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Energy Demonstration Trailer Assessment

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ENERGY DEMONSTRATION TRAILER ASSESSMENT



An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
by:

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Date: May 4, 2006

Report Submitted to:
Prof. Chrysanthe Demetry
Prof. Richard Vaz
Dr. Robert Schultz & the Habitat Research
and Development Centre,
Windhoek, Namibia

ABSTRACT

The Energy Demonstration Trailer is a mobile showcase of renewable energy and energy efficient technologies. The trailer was developed by the Habitat Research and Development Centre in Namibia, with the intention to enhance awareness of sustainable energy alternatives. Our project involved preparing the trailer for use by expanding the trailer's educational capacities. We conducted three demonstrations with the trailer and assessed its performance and the audience's interactions. Modifications were made to the trailer based on the assessment, along with recommendations for additional improvements.

EXECUTIVE SUMMARY

Like many countries in the developing world, Namibia is struggling to provide reliable and affordable electricity to its population. The national demand for electricity is growing while the generation and transmission system is ageing and insufficient. In 2005, Namibia had to import 1.065 billion kWh of electricity from South Africa, roughly 45% of the electricity consumed that year (CIA, 2005). Namibia's electricity provider, NamPower, has recently warned that with current economic development trends, electricity demand in Namibia is steadily encroaching upon and could exceed supply in a few years, and by 2010 South Africa may not have a surplus supply to sell to Namibia (Hite, 2004).

The problem of insufficient electricity generation is compounded by the fact that the power grid is limited and excludes many poor urban communities and rural villages. This leaves thousands of Namibians without electricity, leaving them to rely on fuels like wood, kerosene, charcoal, propane, and paraffin. Reliance on these fuels has created new problems for Namibia and its population. The widespread use of wood is resulting in deforestation which may lead to desertification, and at the current rate trees are falling, it has been estimated that by 2045 there could be no trees left in all of Namibia to see or burn (Terrasol, 2005). Other problems with using wood, charcoal, kerosene, or liquefied petroleum gas (LPG) are the production of carcinogenic hydrocarbons (Zhang & Smith, 1996) and the possibility of shack fires (Poor Can Now Warm Up Their Shacks, 2004).

The escalation of each of these problems suggests the importance of addressing Namibia's energy situation and presents the opportunity of developing sustainable and environmentally friendly solutions using renewable energy and energy efficient technologies. The Habitat Research and Development Centre (HRDC), a non-governmental organization that addresses energy issues in Namibia, has developed an Energy Demonstration Trailer intending to alleviate Namibia's energy problems (Birmingham et al., 2005). The purpose of the Energy Demonstration Trailer is to travel to rural and urban communities and schools to educate people about available renewable energies and how to conserve energy. In 2005 the HRDC involved a team of Worcester

Polytechnic Institute (WPI) students in the design of the energy trailer and its contents. The trailer contains electrical appliances that are powered by solar panels and a wind charger. For a listing of the contents of the trailer refer to Appendix B. The basic trailer components were completed in early 2006 but did not yet have a complete educational program and had not been tested.

The goal of this project was to deliver recommendations to the Habitat Research and Development Centre (HRDC) to enhance the Energy Demonstration Trailer's ability to encourage Namibians' use of energy efficient techniques and renewable energy technologies. In order to accomplish our goal, we devised and executed four objectives. First, we assessed energy use and constraints in various types of communities in order to better understand peoples' energy needs. We then used that knowledge to expand the educational capacity of the trailer, making some additions and modifications before the first visit. We took the trailer on three trips where we performed demonstrations. During these trips, demonstrations and trailer contents were assessed and recorded. Finally, we used these assessments to make improvements to the trailer and its contents. We improved models and displays and added hardware to the trailer that would aid in performing demonstrations. We also made recommendations on how to perform the demonstrations in various communities.

In order to assess energy use and constraints in communities we made trips to an urban un-electrified community and to rural electrified and un-electrified communities. During our first trip to Okondjatu, a rural community northeast of Windhoek, we visited the electrified community and un-electrified farming village. We also visited the Barcelona settlement, an un-electrified urban community in Katutura. During each trip, we interviewed community members to better understand their energy uses and constraints. From this information, we developed community profiles to aid in the enhancement of the trailer's educational capacity. We also assessed the needs of an urban electrified community through background research.

