia is currently ranked 128 of 186 with an education index of 0.557 (UNDP, 2013). The countries that are labelled as having a low standard of living are the same countries that have a relatively low level of education. This similarity illustrates the correlation between a country's poor education and their standard of living.

Once a region falls into a trend of poor education, it is difficult to overcome. Eventually, the area falls into a stagnancy of poor living conditions where the families born in the region will have a difficult time increasing their social standards (Shilango, 2004). This was even more

challenging after Namibia gained independence from South Africa due to the racial segregation in place at the time which created a structure difficult for the people to move out of.

2.2.2 Structure of Schooling in Namibia

Following independence the Namibian government had to completely reform an education system that was previously based on the inequality of apartheid standards. Under Apartheid regulations, such as the Bantu Education Act, 1953, and the Extension of University Education Act, 1959, Namibia's schools were separated into whites- and blacks-only schools. Namibia's constitution, which was adopted in 1990, states that everyone has the right to free education provided by the State and that children are required to attend school until they have completed up to grade seven or reached the age of sixteen, whichever comes first (Nam. Const. art. 20). The public school system can be divided into four sections: lower primary (grades one through four), upper primary (grades five through seven), junior secondary (grades eight through ten), and senior secondary (grades eleven and twelve) (Wikan, 2008).

In order for a Namibian student to be accepted in the public secondary schools, he or she must first pass the Junior Secondary Certification (JSC) examination upon completion of grade ten. The JSC exam covers a variety of topics, ranging from Afrikaans to agriculture to mathematics**.** Those who fail to pass the JSC can still attempt to further their education by enrolling part-time in private study centers that will prepare them to retake the JSC in the following year (Harber, 2013). Many of the students who fail these exams do not have the financial resources to afford these part-time courses (Minongelwa, 2014). Because of this restraint, the JSC places a tremendous amount of pressure on students who are looking to continue their education.

2.2.3 Student Performances

While Namibia has a very high attendance rate for primary education, this number drops significantly in the years following the JSC examinations. As of 2011, the primary school attendance rate dropped from 91% to 47% and from 93% to 62% for female and male students, respectively (UNICEF, 2011). These statistics demonstrate the effect of the JSC exams. A majority of high school students do not pass this exam and are forced to either spend money that they do not have in order to pass, or drop out, giving up on the hopes of furthering their education.

2.2.4 Accessibility to School Resources

In schools in Windhoek, students face many struggles in the learning environment and some students cannot afford all of the necessary supplies. While the Namibian government provides some free education, students must pay a yearly fee to attend school after grade seven. In addition to this fee, students must also pay for their own school uniforms. Schools will provide free textbooks, but they are often in poor condition and do not meet the number of students who need them. Students who do not receive one of the free textbooks must either share with another student or purchase their own (Minongelwa, 2014). While all of these fees may not be too substantial for students coming from stable, urban backgrounds, students in the informal settlements have a difficult time paying for them. In addition to these fees, students are also forced to learn in overcrowded classrooms, where the student-teacher ratio can be as high as 40-1 (Figure 7).

Figure 7: Classrooms are often overcrowded, with more students than available seats.

While the cost of education causes difficulties for students, the aspect that contributes the most to the informal settlements' level of education is students' accessibility to school buildings and other school resources. In the informal settlements of Windhoek, students have to travel great distances to school. Some students spend up to two hours a day walking to and from school (SECMAQ, 2013). Given a great distance to cover, the number of hours in a day become a problem. Students are expected to contribute to various family chores that further hinder their time for studies. Once a student is finished travelling to and from school and performing the household chores, it is typically past the hours of daylight. Students cannot prioritize school work over their chores because they need to be able to ensure that they, as well as their families, are able to fulfill all of their basic needs (Minongelwa, 2014).

Students can meet some of their basic needs through completing some of their chores, such as going out and collecting water and food, but there are still more setbacks students must overcome to succeed at educating themselves. The most dominant setback is the lack of electricity

in the students' households. Since it is usually dark once students finish their chores, a source of artificial light is needed to study or complete school work. A majority of families rely on candle light. The use of candles is a fire hazard if they fall over and, despite being a cheaper means of lighting as opposed to electric or gas, are still a financial concern (Minongelwa, 2014). While students can continually make the effort to study to the best of their ability, they are always going to be restricted by the difficulties encountered in the informal settlements.

2.3 Electricity in Namibia

Energy is an essential pillar of any economy, therefore, the availability, affordability and security of energy supplies are necessary for development. Most first world nations have been electrified for decades and rely on electricity for nearly all aspects of everyday life. However, according to the United Nations Environment Programme (UNEP) there are 1.3 billion people around the world without access to electricity, the majority of whom live in underdeveloped rural areas. Recently, technologies using renewable energy sources, such as wind farms and solar-powered photovoltaic systems, have become increasingly more popular (UNEP, 2013). Even with a rise in popularity, these systems are still not used nearly as often as those in the non-renewable sector. According to the International Energy Agency (IEA), in 2012 renewable energy, which included hydropower, biofuels/biomass, geothermal, solar, wind, and heat sources, accounted for 13.2% of the total primary energy supply of the world with the remaining came from non-renewable sources, which included coal, oil, natural gas, and nuclear.

2.3.1 Accessibility

The days of cheap electricity are over and Namibia's current energy supply can no longer sustain the demand for electrical energy. Regional electricity supply capacities have become substantially constrained causing Namibia to no longer be able to rely upon its neighbors for

importing electricity. In recent years, Namibia has relied upon oil, hydropower, and biofuels/waste for their supply of electricity (Figure 8) (IEA, 2012).

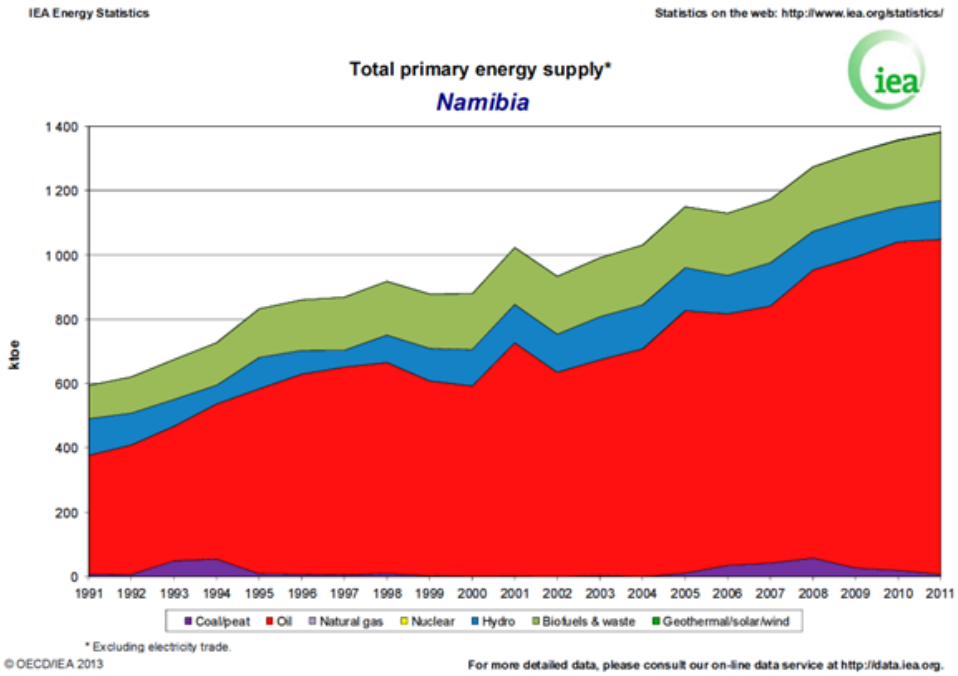

Figure 8: Total Primary Energy Supply of Namibia (IEA, 2012).

Electrical energy is generated at four main local power plants within the country, in addition to that generated by neighboring countries. The four plants are: Ruacana (a hydroelectric power station), van Eck (a coal-fired station), Paratus station (which uses heavy fuel-oil), and Anixas (another heavy fuel-oil power plant). Each of these plants have major pitfalls ranging from an inability to provide enough power consistently to being outdated and being extremely cost inefficient (NamPower, 2013). The main transmission line runs from the Ruacana Power Stations (Hydropower) in the north to the south where it connects with the South African grid and run into Windhoek, which is the center for power transmission in Namibia (Leskale, 2012). With the shortage of power, not all of Namibia is able to be connected to the grid specifically informal settlements and rural households.

Many people in the informal settlements are unable to afford electricity and, because of this, must turn to alternative means. Some will connect into the grid by using an extension cord from houses that do have electricity at the cost of a small fee. This family may then branch out and provide power to other homes in order to make a profit putting a significant load on the already strained system. People will create branching connections until either the system short circuits or the original house that provides to all is shut down by the government. People in the informal settlements may also use other forms of energy such as gas generators, either purchased or stolen, or fire, in order to meet their daily energy needs. (Ganeb, 2014)

2.3.2 Safety and Risks

Numerous health and safety risks can be directly associated with the lack of accessibility to electricity in rural areas and informal settlements. One solution that approximately 38% of Namibians will take to fix their lack of lighting is to use candles for light in their households (Namibian Statistics Agency 2011). Doing this runs the risk of creating household fires, from July 2012 to May 2013, there were over 100 reported shack fires during the winter season. Section Head of Fire, Safety and Prevention in the Emergency Management Division of the City of Windhoek, Tangeni Uusiku, says the causes usually stem from unattended candles, electrical hazards, cooking, as well as heating (Kazondovi, 2013). During the day, many children light candles in order to study since the shack dwellings are typically dark because they are built without windows. This not only increases the risk of a fire starting in a shack, but it also traps any smoke emitted by the candle due to lack of proper air circulation. This creates a risk for all homes in the informal settlement because the shacks are built so close together and are often built of flammable material, a fire in one home could easily spread and damage a large percentage of the settlement (Kazondovi, 2013). Some families, however, are unable to afford many candles creating a problem

for students who are trying to study especially in the winter months when the sun sets earlier in the day. They must ration their candles or some must study outside during the limited time from when they get home until the sun goes down or they need to start their chores. Some do not even bother with candles due to the risks they cause or the cost (DRFN, 2009).

Fire is not the only alternative people use in the informal settlements, other alternatives include plugging into the grid illegally or using a gas powered generator. These alternatives to having electricity can be just as dangerous. Typically when people illegally plug into the Namibian grid they will use their home as a distribution center. The owner will sell electricity to others in the area creating a large network based off of one main source (NamibianSun, 2014). The source can eventually be overloaded by having too many branching connections, which will cause the plugs to spark, thus creating fires if there are any flammable items nearby (Sapa, 2014).

As stated above, because most shacks are built out of combustible material the chance of a fire starting is extremely high (Kazondovi, 2013). People in the settlements also try to market gas generators to others as a source of power, causing even more of a risk than just overloading an electrical source. If used improperly, generators can create hazards such as carbon monoxide poisoning or electrical hazards. Generators should never be used indoors and should never be set up to power house appliances unless set up by a qualified electrician (U.S. Fire Administration, 2013). Recently, the Namibian government has been cracking down on those who are plugging into the grid illegally. Once they are stripped of their access to the grid, the majority will switch to gas generators in order to keep their business running (The Namibian, 2014). One of the main alternatives that is overlooked by the villagers of these informal settlements is solar power, which provides a safe and renewable source for generating electricity for lighting, appliances, and other needs.

2.4 Solar Power in Namibia

Due to the lack of accessibility to electricity and other forms of conventional energy, a need for alternative and renewable energy sources arises. Namibia is one of the most suitable countries to implement solar power because it experiences more than 300 days of sunshine per year and up to 10 hours of sunlight per day (Leskelä, 2013). Figure 9 shows the solar horizontal irradiation in Namibia from 1994 to 2011, which is the measurement of solar power received by a surface horizontal to the ground. In most areas of the country, the annual energy yields range from 2,150 to 2,350 kWh/kWp, proving that solar energy is a prime sustainable asset for Namibia (Haibach, 2012).

