Alternative Energy Solutions for the Redevelopment of Monwabisi Park, Cape Town

An Interactive Qualifying Project proposal to be submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

Submitted by:

David Arnold

Nina Bass

Amanda Clark

Submitted to:

Project Advisors:

Prof. Scott Jiusto

Prof. Joseph Petruccelli

Project Liaison:

Cindy Jacobs

City of Cape Town Environmental Resource Management Department

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Chapter 1: Introduction

On the outskirts of Cape Town lie a number of informal settlements where people are subject to subpar living conditions daily, where there are multiple issues with respect to energy use. There is limited access to energy in the community which leads to dangerous and inefficient practices. There is a large need for affordable and sustainable energy in the community. Access to energy sources such as electricity are also limited and make it difficult for many residents to adequately heat or cook in their homes. Pollution levels within homes in informal settlements throughout South Africa are up to ten times higher than prescribed by the World Health Organization (Matthews, 1998). Change needs to be implemented in the form of safer more efficient sources of energy.

Monwabisi Park is one of these informal settlements, and has drawn the attention of multiple organizations because the living conditions there are so poor; the densely populated communities of the shack homes have minimal infrastructure and service provision (WPI CTPC, 2008). Residents use harmful methods to cook their food and heat their homes in the winter, one of the most common alternatives being paraffin. This fuel is burned in stoves and negatively affects the air quality in homes, creating a multitude of safety issues. When used improperly, a paraffin stove can set fire to a shack which can easily spread to other shacks before the flames are extinguished. According to UNICEF, burns are the fourth highest cause of death in children under fourteen in South Africa (Ward, 2008). It is clear that there are serious problems with the current heating and cooking techniques and a new system must be established.

Attempts have been made in the past to improve the lives of the residents of Monwabisi Park as well as other informal settlements in the area. One initiative taken by the government in an attempt to draw residents of informal settlements away from the use of paraffin was to make gas more accessible. This attempt was not well received because the gas containers were difficult to transport (Eskom). Other than accessibility, expenditures on energy are a primary concern. Since people do not have much to spend, it is important to decrease the amount wasted through inefficient energy practices. It was shown that in Khayelitsha, about twenty percent of one's monthly income is spent on energy (Palmer Development Group, 2007). The current housing lacks insulation which allows energy to escape through the walls and roofs of their homes (Ward, 2008). The City of Cape Town Environmental Resource Management Department is currently making efforts in the informal settlements to improve the

insulation of current housing. They have begun to implement the Kuyasa Energy Efficiency Project, which focuses on low income housing. The Project has three clear objectives, one of which is to provide insulated ceilings that will improve the thermal efficiency of the household units (City of Cape Town, 2009). Another study completed in 2008 by a group of students from Worcester Polytechnic Institute (WPI), in Monwabisi Park collected useful data on existing conditions, but left much to explore specifically regarding heating and cooking (Kehrer *et al*., 2008).

While these past studies, along with many others outline the problem well and begin to offer solutions, the past attempts have still fallen short of improving the major problems around energy. Plans for new housing in Monwabisi Park are already in place, yet it is unclear how the homes will safely be heated and what less hazardous ways of cooking can be implemented. There is a major concern between tightening the houses up with improved insulation, while fixing the issues of air quality. If paraffin was still used as the primary source, then fires will persist and the efforts spent putting up the new housing will have gone to waste. These issues have come to the forefront of the design because the homes need to be sustainable and if the current energy practices continue, the longevity homes will be threatened by fires and poor air quality.

The primary goal of this project is to offer a better means of heating and cooking for the new housing in Monwabisi Park, South Africa that will maximize the following criteria: safe, healthful, efficient, inexpensive, socially acceptable, and sustainable. We also look to teach members of the community ways to reduce energy consumption that will better their health and safety. Understanding of existing practices in Monwabisi Park through research and interaction within the community will provide us with in depth knowledge that we can apply to our project. This information will be taken into account when planning and designing a sustainable and healthy heating system for the new housing as well as suggesting alternatives to current cooking methods. Furthermore, we will offer improvements to the existing shacks that will help to reduce energy consumption in the community. Finally, we look to find an effective method of educating the residents about the importance of efficient and safe energy practices that will be passed on to other community members even after our departure.

Chapter 2: Background

After the apartheid era in South Africa ended in February of 1990 (US Department of State, 2009), thousands of people flocked from country-side homes to stay outside of the City of Cape Town in search of jobs. The small shacks that they built, once meant to be only temporary, are now becoming permanent housing in what is known as an informal settlement. Monwabisi Park is an example of one such informal settlement in a neighborhood called Khayelitsha. Since people moved into the area so quickly, roads could not be built to make homes accessible to emergency vehicles, and important resources such as wide-spread electrical grid could not be established, which gives rise to many concerns. Even though South Africa is one of the most electrified countries in Africa, using approximately half of all electricity supplied to all of Africa, there is still a great deal that needs to be improved in informal settlements (Karekezi, 2002). A more in depth discussion on energy use in South Africa and Cape Town can be found in Appendix F.

Unfortunately, it is hard to improve the conditions because there is tension between the people in Monwabisi Park, the government, and various other organizations. While the government would like to help, it is reluctant to provide funding for redevelopment options for a number of reasons. There is also a stereotype that the people inhabiting informal settlements are squatting on land because they do not own the land or pay taxes for it. For this reason there are few government officials who are skeptical to offer aid. On the other hand, there are also trust issues from the eyes of the people in the informal settlement as a result of living through the apartheid era. This makes it hard to trust outsiders who recommend different options, because they are afraid that they are being manipulated. Therefore, people yearning to help the people of Monwabisi Park must first establish a good relationship with the community in order to build a mutual trust between the two parties. These relationships are difficult to repair with many residents after living through the apartheid era. Our role as a group will not only be to implement new sources of energy but to also act as liaisons between Monwabisi Park, the government and energy providers, specifically Eskom. In this chapter we will discuss the current practices as well as offer possible alternatives to the current situation.

2.1 Current Practices in Monwabisi Park

It is important to understand the existing practices in Monwabisi Park that people use to heat and cook in order to design new alternatives, so a group of students from Worcester Polytechnic Institute surveyed eighty-six homes in the C-section of Monwabisi Park and asked what they use to cook and heat their homes. The tables below in Figure 1 summarize the results:

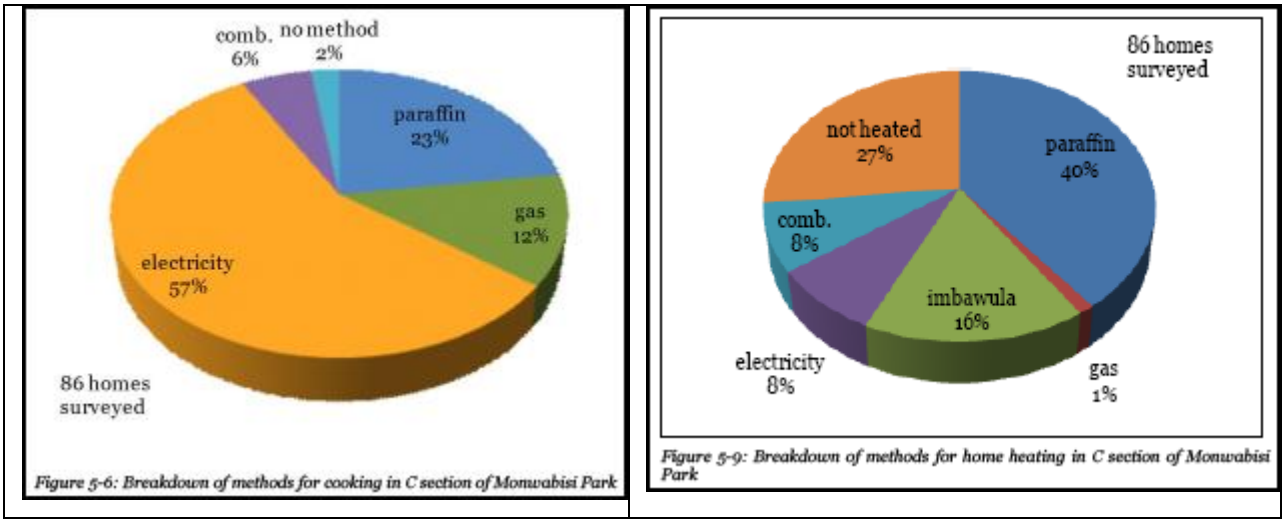


Figure 1: Methods of Cooking and Heating in Monwabisi Park (Kehrer *et al.*, 2008)

The major cooking sources in the settlement presently include electricity, paraffin and gas. While electricity is the least expensive form of cooking, many people do not have access to the grid or access is unreliable as previously discussed. This lack of availability forces others to use alternatives without taking into consideration the effects on their own health and the major safety issues regarding the use of such alternatives. The major home heating sources are paraffin and imbawulas. As the figure on the right shows, a shocking twenty-seven percent of homes are not heated at all (Kehrer *et al,* 2008).

2.2.1 Lack of Insulation

The existing homes in Monwabisi Park are not well-insulated, which leads to significant energy loss through the walls, windows, and ceilings. This is an important issue because not only is it hard to heat the homes, but also because people end up spending more money than necessary. The poorly-built shacks often have holes and cracks around doors and windows, as well as in the roofs, creating unwanted drafts in the homes and places for energy to escape. The only materials available for insulation are cardboard, newspaper, and metal scraps, none of which are sufficient to reduce energy loss through the building. This decreases energy efficiency in the shacks, forcing people to spend more than necessary to heat the home (WPI CTPC, 2008). An improvement in insulation is a key factor when designing new homes, and is also a consideration when suggesting improvements to the existing homes.

2.2.2 Electricity

Currently in Monwabisi Park, people are practicing unsafe, inefficient methods to cook food and heat homes because access to electricity is limited. Anywhere from 2 to 8 households share the same power line which leads to shortages. This means that the current electricity supplied to the settlement is unreliable, especially since homes can be without power for up to a month (Kehrer *et al*., 2008). A study completed in Khayelitsha reported that the main reasons for the difficulties in getting electricity are vendors being too far away and running out of electricity themselves. In a study done by Annecke in 2005, it was shown that in Khayelitsha about twenty percent of one's monthly income is spent on energy, where anything above ten percent is defined as energy poverty (State of Energy Report, 2007). It is clear that the residents of Monwabisi Park are, by definition, living in energy poverty which raises major concerns. Therefore, energy sources that are not only economical but also accessible are very important to improve lives in Monwabisi Park.

2.2.3 Liquefied Petroleum Gas (LPG)

Currently less than one percent of the residents in Monwabisi Park use gas to heat their homes in the winter (Kehrer *et al.,* 2008). LPG provides a safer alternative to paraffin because it comes in propane tanks that are not nearly as combustible as paraffin. Additionally, LPG is a less expensive fuel and emits less pollution into the home than the current paraffin stoves. The City of Cape Town has made previous attempts to implement gas into informal settlements in Cape Town, which were ineffective. During one such attempt, residents were given free gas stoves, containers and coupons for gas. Gas containers were relatively heavy, and since gas was not sold in the community, residents were forced to carry these containers long distances in order to get the free gas refills. Because of this, many people continued to use paraffin because it was much easier to access, even though gas was free. These attempts were unsuccessful because the LPG was not easily accessible to the residents and they had little knowledge on how to use it (Jacobs, 2009). Currently in the C section of Monwabisi Park, LPG is sold and is fairly accessible to the residents, which leads us to believe that there is potential for LPG in Monwabisi Park. LPG's advantages over paraffin make its promotion in Monwabisi Park an attractive substitute for paraffin.