From these assessments, we determined what technologies to emphasize at each location and added information about technologies that address the communities' energy needs. We found that electrified communities may be interested in energy saving lighting

technologies, and un-electrified communities may be interested in solar cookers and efficient wood stoves. Also, those living in urban communities typically have bank accounts so they may be interested in the financing options available to them. We then collected relevant materials from suppliers, such as business cards and pamphlets. We also constructed four models that applied to the energy needs of these communities and packed them in the trailer. These models were a fluorescent light display, and energy efficient shack model, a solar water heater model, and solar water pump model.

In order to provide recommendations for demonstrations in various types of communities, we took the trailer on its first visits and assessed these visits. We performed demonstrations in two communities of Okondjatu and at the HRDC Open Day. We made suggestions on how to best use the materials on the trailer, as well as how to interact with the audience. Our assessments were based on discussion of the following questions:

- Did we have difficulty explaining any demonstrations? If so, what materials would be needed to make explanations simpler?
- Did any questions from participants recur throughout the demonstration? If so, what were they?
- Did any of the models fail to fulfill their purpose? If so, how can they be improved?
- Which demonstrations received the most attention in the community?

The trailer's structure and sturdiness were also observed during travel to demonstration sites and during the demonstrations.

Our findings were drawn from background research, data collected and observations made during each of our demonstrations in Okondjatu and at the HRDC. We compiled a list of recommendations based on our experiences with the trailer in the visited communities and implemented several of them. We found that most demonstrations were effective in communicating their purposes, but there were alterations that could be made, which we believe would improve the trailer as a whole. In order to improve the trailer we:

- *Constructed a more durable energy efficient shack model.* The new model has two differently designed shacks side by side. This approach helps to present a more effective demonstration by showing a greater temperature difference between the two shacks.

- *Arranged for construction of a collapsible stand for the parabolic cooker.* The parabolic cooker may attract more participants if taken off its mounted hinged frame and placed on the collapsible stand so that it can be properly aligned with the sun.
- *Improved the solar water heater model.* The original solar water heater model produced hot water only after several hours and did not insulate the water that was eventually heated. The new model is smaller and intended to heat water more quickly.
- *Improved the trailer's structure and made hardware additions.* Improvements to the trailer were made, such as strengthening the jockey pulley, adding a plank under the computer's monitor to access the back of the computer, installing a venting system to reduce overpressure, and sealing the screws for the solar array. Hardware additions consisted of a ratchet, a jack, and a tire iron.
- *Created a User Manual.* This manual is intended to be used by individuals setting up the trailer and performing demonstrations. This manual includes instructions for:
 - *Initial trailer set-up*
 - *Setting up camping equipment*
 - *Setting up and using the demonstration*
 - *Site-specific recommendations.* Types of sites include urban electrified, urban un-electrified, rural electrified, rural un-electrified, and schools.

Based on our experiences with the Energy Demonstration Trailer in different communities, we developed recommendations for the operations and long-term financial support of the trailer. These recommendations consist of:

- *Conducting visits to demonstration sites before bringing the trailer.* We found initial visits to communities to be useful in gaining the communities' trust and ensuring an audience is present for demonstrations.
- *Showing movies at night after demonstrations.* To entertain people at night while they linger around the trailer after demonstrations, movies can be shown. While people are gathered before a movie, there is an opportunity for discussion in order to receive feedback about demonstrations.
- *Providing a way for people to order technologies.* Another recommendation is to provide a way for people to order the solar cookers and efficient wood stoves from the trailer. This recommendation is based on our visit to

Okondjatu, during which we were asked numerous times if people could purchase the demonstration cookers.

- *Conducting demonstrations with four (possibly multilingual) demonstrators for groups of more than thirty people.* After conducting demonstrations we found that two demonstrators were inadequate to handle large crowds, whereas with four we could handle approximately sixty people. Multilingual demonstrators could also be an advantage when traveling with the trailer.
- *Charging product suppliers a fee for advertising.* Charging suppliers advertising fees provides financing for implementing some recommendations and for future trips with the Energy Demonstration Trailer. We distributed many specific suppliers' contact information, and our sponsor could be compensated for this service. We recommend that further research be conducted on this topic, such as how to provide suppliers with evidence that the trailer advertising works.