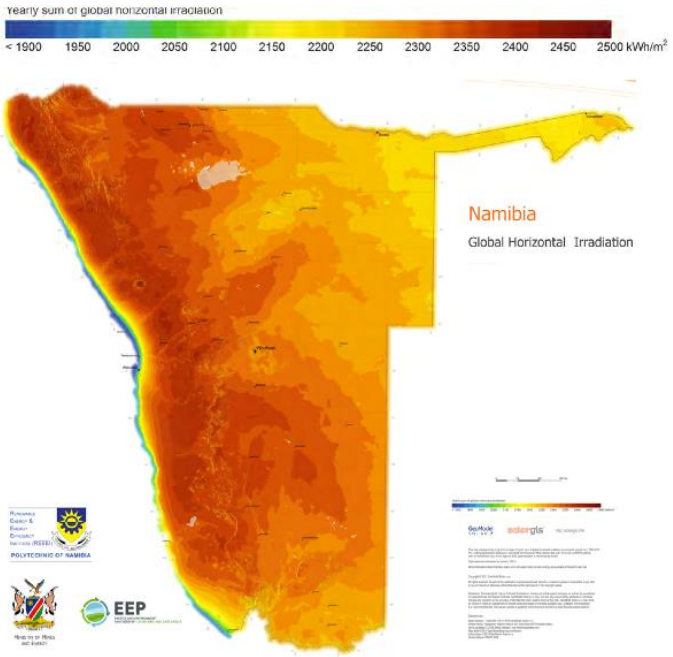

Figure 9: Horizontal Irradiation of Namibia (Haibach, 2012)

The Namibian government, with the assistance of organizations such as the Renewable Energy and Energy Efficiency and Institute (REEEI), and various others are trying to increase both awareness and installations of solar energy technologies. The Ministry of Mines and Energy is aware of the fact that solar power is likely to become the most widely utilized renewable energy

source due to many open and flat spaces in Namibia and the possibilities of establishing a strong connection to the national grid (Ministry of Mines and Energy, 2012). Solar energy can accelerate the process of electrification in informal settlements due to its easy installation, sustainability, and because it does not require extensive equipment to function.

2.4.1 Solar Home System Projects Worldwide

There is usually a large discrepancy between the formal and the informal settlements' access to electricity. The informal settlements are usually too far away to access the city's electrical grid or cannot afford the upfront costs (UN-Habitat, 2009). Because of these problems, organizations continually attempt to provide a solution. The idea of bringing solar power systems into the homes of those unable to access the electrical grid is one that has been addressed many times worldwide.

Success in Past Projects

When looking at case studies of past project, a wide variety of benefits were brought to the rural settlements from the implementation of solar projects. The most widely acclaimed benefit was that the households experience a much higher quality and brightness of light with the solar units compared to previous methods. The quality of light was drastically improved in countries such as Zambia, Senegal, and Nicaragua once solar systems were introduced to the informal settlements (Gustavsson & Ellegard, 2004; Nieuwenhout et al., 2001; Motta & Reiche, 2001). Another benefit that was experienced in multiple countries was a large increase in the amount of studying students were able to do at night. The percentage of students who gained access to nighttime studying was as high as 58% in countries such as Zambia and Ethiopia (Gustavsson & Ellegard, 2004; Muggenburg, Tillmans, Schweizer-Ries, Raabe, & Adelmann, 2012). Households in Mongolia, Bangladesh, and Ghana also managed to see an increase in income generation by allowing people to charge their phones with the solar systems for a small fee (Martinot, Chaurey,

Lew, Moreira, & Wamukonya, 2002; Nieuwenhout et al., 2001). This is just a small example of the numerous benefits that families in informal settlements have gained from projects focused on bringing solar home systems into their homes.

Problems in Past Projects

While there are a large number of benefits shared among projects in different regions, common problems have been identified. The biggest setback of introducing solar systems into the homes of informal settlements is the typically large initial and maintenance costs. This was the main concern voiced by families in countries such as Kenya, Kiribati, Fiji, and Mexico (Greenpeace, 2001; Dornan, 2011; Mallet, 2007). With such high costs, some families could not afford to implement these systems into their homes. However, those who were able to do so, generally were happy with their investment. Another common problem shared among these solar system projects is that they are difficult to maintain and more elaborate systems rely on expert assistance. Fiji and Tunisia are countries where the difficulty of maintaining the systems was very evident (Dornan, 2011; Nieuwenhout et al., 2000). In these countries, the families were frustrated by how often the systems broke down and struggled to keep the systems in a working order.

Further potential problems arise since most informal settlements are known to have high levels of crime, such as theft. Solar home systems that are left out overnight are easy targets for theft or vandalism, but this threat of crime varies from country to country. For example, in South Africa, 10% of their 6,000 systems were stolen while only 0.2% of the 500 systems in Zambia were stolen (Ellegard, Arvidson, Nordstrom, Kalumiana, & Mwanza, 2004). Theft can generally be countered by bringing in the systems overnight since they are usually small enough to be moved without a hassle.

Past Projects' Effect on Education

While there is extensive coverage on solar home system projects all over the world, there is a lack of record on the educational benefits of the systems. Most reports argue that bringing solar systems into the homes of students with positively impact them, but do not go into any specifics, such as stating that "one of the highest priorities for most families...is better lighting…for children's homework," but lacking further support of the claim (Foley, 1995). There is generally a "lack of documentary information on actual experience of households with solar home systems" that prevents reports from demonstrating the full scope of the impact of the solar home systems (Nieuwenhout et al., 2001).

However, in a 2007 article, Mathias Gustavsson specifically looks into the educational benefits of 1999 solar home system program in eastern Zambia, where over 400 systems were distributed to homes, shops, and public buildings. Gustavsson assessed the educational impact by distributing two surveys to the families who received the system, as well as neighbors, in 2001 and 2002. These surveys identified how the systems were being used by the families that received them. Before receiving the systems, about half of the students complained about the quality of light from candles in regards to studying. Through the surveys, it was discovered that about 70% of students increased the amount of time spent studying and 71% have seen improvements in their grades (Gustavvson, 2007). The results discussed in Gustavvson's report provided substantial evidence that the systems are beneficial to students' studies. The Desert Research Foundation of Namibia hopes to recreate these educational benefits for students in Windhoek, Namibia.

2.5 The Desert Research Foundation of Namibia

"The Desert Research Foundation of Namibia (DRFN) empowers decision-makers at all levels through its research, training and consultancy activities, thereby fostering sustainable

development in Namibia" (DRFN). This is the mission statement of the DRFN; their goal is to work towards a sustainable future for Namibia by completing projects that will achieve the goals set by Vision 2030. Vision 2030 was adopted by Namibia in 2004 to improve the quality of life of the people of Namibia to the level of their counterparts in the developed world by the year 2030. By conducting the Pico Solar Home Systems pilot program, DRFN hopes to promote and implement solar power in developing areas of the country which do not have access to electricity by distributing the Solar Home Systems. For the Pico Solar Home Systems program, DRFN is targeting students at Immanuel Shifidi Secondary School, located in Katutura, to receive the systems to assist them in their school work. In addition, by targeting students, DRFN is working to educate them about the benefits of solar energy and about environmental issues that Namibia faces.

2.5.1 Pico Solar Home System

The Pico Solar Home System Project is aimed at students who do not have access to adequate lighting to complete their schoolwork at night. The Pico Solar Home System, produced by Solar Age Namibia, contains a small solar panel that uses sunlight to charge a battery during the day in order to power two LED ceiling lamps, a radio, and/or a phone charger. The phone charger has the capacity to fully charge two cell phones (or one smartphone) per full charge of the solar battery. The system costs N$1,614.60 (US$151.89) (Figure 10). The system is also easily repairable and, if properly kept, can work for up to five years.

Figure 10: The Pico Solar Home System includes a small solar panel, a battery, two ceiling lights, a radio, and cell phone chargers.

2.6 Summary

While all of Namibia is negatively affected by the lack of lighting at night, students are the ones who suffer the most. Without access to light, students lose a large portion of the day to study and complete their homework assignments, making it difficult for them to continue their education. Because using candles is dangerous to the students' homes and electricity is too expensive for the families to afford, bringing solar energy to the students will benefit the entire household. In the following chapter, we describe our process of creating the Pico Solar Home System Pilot program, including the selection process, the installation of the systems, and the monitoring of the students' performance.

3. Methodology

The goal of our project was to assist the Desert Research Foundation of Namibia (DRFN) in creating a model for distribution of Pico Solar Home Systems and to select secondary school students from the informal settlements of Windhoek, Namibia to participate in the pilot of this program. Through this project, we sought to improve opportunities for students to study at night in the hopes that it will improve academic performance. To achieve this goal we needed to accomplish the following four objectives:

1. Build and Develop relations within the school community in order to assess the demand for the Pico Solar Home System.
2. Generate a process to equitably distribute a select number of Pico Solar Home Systems to students within the school district
3. Ensure that students who receive the systems have support if any problems arise during installation or usage
4. Establish methods for Immanuel Shifidi and DRFN to evaluate the impact of the systems on the students

3.1 Objective 1: Build and Develop relations within the school community in order to assess the demand for the Pico Solar Home System.

Because we are not members of the community, it was important for us to first establish relationships and acquaint ourselves with the school community before conducting interviews or beginning the selection process. To accomplish this, we visited the school on several occasions during the first two weeks of the project in order to familiarize ourselves with the school staff and the students. During our visits, we conducted informal interviews with several individuals

including: science and life skills teachers, heads of several academic departments, a student counselor, and the principal.

Our first interviewee was Martha Minongelwa, who is a science teacher and our primary contact at the Immanuel Shifidi Secondary. She provided us with information regarding the background and history of the school. She also introduced us to students and other members of the school staff with whom we would be working. We conducted another interview with Mrs. !Gaoses, a life skills teacher, which is a school course that teaches students general skills necessary in their everyday lives such as: drug awareness, HIV/AIDS, and sex education. She provided us with a list of students who were considered "orphan and/or vulnerable" in the school. A vulnerable child is defined as being under the age of 18 years and currently at high risk of lacking adequate care and protection (HGSF, 2013). This list helped us identify the target group of students whom would receive the systems. We also interviewed the head of the social sciences department who assisted us with the creation of the student questionnaire, which will be discussed in the next section, and a schedule for individual interviews with the students.

In addition to this information, the interviews allowed us to gain background information regarding the students and the staffs' opinions regarding how to best select the students who would receive the systems. During these interviews we used the following questions to guide our conversations:

- If you had the option, would you give the system to students who are succeeding academic or those that are struggling with their studies?
- What criteria would you use to select the students?
- How much should the students be charged (if at all) for the systems?

- What are your opinions on the ownership of the system, should it be rented out for a year or should the students own them?
- Do you foresee any problems that may arise during distribution of the systems?

By receiving this initial feedback from the school staff we were better able to generate a selection criteria that fit the needs of the students and their families.

We were also given the opportunity to speak with several students including a class of 11th graders who gave us valuable insight into how they prepared themselves for the JSC exam they took the year before. Through our discussions with school staff and the students, we were able to generate selection criteria and a distribution process that specifically targeted poor and vulnerable students in the 10th grade.

3.2 Objective 2: Generate a process to equitably distribute a select number of Pico Solar Home Systems to students within the school district

During the various interviews with staff and teachers, mentioned previously, we were able to narrow down the pool of students from which the program has to select from. First, we decided that it would be best to target students in grade ten because at the end of their tenth year they are required to take the JSC exam which determines whether or not they will continue their education. From here we created a questionnaire/application for the tenth grade students to fill out that were interested in the program. This questionnaire acted as an initial screening in order for us to narrow down the pool of students and get those who are interested and motivated. The questionnaire was also there to give us some general background information on each student that applied. Some of the information we gathered was their name, age, number of siblings, what they use for lighting at home, and how much time they spend studying, the full questionnaire can be found in Appendix D. The plan was to make the questionnaires available to all tenth grade students

then to return to the school a few days later and collect any completed questionnaires as well as a list of orphaned and vulnerable children from the life skills teacher who she thought would be excellent fits for the program. The names from the questionnaires would then be cross referenced with the list from the life skills teacher and names that appeared on both would move onto the next round of selection which was an interview process. This would sort out students who lacked motivation, if they truly cared about improving their situation they would have taken the time to fill out the questionnaire. However, the school decided it would be best if they were to just distribute the questionnaires to all tenth grade students during their first class period of the day and have them fill it out. The school then returned all the completed questionnaires to us which we then began to sort through.

After we had all the questionnaires, we continued our process to narrow down the students to ten. We sorted through the questionnaires and were able to narrow down the number of students by removing all those that had electricity and those that responded that they were not willing to do community service to contribute towards the system. We then compared this list with the list of fifteen students given to us by the life skills teacher, Mrs. !Gaoses, adding a few names from her list to our list. Once we narrowed down the original set of 10^{th} grade students, we then went to the school and had the students from our list stay after in order to conduct interviews with each one of them separately.

During these interviews, we gathered more background information on each student and determined how motivated they were to be part of this program and to improve their education as well as making sure that everything they filled out in their questionnaire was true. We split up into teams of two in order to expedite the process. On each team we had one person leading the interview and the other constantly writing notes. We asked many of the same questions we did in

the questionnaire such as where they live, how long it takes them to get to school, and what they use as a source of light. In the interviews however we were able to go more in depth with the questions to get information on how they spend their time after school, what their home life is like (number of parents/guardians, siblings, who works in their home, etc.), and get to know them and their personality better through conversation. One important piece of information that we sought was a way to contact the students and permission to interview them at their home if they were to advance to the next stage of selection. This contact information was vital because the students had only one week left of school before break at the time we were conducting the interviews. The complete interview protocol can be found in Appendix F.