2.2.4 Imbawula

One method of heating is to use an "imbawula," which is essentially a recycled metal container that is filled with scrap materials that will are burned to produce heat. In 2008, students from WPI surveyed people living in the C-Section of Monwabisi Park about their current heating methods, and discovered that well over sixteen percent admitted to using imbawulas (Kehrer *et al,* 2008). There is a stigma

surrounding the use of imbawulas that those who use it are very poor because they cannot afford fuel. Therefore, it is hard to get accurate numbers of people who use this method, as people are usually too ashamed to admit that they use imbawulas.

2.2.5 Paraffin

As previously mentioned, paraffin fuel is used more than electricity for heating in informal settlements even though it is more expensive (State of Energy Report, 2007). Paraffin is also used for cooking when electricity is not a viable option due to grid constraints. There are various underlying reasons for this continued dependence on paraffin, one of which is habit. Residents are often reluctant to change because paraffin is so accessible and prevalent in Monwabisi Park. According to a study done by Cowan (2004), seventy eight percent of residents in Khayelitsha were aware of the dangers of paraffin. So even though a majority of people are privy to the risks involved with its use, paraffin continues to be a primary source of energy. The risks of using paraffin will be further discussed in detail later in section 2.2.3.

2.3 Considerations

The major areas that will need to be looked into for new proposed energy methods include accessibility, cost, sustainability, environmental impact, and health concerns. Each of these criteria needs to be considered when proposing new methods of cooking and heating. Any replacement or upgrade would need to reduce emissions that are harmful to the people and the environment. The cost would need to be in the realm of the current expenditures or less so the residents could afford it. If you propose something more expensive, the community is certain to ignore the proposal and continue with their current practices. Along with initial cost is the efficiency of the product since a highly efficient device will consume less energy and therefore reduce the amount spent on energy per month. The accessibility of the materials and fuel is extremely important for the sustainability of the proposed method. If people have to travel far or carry heavy cans to get more of the fuel, they are less likely to convert from their current method to a new one. Ultimately, the community needs to embrace the new process and find it to be an improvement on their current practices. They are the key factors in the success of the proposed improvements and it is of utmost importance that we cater to their desires.

2.3.1 Accessibility

Access to supplies in Monwabisi Park is a large concern because there are limited resources and funding. There is only one main road in Monwabisi Park, making it difficult to disperse products throughout the community. Convenience is a deciding factor in whether or not certain solutions will be viable. This was

specifically the case when the City of Cape Town attempted to implement LPG as a source of heating in an informal settlement. The gas initiative provided gas stoves, as well as containers and vouchers for free fuel – but ultimately was unsuccessful because the fuel was not as accessible as paraffin in the settlement (Jacobs, 2009). This case exemplifies the problem of accessibility when attempting to implement a new source of heating or cooking. Additionally, some residents are often reluctant to change because they feel comfortable using paraffin, especially since most have used it throughout their lives (Kehrer, 2009). There is much to consider when determining the accessibility of a product: direct access to the product, ease of transportation, and how easily it can be implemented into a home. By accommodating the residents and allowing them to exert the least amount of effort when implementing a new source, the likeliness of it succeeding increases.

2.3.2 Cost and Efficiency

Cost and efficiency are near the top of our considerations as we plan to implement a new energy source in Monwabisi Park. The initial investment cost for a product must be weighed against the long term costs as well as savings. If a product has a high start up cost but can offer a one hundred percent return on the investment over just a few years, then efforts will be made to defer the initial cost. This is something that must be worked on closely with the economy team. However products with a low start up cost are more convenient and likely to be successful because of the limited funds in the community. Any product we plan to implement must be more efficient than the current methods otherwise it will not be valuable in the long term.

2.3.3 Health Risks and the Environment

The current energy practices in Monwabisi Park are causes for serious concerns regarding the health and safety of the people and the environment. Currently there is a seasonal brown haze that surfaces over Cape Town. The brown haze is largely caused by the burning of paraffin and other items. Khayelitsha in particular was identified as an area in the Western Cape which has very poor air quality that produces many serious health risks (State of Energy Report, 2007). Cape Town has begun to implement a plan called the Khayelitsha Air Pollution Strategy (KAPS), which primarily aims to reduce air pollution and minimize health risks. This is a step in the right direction for the informal settlements and it is important that we follow up with this idea. The new energy sources should reduce the discharge of green house gases into the atmosphere. While this is not the most pressing issue, it is still one to be aware of when designing new methods because of the universal issue of global warming.

Fires are one risk prevalent in Monwabisi Park due to the use of paraffin and imbawulas. After speaking with Cindy Jacobs, a project manager working for the City of Cape Town Environmental Resource Management department, we learned the severity of the problem of fires in informal settlements. According to Cindy, the residents are not aware of safe practices, so fires occur frequently. This is a major issue since fire trucks cannot reach many sections of the park because of the narrow roads. The fires spread quickly and little can be done to stop them. One example of this was in 1999 when there were seven major fires caused by paraffin at the Joe Slovo settlement outside of Cape Town. 887 homes were burnt down and several people died. Most people lost everything, with no chance of compensation. Every year over 200,000 people are affected by paraffin related fires (Ward, 2008).

Not only are fires a major concern but the consequences on one's health are also severe. Paraffin is toxic if swallowed, which frequently happens with young children since it is not properly labeled. It also releases carcinogenic gases into homes, and is a main cause of respiratory infections in the community (Brent, 2009). Burning hazardous fuels indoors can distribute high pollutants such as carbon monoxide, particulate matter and other organic compounds into the shacks. Exposure to indoor air pollution has been associated with a number of health outcomes, including Acute Lower Respiratory Infections (ALRI) such as pneumonia amongst children less than five years old (MRC, 2004). According to UNICEF, respiratory illness from air pollution is the fourth highest cause of death in children under five in South Africa (Ward, 2008). Despite this, no systematic household air pollution monitoring is in place within the City of Cape Town (State of Energy Report, 2007). The multitude of health risks associated with the current practices is concerning and makes it clear that the issue is dire and needs to be addressed.

2.3.4 Need for Sustainability

The development of sustainable energy sources and practices is a key aspect of our project. This follows along with the overall goals of the sponsors and the project center, which is to create a sustainable community in the informal settlement of Monwabisi Park. The vision of a sustainable community includes satisfying all of the criteria mentioned above: low cost, efficient, safe. In addition to these conditions, the proposed new ideas must be able to continue long after we leave the project center. One definition of "sustainable," given by the Merriam-Webster Dictionary, is using a resource so that it is not depleted or permanently damaged. This is crucial for informal settlements because they have few resources available to begin with, so it becomes important to use the resources that are available in a smart and efficient manner.

2.4 Possible Solutions and Suggestions

As discussed above, there are serious concerns with the current practices in Monwabisi Park. After outlining the criteria, the next step is to look into replacements and improvements for heating and cooking techniques. Wind and solar energy were considered, but were ruled out for the purpose of this project because they are too expensive. A brief description of these renewable technologies can be found in Appendix G. The following section looks into various options for testing and evaluating in the community based on afore mentioned criteria.

2.4.1 Insulation

Home heating, especially during the cold and usually rainy winter season, is a primary concern for the homes in Monwabisi Park, because currently over one quarter of the homes in Monwabisi Park are without a source of heat in the winter (Kehrer *et al.,* 2008). Instituting a new way of heating the homes in Monwabisi Park has been a difficult process and has seen its share of failures. Paraffin has been embraced by the residents and getting them to change seems all but hopeless in the short term (Jacobs, 2009). For this reason, a main focus of our redevelopment with respect to heating will be to focus on insulation.

Heat is lost through the ceiling since heat rises and the homes in Monwabisi Park lack proper insulation in their roofs. A middle-income home loses up to twenty-five percent of its energy through the ceiling in winter and gains a similar amount in summer (Aerolite, 2009). That energy loss is even more significant in Monwabisi Park, as the shacks are not constructed nearly as efficient as a middle-income home. The residents already are constricted by tight budgets, which make proper insulation crucial. The thermal heat loss in a low income house is shown below in Figure 2 and shows the importance of roofing and insulation.

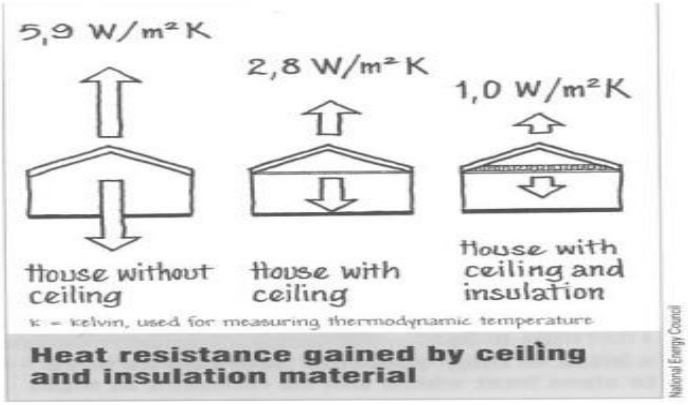


Figure 2: Thermal Heat Loss (Ward, 2008)

Waste products are currently the most effective way of insulating homes because of their accessibility and virtually nonexistent cost. The existing residents presently use paper to patch holes around windows or in the ceiling which does little to prevent energy from escaping (CTPC, 2009). There are other waste products that have shown recent promise such as sheet rubber. Rubber has proved to the superior choice of insulation over glass, wool, and cardboard (Matthews, 1999). Recycled tires would be the main source for the insulation and once obtained it would be processed with additives to produce granular rubber. Additives are used to decrease the density of the rubber, make it fire retardant, as well as make it UV and water resistant (Matthews, 1999). The additives used in this process do not make the insulation completely fire retardant and more testing must be done to improve upon this. If the rubber does catch fire it will release harmful toxins into the environment and the homes. Recycled rubber as a source of insulation satisfies three of our criteria adequately but work needs to be done on the ecological effects as well as its flammability. These negatives make implementing a waste product as a source of insulation is unlikely in any of the new homes.

Last year's project helped implement sandbags as insulation for the walls to help drastically reduce heat loss in the winter. Sand bags were implemented as the primary wall insulation for the new houses and were beneficial to more than just the specific homeowner. The addition of the sewing factory allowed the insulation to benefit not only the energy team but also the building and economy teams (WPI CTPC, 2008).

This concept can be used as a model when looking into other aspects of insulation. If something similar to the sewing factory could be done with insulation then rubber could be a possible source of insulation. This would entail attaining the raw materials, mainly recycled tires, training members of the community, and finding available space to run the business from. Just as the sewing factory was beneficial the local economy and the residents who were lucky enough to have insulation installed in their homes this project would do the same. Unfortunately this course is more complicated than the sewing factory because much more processing is involved the production and it is unlikely that the resources will be available in the park. These obstacles make implementing a waste product as a source of insulation is unlikely in Monwabisi Park.

The City of Cape Town has performed studies on energy costs in low-cost housing throughout Cape Town. These studies are valuable because they show that the two most effective ways to reduce energy costs throughout the home is through ceiling and wall insulation. The monetary benefits of various improvements are shown in Figure 3.