Further additions and modifications can be made to the trailer and its demonstration material to enhance its design and make demonstrations more interactive and informative. We recommend that the HRDC:

- *Construct a solar water heater model using a washing stand.* We recommend that a solar water heater model be created using a dish washing stand to store water so participants can feel the warm water. We also recommend showing a small scale cross section poster or model of how home solar water heating systems work.
- *Design a hand-out on how to construct a solar box cooker.* Solar box cookers are easy to use and have a simple design. People were interested in constructing their own solar box cooker during our visit to Okondjatu, so information on how to do so will be useful on the trailer.
- *Design a pamphlet that includes purchasing information about all technologies presented.* A helpful tool to be included on the Energy Demonstration Trailer is a pamphlet that includes all purchasing information about each technology being presented. This pamphlet will reduce the overall number of pamphlets to keep stocked on the trailer.
- *Make further alterations to the trailer's structure and hardware additions.* Hardware additions include food coloring for the solar water pump display and trash bags. We also recommend dust covers for the computer and refrigerator as these electronics gathered large amounts of dust during travel.

In order to determine how effective the trailer is in spreading the use of renewable energy and energy efficient technologies, either with or without implementing all of our recommendations, we recommend further studies be carried out. Specifically, we recommend that additional visits to demonstration sites be conducted in the future to determine if any of the demonstrated technologies or techniques have been purchased or employed once the Energy Demonstration Trailer has left.

The adoption of the technologies the Energy Demonstration Trailer presents could decrease the use of current non-renewable energy sources, including wood, propane, and electricity from power plants. These same technologies may also potentially result in reduced demand from power plants and lower rates of desertification and health problems in Namibia due to the burning of wood and fossil fuels.

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AUTHORSHIP

All sections of this report have been reviewed by all members of the team.

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CHAPTER 1: INTRODUCTION

Since receiving its independence from South Africa in 1990, Namibia has remained a developing nation in an impoverished part of the world. Like many countries in the developing world, Namibia is struggling to provide reliable and affordable electricity to its population. Namibia has few power generation facilities and imports roughly 50% of its electricity from South Africa. NamPower, Namibia's electricity distributor, has warned that electricity demand in Namibia could exceed supply in the upcoming years, while South Africa's demand could exceed supply by 2010 (Hite, 2004). Continuing to import energy will be costly and is not a long term solution to Namibia's electricity generation problems.

An additional challenge that Namibia faces is extending power lines to people in informal settlements and remote regions. In 2001, less than 10% of the rural population was provided with electricity, and the government has set a goal of increasing that to 25% by the year 2010 (Davis & Wamukonya, 2001). However, NamPower has not made expanding the grid to these rural areas a priority due to the high cost of installing power lines. Few people in settlements and rural areas can afford electricity, so running lines into these poor rural areas is not cost effective (Ministry of Mines and Energy, 2000). Currently, the Namibian power grid is supplying electricity to mainly urban and high density areas while the remaining population relies on fossil fuels and wood for much of their cooking, lighting, and heating.

The thousands of Namibians without electricity are relying on fuels like wood, kerosene, charcoal, propane, and paraffin. Reliance on these fuels has created new problems for Namibia and its population. The widespread use of wood is resulting in deforestation which may lead to desertification, and at the current rate trees are falling, it has been estimated that by 2045 there could be no trees left in all of Namibia (Terrasol, 2005). Other problems associated with using wood, charcoal, kerosene, or liquefied petroleum gas (LPG) are the production of carcinogenic hydrocarbons (Zhang & Smith, 1996) and the possibility of shack fires (Poor Can Now Warm Up Their Shacks, 2004).

One possible approach to reduce dependence on NamPower and fossil fuels is to encourage the use of renewable energy sources and energy efficient techniques.

Renewable energy (RE) is energy obtained from sources that are essentially inexhaustible, such as wind, photovoltaic, and solar thermal energy (Natsource, 2006). Energy efficiency (EE) refers to products or systems that perform as well as or better than conventional products or systems while using less energy. Energy efficiency has been shown to save energy, save money, and help protect the environment by reducing the amount of electricity that needs to be generated.