Upon completion of the interviews, we then reviewed all the information gathered on each of the students in the final pool. We compared each student against a set list of criteria to narrow down the remaining students into a set of ten that would be selected to receive the Pico Solar Home System. First we made sure that the student responded by saying that they do not have access to electricity as the system will be beneficial only to those without. We also removed any students that would not be willing to participate in a type of community service as payment. From there we looked at a student's home life; the number of people they live with, if they have parents, who works in the household. Students with more siblings still in school were ranked higher than those without.

We also felt that students who did not have a stable source of income would benefit more than those that did because they had no way of getting light either through kerosene, electricity or a generator. The number of parents fell in with the source of income question as to if they have to work themselves or if both parents are providing for them. Those that had both parents providing for them were ranked lower. One other major consideration was how well the interview went in

general. The students' attitude was a big factor during interviews as some were very uninterested in the program and did not want to participate. The students who displayed this sort of attitude were not considered to receive the system.

The final thing we looked at were the grades of each student based upon their performance in ninth grade. Students that rested around the average were ranked higher than those with extremely low and extremely high grades. We made this decision because according to teachers at Immanuel Shifidi those that are around the average have a higher chance of benefiting from this program as opposed to those that are excelling with little room to improve or those that are extremely below the average that have little chance to improve. Upon review of all the students, we were able to narrow it down to ten students. We also ranked the remaining four students in the event that if someone were to decline the offer to participate in the program, was unreachable for the at-home check, had access to electricity, or was removed from the program in the future there would be a backup.

The final stage in our selection process was an at home interview. This interview's main purpose was to get a look at the students' home and its surroundings to ensure that the students had been truthful during the previous interview and questionnaire. With the assistance of DRFN member Lucky Ganeb, we contacted each student's parent/guardian whose number was provided during the school interview and set up a time to meet with them at their home. During the interviews, we asked for a tour of their home while making conversation and asking about what the family currently uses for a light source. While the interview was ongoing, we were looking for any red flags such as families that did have access to electricity, parents that did not seem supportive of their children, or a family that makes enough money to move out of the informal settlements or afford electricity. Any student that displayed any red flags was removed from the

selection pool to ensure that only students that deserved the Pico Solar Home System would receive it. This part of the process is one of the most important because it was our only way of seeing whether or not the students were telling the truth about their home situation. Once all the at home checks were completed, we finalized our selected students and returned to provide them with the systems and help them through the installation.

3.3 Objective 3: Ensure that students who receive the systems have support if any problems arise during installation or usage

After we developed our method to distribute the Pico Solar Home Systems, the next step was to ensure that the families experience minimal issues during the installation process and for as long as the family owns the system. In order to become more informed about the systems, we interviewed Conrad Roedern, owner of Solar Age Namibia, who gave us an overview of the solar home systems. We pursued two approaches to guarantee that the families in Katutura had no problems installing their systems. The first method was the creation of an operations manual and the second was personally assisting the families with the installation process. This ensured that the families could utilize the systems to their full extent with limited problems.

By visiting the students in their household and personally familiarizing them about the systems and helping them with the installation, we further reduced the possibility of problems arising. Our team being at the students' homes while we installed their systems allowed us to answer any specific questions that the students had that were not covered in the product operations manual. Using only a screwdriver and the materials provided in the kit by Solar Age, we, with the help of DRFN member Ganeb, were able to successfully install the systems in the students' homes.

In order to reduce the number of problems that the family may experience after the system is installed and running, we decided to initiate contact between a teacher at Immanuel Shifidi and Solar Age Namibia. Roedern has shown interest in educating one of the teachers on the system in order to fix any problems that may arise with the students' systems. After informing the principal of Immanuel Shifidi of our idea, he agreed with our proposal and decided that a teacher will be selected once the school returns from holiday break.

3.4 Objective 4: Establish methods for Immanuel Shifidi and DRFN to evaluate the impact of the systems on the students

To ensure that the project was effective and beneficial to the students, we created a monitoring scheme where DRFN will be evaluating the impacts of the system on students' lives. We are planning on having two different ways of assessing the effects on students. The first approach will be asking teachers to track the students' grades on exams and homework as well as their overall academic performance. The teachers will fax DRFN the grades of the students and will describe if they have noticed any changes in their academic performance in terms of their participation and attendance. We will also ask the teachers and DRFN to compare the grades from the previous year to analyze the academic trend of the students. Secondly, we would like to receive a reflection from the students where they will be required to complete an open-end writing assignment on a quarterly basis. This assignment focuses on the students' experiences with the systems, providing further insight on how the systems impacted the students' lives rather than just looking at their academic performance. By having both systems in place it will provide both a qualitative and quantitative way to observe the students' performance. An example of a writing prompt that could be used can be found in Appendix K.

3.5 Summary

We conducted interviews of school staff, students, their families, and members of several organizations and distributed questionnaires to collect information to achieve our four objectives. Our findings from our research can be found in the following chapter.

4. Findings

During the development of our selection process we interviewed students and school staff at Immanuel Shifidi, family members of the students, and various organizations. Through these interviews we developed a collaborative approach to select students, install the solar device in students' homes, and evaluate the impact of solar lighting on student academic performance and on their daily lives. Our findings are organized as follows:

- Understanding the school environment at Immanuel Shifidi Secondary School
- Developing the Pico Solar Home System pilot program
- Learning about students' lives and their perspectives
- Installing the systems
- Designing a process to evaluate project impacts

4.1 Understanding the School Environment at Immanuel Shifidi Secondary School

Immanuel Shifidi is a large secondary school, founded in 1977, and is one of three secondary schools located in Katutura (Figure 11).

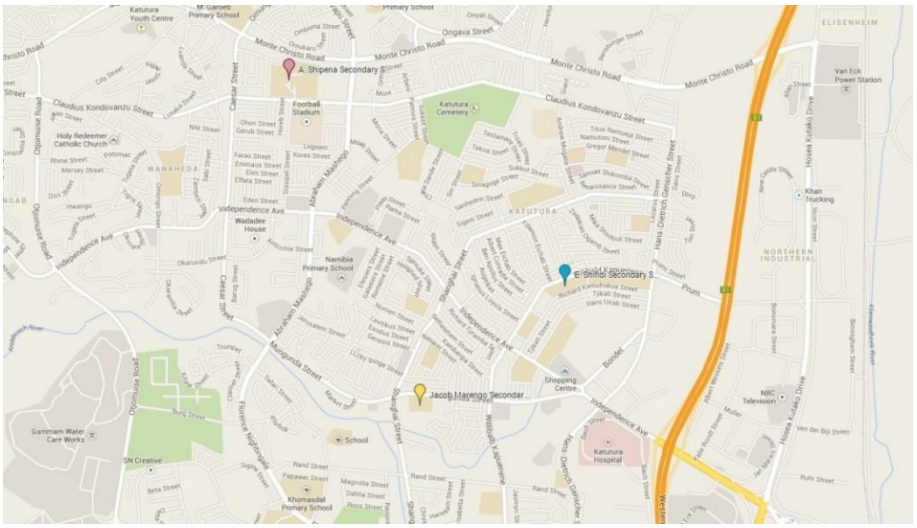

Figure 11: Immanuel Shifidi (indicated by the blue pin) is one of three main primary schools in Katutura (Google Maps, 2014).

The school has approximately thirty-six teachers and one thousand students in grades eight-twelve with 219 in grade ten alone (Minongelwa, 2014). However, enrollment after grade ten drops significantly with only thirty-five students remaining in the class by the beginning of grade twelve. This decrease in attendance, as mentioned earlier, is due to the high failure rate of the JSC exam. Immanuel Shifidi will be the primary school of interest during the selection and distribution process of our project.

In our first visit to Immanuel Shifidi Secondary School we were introduced to Martha Minongelwa, the science teacher for grade nine and ten students. During our talk with her, she gave more insight about the school and education system in Namibia. Every day, teachers assign homework that will take one to three hours of the students' time. There are study sessions after school for students to do their homework and ask questions to their teachers. She put a strong emphasis on the importance of the JSC exam that students are going to take in October. It is a stressful time for the students because it is a competitive exam that determines their future education. Some students are able to pay for private tutoring, which helps them study for the exam however, not everyone has the same opportunity. It was shocking to learn that only 19% of Immanuel Shifidi's tenth graders pass the exam. So in a class of 200 students only thirty-eight students would continue on to 11^{th} grade. Many of the students who fail the exam start looking for jobs in order to support their family instead of retaking the test and attempting to continue their education the following year. Every student learns at a different pace so it is hard to reach out to every student. Minongelwa suggested that if the classes were split by their skills and educational success, it would be easier to teach the material they need.

When we asked her about the home situations of the students, she answered that there is a clear distinction between the privileged and underprivileged students. According to Minongelwa,

most of the students must walk long distances to get to school. She mentioned that some students use this as an excuse to not do their homework when others are motivated to get out from their current situations so they try harder. Those ambitious, hardworking and self-motivated students are the students that we were looking for. These are the students with a less fortunate situation but deserving of the opportunity to improve their lives.

We also had the opportunity to interact with students when we were invited to a grade eleven life skills class. As we entered the classroom, all of the students started smiling and waving to us. They were interested in getting to know us and they were all wondering why we were there. There were about fifteen students and there was only one boy who was sitting on the other side of the classroom away from the girls. We introduced ourselves by telling our majors and explained to them why we were there. Immediately, the boy asked questions like what our majors are, our opinions of Namibia, how it is different from the United States and he even challenged Westley in a game of chess (Figure 11).

Figure 12: Westley Playing a Student in Chess

He was speaking very softly which made it hard for us to hear him so we had to walk closer to him. It was interesting to see how girls were shy to talk and that one boy carried the conversation. It made us question if Namibia is also a patriarchal society where males are more confident to address people. So we asked other girls to explain their experience with last year's exam. They mentioned that it was very difficult and they had to study a lot for it. They also said that many of their friends dropped out and that the classroom used to be full. Talking to these eleventh graders made it clear to us that grade ten is a crucial year for the students who want to further their education. It was also beneficial in terms of shaping our project to hear the perspectives of students who have already experienced grade ten.

4.2 Developing the Pico Solar Home System pilot program

4.2.1 Ownership of the Systems

Before we could begin selecting students to receive the Pico Solar Home Systems, we had to decide on two main questions: who will own the system and how will the student contribute to the cost of the system? We were able to answer these questions through interviews with various groups, such as Solar Age, teachers of Immanuel Shifidi, and REEEI.

Our original idea for distributing the systems was to cycle the Solar Home Systems through tenth grade students from year to year allowing for the maximum number of students to have access to light. However, our interview with Helvi Ileka and Abraham Hangula of REEEI made us realize that this was not the most ideal scenario. REEEI ran a similar system with energy shops in Namibia. An energy shop is a shop that provides the community with a source to purchase renewable energy products. An interactive display board was given to a select number of energy shops in order to develop interest in the shops from community members. After a year, REEEI tried to redistribute these display boards to other energy shops. The energy shops that had the

posters initially did not respond well to this system because they had become used to the business they brought in. Although these businesses may have been more reluctant to give back the system because it could affect their income, these families would still be in a similar situation. While taking the lighting away from the families would not affect their income, they would still be affected by the sense of complacency they experienced in the year they had their system before it was taken away from them. These families, like the energy shop owners, would be positively impacted by the systems and have their lives improved by them, only to be forced to revert to their prior conditions. Hangula described this process as "inhumane." Upon completion of the interview, we decided to take the information we received and reevaluate our idea to cycle the system amongst tenth graders.

While cycling the systems would provide more students with the opportunity to study for the JSCs, it was very obvious to us that it would be too detrimental to the families to take away from such a vital necessity like light after providing it to them for a full year. Although more families would benefit for the year they own the system, the "inhumane" removal of the system largely outweighed those benefits. The most effective way to distribute these systems would be to allow the family to fully own the systems. By owning the systems, it also provides students and their younger siblings with light throughout their schooling. We then spoke to Viviane Kinyaga, the director of DRFN, regarding the idea of letting the families own the system themselves. She also agreed with our decision that the families should own the systems since grades eleven and twelve are just as important to students who are looking to continue their education. These two interviews helped us realize cycling the systems would cause more harm than good to the families and that it would be best for the families to have full ownership over the systems once they were selected to receive them.