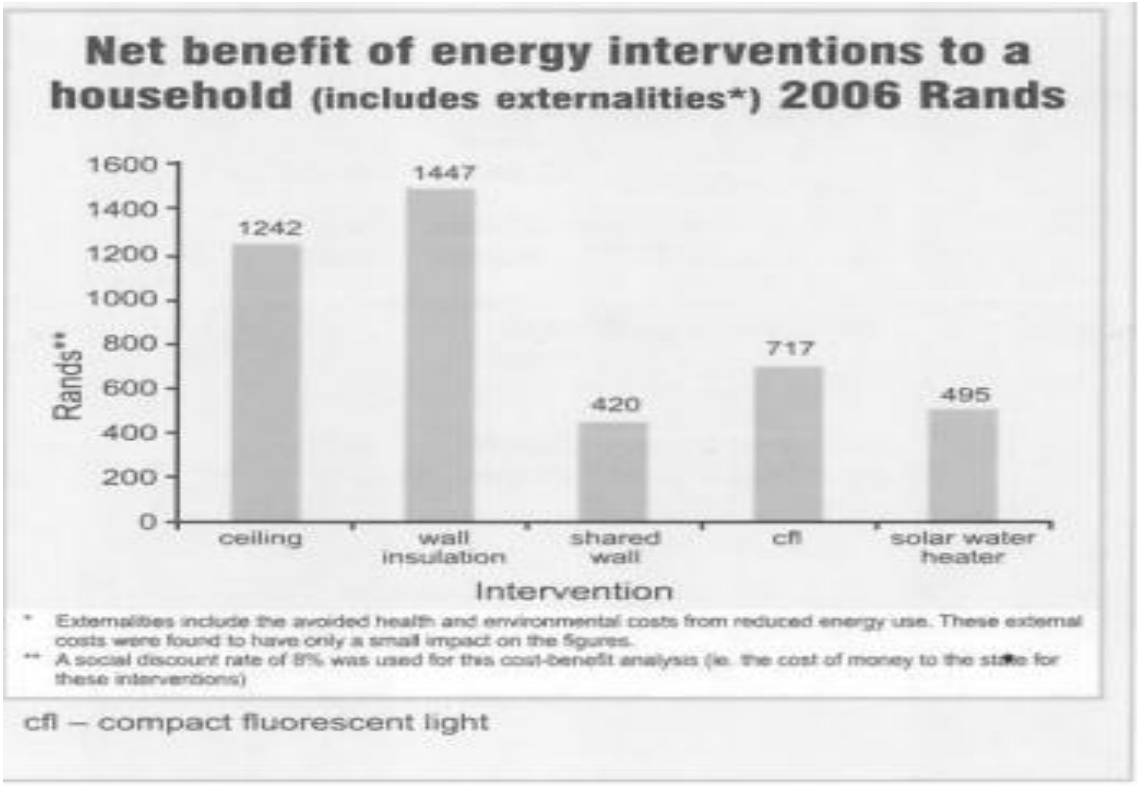


Figure 3: Net Benefit of Energy Interventions to a Household (Ward, 2008)

The energy savings results in lower costs for homeowners which creates a large market for insulation in South Africa. Numerous companies market insulation with relatively low start up costs. One company, Aerolite, effectively markets its "Think Pink "insulation throughout the region as an affordable eco-friendly option. Aerolite has a wide variety of insulation including glass wool, foam, thermal and fire resistant materials. This insulation can be purchased directly from Aerolite or through a private seller. Aerolite does not list specific prices on their website but a 1 x 10m x 1.2m equal to $12m^2$ can be purchased for R120 through want ads in the area (Cape Ads, 2009). The relatively low start up cost coupled with the long term savings ceiling insulation can make this a viable option. In the diagram below, Aerolite shows how their insulation retains heat in winter (Figure 4).

Figure 4: Effect of Aerolite Think Pink Insulation in the Winter (http://www.thinkpink.co.za/content_sub.asp?ssID=5)

Although insulation has proven to be the most effective way of energy conservation in Monwabisi Park there are also other factors to consider. Windows are another source of significant heat loss in the home and simple solutions can be made to reduce heat loss. Windows have the lowest resistance value among sources of insulation used in the houses. Resistance value (R-value) is the measure of thermal insulation in a specific product; the higher the R-value, the greater the insulation. A typical single pane window has an R-value of 0.91 compared to fiberglass wall insulation which has an R-value of between 3.7 and 4.3 (Colorado energy, 2008). The resistance value of a structure is determined by adding up the R-values of all its components. By adding insulation to the windows such as “window blankets” the R-value of windows can be increased substantially. “Window blankets” can be made from nearly any material and to any thickness making for a wide range of possible solutions. This will significantly reduce heat loss through the window and help to reduce heating costs (Arnold, 2009). Additionally the size and placement of windows in the houses in Monwabisi Park should be focused on as when building new housing. Smaller window sizes and orientation of windows should be thoroughly studied before installing them.

2.4.2 Infrared Heaters

Another way to heat homes is by using an infrared heater, which can be powered using electricity or propane, making it less expensive than paraffin. Infrared heaters do not release harmful fumes or greenhouse gases into the air. Another advantage is that electric infrared heaters also don't rely on fuel or gas lines, which is beneficial to the environment (Jackson, 2009). Infrared heaters also do not emit UV rays. Furthermore, burn hazards are eliminated since most infrared heaters have a protective sheath that covers the heating elements (Global Spec). Therefore, infrared heaters would be healthier for the residents of Monwabisi Park to use to heat their homes, and would also be better for the environment. Since they have a long life expectancy, are easy to install and use, and require little maintenance, the heaters are likely to be sustainable in Monwabisi Park (Alabama Power).

Infrared heaters work by emitting light not visible to the human eye that radiates heat, similar to how sunlight heats. Human skin and clothing absorbs the heat and when the light emitted from the infrared heater is not directed at an object the effect is similar to being in a shaded area away from sunlight. Therefore, infrared heaters are very useful when wishing to heat a particular area or object. While this makes heating an open area in a home more difficult some infrared heaters now contain three parts that create heat. There are infrared light bulbs, a heat exchanger (such as a good metal conductor like copper) and a fan that blows air onto the exchanger to create the heat (Wasch). This air could be used to spread the heat beyond the light's reach, allowing the infrared heater to function similar to a conventional electric space heater.

There are important parameters that must be considered when specifying an infrared heater, such as: maximum sheath temperature, maximum AC voltage, watts, and maximum watt density. The maximum sheath temperature refers to the highest temperature that material used to cover the heater can reach, and is not related to what is being heated. The maximum AC voltage is the maximum voltage that the heater can use. The wattage available from the heater is represented by watts, where the maximum watt density refers to the amount of wattage for every square inch that the heater is capable of producing. Watt density is a good way to represent how quickly a heater can heat a substance, and is calculated by dividing the available wattage by the total heated area (Global Spec).

2.4.2.1 The Far Infrared Heater

Figure 5: A Far Infrared Heater Design (Tools for Wellness)

A Far Infrared Heater, such as the one pictured above in Figure 5, combines the benefits of a direct infrared heater with an infrared space heater. It is healthful, safe for the residents and environment, cost-efficient, and sustainable. Far Infrared Ray (FIR) energy has a small wavelength – approximately 8-14 microns – which is the optimum energy that is readily absorbed by the human body, making it a great natural healer and maintainer of body vitality. FIR energy also has unique physical properties that can kill bacteria, mildew, and fungi. It also is an excellent drying agent and can eliminate odors. The guard grill, which is used to cover the heater, will only heat to a safe temperature, so a user will not get burned if it is accidentally touched and will not present a fire hazard. It is even designed with a safety button that will cut off the electricity supply to the unit if it is toppled, making it drastically more safe than when using paraffin. It has no emissions, so it is not detrimental to a user's respiratory system or to the environment. It uses halogen tubes, which have a lower wattage, so it will maintain the same thermal heating while using much less energy than a regular space heater. It also has low and high temperature adjustments and oscillates a full 180 degrees to better heat a space. This design is also easy to use, and uses bulbs that last over 5,000 hours – making it a sustainable home heating option (Tools for Wellness).

2.4.3 Promoting the Use of Safer Methods

2.4.3.1 Electric Stove

Electricity is a source of clean energy for in home use in both the heating and cooking sector. Since the new homes will have access to electricity, it is reasonable to suggest electricity as one of the options for cooking. This is especially true since over half of the population currently uses electric stoves and hot plates (Kehrer *et al.*, 2008). Using electricity for cooking would solve air quality problems in the homes

and prevent fires. However, the cost of using electricity for cooking needs to be researched more in comparison to the other methods. Electricity can also be used for heating; however, this can be expensive as well. If the insulation in the new homes works well enough and little heat is needed in the winter to maintain a suitable temperature in the home, then electricity may be a possibility for in home heating for the new housing. It is unlikely that electricity can be offered as a source to the existing housing since the accessibility to the grid is limited and is already over-stretching the boundaries of the current grid setup.

2.4.3.2 Safer Paraffin Usage

The use of paraffin is so prevalent in the homes of Monwabisi Park that it is unlikely any change is foreseeable in the near future regarding home heating. Despite this there are still improvements that can be made in Monwabisi Park regarding paraffin usage. One simple method of improving the safety of paraffin stoves in Monwabisi Park is by positioning the stoves in safer locations. Stoves are often placed in high traffic areas because of a lack of other options. As a result of this the stoves are easily knocked over, which is dangerous when the stove is hot. Paraffin stoves have a very low flash point at just 122^{o}F (50^{o} C), which makes fire likely if the stove is hot (Bank, 1998). The combustibility of paraffin combined with young children walking around make a deadly combination: in 2007 paraffin accounted for 17% of all toddler deaths in low income communities (WHO, 2009). The risk of the fire spreading quickly is also possible, as last year's teams witnessed. By placing the stoves in safer locations the number of fires and injuries can be reduced. Additionally, the design of the stove itself can be improved and a few companies are beginning to market these safer designs. One main fault with current stoves is that the fuel tank heats up during use and retains the heat after use. A stove that cooled down faster or covered the area that remained hot would be great improvements to the design. Also, if the stoves had more stability, then they may be knocked over less, reducing the number of incidents. ReadyMade of South Africa has come out with an Arivi Paraffin Stove that has made a large impact, and was a 2009 INDEX award finalist (ReadyMade, 2009). There are multiple advantages to this stove over current designs in Monwabisi Park. When the stove is tipped over or being refilled, the flame extinguishes and eliminates the risk of fire. The stove has also shown to reduce the monthly cost of paraffin by thirty-two percent while producing nearly zero emissions (Myarivi, 2009). The Arivi Paraffin Stove, pictured below in Figure 6, is designed specifically for the use in low income housing and retails for R500.

Figure 6: Safe Paraffin Stove (http://sarocks.co.za/2009/06/23/arivi-paraffin-stove-finalist-in-2009-index-awards)

2.4.4 Offer New Alternatives for Cooking

One of the vital issues regarding the development of new housing in Monwabisi Park is to find a new method of cooking that will move towards a healthier and safer environment. We have looked into a number of technologies that either eliminate or significantly reduce the use of paraffin for cooking. Such technologies include solar ovens, Rocket Stoves Hot boxes and the Arivi Safe Paraffin Stove.