While broader use of RE and EE technologies in Namibia has the potential to address the country's energy supply problems, there are barriers to the adoption of these new technologies. Lack of information and high costs are two factors that hinder the expansion of RE and EE technology use. Konga Investments, a local financing company in Windhoek, Namibia, has issued only 375 loans for renewable energy technology purchases over the past year (Kalompo, 2006). With approximately fifty percent of the Namibian population below the poverty level, investing in alternative energy may not be a high priority (CIA, 2005). On the other hand, there are several RE and EE cooking technologies that are quite affordable, but that many people are not aware of.

The Habitat Research and Development Centre (HRDC) is an organization that attempts to address the barriers to RE and EE technology adoption. The HRDC has many RE and EE resources that distant communities may not have the opportunity to utilize due to its sole location in Windhoek and its hours of operation; all major towns of Namibia are located at least 100km from Windhoek. With so many Namibians living in remote areas, information regarding RE and EE technologies is not conveniently accessible.

In order to address some of these barriers, a demonstration trailer focusing on RE and EE technologies was proposed by the Renewable Energy and Energy Efficiency Bureau of Namibia (R3E) to popularize energy efficient technologies among people in primarily rural areas (Tjaronda, 2004). The Energy Demonstration Trailer was designed through a collaborative effort of the HRDC, the Desert Research Foundation of Namibia, and a team of WPI students in 2005. The trailer was intended to be brought to communities throughout Namibia to demonstrate RE technologies and EE techniques and includes various sample technologies to be used in demonstrations, as well as supplies for the demonstrators. The trailer contains electrical appliances that are powered by solar

panels and a wind charger. For a listing of the contents of the trailer refer to Appendix B. The trailer was completed in early 2006, but did not yet have a complete educational program and had not been tested.

In order to enhance the trailer's effectiveness in different communities, the HRDC wants to understand which educational approaches with the trailer will be appropriate and accepted by communities. Therefore, the goal of this project was to deliver recommendations to the HRDC to enhance the Energy Demonstration Trailer's ability to encourage Namibians' use of energy efficient techniques and renewable energy technologies. We researched the energy uses and constraints of each type of community we visited and modified the trailer's educational materials and contents based on our research. We conducted demonstrations with children and adults in several types of communities and determined the appropriateness of the trailer's contents and educational approaches in each setting. We have made suggestions to the HRDC for future alterations and additions to the Energy Demonstration Trailer aiming to enhance its effectiveness in encouraging the use of RE and EE technologies.

CHAPTER 2: BACKGROUND

In this chapter, we will explain the energy crisis common throughout much of Africa and how these issues specifically affect Namibia. We will also describe current commercially available renewable energy (RE) and energy efficient (EE) technologies as well as financing plans for these technologies. We will report research from projects involving community education to specify which techniques we considered to be practical for the trailer. Finally, we will report on the construction and intentions of the Energy Demonstration Trailer on which this project is based.

The Energy Crisis in Southern Africa and Namibia

According to the Energy Information Administration, power usage in Southern African countries jumped an average of 2.3% each year from 1995 – 2003, as can be seen in Table 1 (Energy Information Administration, 2005). This growth is the result of increasing economic development and population growth. The trend towards higher standards of living may also contribute to the growth of power usage. More households throughout Southern Africa are connecting to the power grid and investing in high-energy appliances (Hite, 2004). Investing in conventional fuel burning power plants is not an appealing solution for developing countries since they are expensive to construct and harmful to the environment.

These problems are prevalent through much of Africa, including Namibia. The energy use of Namibia increased approximately 37% between 1995 and 2003 (Energy Information Administration, 2003). This energy use includes electricity, residential use of fossil fuels, and renewable energies. In this section, we will discuss the uses for and sources of these types of energy.