4.2.2 Compensation for the Systems

Once we decided that the families would own the systems themselves, we then had to decide how to have the families compensate DRFN for the systems. In our first week in Namibia, we interviewed Roedern, of Solar Age Namibia, the company responsible for providing the Pico Solar Home Systems. When asked about whether he believed the system should be given away for free, he responded, "What costs nothing, is worth nothing." This meant that if the students were given the systems for free, they may not treat them with the same respect as if they bought them. Because of this, Roedern proposed that the students pay a highly subsidized fee to receive the systems (around N$200 as opposed to N$1500). However, after speaking to teachers at Immanuel Shifidi, Hangula and Ileka of REEEI, and members of DRFN, it became evident that the students who need the systems the most cannot afford to pay a monetary fee. Minongelwa informed us that most students can barely afford school uniforms and are forced to either share worn-out textbooks, or go without one entirely. Her claims were confirmed during our visits to the school where we could see that there was a great difference between the number of students and available textbooks—a majority of which were barely still in one piece. Following these interviews, we faced a new dilemma in deciding the payment for the systems—do we give it for free to the students who need the system the most, or give it to the less needy students who could afford to pay for the system? Although it is absolutely crucial that the students take great care of the systems, our overall goal of the project was to help those students who really needed it; the students who faced many struggles while studying due to their less fortunate situations. Because of this, we decided that it was the poorer, needier students who should receive the systems. With this decision, it was obvious that paying for the systems, even at a subsidized price, was not feasible.

We discussed with Kinyaga, the reasons for wanting the system to be provided to the deserving students for free. She agreed with us that the students that need them the most cannot afford them, but that we still were faced with the problem that Roedern brought up in our interview—how can we ensure that the students take proper care of a free system? In an attempt to solve this problem, we came up with the idea to have the students take part in community service in order to remunerate DRFN for the systems. Because our overall goal was to help the students with their studies, we did not want the community service to overtake all of their study time. Our original ideas of community service was to see if Immanuel Shifidi or any other organizations in the community host formal community service activities, such as tutoring or volunteering programs. A weekly program would work the best since the student will be able to actively participate while still having plenty of time for schoolwork. However, after interviewing the Shack Dwellers Federation of Namibia, we learned that there is very little community service in the informal settlements. Due to this lack of a structured community service system, we needed to find a way to provide the students with community service activities. During our in school interviews with the students, one student mentioned the idea of an environmental club. Since the students were receiving a solar powered system and solar power is one of the most discussed environmental topics, we decided that this was the best idea for the students to give back for the systems by having the students become more aware of environmental issues in Namibia.

To gain more information about the formation of an environmental club, we interviewed Liina Nantinda, the director of Hochland High School and the coordinator of all environmental clubs in Namibia. The Hochland environmental club has been involved in many different projects, locally and nationally. The local projects involve planting gardens and orchards around Namibia while the national projects involve travelling to the United Nations Climate Change conventions

in various countries from Copenhagen, Denmark to Cancun, Mexico to Durban, South Africa. From her, we learned that the environmental club at Hochland started in 2006 with the same number of students as our project--ten. In order for an environmental club to be started in a school, the principal must support the idea and appoint a teacher who would be willing to put in the time and effort it takes to run the club, including weekly meetings with the students. When we brought up the idea to the principal of Immanuel Shifidi, Mr. Herman Katjiuongua, he said "you have my support 120%, no joke at all. This idea is long overdue and is something we really need here in this school" and "the idea itself is amazing" (Katjiuongua, 2014). Once the school resumes classes in May, he said that he would bring the teachers together and find one who would be dedicated to running the club.

However, since our team will not be able to personally oversee the initiation of the environmental club, we must rely on Nantinda and DRFN to assist the club. DRFN and Nantinda have both already stated that they would be willing to work with the Immanuel Shifidi environmental club to include them in activities relating to environmental and energy awareness. Nantinda and the rest of Hochland's environmental club also began as only ten students and one teacher and has quickly grown to be very successful. In a separate interview with the WPI group working with EduVentures, students of Hochland's environmental club expressed interest in helping other schools start their own club. They expressed concern that they were the only youth environmental club representatives at one of their environment conferences last year (Gutierrez, Hanna, Martel, Sevigny, 2014). If the students of Hochland are willing to assist with spreading environmental clubs to other secondary schools, then we hope that Nantinda will be a vital component in getting Immanuel Shifidi's club started.

In addition to the help from outside sources, the students themselves have shown enthusiasm towards the environmental club. During our at home interviews, we asked each student about their willingness to partake in the environmental club and were met with unanimous support. We hope that between Nantinda and DRFN's involvement and the students' apparent willingness to participate, the environmental club will become a sustainable program at Immanuel Shifidi. From the initiation of this program at Immanuel Shifidi, we were able to fulfill DRFN's idea of having the students pay for the system, in a way that is not monetary, by becoming more aware of environmental issues.

4.2.3 Selection Process

The ownership and payment decisions were made and the final step to finalizing the foundation of Pico Solar Home System pilot program was to decide how students would be selected to receive the systems. As stated in our methodology, we decided that the first step of selection would be to create and distribute a questionnaire to all grade ten students at Immanuel Shifidi. In our first interview with Roedern, he provided us with sample questions that we could include on our questionnaire. These ranged from questions involving how much the family would/could pay for the system to how many school-going members live in the household.

Using these questions we created the questionnaire and we then had to decide how to select the students based on their responses. Study habits and access to electricity were the two main focuses of our selection criteria. We were able to identify the ambitious students from the answers to their daily schedules. Students who spent over four hours watching television were clearly less motivated students than those who spent over four hours studying instead. We also wanted to ensure that the students receiving the systems were the ones who needed it the most. So we were able to identify students who did not have access to electricity. From these two criteria in addition

to the student's willingness to participate in Immanuel Shifidi's environmental club, we were able to narrow down the selection pool enough to distribute the systems. Although this worked in the pilot study, in future expansions of this project other criteria such as number of siblings and distance walked to school may need to be considered.

4.3 Learning about students' lives from their perspectives

4.3.1 Questionnaires

Once we developed our selection criteria and process, which can be found in Chapter 3.2 of the Methodology section, we began to put it into action. Our questionnaire was a way for us to gain a better understanding of these students' lives and to get an initial idea of how much the community needed this system. It was also a way for us to narrow down our selection pool because we felt that only the motivated or those that needed it would complete the survey. From our previous interviews, we decided that the main information we needed to gather was: the students access to electricity; if the student walks or gets a ride to school; how long it takes them to get to and from school; how much time they spend on their homework; any problems they experience while doing their homework; and if they would be willing to do community service as payment for the system. Of the 220 surveys that we distributed, we received 142 responses. To our surprise, we found that most of the students at Immanuel Shifidi Secondary School already had access to electricity according to how they answered the survey. Of the 142 responses, we received about 108 students claimed that they have access to electricity. Figure 13 shows the responses from the question of what do the students use for light at home.

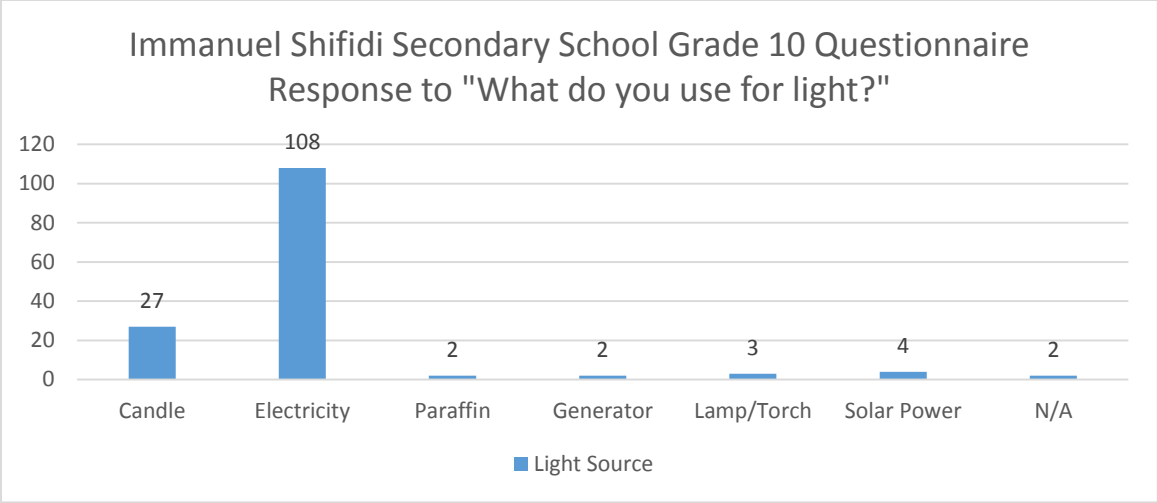

Figure 13: This figure shows the grade ten students' questionnaire responses to "What do you use for light?" from Immanuel Shifidi Secondary School.

Even though the majority of students claimed to have access to electricity, not all had a reliable source of electricity, allowing us to continue our selection process at Immanuel Shifidi. In the questionnaires, we left a space for any comments or questions the students wanted us give us. Some notable themes from the comments were: students asking us to help those students without electricity; asking us why the government has yet to step in to help those in the informal settlements and give them proper access to electricity; and for those without electricity asking us if we were going to help them. From the perspective of these students, it seemed as though the government has just forgotten about the challenges residents of the informal settlements face.

From the questionnaires we were also able to gather more data besides what they use for light such as: how far most of the students lived from the school, how many were willing to do community service, what problems most students encounter while studying; and how many plan to continue their education if possible. These results can be seen in Figures 14 – 16 seen below and a full breakdown of all data received from the questionnaires can be seen in Appendix E.

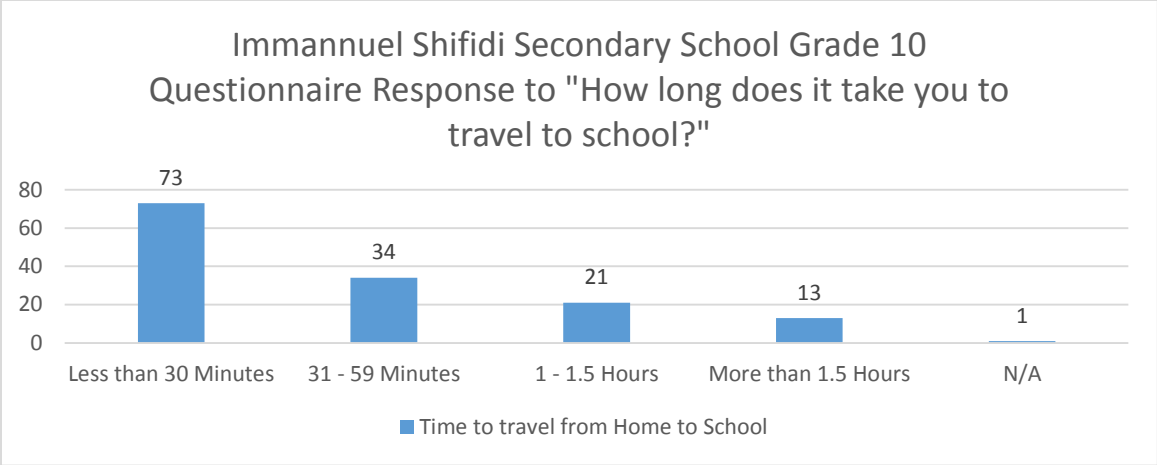

Figure 14: This figure displays the grade ten students' questionnaire responses to the question "How long does it take you to travel to school?" from Immanuel Shifidi Secondary School

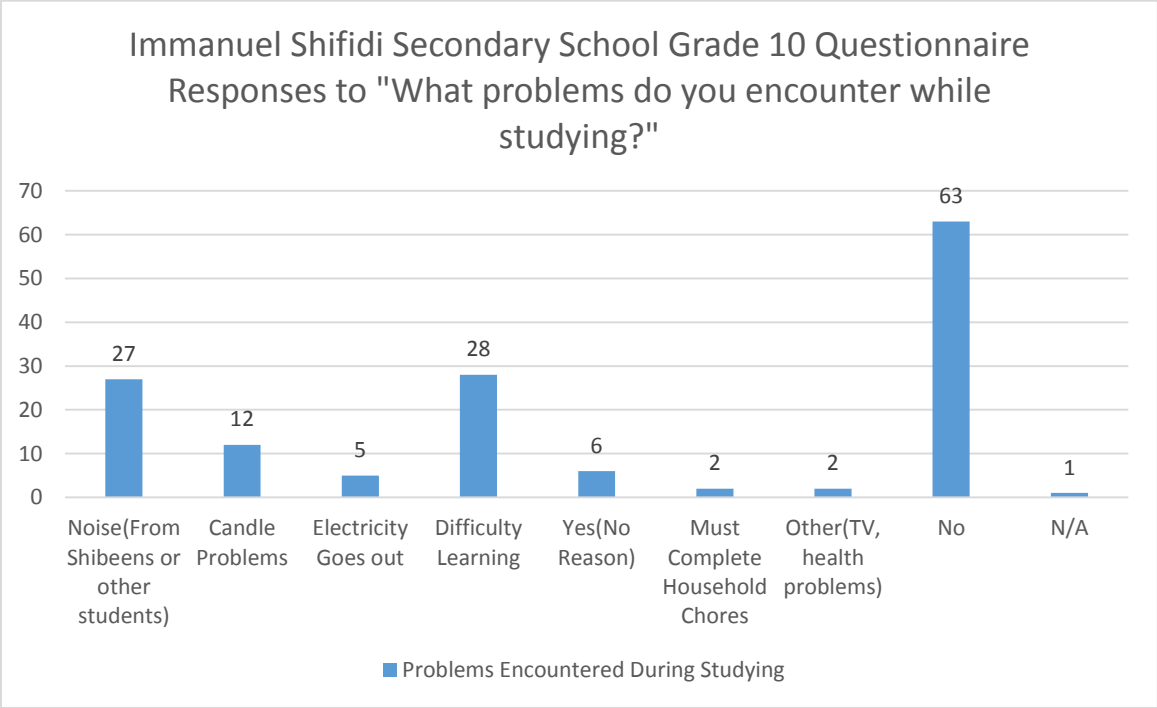

Figure 15: This figure displays the grade ten students' questionnaire responses to the question "What problems do you encounter while studying" from Immanuel Shifidi Secondary School