2.4.4.1 SUNSTOVES

The first area we plan to look into is the solar oven called the Sunstove. Since the stove was designed and manufactured in South Africa particularly with mass production in mind, many concerns have been addressed by the designer. The stoves are stackable to make them easy to ship or transport, they cost about R76, which is much less expensive than current paraffin stoves. The Fabricated SUNSTOVE solar cooker, pictured in Figure 7, was designed to be mass produced with hand tools and materials that are available in every country (Wareham, 1999). Tools necessary for building this simple stove are:

- Hand riveter and rivets; industrial stapler and staples
- Hand staple gun and staples; hammer and large tacks
- Screwdriver, wood screws, nails, and paint brush
- Tape measure, wood saw, tin snips, scissors, knife

(Wareham, 1999)

The simplicity of the design and accessibility of these tools make this stove an ideal solution for Monwabisi Park. The SUNSTOVE website (www.sungravity.com) includes diagrams on how to construct the stove and provides positive feedback from testers in South Africa well as suggested improvements. Below is a picture of one option for the SUNSTOVE.

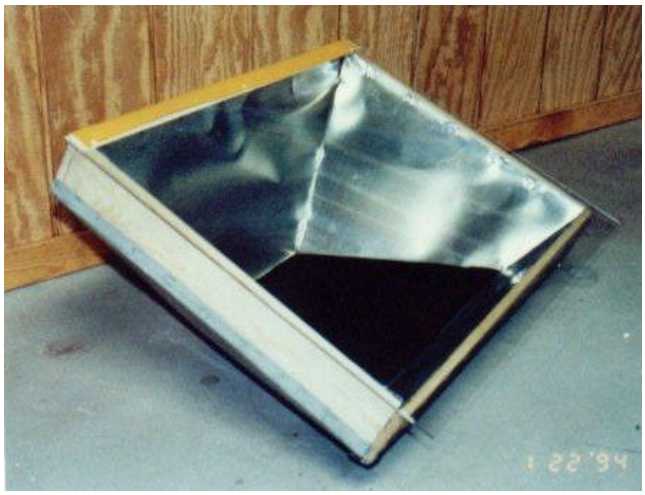
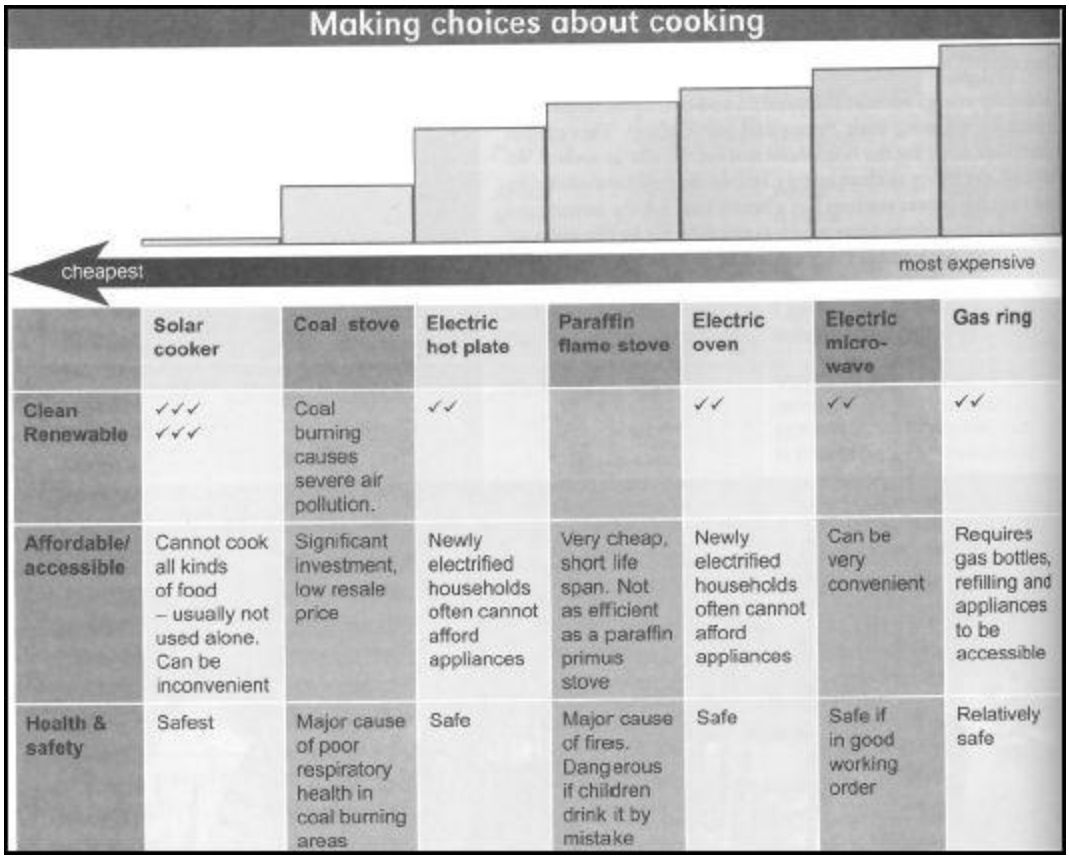


Figure 7: SUNSTOVE (www.sungravity.com)

Obviously there are great benefits of using a completely renewable stove. The main factor is the lack of emissions which would significantly improve the air quality as well as decrease environmental effects of cooking. Health risks are completely eliminated since there is no carbon dioxide or other toxins produced. Furthermore, as far as safety goes, the threat of fires would potentially be eliminated. Another benefit is that the source (the sun) is completely renewable and will never run out unlike fossil fuels. The SUNSTOVE is also inexpensive to make and more importantly, once it's been made there are no costs for fuel since the sun's rays are available to everyone.

However, there are many details that would need to be looked into before the implementation of such a stove. The main shortcoming of the SUNSTOVE is that for it to function, it requires the sun to be out. There are many occasions where the sun is not out, including night time, rainy days, and cloudy days. For this reason, this solar stove could only act as a supplement to other cooking methods and could not be the main cooking method in the new homes.



	Solar cooker	Coal stove	Electric hot plate	Paraffin flame stove	Electric oven	Electric micro-wave	Gas ring
Clean Renewable	✓✓✓ ✓✓✓	Coal burning causes severe air pollution.	✓✓		✓✓	✓✓	✓✓
Affordable/ accessible	Cannot cook all kinds of food – usually not used alone. Can be inconvenient	Significant investment, low resale price	Newly electrified households often cannot afford appliances	Very cheap, short life span. Not as efficient as a paraffin primus stove	Newly electrified households often cannot afford appliances	Can be very convenient	Requires gas bottles, refilling and appliances to be accessible
Health & safety	Safest	Major cause of poor respiratory health in coal burning areas	Safe	Major cause of fires. Dangerous if children drink it by mistake	Safe	Safe if in good working order	Relatively safe

Figure 8: Characteristics of Several Cooking Methods (Ward, 2008)

From Figure 8 you can see all of the positives and negatives of various cooking methods including a solar cooker, coal stove, electric hot plate, paraffin flame stove, electric oven, electric microwave, and a gas ring. The coal stove is inexpensive but causes health issues as well as environmental issues. The same concerns arise for the Paraffin flame stove, however it is even more dangerous if knocked over or ingested. If electricity is available, the electric hot plate would be the best cooking source since it is less expensive than Paraffin, is clean, renewable, and safe (Ward, 2008). The problem arises when electricity is not available because the only affordable stoves are either dangerous, harmful to the environment or will not cook all kinds of food. For these reasons, a solar cooker could only be used as a supplement to other methods. At this point, we need to look at other potential designs for stoves that maybe have not been tried in the area but could have potential.

2.4.4.2 Rocket Stoves

This leads us to an extremely efficient wood burning stove that has been used in outdoor campgrounds call “the Rocket Stove”. For a small scale version that will be easier to teach the community all you need

is two pipes, a skillet or some sort of flat cooking surface, and twigs. The general setup of the stove is a small hole in the ground, which will be filled with twigs and set on fire then covered with an upside-down skillet. The two pipes would be placed on opposite ends of the pan, one used as the feed pipe one used as the chimney. The setup can be seen more clearly below in Figure 9:

Figure 9: An Example of a Rocket Stove (Crimmins, 2009)

Another more advanced rocket stove that has been used in Rwanda might be a better decision for the design. The newest version of the rocket stove is one unit, shaped like a boot and built from clay, shavings, sawdust, and water. The fire chamber and chimney are made using either banana stem or PVC pipe that can be bought for around three to four US dollars. Dimension of the chimney and combustion chamber are critical in order to maintain a smokeless stove. The consequences of improper design include the emission of smoke, a loss of efficiency, an increase cost and more fuel wood would be wasted to cook the same amount of food. Placing a wind skirt around the pot is vital to directing heat upward and around the pot, keeping the heat in and cooking the food faster (Pimentel, Marie, 2005).

The main advantage to using this method of cooking verses open fires or other wood stoves is that it drastically decreases the amount of wood needed to cook a meal by increasing the efficiency of combustion. One possible design includes a chimney which will channel the emissions to a specific area which would be beneficial for use in the new homes since ventilation needs to be added. Research has shown that rocket stoves reduce carbon dioxide emissions as well as emissions of particulate matter (Drouin, 2008). Also, since these stoves use wood, there would not be any of the concerns associated with burning paraffin such as children ingesting the paraffin or anyone accidentally knocking over the stove and setting the house on fire.

While there are many advantages to using the rocket stove, there are also many setbacks that would potentially make its use difficult in Monwabisi Park. The largest concern is the availability of wood in the area because even if it only takes a small amount of wood to cook a meal, if there is no wood available

to burn, the family will certainly revert back to paraffin. Not to mention the current practices of the imbawula where the residents burn any scraps they find which could be detrimental to the stove and the environment if they decided to replace wood with metal scraps. Also, the design of the chimney would need to be added into the new homes. This could be an issue if the plan for the new homes goes through and there is no time to add a place for the chimney into the design.

One example of an area that shares our current goal of finding more efficient and sustainable cooking methods can be found in Kinihira and Kigali, Rwanda. It was there that some rotary club volunteers implemented an Integrated Cooking Method and had workshops to teach the rural poor about the combined use of solar cookers, fuel efficient stoves (rocket stoves), and heat retained cookers (hay baskets). The solar cookers and rocket stoves match design that has previously been described. The hay baskets are similar to the idea of the hot box but can be made using cloth and cotton stuffing used to make pillows, placed in a basket, box or sack. These pillows provide insulation for the pots to keep cooking after the pot has been heated in the solar cooker or rocket stove (Pimentel, Marie, 2005).

After a year, the new plan had rapidly spread and more and more people became educated on and started to employ these methods. A 'Solar Cooker Rwanda Association' was formed in the local government which then started training local men and women in the manufacturing and use of each of the cookers. Then these trained men and women could bring back this new knowledge to their neighbors and teach them. This kind of arrangement is exactly what we would need in order to make a new form of cooking sustainable in Monwabisi Park. Before this can happen, there are certain design aspects that must be addressed.

One important design aspect is determining which materials to use for the proposed new stove. The most efficient materials are sand-clay, concrete, metal, and ceramic (Baldwin, Samuel F., 2006). However, once again availability is important in the design, thus ceramic, concrete, and sand-clay will most likely not work in our case. Another option could be mud stoves which are used in many areas of the world. This would be a sustainable selection since it is made of the earth. Metal seems to be easily obtained by the community, since that is mainly what is used to build the existing shacks. A perk of using metal in the design is the durability which is an important factor in the sustainability of the stove.

Through our research, we have found a variety of ways to construct a rocket stove and have found a design that will be practical for use in Monwabisi Park. This design is based off of several articles and

reports that use recycled cans as the starting point as well as flexible piping and some common tools such as a hammer, tin cutters, a knife, pliers, and gloves. The can is used as the body of the stove and the pipe is cut so that it is the combustion chamber of the stove where the fuel (wood or paper pellets) will be burned. The pipe guides the heat up towards the pot or pan that needs to be heated, cooking the food. There is also a lid that covers the space between the outside of the pipe and the inside of the recycled can, closing the gap between the two. There is a video on YouTube which follows a guide written by one of our major sources which goes through the step by step process of making a rocket stove (http://www.youtube.com/watch?v=PeKcb-Fw-bo). This video and guide will be useful in our own design, which will correspond to Figure 10, and will help direct us in our building process.

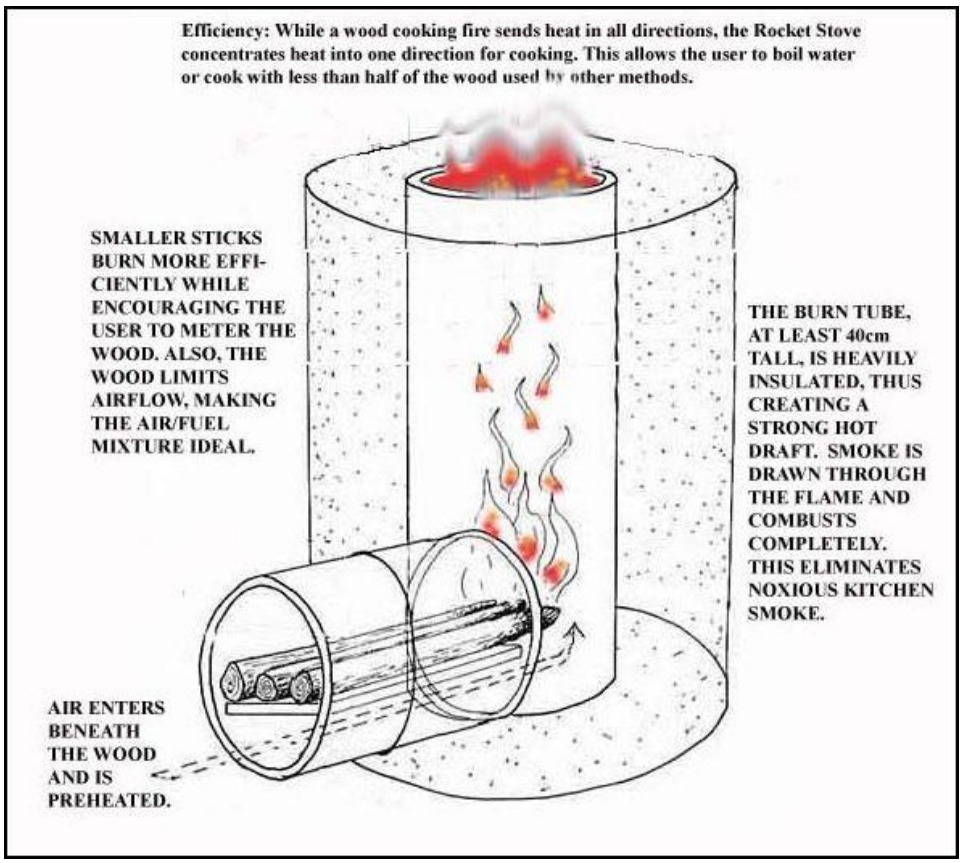


Figure 10: Design for a Rocket Stove (http://www.emeraldmine.com/images/RocketStove_000.jpg)

To replace the wood in the rocket stove, since the residents of Monwabisi Park do not have sufficient access to a large wood supply, we could use paper pellets made from recycled paper. A group of volunteers has recently done this in the community of Tutengeni outside of Windhoek, Namibia. This community faces many of the same challenges as Monwabisi Park, where the only services provided to them are water and sewage. The group recognized that one kilogram of recycled paper pellets has been

sold for N$10, approximately R10.6, which can last for up to five days of cooking (Tjaronda, 2009). In this case, the new stoves were welcomed by the community since power and energy were such an issue in the area. The engineers even looked into starting up a small business within the community to make the pellets which would be an applicable idea in our case that could be brought to the economy team. This does not mean the Monwabisi Park will react in the same way; however it does shed light on the possibility of using recycled paper as a source of fuel for a stove.

Chapter 3: Methodology

The primary goal of this project is to offer a better means of heating and cooking for the new housing in Monwabisi Park, South Africa that will maximize the following criteria: safe, healthful, efficient, inexpensive, socially acceptable, and sustainable. We also look to teach members of the community ways to reduce energy consumption that will better their health and safety with respect to energy use.

The project will be completed on site from October 23, 2009 to December 19, 2009. The following steps will be taken in order to accomplish our goal:

- Understanding the existing energy practices in Monwabisi Park.
- Planning and designing a sustainable and healthful heating system for new housing
- Planning and designing sustainable and healthy alternatives to current cooking methods.
- Offering improvements to existing shacks that will reduce energy consumption.
- Developing a plan for informing the residents of the benefits of efficient and safe energy practices.

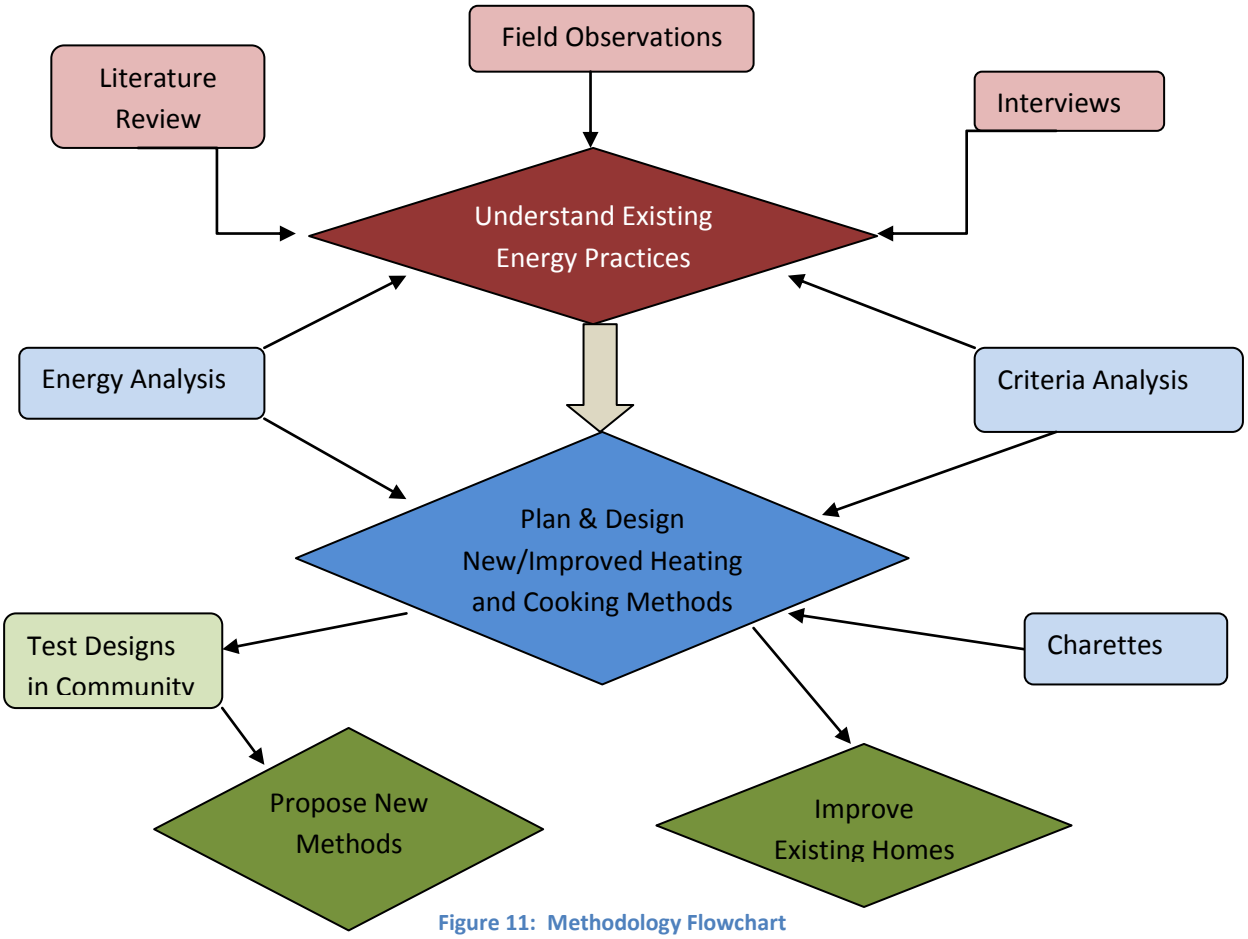


Figure 11: Methodology Flowchart

3.1 Literature Review

The first step was to complete a literature review to get a good grounding for understanding the issues and what can be done to improve the situation. In this literature review, we studied the efforts and proposals of WPI's previous year's project teams while also uncovering new sources and data of our own. We found relevant case studies that will be useful in determining the direction of our project.

Specifically in this research we looked into finding data on energy consumption in the Monwabisi Park area as well as ideas of renewable energy around the globe. Then we narrowed the search down to topics related to heating and cooking in peri-urban settings similar to Monwabisi Park. Once we began digging into this information, we uncovered a few options and it was then necessary to determine which solutions would work best in this particular application. We will continue to research once we are at Monwabisi Park by observing, conducting interviews, and reading other resources on the internet.

3.2 Understanding the Existing Practices in Monwabisi Park

While last year's group from WPI gave us a good basis for where to start, there are still a few areas that we would like to dig into more before offering our suggestions for new heating sources and cooking practices. We will need to speak with members of the community to find out their current concerns related to our project, as well as document our own observations of the current situation.

First we will document our initial impressions of the heating and cooking techniques in the existing homes. This can be done by recording observations such as the type of heating source in each home we visit, the current orientation of the shack, the color of the shack, the number of windows and their size. As far as cooking we can record any unsafe practices we notice as we examine homes during interviews, the proximity of the stove to flammable objects, any sort of protection from the stove being knocked over and any other concerns that arise. Another important aspect of the field observations will be taking pictures of risky setups and key observations. These pictures will be extremely helpful in our final report and presentation because they will show the reader that there is a large problem with the current practices and the implementation of our suggested methods is needed. Pictures could also be used in any educational tools that we decide to use and would enhance the website for the project center.

While completing our own field observations, it will be important to interview members of the community in order to get current information regarding our topic. We look to interview as many people as we can in order to get a good sense of the feelings in the community. As far as subjects, it will

be valuable to hear the opinions of people who use differing sources of heating and cooking. That way we can learn from them the reasons behind their preferred or present energy source. This will be important for us in choosing a method because we will hopefully get a sense of the most important deciding factors between energy sources. Furthermore, we'll be looking for which method they would like to see more of in the community. For our suggestions to be accepted, it is important that we work with the residents who will be affected by our proposal to give them something that fulfills their needs. Sample questions we will ask during interviews can be found in Appendix E.