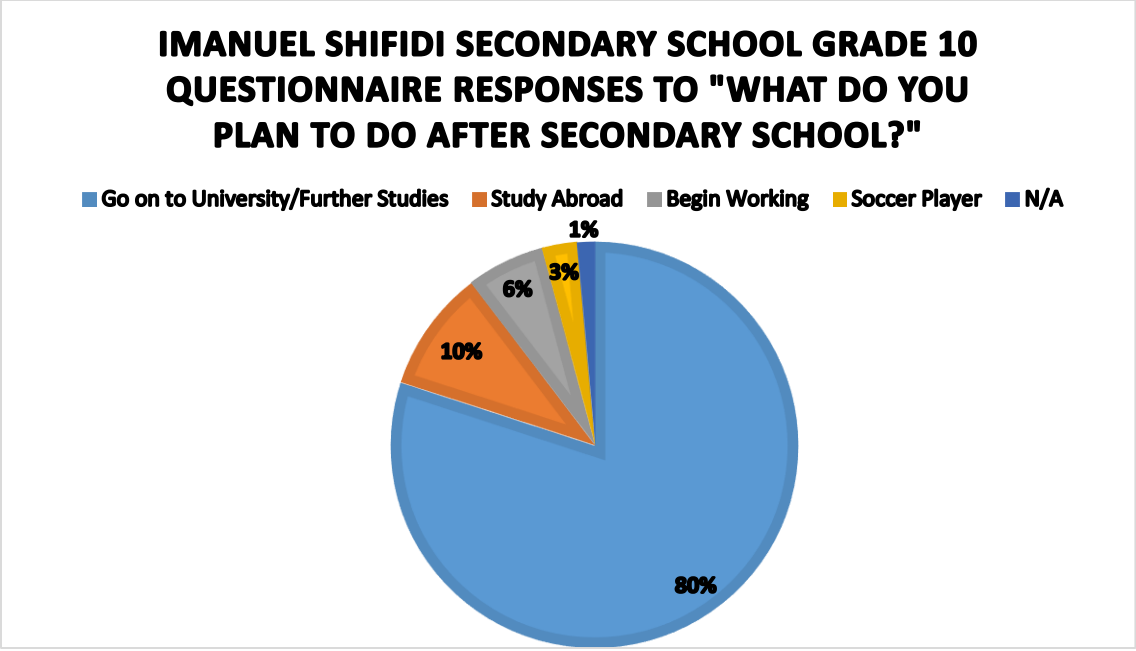

Figure 16: This figure displays the grade ten students' questionnaire responses to the question "What do you plan to do after secondary school?" from Immanuel Shifidi Secondary School

Seeing that we had so few students to choose from at the start (twenty-four) made us somewhat relieved since it made it easier for us to continue to diminish the selection pool. However, we were also somewhat disappointed since we could not test our all of selection criteria, such as distance to school, or number of siblings, on a large set of students without electricity. We then created a subset of students from the responses we received, based on those without electricity and those willing to do community service, and returned them to the school to compare our list with the list the life skills teacher, Mrs. !Gaoses provided us. The list she provided us was a set of students who she felt would benefit most from receiving the system. We had originally planned to use the list from the life skills teacher to narrow down our selection even further by only interviewing students that appeared on both lists. Because our pool was already smaller than we initially thought it would be, and since most of the students on our list appeared on the life skills list, we decided to add the students from the life skills list to our list of students. This was done in

order to increase the number of students to be interviewed from twenty-four to twenty-eight so we could hopefully use more of our selection criteria in testing our process. It was an exciting moment when we saw that both lists were very similar because it meant that at that point our process was working as intended to find those students who are in need of light and whose lives and academic performance would improve upon receiving the system.

4.2.2 At-School Interviews

We then entered the next stage of our selection process, the at-school interviews. These interviews were a way for us to see what type of people these students were, get more information from them, and to verify any questionable information gathered from the questionnaires. We sent our list of students to Minongelwa. She then contacted each student on the appropriate day for their interview to make sure they knew to stay after. In Figure 17 she can be seen gathering the students after school and lining them up to help us put a face to their name.

Figure 17: Ms. Miningelwa Gathering Students for the At-School Interviews

Going into these interviews, we were excited to meet these students and continue our process. We figured that the majority, if not all, the students would be interested in the project and excited at the chance to receive the solar home system. During the course of our interviews, we were disheartened by the fact that some of the students did not show up to the interviews, or gave the impression that we were wasting their time. We had the students who were in attendance call their absent friends and ask where they were. The missing students responded by saying they were not coming because they "had to go home" or "did not want it", and did not want to reschedule. During these interviews we also found that some students had misrepresented their electricity use on their questionnaire. When asked again during the at-school interview, some students told us that they did have electricity when on the questionnaire they responded by saying that they did not. This could be due to the fact that they did not understand the question or wanted to seem like better candidates for selection by providing false information on the questionnaire. On the other hand, we did meet some students who were prime candidates for this pilot program. One student lives by herself in the informal settlements, about a two hour walk from the school. Her mother left her to go back up north to the village and now she must provide for herself. She even has a garden which she uses to grow her own food. She has no electricity and has to use the torch light from her phone in order to study at night. Her full profile can be seen in Appendix J.2.

Although the in-school interviews were informative and allowed us to further narrow down, by the process that can be seen in Chapter 3.2, the pool of eligible students, it did not allow us to witness all the challenges that the students faced or whether they were being truthful, such as whether or not they had electricity, when answering our questions during the interview. Therefore, we decided that it was best to hold at home interviews in order to gain more insight into the students' daily lives and involve the parents. After the interviews at the school were completed,

we came together as a group to select the students whom we would conduct at-home interviews with. Since we had such a small pool to start, it was easy to place nine of the twenty into the top ten that would be interviewed based on our selection criteria. For the tenth spot, we had six students that all seemed equally deserving, where none of them stood out during their interviews as the other nine had. To select one student from the six, we went through each part of our selection criteria and removed students one by one until we had only one left. The main criteria we were looking at were: distance to the school; number of siblings; and what they do in their spare time. Those students that spent most of their time playing or sleeping and less time studying were removed first. We then removed the students who lived closer and finally we used the number of siblings still in school to select the final candidate. The remaining would also be interviewed in addition to the top ten but would be treated as alternates in case a problem arose with one of the top ten.

4.3.3 At-Home Interviews

The at home interviews were a valuable way for us to become acquainted with the students' families and become familiar with their living conditions. Upon arrival to their shacks, the families were all very welcoming and either the student or their guardian gave us a quick tour of their home. The style of the shacks varied with some containing as many as four to six rooms and the smallest containing only one. Some students lived in very impoverished areas and their shacks were small, cramped, and hot while others had larger shacks that were located in better neighborhoods. The different types of shack can be seen in Figure 18 and Figure 19:

Figure 18: A Small Shack in Babylon

Figure 19: A Student and Her Family in Front of Their Large Shack in Okahandja Park

All the families and students were welcoming to us when we arrived at their home and expressed this by offering us a place to sit and beverages to enjoy while we conducted our interview. During our interviews, the families showed us where they conducted their daily activities and pointed out where the students usually studied once they returned home from school. We then sat down and discussed with the families what the system was and what its purpose was. The families were all more than willing to answer our questions and tried their best to speak in English. Although we often had a language barrier with the family and had difficulty understanding them, our translator Ganeb was able to convey our message appropriately. Even with the barrier, the families were receptive of the project and were happy that the students were being given this opportunity.

In several of the shacks, however, it was difficult to see the family we were talking with or just a few feet in front of us, even in the middle of the day, as little light was able to penetrate the metal walls. They would often light a candle and place it in the middle of the room, but it was still exceedingly difficult to see. These at homes visits allowed us to experience first-hand how difficult it is for students to study and conduct other household activities.

Three of the shacks that we visited owned large generators inside which suggests that they have readily available access to electricity. Upon discussing them with the families, they dismissed the generators saying that they could not afford to pay for the gas to fuel the generators and had to rely solely on candles for light. This was seen as a red flag and the students that possessed the generators were removed from the selection pool. The decision to do so, was also based on the overall home check as many of the homes that had generators also owned large electrical

appliances including TVs, DVD players, and microwaves. A few examples of these homes can be seen in Figure 20 and Figure 21.

Figure 20: A Student who had access to electricity via an informal connection who was removed from the selection pool

Figure 21: A Student who had intermittent use of a generator who was removed from the selection pool

Unfortunately, we were not able to contact two of the students as they provided us with an incorrect contact number during the at-school interview and we were not able to obtain the correct number from the school. From the students that we were able to interview, we selected ten of them in total in nine different households, because two who made the list, Martha and Thomas, are cousins and live in the same shack. Their profiles can be seen in Appendix J.9 and Appendix J.10 respectively.

4.4 Installing the systems

The installation of the systems was easy and efficient largely due to the assistance of Lucky Ganeb. The location of the students shacks were spread out over several suburbs of Katutura including: Babylon (red), Okahandja Park(green), and Okuryangaea (blue) (Figure 22).

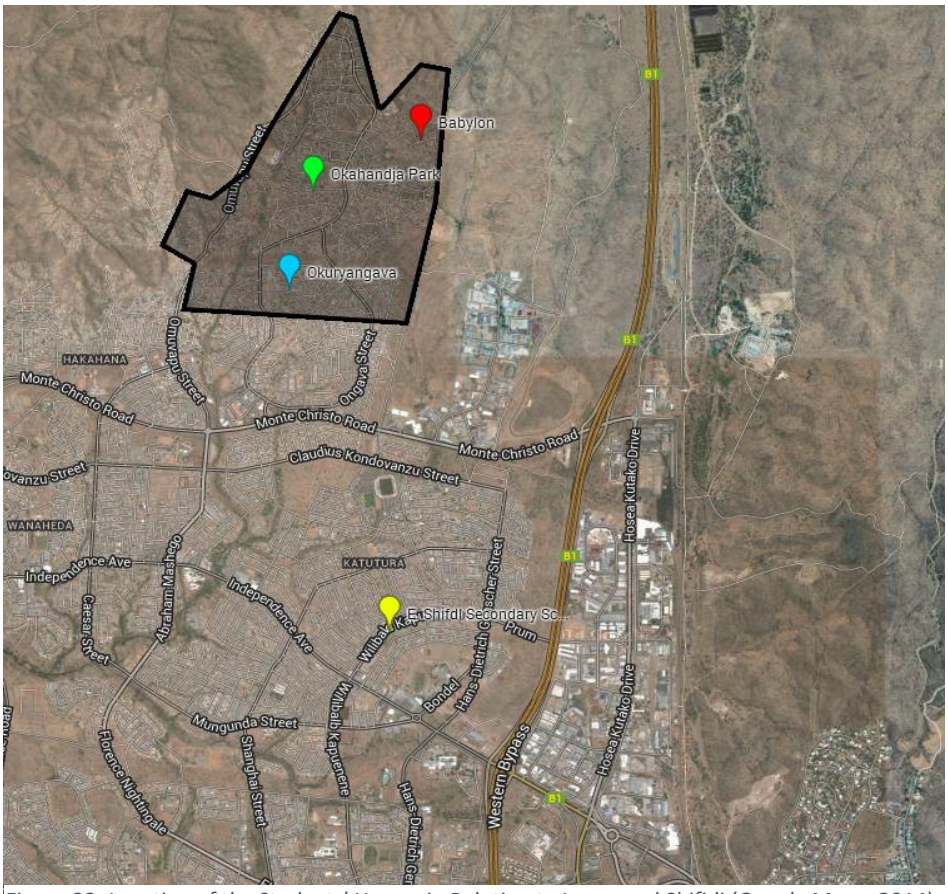

Figure 22: Location of the Students' Homes in Relation to Immanuel Shifidi (Google Maps, 2014)

When we first arrived at the homes and told the students that they were receiving the systems, they were excited and would not stop smiling. Many were more than willing to assist us in the installation, such as helping string wires through the ceiling, and loved taking pictures with their new systems. They all mentioned that it would have a great impact on their study habits with one saying, “Now I can even wake up anytime and study because I have LIGHT!” (Ansie, 2014). In Figures 23-27, we show how we installed the systems.