3.3 Planning and Designing a Sustainable and Healthy Heating System

Shortly upon arrival, we will need to complete an energy analysis of the guest house as well as a typical existing shack. This heat loss analysis will tell us how much energy is being lost through poorly-insulated shacks and well-insulated buildings, and thus how much energy will be needed in the winter. A detailed description of the heat loss analysis can be found in Appendix D.

After obtaining the results of the analysis, we will use the data collected to help us select an appropriate method for heating the new homes as well as an idea of how much money can be saved by insulating a home. It will serve as a great tool for informing the residents of the major savings that they will incur by living in the new homes and will also hopefully aid in the approval of new ways to conserve energy. We will also use the data to specifically look at the amount of energy required to heat the new homes and use that when weighing the different options for heating sources with respect to the six criteria that we have already deemed important:

- Accessibility
- Cost and efficiency
- Safety
- Health Risks
- Sustainability
- Social Acceptability

Upon completion of the energy analysis, we will rank each heating method on a scale of 1-5 (one being the worst, five being the best) for each of the six criteria we have established. We will include these conclusions in the chart shown in Figure 12, which will also be based on our background research, the interviews we conduct, and any tests we run. After completing charts for each option, we will compile the charts and rank each option based on their overall score.

Product			
Criteria	**Specifics**	**Rank (1-5)**	**Comments**
Accessibility	Availability in Park		
	Distance from Housing		
	Overall		
Cost	Capital/start up		
	Monthly		
	Overall		
Efficiency	Energy Savings		
	Energy Consumed		
	Overall		
Safety	Flammability		
	Stability		
	Placement		
	Overall		
Health Risks	Green House Gas Emissions		
	Indoor Air Quality		
	Overall		
Sustainability	Longevity of Product		
	Simplicity of Use		
	Overall		
Social Acceptability	Overall		

Figure 12: Chart for a Method Based on Our Criteria

One heater which we plan to analyze is the infrared heater discussed in background section 2.4.2. An energy analysis would need to be done to see which type of infrared heater would be most efficient for the homes of Monwabisi Park. For example, we might want to use an infrared space heater and compare it to the use of one or two infrared lamps (also called direct infrared heaters) strategically placed throughout a home. We can see if an infrared lamp can be used in conjunction with a Sunstove in order to cook food when there is no sunlight available. After analyzing the heaters, we will fill out the chart of criteria in Figure 12 and rank it accordingly.

From this ranking we will determine our top choice and will look into either building or purchasing one heating device. A series of experiments will be conducted on the device to thoroughly understand its capability and application in both new and existing housing before suggesting it to the community. Each experiment will be well documented with a procedure and results discussion to allow for people to replicate such tests in the future. If the experiments prove successful, then the device will continue through the process to be brought to the community through charettes.

For the charettes, we will prepare a presentation on the chosen heating method. This presentation will begin with a brief overview of the current practices and then will move into how the new method works and how to use it. We will then look for feedback from the community members through discussion and possibly offer them an opportunity to test out the device. It is important for us to get input from the population so that we can gauge the level of social acceptance. Based on the charettes, we will update our chart on the social acceptability of the proposed method and determine whether or not a new heating method needs to be proposed.

3.4 Planning and Designing Sustainable and Healthy Alternatives for Cooking

As far as planning and designing a new cooking technique, we will begin by finding out the meals most commonly cooked using the current stoves. We will discover this information by asking a few co-researchers as well as a few community members. We might even try to observe the preparation of a few meals in the existing shacks to get a better sense of what will be needed from our new design, such as the number of burners or pots used in preparing a meal, the average size of the pots that are used to cook, the length of time it takes to prepare the meal, and any other cooking needs that we may have overlooked. This will be an important basis for us in brainstorming the design of our cooking method.

Through the interviews that we will have conducted in the first few weeks, we will narrow down the cooking methods to a maximum of three and proceed to plotting out the specifics of the design on those two or three methods. Right now, we believe that we should design, build, and test the rocket stove. We will follow designs discussed in the background section to use as a guide and possibly a step-by-step procedure for the fabrication of the stove. Additionally, we plan to look into buying a solar oven to test as a supplement to the rocket stove or other stove that is chosen.

Once the two methods have been carefully designed and built, we will move into testing the ovens. We will test their cooking ability, timing, efficiency, and safety. We will cook a traditional meal with the guidance of a co-researcher as a definite way of testing the oven. We will record the length of time to

prepare the meal, how much of the fuel source is consumed in the process, the amount of emissions, as well as any observations pertaining to safety or other concerns. We will record in detail all of this information. If we determine that the method is safe for testing, we will then ask multiple co-researchers and other community members to come to the guest house to prepare a meal and we will record the same data collected when we ran the test as well as ask for their opinions on how it worked and whether or not they would use it in their own homes.

After compiling the results of the tests, we will analyze them and look to address any concerns by modifying the stove. Once again we will determine if the method will work for the community based on the criteria previously listed. If the method fits the criteria well, we will look to recommend it to the residents and people in charge of the development of the new housing. If we find that the method is unsuccessful, we will summarize why it did not work and then look to making the current methods safer or promoting the other safer methods over paraffin.

3.5 Offer Improvements to Existing Shacks

The main focus of the project is on developing the new heating and cooking techniques for the new housing. However it is still important to address some of the energy concerns in the existing housing. Along with offering the new methods to the community, we will also promote the use of energy-saving light bulbs based on previous programs. Furthermore, we look to work with the economy team to establish a sewing program for hay-baskets which are similar in concept to hot boxes but can be made in the sewing center.

In order to establish a hay-basket industry, we will first look to purchase one and make one of our own. They can be made from scrap cloth and cotton padding or possibly sand. We will determine the best insulating material for this use as one aspect of the test. Then we will follow concepts of the cooking tests, such as the time it takes to finish cooking a meal in the hay-basket. We will need to test a variety of foods in the hay-basket so we know which can and cannot be cooked in this manner. After recording our results, it will be time to bring the idea to the co-researchers for feedback and opinions. One of the main issues that we would like to hear their response to is the time needed to cook in the hay-basket. We will make a few hay-baskets to be tested either with the new method of cooking or with their own current stove. It will be important to note at what stage in cooking they place the meal in the hay-basket, as well as their feelings on modifying their cooking schedule around the time needed to fully cook the meal. Also, we would like to know if there are concerns about whether or not the food is fully cooked and thus safe to eat.

3.6 Raising Awareness and Informing the Residents

An important aspect of sustainability is raising awareness in the community about the importance of energy conservation and the health risks that they may be affected by in the current practices. This can be a sensitive subject since we are new to the area and are only there for a short time. It will be important that we respect the members of the community when looking into educational tools that we may try to implement for the long term. One idea is to work with the communications team to make a video that will address issues around energy use and simple ways to conserve energy such as changing light bulbs or unplugging appliances. This video would be broadcast on Endlovini Television and available for viewing in the community center.

Another idea is to set up a workshop for the new methods of heating and cooking that will teach people how to use the new heaters and stoves properly and safely so as to avoid dangers in the future. For this workshop to be continued after our departure, we would work with co-researchers to make sure that they are willing and able to run the workshops year round. In doing so, we hope that the use of the new methods will spread to other areas of the community as was the case in the case study in Rwanda (Pimentel, 2005). Informing the residents is a key aspect of sustainability and will hopefully be the last piece of the puzzle that will solidify the integration of the proposed methods of heating, cooking and energy savings into the community.

3.7 Projected Timeline

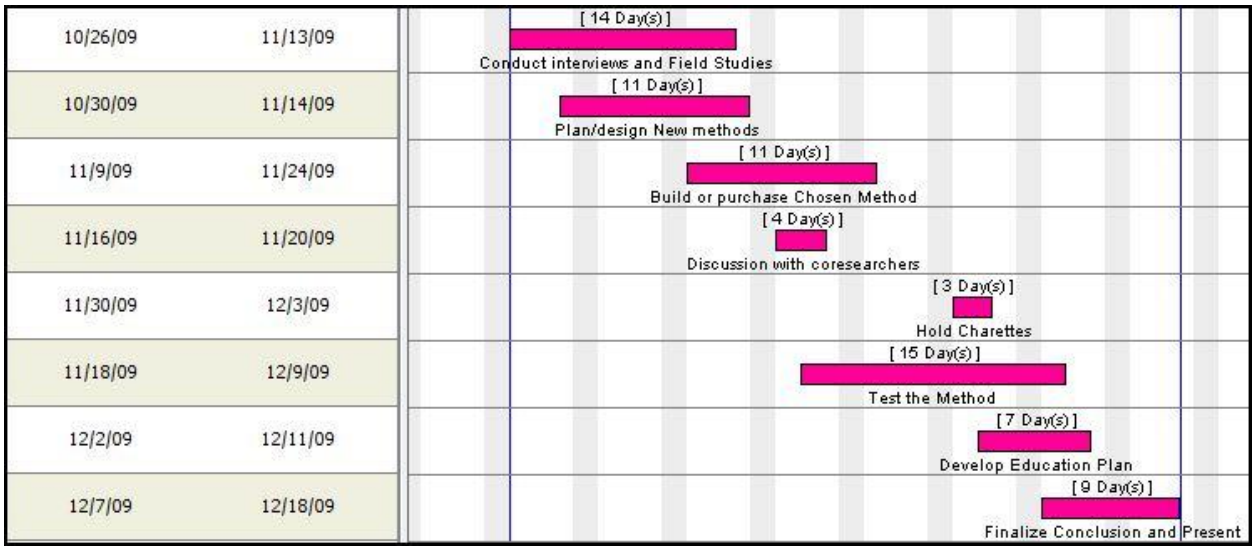


Figure 13: A Basic Timeline for Our Project

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Appendix A: Annotated Bibliography

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Useful source. This website had a lot of information that we used to write the section about the safe paraffin stove.

[2] Arnold. Personal Interview. September 2009.

Somewhat useful interview. Learned about "window blankets."

[3] Bank, L and Mlomo, B. 1996. *We Live in Paraffin and Burn in it: Fire, Fuel Use and Social Dislocation in an East London Township*, 1986-96, J Energy in SA 7 pp118-123.

Useful source that had a lot of good information about paraffin.

[4] Brent, A. C., & Rogers, D. E. (2010). Renewable Rural Electrification: Sustainability Assessment of Mini-Hybrid Off-Grid Technological Systems in the African Context. *Renewable Energy, 35*(1), 257-265.

Very useful. This article touches on every aspect of renewable energy in rural settlements such as demand, energy output, and institutional issues. It also includes many relevant diagrams and charts that would work well with our report.

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This is a study completed in Khayelitsha by researchers from the University of Cape Town. In the study are multiple useful data tables and charts regarding energy consumption and income specific to Khayelitsha. This is extremely important background information.

[7] Jacobs, Cindy. Personal Interview. 18 September 2009.

This was a very helpful interview because we learned a lot about the tension between the City of Cape Town government and the residents of Monwabisi Park. We learned of several very useful contacts/sources as well as the importance of accessibility and affordability of new alternatives.

[8] Jiusto, J. S., & et al. (2008). *Envisioning Endlovini -- Options for Redevelopment in Monwabisi Park, Cape Town, South Africa* (1st ed.). Worcester, MA: Worcester Polytechnic Institute. Retrieved from <http://www.wpi-capetown.org/Atlas.pdf>

A vital source for this project. It has specific information relating to our project. There is a lot of great information about the existing practices in Monwabisi Park. This is the book with the projects from last year, and without it we would have to start back at square one.

[9] Karekezi, S. (2002). Poverty and Energy in Africa—A Brief Review. *Energy Policy, 30*(11-12), 915-919. DOI: 10.1016/S0301-4215(02)00047-2

Very useful source. This report explains several options for energy other than solar power, and talks specifically about household energy in Africa, which is a huge topic for our project since we need to develop a safe method of cooking within the new buildings.

[10] Martin, R. L. (2007). *ColoradoENERGY.org.* Retrieved 9/20/2009, 2009, from <http://www.coloradoenergy.org/> and <http://www.coloradoenergy.org/procorner/stuff/r-values.htm>

Useful source used to collect more data and research when discussing insulation.

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This source is great because it has economical data for several types of good insulators that we would need to use to insulate existing shacks. This good insulation will also help homes to be more energy efficient.

[12] Palmer Development Group. (2007). *State of Energy Report: City of Cape Town 2007.*, Accessed 2009, from http://www.capetown.gov.za/en/EnvironmentalResourceManagement/publications/Documents/StateOfEnergy_Report_2007_v2.pdf

Extremely useful source. It has a lot of data about specific energy use in South Africa and Cape Town. It summarizes the use and even offers suggestions to improve upon energy use methods by pointing out specific problems. Since it was completed in 2007, it is very current information which is also very important for our report.

[13] Pimentel, M., & Pimentel, W. (2005). A Land of a Thousand Hills. <http://solarcooking.org/regional/Rwanda/Rotary-Rwanda-Report-Jan2005.htm>

Good case study. This is a useful example of a new cooking system being implemented in settlements in Rwanda. In this project, the three main cooking methods were solar cooker, rocket stove and the peacemaker which is similar to the hay-basket. It serves as inspiration for a possible solution to the issue of cooking in Monwabisi Park.

[14] Readymade of South Africa. From <http://www.readymade.co.za/Sustainability.asp>

This was a good source that we used to gain a better understanding of the safe paraffin stove.

[15] SANS 1906 *Safety of Non-Pressure Stoves and Heaters*, First Ed 1998, Pretoria. From <http://www.hedon.info/BP56:DevelopingSafeParaffinAppliancesInSouthAfrica >

This is a very useful source because it has a lot of information about how to develop safe paraffin appliances, which was a big topic of discussion in our project proposal.

[16] Tjaronda, W. (2009, 29 July 2009). New Eco-Friendly Stoves Launched. *New Era,* Retrieved from <http://www.newera.com.na/article.php?articleid=5794>

Initial source from a project in Namibia that uses paper pellets in a cooking stove. This will be good to look into more since there is a good amount of recycled paper that would be available for use in Monwabisi Park.

[17] US Department of State. *The End of Apartheid.* Accessed September 2009, from <http://www.state.gov/r/pa/ho/time/pcw/98678.htm>

Good source, but it was only used to find the exact dates for when the apartheid ended.

[18] Ward, S. (2008). *The New Energy Book for Urban Development in South Africa* . South Africa: Sustainable Energy Africa.

Extremely useful. Sarah Ward, who works for the City of Cape Town, wrote this book which covers many of the issues we are currently considering. A good amount of useful data about energy conditions in the informal settlements was obtained from various chapters of the book.

[19] Wareham, R. (1999). The Features and Qualities Necessary for the Acceptance, Manufacture and Distribution of Large Quantities of Solar Cookers, 2009, from <http://www.sungravity.com/solar_cooking__overview.html#Top>

Extremely useful. On this website are many designs for how to make a solar cooker as well a interesting discussion of the use of the ovens. This serves as one of the main sources for solar cookers.

Appendix B: Key Informant Interviews

Interview with Cindy Jacobs: September 18, 2009

Background on Cindy

- Her department falls under the strategy and planning department
    - Focus on "sustainable livelihoods"
    - Energy and resource use
    - Environmental education programs
- Project manager
- Used to research low-income residential areas at a university

Heating

- Alternatives must be ACCESSIBLE as well as AFFORDABLE
    - Tried biofuels and gas
        - People were actually given free gas stoves, gas, coupons for new gas and it still did not make a huge difference because it was not as convenient as paraffin and they had little to no education about it. Once the initial supply was diminished residents stopped using the gas.
            - How would the gas get to the homes?
            - Maybe have a small business set up inside the settlement to exchange empty gas cans with new ones
            - Also need to be educated on benefits of using gas
- Main method being looked into are **solar water heaters**
    - Need partnership with the housing department (is it possible?)
    - Quiafa: some heaters have been installed here
        - Social surveys and research will be completed by October
    - Solar water heater bylaw
- Other source: wind energy looked at outside of center
- Insulation: Not much has been done at all in this area
- Paraffin
    - Will be very hard to get rid of because it is so easy to access inside the settlements
    - People need to be better educated on dangers of paraffin and WHY using an alternative such as gas would be beneficial to them

Cooking

- Cindy is not involved in this
    - Does not believe it has been looked into at all
    - Referred us to Sarah Ward

Social Aspects Learned

- Informal Settlements:
    - ACCESSIBILITY is a major problem
        - Refuse removal, electricity, schools, etc. are not accessible
    - Very neglected
    - "Squatter Camp" problem
        - People claim land but don't own it.
        - Creates huge tension between the government and the citizens

Major People to Contact:

1. Sarah Ward: sarah.ward@capetown.gov.za
    a. Wrote a book, has a core focus on energy
    b. In Energy and Climate Change Unit
2. Gerry Adlard: Gerry.adlard@capetown.gov.za, phone: 021 400 3445
    a. Works in the housing department dealing specifically with informal settlements

Major Resource to Look Into:

1. Sustainable Energy Africa: www. sustainable.org.za, email info@sustainable.org.za
    a. Phone: 021 702 3622
    b. Support local governments, renewable energy

Interview with 2008 WPI Energy Services Team: September 29, 2009

Methods for Interviewing and Surveying

- Need to be straightforward with questions. Wording needs to be direct
- Language is tough/different, co researcher swill do their best but won't be full translators
- Co researchers will do introductions
- Important to be flexible. You will get a "feel" for the interview and how to conduct it
    - Won't get a perfect answer to each question
- Don't have TOO many questions
- Ask one or two open ended questions at the end for sure
    - What are your biggest concerns with electricity
- Make observations while you interview. Take lots of pictures.
- As soon as we can go out and ask big questions from interviews/surveys and see how they go
    - See if wording, etc needs to be changed
- Be aware that data probably won't be exact and will be in ball park, but not worth statistically analyzing

Should we propose things to do for existing conditions or focus on things for new buildings?

- If you build something, you need to plan it out so you don't have a waste of time
- EcoBeam guy has a shop for us to work in, but he's so busy you can't get straight answers out of him

What information should we try to obtain?

- Interviewing is incredibly helpful. Wish they had done more of it. Contact with community is very valuable
- Energy profiling with people near center that Bowiswa knows would be best idea
    - About finding people to keep records of their energy use for a month

How they got the figures for monthly costs, energy wattage, etc

- Average numbers, wattage says on actual appliances, research online for average wattage of a radio, cell phone

How to start once we are down there?

- Solar oven did not go well. Problems: if it doesn't cook what they're eating, they're not going to use it
    - Food that is cooked: beans and samp (it's some sort of potato/legume). Meat is expensive, but there are local butchers where it is available to cook.
    - Cardboard with tin foil actually worked very well
    - Wood box painted black
    - Didn't work so it couldn't even be shown that it didn't work
- Hot box had potential
    - People are afraid it won't cook the food well
- Approach… became determined to build it later on and didn't see it wasn't going to work, took a long time to make it.
    - Have plans and designs ready before we get there. Must be REALLY well thought out. Find out right away how to get/find materials to build
        - Building something WILL be tough
    - Don't put all of your efforts into building one thing unless it will really work and that we know for sure will be successful and that people want
    - Wont typically want something that they've never heard of
        - Even if given in new housing and are educating to use different methods, they will usually resort back to what they are accustomed to and what they have known all of their lives
    - City of Cape Town could have ways to get materials for us. Order materials for us, etc.
- Education will be a touchy subject. Be careful. DO NOT use the word "educate"

Any ideas? Advice?

- Heating

    - Gas = propane
    - Ethanol gel fuel
    - New houses: go for electric
    - Big problem with the winter/cold is the fact that there are drafts/leaks. Homes that are cold and windy make it a lot colder than it has to be if homes were dry and "tighter"
    - Can see how much wattage a home would need, how much would be lost
- Cooking
    - Have new homes come with hotplates
    - Electric stoves for new homes? People shy away from it because the stoves are so expensive
- All solutions will have obstacles. Don't let that keep us from finding or implementing one

Other

- Never conducted a charette
    - Went to one and it was interesting
    - Need subject matter, it's kind of like teaching a class
    - They're a big deal and you know about them for weeks
- Can get together with co researchers on the fly, doesn't need to be as well-planned

Appendix C: Charts

Product			
Criteria	**Specifics**	**Rank (1-5)**	**Comments**
Accessibility	Availability in Park		
	Distance from Housing		
	Overall		
Cost	Capital/start up		
	Monthly		
	Overall		
Efficiency	Energy Savings		
	Energy Consumed		
	Overall		
Safety	Flammability		
	Stability		
	Placement		
	Overall		
Health Risks	Green House Gas Emissions		
	Indoor Air Quality		
	Overall		
Sustainability	Longevity of Product		
	Simplicity of Use		
	Overall		
Social Acceptability	Overall		

Figure 14: Chart from Methodology: Analysis of a Method Based on Our Criteria

Appendix D: Heat Loss Analysis

In order to determine the heat flowing out of the buildings, we will calculate the U-coefficient of resistance of heat loss. To estimate the U-value, we will first need to find out all of the materials that are in the walls and ceilings of the new and existing homes and the approximate surface areas of each material. Then we can look up the R-values in a table (http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=2554&VerticalID=0) and factor in the surface area of each material as well as the temperature difference between the inside of the home and the outside. All measurements and values will be entered into an excel spreadsheet to easily calculate the U-value using the following equation.

$$U = \frac{1}{R{\sim}Value}$$

$$U = \Delta Temperature \times (Building\ Total\ Surface\ Area) \times \sum_{each\ material} (Surface\ Area \times R{\sim}Value)$$

http://www.inspect-ny.com/interiors/Heat-Loss-Calculation.htm

After calculating the U values for both the new housing (using the guest house or the plans for the new houses) and for the existing shacks, we can compare to see how much better the insulation is comparatively. Also, according to the U.S. Department of Energy, the R-value of the first floor perimeter should be at least 19. This is a preliminary way to determine the amount of energy that would be required to heat a home. There is also a variety of free online software that calculates energy loss such as www.builditsolar.com (http://www.builditsolar.com/References/Calculators/HeatLoss/HeatLoss.htm).

Also, Sarah Ward (2008) provides us with a calculation for life cycle costing which is a way of looking at all of the costs that will be incurred by buying and using the appliance. The calculation includes:

$$LCC = Initial\ Energy\ \$ + Initial\ Appliance\$ + Regular\ Energy\$ + \frac{Maintenance\ \$}{Replacements\$} + Other\ \$$$

Where the initial energy costs include the cost of the electricity connection or deposit on gas bottles, the initial appliance costs are from buying the appliance, and the regular energy cost is from fuel or electricity. We would set a time frame to record all of the costs in, could be five years (not realistic for our project, but the same concept can be applied in a month).