Figure 23: Placing the Solar Panel on the Roof

Figure 24: Mounting the Control Box and Setting up the Lights

Figure 25: Plugging Everything In

Figure 26: Ganeb Reviewing the Operations Manual with a Parent

Figure 27: Newaka Signing the Contract and Consent Forms

The first part of installation was congratulating the students and explaining the different components that are included with the system. Next, we asked them where their primary study area was in order to place a light there. In addition, we asked what other room they would like to have a light in, which in all cases was either their room, if this was not their primary study location, or in a common room of the home. By placing a light in their room, it would allow them to study even if people were visiting the home and occupying the common area because, as Ganeb stated, more people might visit the shack since it will have lighting.

After figuring out where the lights would be located, we began assembling the system. The control box was either screwed into a wooden support beam so it was mounted or it was placed on a sturdy, flat surface depending on the structure of the shack. Once the control box was set-up, the wire from the solar panel was threaded down from the roof in between where the wall and ceiling met and was connected to the box. While most roof heights were manageable, there was one that

required the assistance of stepping on a chair. This could pose a possible problem for the family when they are removing and then placing the solar panel back. However, this was not a major problem as using a chair or large rock would be suitable for reaching the roof.

Next, the lights were connected to the control box and the student was shown where each attachment plugged in. They were also shown how to test the battery to see how full it was and how to appropriately use the cell phone charging port without draining the battery. We also provided them with the operations manual.

Our operations manual is primarily picture-based and was provided to each of the participating families. The manual was used to help guide the families through setup, how to use their new solar home systems, and the usage restrictions on the system (such as number of hours of light per full charge). Our idea to include mainly pictures and tables in the manual was to avoid any language barriers that may arise and to provide a simple guide to follow. Brief written descriptions were also included, but just as a secondary means to explain the process. By using this universal manner of communication, we ensured minimal problems during the installation phase of the project. Our operations manual can be found in Appendix H.

Once all the installation was completed, Ganeb turned on both the lights and the radio and we got to witness the sheer joy on the families' faces when they saw how the lights illuminated the rooms. Lastly, we reviewed the contract and consent forms with the students and their caregivers. The contract contained guidelines for how the system should be used, that the student agrees to partake in the environmental club, and that if a problem with the system shall arise they should contact the designated teacher. The full student contract can be seen in Appendix L. The consent form stated that the student agrees to allow us to use their name, pictures, and video in the paper and can be found in Appendix M.

At the end of the installation, we asked the students to take a quick video where they told us a little about themselves, like their name, age, and how long it takes them to school as well as how the system would positively affect their study habits. We also provided them with the operations guide to assist them in using their systems and Ganeb was kind enough to provide his number so that they could contact him with any issues or concerns that they had.

During installation, we faced a few problems, however, we were easily able to overcome them. One of the most concerning was the heat that the shacks' metal walls conduct, which prevented us from mounting the control boxes on the walls in some of the shacks for fear that it would overheat the battery. Instead, we placed the box on a nearby table or fastened it to wooden supports. One other concern that we had was having the wires crisscross, creating a hazard for the residents. Luckily, there were several areas for us to thread and fasten the wires to the ceiling and the roof of the shacks.

The main issue that we had to address with the families was the threat of theft. Because the solar panel was placed on the roof, it is visible to someone walking by, especially in the shacks with lower roofs and those located near main roads. To counteract this, we advised them to remove the panel from the roof at night and when they would not be at the shack for an extended period of time and place it safely inside.

Besides these issues and concerns, the overall installation went very smoothly and although we were all covered in dust and dirt by the time we were finished, it was well worth it to see how excited the students were with their new systems.

4.5 Designing a process to evaluate project impacts.

After the pilot program was put into effect, we needed to design a process to inform DRFN of how beneficial the systems actually were to the students. Our primary idea to evaluate this

impact was to monitor the change in academic performance of the students. Since the main objective of providing the students with these systems is to better there studying habits, we hope that their grades would improve throughout the year. As stated in our methodology chapter, our solution to this is to have the teachers at Immanuel Shifidi submit the students' grades to DRFN in order to observe the changes. The only question we had in regards to monitoring the academic progress was how often should the grades be submitted? We expected to see the most improvements over the first few months of using the system since the students will immediately be able to increase the number of hours they can do schoolwork. After the first few months, the student should be relieved of any light-related studying problems and their grade improvements should start to level off. Because of these expectations, we believed that monthly academic reports would be suitable at the start of the program and then reduced to less frequent reports after a set period of time. When we asked DRFN what their expectations were of the number of academic reports, Kinyaga informed us that she would like them to send monthly reports for the first year, and then quarterly reports after that. This matched our initial idea and we informed Katjiuongua of the decision. He agreed to our proposal and said he would fax DRFN the students' grades when they were submitted.

While our main focus is to improve the students' academic performance, there are more factors that contribute to the overall impact of the systems. Sometimes there are personal events occurring in a student's life that may prevent him from performing his best in school. In order to get the bigger picture of how the systems impacted the students' lives, we needed to find a way to see beyond the grades. We decided that the best way to learn about any personal setbacks would be to have the student speak for themselves. As stated in our methodology, we also included a writing prompt for the students to fill out and return to Immanuel Shifidi. We wanted to provide

the students with an opportunity to personally tell their story about how the system has affected their lives as well as any problems they were experiencing. In order to get this information from them, we specifically asked them to write about any problems they had, how their studying has changed, and to just openly write about the impacts the system has had on their daily lives. We decided to make the question open ended so the students can write whatever they would like to, without being restricted.

One concern with the writing assignment was that we did not want to overwhelm the student with work and take too much time away from their studying. Also, if this assignment was submitted with the monthly reports, the students would not witness any major changes and would start filling the prompt out just as another homework assignment, as opposed to a chance for the student to really tell their story. To counteract this, we decided to have the prompt be distributed quarterly so there is plenty of time between each report. Since it is more spread out, we hope that the student would be more willing to fully describe their experiences, positive or negative, with the systems. By monitoring the grades and having the students tell their own story, we hope to effectively notice the effect the systems have on the student. Observing the effect is crucial to determining the overall success of this project and to see how much, if at all, student's lives can be improved with the Pico Solar Home Systems.

5. Recommendations and Conclusions

5.1 Recommendations

After completion of data analysis, interviews, at home visits with students, and distribution of the Solar Home Systems we have generated several recommendations for DRFN, Immanuel Shifidi Secondary School, Solar Age Namibia, and the families who received the systems. The purpose of this section is to assist these organizations in improving upon the pilot study that was conducted in order to allow for the expansion of the project to other schools within Namibia.

5.1.1 Recommendations for DRFN

We recommend that DRFN expand the Pico Solar Home Systems Project to rural schools outside of Windhoek.

From the results obtained through the student questionnaires and the at home interviews we found that the majority of tenth grade students at Immanuel Shifidi have access to electricity. We also learned that even those who did not have a formal connection to the grid often use a gas generator or receive electricity from a neighboring house through a makeshift wire connection. Out of the twelve students that were interviewed at their homes three had access to electricity through one of these methods. Therefore, the Solar Home Systems should be distributed to students who reside in the rural areas and would possibly benefit most from the systems as they do not presently have the opportunity to acquire an adequate lighting source due to the lack of a formal electrical grid in their areas.

If DRFN is to expand the project in the future, we recommend they use the selection criteria that we have created for this project. This primarily included the student's access to electricity and their willingness to partake in Immanuel Shifidi's environmental club. This was sufficient to narrow down the selection pool of tenth grade students to a manageable level. In the event of

DRFN expanding the project to a community with less access to electricity, the selection criteria should be expanded to possibly include: distance travelled to school, number of siblings attending school, number of people in the household and the students' past academic performance. They should also alter the questionnaire to fit the needs of the community where it will be distributed. For example, if they were distributing the questionnaires in a more rural location they may add questions that include:

- What are some ways that you access electricity at home?
- Is it difficult for you to obtain candles, paraffin, and kerosene?
- Is it difficult for you to travel to your school?

We recommend that DRFN conduct monthly or bi-monthly at-home checks to ensure that the system is being used properly according to the operations manual and in the student contract.

During our installation process, Ganeb informed the students that he would be checking in, unannounced, on a monthly basis to ensure that the system was being used properly. By conducting these checks, DRFN can assure that the students are following the guidelines outlined in their contract. It will also allow DRFN to see if the systems are still present in the household as theft is a possible concern. DRFN should continuously remind the families that panels should be brought into the home at night and whenever they are not present to protect it from theft and damage.

We recommend that when the systems are installed DRFN or an appointed individual, that the control box is not mounted on the house walls, if they are all metal, and rather placed out of sunlight on a flat surface.

During a few of our at home visits conducted during the middle of the day, we noticed that the metal walls of the shacks tend to become extremely hot. Hence, it is highly recommended that

the students do not mount the control box on the wall as it may cause the lithium ion battery within the pack to overheat and render the Solar Home Systems unusable. Instead they may place it on their counter or other hard surface that is not in a position where it could be knocked off or bumped by an occupant of the household. As stated in the operations manual and as it was installed during the pilot program, if the control box should need to be moved or during the installation of a new one, it should remain out of direct sunlight and rain.

We recommend DRFN to encourage the formation of an environmental club at Immanuel Shifidi and collaborate with this club to organize trips to the main office in Windhoek and the Gobabeb Desert research facility.

Through the formation of an environmental club, as mentioned previously in the findings chapter, it would allow the students to become more aware about solar power and environmental issues. It would allow the students who received the systems to connect with one another and share their experiences. DRFN could also actively participate in this club in the following ways mentioned below.

By giving the students a tour of the DRFN main office, it would allow them to see what projects DRFN is working on and get the opportunity to meet the staff who made the Solar Home System project possible. They are several visual agents that DRFN currently uses to promote renewable energies including a trailer that is powered by a solar panel and contains a computer, fridge, and radio that would be of interest to students. It is used as a mobile educational unit and is brought into rural areas to spread awareness of the potentials of renewable energy.

After speaking with Dr. Seely, the founder of DRFN, it would also be beneficial for the students to visit the Gobabeb Desert research facility, possibly for an overnight trip, to educate them about the large solar panels that are in use at the facility. By working hands-on with projects,

it will help the students gain a better understanding of the importance of sustainability as students tend to grasp concepts easier in this way (Guitierrez, Hanna, Martel, Sevigny, 2014). Also, by DRFN including the environmental club in their projects, the students will have an opportunity to feel as if they are personally contributing to the betterment of Namibia (Newaka, 2014). DRFN's involvement with the environmental club is critical in ensuring that the club will be able to continue functioning after the original ten students from the pilot program leave Immanuel Shifidi.

DRFN should also attend an environmental club meeting once a month to ensure that the club is functioning properly and to promote new ideas and activities for the students to partake in. DRFN should contact guest lectures to speak to the students in the club, or in the school as whole, to increase awareness about climate change, renewable energy, and other environmental challenges facing Namibia. Guest speakers could include: Helvi Ileka and Abraham Hangula from REEEI, Clarence Ntesa from the Polytechnic of Namibia, Corris Kaapehi from Eduventures and Conrad Roedern from Solar Age Namibia.

5.1.2 Recommendations for Immanuel Shifidi Secondary School

We recommend that Immanuel Shifidi Secondary School establishes and develops an environmental club.

Through our research and interviews, we found that there is a lack of environmental education programs at Immanuel Shifidi. As part of the community service requirement, the students who receive the Solar Home Systems can participate in this environmental club at the school. By participating in this club or even if the club is not established, they can express the benefits of using solar energy, like their solar home systems, and other types of renewable energy to their classmates and possibly to their communities. In addition, by establishing an environmental club, it would allow other students to become educated about renewable and sustainable energy

and help raise awareness about environmental issues facing Namibia such as desertification, erosion, and pollution. Several ideas for initial projects for the students could include: creating a community garden at the school and trash pick-up around the school and community.

In order to make the club successful and sustainable, the principal will need to identify a teacher who is willing to volunteer to become the director of the club. This teacher should be highly motivated, enthusiastic, and willing to spend after-school and some weekend hours working with the students in the club. Possible incentives for teachers could be compensation for their time or the intrinsic value of improving their community. However, directors of other clubs do not receive financial compensation but rather volunteer because they are passionate about it (Guitierrez, Hanna, Martel, Sevigny, 2014). This director will be responsible for holding weekly meetings with the students and collaborating with Liina Nantinda and DRFN to create projects and programs for the students to complete. Once the club has been established and began working on its first projects, we also recommend that the principal appoint one or more teachers to assist the director.

By joining the club, it allows the students to gain valuable professional and leadership experience. The club teaches them to be loyal, patient, and disciplined. It also teaches them the value of teamwork, taking accountability for their actions, and establishing goals for themselves all while working towards the betterment of their community (Guitierrez, Hanna, Martel, Sevigny, 2014).

We recommend for Immanuel Shifidi Secondary School to identify a teacher to be in charge of contacting Solar Age Namibia if problems with any of the Pico Solar Home Systems arise.

Originally, we planned on identifying one member of each region where a system was distributed to be in charge of maintaining the systems. However, we decided that it would not be

optimal for us to be in charge of selecting one of the community members to be in charge of this. In the event of any problems arising with the systems, the students can easily get in touch with a teacher at their school. This also creates a safer medium for the student to contact rather than an unfamiliar member of their community who they may not feel safe or comfortable approaching. For these reasons and through our interviews and other discussions, we decided that it would be a better idea to set up contact between Solar Age Namibia and a teacher of Immanuel Shifidi.

We recommend that Immanuel Shifidi Secondary School monitor the impact which the Pico Solar Home System has on students' lives as well as their academic performance.

Because various factors can affect the grades of students, such as emotional distress or changes in their daily lives, it would be beneficial for the school to have the students complete a writing prompt which can be found in Appendix K. It is recommended that the students complete this prompt on a quarterly basis as to not overwhelm them with additional work and should be submitted by the teacher, along with their grades, to DRFN for review. This would allow the students to express how the system is affecting them and any concerns they may have in writing as opposed monitoring the systems strictly based on the students' academic standings.

5.1.3 Recommendation for Solar Age Namibia

We recommend that Solar Age Namibia educates a teacher from Immanuel Shifidi about the system and how to solve malfunctions that arise.

The main problem that occurs with Solar Home System projects around the world is that they can break and the owners do not have easy access to parts to repair the systems or to someone who is knowledgeable about how to repair them. After speaking initially to Roedern about the Pico systems, we were informed that the systems were easily repairable and if a part breaks, it can be replaced. Replacements can be purchased at Solar Age Namibia, however as Roedern mentioned

during our interview, the system will last for around four to five years without needing repair as long it is properly taken care of. In the unlikely case that the system or a part of the system should break, the students and their families would be responsible for buying the replacement parts.

As stated before, we believe that a teacher from Immanuel Shifidi would be the best contact person for the students. A possible incentive for the teacher to be trained could be monetary compensation for their time. In order to ensure that this works, Solar Age would need to educate the teacher on the system in order to fix small problems such as replacing a battery or a malfunction of the solar panel. If a larger problem arises, such as a broken piece, the teacher can communicate with Solar Age in order to obtain the replacement parts and repair the system. Since the school is located in Windhoek, less than ten minutes away from Solar Age, it will be easy for any parts to be delivered. If there is not a teacher who wishes to volunteer to be trained, we recommend that Solar Age Namibia and DRFN be in charge of the maintenance of the system.

5.1.4 Summary

These recommendations can be used to assist in the implementation of the Solar Home Systems Program by DRFN. They encompass various aspects of the program including the promotion of environmental issues and renewable energies, monitoring of the impact on the students, and upkeep of the system after installation. We encourage DRFN to consider our recommendations to help the pilot program become more sustainable.

5.2 Conclusions

By providing the students with the Solar Home Systems, we hope that their academic performance and overall quality of life will be greatly improved, as many of the students believe it will be. The availability of a renewable energy source will allow the students to study at night and slightly help to alleviate the financial burden that purchasing candles or kerosene placed on

their families. It also diminishes the health risks that the residents face while using candles as their main source of light.

With the creation of the selection criteria and development of a process to evaluate the impact of the systems on the students, DRFN has the means to expand the project to other areas in the future. Because the majority of students at Immanuel Shifidi reside in electrified areas, we were only able to assist a limited number of students. By expanding the project to rural and un-electrified areas, DRFN can impact more students' lives.

Through expansion of the project, DRFN will also be able to demonstrate to students and their communities, the advantages of renewable energy and provide them with a form of light while they await connection to the national electrical grid.

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Appendices

Appendix A: Interview with Conrad Roedern

Conrad Roedern is the founder and owner of Solar Age Namibia and provided us with the Solar Home Systems. These were the questions that we asked during our interview:

1. How many systems do we have?
2. What does the system include?
3. What are the costs for these systems?
4. What is the subsidized price for the systems?
5. Can you tell us what is included in the kit that the students will be receiving?
6. Do you think people will be able to afford to pay for them?
7. If they cannot afford them, how would the students "pay" for them?
8. What is the warranty for the system?
9. How difficult is the installation of the Pico Solar Home System?
10. How easy is the maintenance of the system?
11. Are there any examples around the world where this system was implemented?
12. Have there been projects (school models) been conducted elsewhere previously?
13. Who do you suggest us to contact to get more information about these past projects?
14. Do you have any additional recommendations of who we should contact that could assist us in the process?

Appendix B: Interview with Martha Minongelwa

Martha Minongelwa is a science teacher at Immanuel Shifidi Secondary School and was our primary liaison at the school during the project. These were the questions that we asked during our interview:

1. Can you tell us a little about the background of Immanuel Shifidi such as when it was established, what grade attend here, when school begins etc…?
2. How many students and teachers are at Immanuel Shifidi?
3. Out of these students, how many are in the tenth grade?
4. Can you tell us more about the JSC exam that the tenth graders take? Like when the students take it, when they receive their results, passing rates, how the students prepare etc…
5. Does it cost anything to attend the school or for extra tutoring sessions after school?
6. In addition to the tuition, do the students have to buy their own textbooks?
7. Is it difficult for the students to have to share the textbooks?
8. In the classes are the students with different abilities mixed?
9. Because they are mixed, is it more difficult for teachers?
10. Do the advanced student become upset when their classmate does not grasp a concept right away?
11. How do you address this issue?
12. Is there a clear distinction between the students that travel long distances to school?
13. Do the majority of students have to travel far to get to school?
14. Do they struggle to do their school work?
15. How often do you assign homework?

16. Do the vulnerable and orphan students use their at-home situation as an excuse or as motivation when it comes to academics?
17. By providing the solar home system to vulnerable and orphan children would it benefit them academically?
18. Who would you select to receive the systems?
19. Could they afford to pay a monetary fee for the systems?
20. Because they cannot afford to pay for it, would they want to partake in community service activities instead?

Appendix C: Interview with REEEI

Helvi Ileka and Abraham Hangula are both employed by REEEI (The Renewable Energy and Energy Efficiency Institute) and assisted us in determining the conditions by which the students would own the systems. These were the questions that we asked during our interview:

1. Can you tell us about the energy shops?

2. How many are there currently in Namibia?

3. What are the future plans for the shops?

4. What problems did you face when establishing the shops?

5. Do you think we will face similar problems when distributing the Pico Solar Home Systems?

6. What are your opinions on our project?

7. What do you think would be the best way to distribute the systems?

8. How should the students pay for the systems?

9. What if the student cannot afford to pay a monetary fee?

10. In regards to cycling the systems amongst tenth grader, how do you believe the community would react?

11. Who should own the systems? The school or the students?

12. What do you think of the idea of having students using the system to earn money through charging phones?

Appendix D: Student Questionnaires

Desert Research Foundation of Namibia

Solar Home System Questionnaire

The Desert Research Foundation of Namibia is working in collaboration with students from Worcester Polytechnic Institute of the United States to provide 10 solar lighting systems to grade 10 students. The purpose of this questionnaire is to identify interested students and gather general background information. Applications will remain confidential. Completion of the application does ***not*** *mean you will be selected to receive a solar lighting system.*

Name:

Year:

Home Address:

Background Information:

Do you walk or get a ride to school?

How much time does it take you to get to school in the morning?

How many brothers and sisters do you have? (Please list their grades)

Give an example of your daily schedule, including number of hours spent on school work and chores:

Activity	Hours spent

(if you need extra space please use the back of the paper)

What do you use for a lighting source at home?

To obtain a solar light system, would you be willing to complete a monthly requirement of roughly 10 hours of community service (i.e. tutoring, volunteering at an orphanage)?

Do you encounter any problems while studying? If so please explain.

Future Plans:

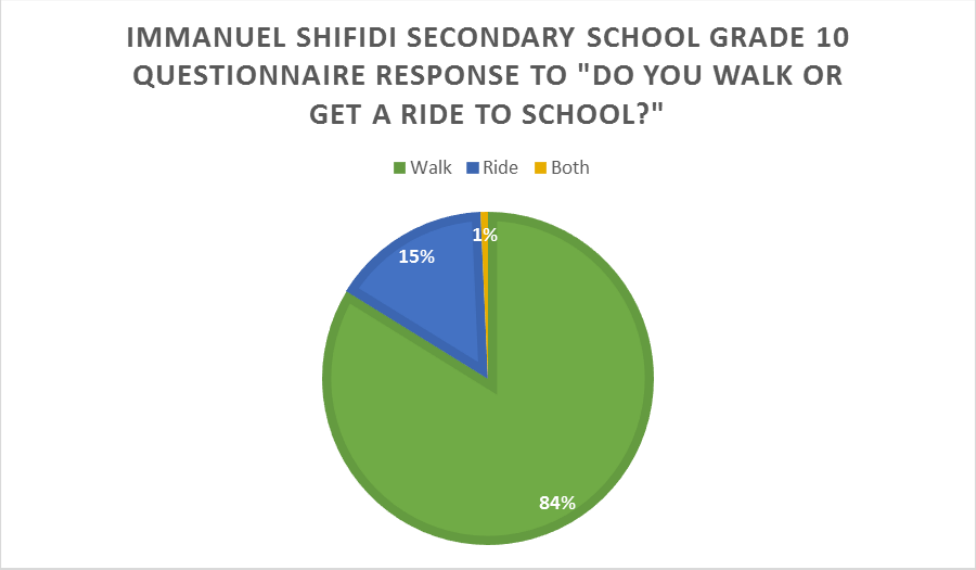
What are your plans after secondary school?

Do you have any questions, comments, or concerns?

Appendix E: Questionnaire Results

Age	Number of Students
15	18
16	57
17	42
18	16
19	2
20	1
21	1
N/A	5

Walk or Ride	Number of Students
Walk	119
Ride	22
Both	1

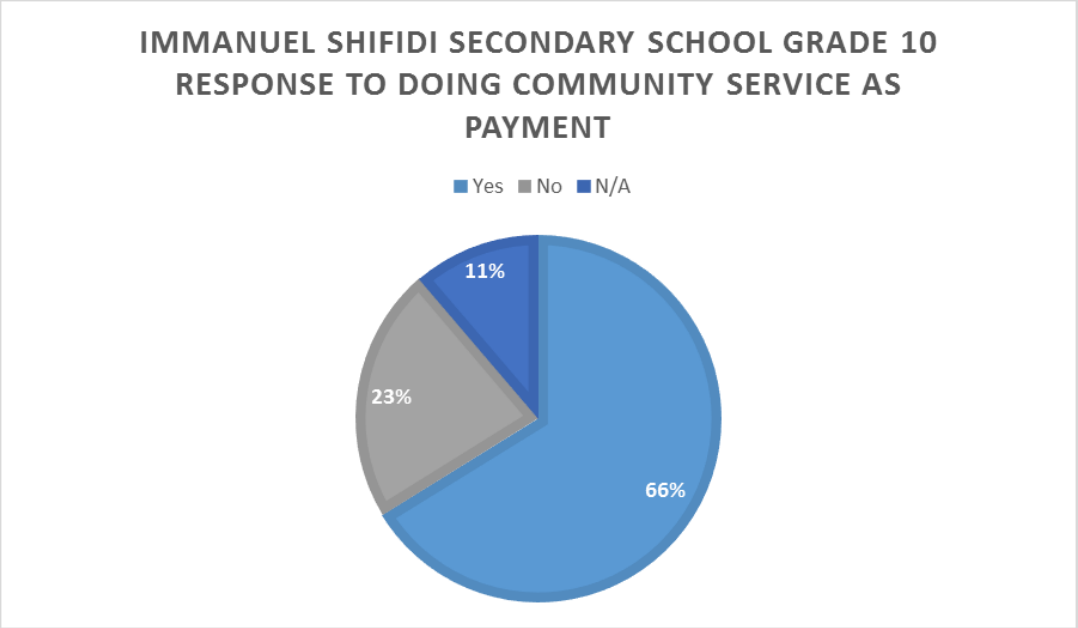


Time to Walk to School	Number of Students
<30 minutes	73
31-59 minutes	34
1-1.5 hours	21
>1.5 hours	13
N/A	1

Light Source	Number of Students
Candle	27
Electricity	108
Paraffin	2
Generator	2
Lamp/Torch	3
Solar Power	4
N/A	2

Total higher than 142 due to students using multiple sources

Willing to do Community Service as Payment?	Number of Students
Yes	94
No	32
N/A	16



Problems Encountered During Studies?	Number of Students
Noise (from shabeens or other students)	27
Candle Problems[1]	12
Electricity Goes Out	5
Difficulty Learning[2]	28
Yes (no reason specified)	6
Must Complete Household Chores	2
Other (TV, health problems)	2
No	63
N/A	1

[1]Candle Problems include: can't afford candles, candles go out too easily, candles do not provide enough lighting
[2]Difficulty Learning includes: student cannot concentrate, student is a slow leaner, student does not want to work
Total higher than 142 due to students using multiple sources

Future Plans?	Number of Students
Go on to University/Further Studies	116
Study Abroad	14
Begin Working	9
Soccer Player	4
N/A	2

Total higher than 142 due to students using multiple sources

Appendix F: Student At-School Interview Protocol

Date:	Time:
Interviewee Name:	
Age of Interviewee:	
Interviewers:	

Begin with a brief introduction, explain what the project is and why they are being interviewed

General

1. Where do you live?
    a. How long have you lived in _____?

        i. If lived elsewhere:
            1. Where are you originally from?
            2. What are the big differences between where you grew up and where you are now?