Appendix E: Sample Interview Questions

Interview Topics/Ideas

- Ask people using a variety of sources: electricity, paraffin, gas, imbawula
    - Record which source is used and any observations
    - Aim to get middle-aged and old people
    - Equal number of men and women
- Introduce ourselves, give very brief and to the point description of our goals
    - Ask them: Who do you live with, How big is your family, How long have you lived here, What are your interests
        - Basically, basic laid-back questions to open
- Information to draw out of interview:
    - Type of stove used
    - Location of stove
    - Heating source used
    - Reason for using each source – money, convenience, habit/tradition?
    - Health concerns
        - Injuries or accidents in the past?
    - What food is typically cooked/typical meals

Questions

- What do you eat most often?
- What do you cook with?
- How often do you cook?
    - (If not in the home for interview) where in your home do you keep the stove/cook?
    - Do you heat your home?
    - What do you heat with? Or: How do you stay warm in the winter?
- How much do you spend (a week – time frame depends on the source used) on paraffin/electricity/etc?
    - Have you been injured or had any accidents/fires? What injuries/accidents have you seen?
- End With Open-Ended Questions
    - Why do you use this source?
    - What are your main concerns?
    - Are you open to new suggestions/methods?
        - What would you like to see?

Appendix F: More Information on Energy Use in South Africa and Cape Town

South Africa

South Africa is a fast-growing country of over 47 million people that is in need of alternative energy sources. South Africa's economy is incredibly dependent on oil, which makes it entirely dependent on other countries since it has no oil of its own. The country buys approximately 90% of its electricity from a company called Eskom, which is currently having trouble supporting the grids that have been built and is therefore cutting back to prevent more blackouts from occurring. There have also been environmental problems associated with this energy use that are causing respiratory infections in South Africans. It is therefore obvious that alternative energy options must be researched and implemented in South Africa in order to protect the health and safety of South Africans as well as the environment.

As previously stated, the economy of South Africa is dependent upon oil, which creates a large problem when petrol prices rise. The price of oil in South Africa depends mainly on two factors: the supply and demand of oil in the world market and the USD/Rand exchange rate, which can increase the price to over seven times more Rand than US dollars (Palmer Development Group, 2007). With the world oil and coal reserves also dwindling, the need for a sustainable, alternative energy source is growing larger (SMART Handbook, 2009).

Though South Africa's economy is largely oil-dependent, the country itself uses coal predominantly as a source of power for electricity, which is very harmful to the environment. When coal is burned, harmful gases are released into the atmosphere which cause local air pollution as well as creates health risks such as respiratory infections and other diseases. For example, sulfur dioxide, SO_2, is a byproduct released into the air when coal is burned. It dissolves into the water vapor in the atmosphere, which forms acid rain (Palmer Development Group, 2007). This creates problems for animals and plant life especially, which can cause health problems in humans who ingest the sulfur dioxide whether through food or when using the local water supply. The burning of coal is also a major contributing factor to global warming (SMART Handbook, 2009). With most South Africa getting its power from environment-damaging coal, it is easy to see the need for cleaner, more sustainable energy (Karekezi, 2002).

Another problem arises with the distribution of electricity in South Africa, which is very unreliable and fragmented. This results in unequal treatment of customers, inadequate maintenance of networks, and a limited ability to capitalize on the economy to allow for competition (Palmer Development Group, 2007). Electricity supply to the Western Cape is limited by Eskom's Transmission Network. In order to accommodate supply problems, it is best to have electricity reserve margins between fifteen and thirty percent. The reserve capacity for the entire Western Cape is under fifteen percent. In 2005 and 2006, this was the main cause for blackouts and load-shedding (the shutting down of electricity in planned areas to attempt to prevent blackouts). If a transmission line trips, the Western

Cape could be greatly affected (Palmer Development Group, 2007). This also illustrates the need for South Africa to move away from its dependence on electricity.

South Africa is trying to adopt policies to allow for more energy sources to be sold and regulated in order to ensure stability in the future. The government is also aware of the harmful effects of burning coal, and desires to establish a renewable energy industry in the country to begin to establish an alternative to using fossil fuels. The government is trying to create power generation through wind energy and even nuclear energy. Before implementing these technologies on a large scale, small studies are being done at the Darling Wind Farm and the Pebble Bed Modular Reactor in Koeberg (Palmer Development Group, 2007). Though the country does plan on using renewable, safe energy sources in the near future, little is being done now to protect its people, especially in informal settlements outside of major cities such as Cape Town.

Cape Town

Cape Town, the legislative capital of South Africa, faces the same problems as the country as a whole. The city depends heavily on electricity as an energy source. The city is facing many environmental effects due to a lack of clean energy sources. This appears as a brown haze every year between March and August, which is a peak time of the year for energy use, since it is their winter (Palmer Development Group, 2007). Below in Figure 15 is a picture of the discussed brown haze.

Figure 15: The Brown Haze (http://web.capetown.gov.za/wcms/images/Brown_Haze24420021556133.jpg)

Clearly this haze is detrimental to the environment and the health of the citizens. The city does have a vision of eliminating it through the use of renewable sources.

As aforementioned, the majority of the citizens of Cape Town rely on the availability of electricity. Eighty percent of households use electricity for cooking, seventy five percent for heating, and fifty six percent for lighting. Low-income homes, which cannot afford to use solely electricity, typically use a mix of electricity and paraffin (Palmer Development Group, 2007). Paraffin is used extensively to heat homes and to cook. The chart shown below in Figure 16 shows the respective percentages of energy use in Cape Town by fuel type:

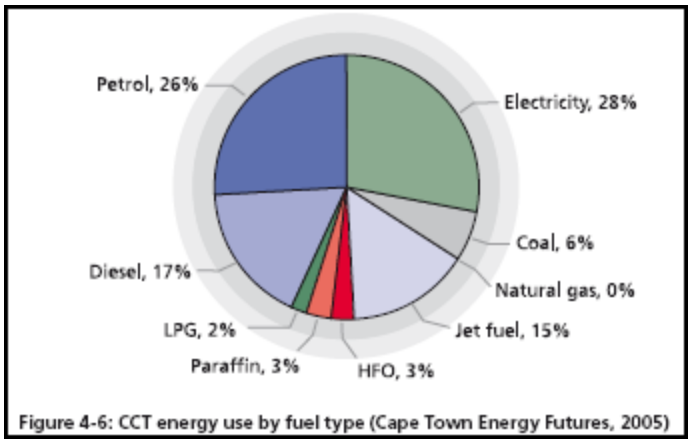

Figure 16: Cape Town Energy Use by Fuel Type (Palmer Development Group, 2007)

Cape Town's reliance upon electricity, "highlights the need to diversify energy supply sources in order to ensure a sustainable economy" (State of Energy Report, 2007).

Energy supply sources are hard for many people to afford because of large difference between economic classes. "According to the 2007/2008 IDP for the CCT, decades of distorted development within the CCT [City of Cape Town] has manifested in skewed distribution of income and wealth" (Palmer Development Group, 2007). Also, the percentage of people living in poverty is increasing every year, along with the percentage of people who are unemployed. Evidence of this skewed distribution can be seen when comparing statistics on water heating. In Cape Town, an "average" person uses about twenty seven percent of their total energy consumption for water heating, while middle to high income users use about fifty percent (Palmer Development Group, 2007). This creates a problem because as the wealthy classes get wealthier, the less and less that people living in poverty will be able to use electricity as an energy source.

Cape Town is looking into alternatives to electricity. The most significant effort is the partnership between the South African government and a nuclear power company called Pebble Bed Modular Reactor (Pty) Limited. The first nuclear reactor is being planned to be built near Cape Town in Koeberg by the year 2020. The reactor could have great potential in international markets, as well as allow the economy to be more stable since it would be less resource-based. Nuclear reactors also provide safe, clean energy (http://www.pbmr.co.za/index.asp?Content=175). However, there needs to be more done in the short term to help solve current problems.

Appendix G: Renewable Energy Technology

Wind Energy

Wind provides an unlimited, clean source of renewable energy. By harnessing the wind, one can generate electricity to power household appliances without emitting greenhouse gases or any toxins. Monwabisi Park would be an ideal location for making use of wind turbines due to the constant coastal winds. We would look into small scale designs for individual houses and also larger scale designs that would be placed atop community buildings.

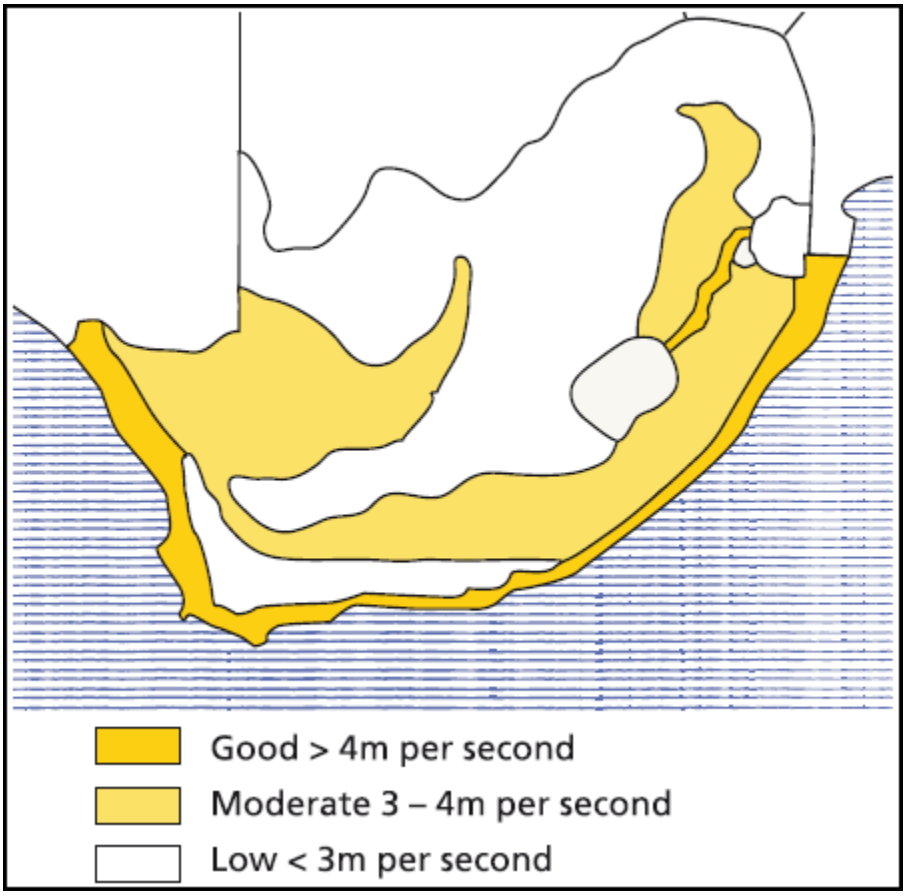

Figure 17: Wind Energy Potential in South Africa (Palmer Development Group, 2007)

Solar Energy

Solar Energy as a renewable source of energy has tremendous potential. If ways to reduce the installation cost can be achieved then implementing solar power as an alternative energy source could be a viable solution. There are still many obstacles in implementing such an advanced source of energy but progress is being made.