            3. What is your favourite thing to do in _____?

2. So you walk to school in the morning, how long does it take you to get to school?
    a. Do you travel alone or with a group?

3. What do you like to do in your spare time?

    a. Do you take part in any after school organizations?

4. Can you tell us a little about your home life?

5. Who do you live with at home? (additional question)
    a. What do you do for work?

    b. How did you get the job?

    c. How many hours a week do you work?
    d. How much of your earnings goes towards food/candles?

School Related

6. What does a typical day look like for you? Take us through the day from when you get up to when you go to bed.

7. What are your best subjects in school?
    a. Why are you interested in those subjects?

8. Most nights how long does it take for you to finish your homework?
    a. What gets in the way of your studying that makes it harder to do homework?

9. How would having electricity change things for you?

10. Where do you see yourself in a few years?
    a. If planning to go to university:
        i. What do you want to study?

        ii. Where do you want to study?

    b. If working:

i. What do you hope to do?

Community Service

11. Have you and your friends been talking about the program?

12. Do you currently do any type of community service work?

13. Are there community meetings where you are from?
    a. Would you be willing to talk about the system at these meetings?

14. We plan on working with DRFN to find community service that relates to the promotion of renewable energy such as solar power. Are you willing to partake in that?

15. Where do you think you could fit in community service that happened regularly or occasionally?

Additional Information

Would you be willing to let us interview you at your home, so we may meet your family and see how they feel about having a solar panel in the house?

Do you have any questions for us?

Explain how if they are selected for the next round we will be contacting them to schedule an at home interview

Ask for phone number of parent and possibly of the student

Appendix G: Student At-Home Interview Protocol

1. How is your break going?
2. How did your exams go?
3. Can you show us around your house?
4. Where do you usually study once you get home from school?
5. When do you start studying?
6. What kind of lighting do you use?
7. How many people live in the house?
8. Do you remember the question about community service in our questionnaire?
9. Will you be interested in participating in an environmental club at your school?

Check Lists

Source for lighting

Candle	Torch	Kerosene	Light bulb

Appliances

Gas Oven	Television	DVD Player	Radio/ Stereo	Kitchen Appliances	Computer	Generator

Appendix H: Operations Manual

System Usage

Option 1

Full day of Charging | 3-4 Hours | 2 Hours | Once per day

Option 2

Full day of Charging | 1-2 Hours | 1-2 Hours | 2 Hours | Once per day

Desert Research Foundation of Namibia
P.O. Box 20232 Windhoek, Namibia
Telephone: +264-61-377500
Fax: +264-61-230172
Email: drfn(at)drfn.org.na

Pico Solar Home System

Operation Manual

PSHS gives you bright light, it powers your radio and it charges your cellphone.

System Overview

Place the controller box at a place where it is **not** exposed to sun and rain.

Place the solar module in a sunny place outside. The module should face north with an angle at least 20 degrees.

Appendix I: Interview with Liina Nantinda

Liina Nantinda is the director of the Hochland High School environmental club and coordinator of environmental clubs in Namibia. These were the questions that we asked during our interview:

1. Can you tell us about the Hochland Environmental club?
2. If Immanuel Shifidi wants to start an environmental club what steps must they take to establish it?
3. Is there a link between all environmental clubs in the country?
4. How many clubs are in Windhoek?
5. Do clubs from various schools meet up and share ideas?
6. Are activities funded by the school or the Ministry of Education?
7. Are there any NGOs you work with to do more activities?
8. How involved is the Ministry of Education in environmental clubs?
9. Is there one representative from each environmental club or is there one representative for all environmental clubs?
10. Would you be interested/willing to be in charge of starting the club?
11. Would you be willing to meet with the teacher and create a presentation to teach them?
12. What happens if the principal is not interested in establishing the club?
13. Is there a way for our ten students to be involved, if the club idea does not work, to be linked with your club?
14. Do you have any other community service ideas that the students can do besides the environmental club or ways they can serve the community?

Appendix J: Profiles of Students Who Were Selected to Receive the Solar Systems

Appendix J.1: Cagney

He has lived in Okahandja Park for the past sixteen years with his grandmother, two brothers and three sisters. In order to get to school, he must walk roughly an hour and a half. At school his favourite subjects are geography, life sciences, and entrepreneurship. He speaks two languages, English and Afrikaans, and loves soccer. At night he must rely on paraffin lamps in order to study and help him achieve his goal of attending UNAM to become an engineer.

Appendix J.2: Newaka

She currently lives in Okuyangava and has lived alone since grade 5. She is originally from the North where the majority of her family still resides. To support herself, she works as a hairdresser on the weekends and grows some of her own food in her garden. She must walk between one to two hours to get to school. Her favourite subjects at school are accounting, geography, and English. To study while she is at home she must use the torch light on her phone or study before school. After completing secondary school she hopes to go to university to become a banker/account and "achieve and make something of herself."

Appendix J.3: Hinananye

He is seventeen years old and has lived in Okahandja Park for his entire life. He lives only with his father and twelve year old brother after his mother passed away in 2012. He walks an hour and a half to school each morning in a group of usually three people or less. At home, he primarily speaks Afrikaans and likes to play and watch soccer, especially Manchester United. He also likes to read and listen to music, but does not have much time to do so because of chores and school. After completing secondary school, he wants to continue his education in hopes of becoming a mechanical engineer.

Appendix J.4 Ihana

He is eighteen years old and moved with his two sisters and parents to Katutura in 2010 from Okahandja Park. His sisters have since moved north, but his mother stays in Katutura for him to finish his education. He walks about one hour by himself every morning to school. He lives with a small group of cousins and one brother amongst three shacks. The shack he lives in alone is very small and dark, but is where he does all of his cooking and studying. He likes to spend time studying, reading the bible, and meeting with his Christian group. He wishes that he could spend even more time studying, often using empty classrooms in a nearby school until he is forced to leave. He wants to attend the University of Namibia and study to become a pilot.

Appendix J.5: Ansie

She moved to Okahandja Park from Katutura in 2010. She has three siblings, but only one, her thirteen year old sister, lives at home. She walks one hour to school with her sister. Her favorite things to do after school are to listen to music and study. She spends up to three hours on homework a night. Her favorite subjects are history and geography and wants to travel to Germany to study law.

Appendix J.6: Nick

She lives in Okahandja Park where it takes her about an hour to get to school. She lives with her mother and father, who both work, and two siblings, a brother and sister, who both go to a different school. Some of her favorite things to do are listen to gospel music and sing. She participates in the school choir and her favorite subjects are geography and business. She can typically only study during the day because she needs to use candles for light which can get expensive if you use one every day. Her dream is to study abroad in Brazil after secondary school in order to become a doctor.

Appendix J.7: Aina

She has lived in Okuryangava her entire life, and currently lives with her mother, cousin, and younger sister. It takes her about forty minutes to walk to school where her favorite subject is geography. Some of her favorite activities include reading, studying, and singing in the school choir. After secondary school she plans to attend the Polytechnic of Namibia in hopes of becoming a doctor.

Appendix J.8: Maria

She is currently living in Okahandja Park where it takes her forty minutes to walk to school. In her free time she enjoys dancing, singing and playing netball. She uses candles to study and spends around two hours completing her homework. Her favorite subject is entrepreneurship and she wants to study law at the University of Namibia.

Appendix J.9: Martha

She lives in Babylon with Thomas and five other people. From there, it takes her an hour and a half to get to school. Her favourite subjects at school include geography, history, and math. In her spare time she enjoys reading and writing. Upon completing secondary school she hopes to attend university where she plans on studying to become a doctor.

Appendix J.10: Thomas

She lives in Babylon with Martha, her cousin. Her favourite subjects in school are business and French. In total she speaks four languages: English, French, Oshiwambo, and Afrikaans. To study at night she and Martha must use a candle or sit outside their house to use the street lamps. In her free time she loves to sing and read fiction novels. After graduating from secondary school, she plans to study psychology at UNAM or travel abroad for university.

Appendix K: Student Writing Prompt

Desert Research Foundation of Namibia

DRFN Pico Solar Home System Quarterly Review

This document should be completed in full within two(2) days of receiving it and returned to the teacher at Immanuel Shifidi Secondary School who distributed this form. The purpose of this document is to provide the Desert Research Foundation of Namibia and Immanuel Shifidi Secondary School a method to gauge the effects and success of the Pico Solar Home System Project. Please answer all questions to the best of your ability and with as much detail as possible to ensure accurate results.

Surname: First Name: Age:

Grade: Home Address

How long have you had the Pico Solar Home System?

Have you experienced any problems with the system? If yes, please explain and have the problems been fixed?

How has using the Pico Solar Home System changed your studying habits?

Explain in detail how receiving the Pico Solar Home System has affected your life. Please go into detail as to what it is used for, who uses it, and how it has/has not changed your household and everyday life. (Continue onto back of page if needed)

Appendix L: Student Contract

Student's Name:
Parent/Guardian's Name:
Home Address:
Contact Number:
Authorized DRFN Member:

Congratulations on receiving the Pico Solar Home System. The Desert Research Foundation of Namibia in collaboration with Worcester Polytechnic Institute of the United States is distributing the Pico Solar Home System. The Desert Research Foundation, through funds received from COP 11 funded the project. The purpose of this project is to provide Solar Home Systems to deserving secondary school students as an alternate light source.

The above individuals agree to receive and use the Pico Solar Home Systems according to the following guidelines:

- The Solar Home System shall be used primarily for studying by the student and their siblings who are currently enrolled in school
- Only attachments provided with the system (two lights, cell phone charger, and radio) may be used with the Solar Home System
- The student agrees to be an active participant in Immanuel Shifidi's environmental club or other designated activities.
- The student agrees to complete the quarterly writing assignment for review by the Desert Research Foundation of Namibia
- The student gives consent that their academic records can be sent to the Desert Research Foundation of Namibia for review of their academic performance on a monthly basis for the first year and then quarterly for the remainder of their secondary school education
- The system may not be sold for monetary funds or traded for personal benefit

If a problem with the system shall arise, it is the duty of the student to report such issues to the designated teacher at Immanuel Shifidi Secondary School who will then take appropriate action.

If the above conditions are not met, the Desert Research Foundation of Namibia has the authority to remove the system from the home or take other appropriate disciplinary action up to their discretion.

Signature of Parent/Guardian: Date:

Signature of Student: Date:

Signature of Authorized DRFN Person: Date:

Appendix M: Student Consent Form

DESERT RESEARCH FOUNDATION OF NAMIBIA AND
WORCESTER POLYTECHNIC INSTITUTE
Image Release Form for Participants
in Research Projects Involving Human Subjects

Title of Project: *Pico Solar Home System Installation for deserving high school students without home electricity*

I, _____, allow the member designated below from the Desert Research Foundation of Namibia and Worcester Polytechnic Institute permission to take my photograph and/or videotape my voice for publication for the above titled IRB approved research only. My name may be used in any publication and the publication may be accessed online. I will make no monetary or other claim against DRFN or WPI for the use of the photograph(s)/video.

Whom to contact if you have questions about the studies: Professor Jeanine Skorinko, Participant Pool Chair, WPI, Dept. of Social Science, 100 Institute Rd., Worcester MA 01609 Tel: (508) 831-5451, Email: skorinko@wpi.edu
Whom to contact about your child's rights in these studies: Chair of the WPI Institutional Review Board (Prof. Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu) or WPI's University Compliance Officer (Michael J. Curley, Tel. 508-831-6919).

I have read and understand the above:

Printed Name:_____ Date: _____

Signature:

Appendix N: Lighting Price Comparison

Light Source	**Initial Cost (N$)**	**Yearly Cost (N$)[1]**	**Cost After One Year (N$)**	**Cost After Three Years (N$)**
Pico SHS	1,614.60	0	1,614.40	1,614.40
60W Lightbulb	0	1,445.40[2]	1,445.40	4,336.2
100W Lightbulb	0	2,409.00[3]	2,409.00	7,227.00
Candle	0	2,190.00[4]	2,190.00	6,570.00

[1]Assuming 4 hours of light per day
[2]Cost: N$0.99/hour
[3]Cost: N$1.65/hour
[4]Assuming 2 candles/day and $3/candle
Electricity Prices Taken from DRFN