Southern Africa Total Energy Use (Quadrillion BTU), 1995-2003

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Angola | 0.087 | 0.084 | 0.094 | 0.085 | 0.094 | 0.091 | 0.119 | 0.127 | 0.135 |
| Botswana | 0.043 | 0.040 | 0.042 | 0.045 | 0.041 | 0.056 | 0.050 | 0.050 | 0.052 |
| Congo (Brazzaville) | 0.015 | 0.015 | 0.015 | 0.014 | 0.012 | 0.013 | 0.016 | 0.015 | 0.015 |
| Congo (Kinshasa) | 0.112 | 0.113 | 0.102 | 0.105 | 0.093 | 0.091 | 0.080 | 0.078 | 0.080 |
| Kenya | 0.141 | 0.147 | 0.145 | 0.151 | 0.144 | 0.143 | 0.145 | 0.150 | 0.154 |
| Madagascar | 0.022 | 0.022 | 0.023 | 0.023 | 0.023 | 0.031 | 0.033 | 0.038 | 0.037 |
| Mozambique | 0.022 | 0.022 | 0.028 | 0.031 | 0.078 | 0.092 | 0.100 | 0.133 | 0.166 |
| Namibia | 0.032 | 0.031 | 0.030 | 0.035 | 0.039 | 0.042 | 0.047 | 0.050 | 0.051 |
| Rwanda | 0.012 | 0.012 | 0.012 | 0.012 | 0.012 | 0.012 | 0.012 | 0.014 | 0.014 |
| South Africa | 4.107 | 4.162 | 4.555 | 4.347 | 4.491 | 4.609 | 4.540 | 4.582 | 4.901 |
| Swaziland | 0.016 | 0.015 | 0.015 | 0.016 | 0.019 | 0.021 | 0.021 | 0.021 | 0.021 |
| Tanzania | 0.049 | 0.051 | 0.048 | 0.055 | 0.058 | 0.058 | 0.068 | 0.075 | 0.078 |
| Zambia | 0.101 | 0.098 | 0.108 | 0.102 | 0.098 | 0.096 | 0.112 | 0.111 | 0.108 |
| Zimbabwe | 0.196 | 0.205 | 0.198 | 0.195 | 0.225 | 0.210 | 0.192 | 0.190 | 0.189 |
| Southern Africa-Total | 4.955 | 5.016 | 5.413 | 5.216 | 5.425 | 5.565 | 5.535 | 5.634 | 6.001 |

Table 1 – Southern Africa Energy Use
Source: <http://www.eia.doc.gov/pub/international/iealf/tablee1.xls>

Use and Sources of Electricity in Namibia

The current electricity demand in Namibia greatly exceeds the amount of electricity being produced in the country. From 2003 through 2005 Namibia used an average 2.372 billion kWh each year, while it only produced an average of 1.464 billion kWh. Namibia imported roughly 1.065 billion kWh (45%) from South Africa during each of these years (CIA, 2005). Due to development in each of these countries, South Africa may not have enough surplus electricity to sell to Namibia in the upcoming years.

Namibia's electricity provider, NamPower, has recently warned that with current economic development trends, electricity demand in Namibia is steadily encroaching upon and could exceed supply in a few years, while South Africa's demand could exceed supply by 2010. The economic development of South Africa over the last twenty years has resulted in greater utilization of their electric resources. There has already been one instance where South Africa had to cancel power to Namibia because a power plant went off-line (Hite, 2004). To compensate for the loss of power, NamPower had to run Namibia's only coal plant at full capacity, at a much higher cost (Hite, 2004). It is only a

matter of time before Namibia requires more electricity than South Africa and NamPower can provide.

Namibia has limited power generation facilities; the country has only three power plants, one being a hydroelectric plant that can only operate at full capacity for 4 months each year. The other two generation facilities include a coal fired plant in Windhoek and a diesel fired plant on the coast. Plans have been made to build an 800 MW power plant in Namibia but in order to supply this large combined cycle gas turbine power plant, there will need to be offshore gas field drilling (Ford, 2005). There are environmental and health risks associated with burning gas fuels, and the building of this power plant will be costly. The current estimated cost is N\$7.317 billion and the emissions would create higher levels of nitrogen oxide and sulfuric gases (NamPower, 2005).

Another issue regarding Namibia's electricity problem is that the power grid does not include many rural areas and informal settlements on the outskirts of urban regions, which leaves tens of thousands of Namibians with no access to electricity. NamPower's current transmission network, seen in Figure 1, shows the large regions which are un-electrified. The present status of electrification is estimated at 75% in urban areas and 9% in rural areas. Namibia's 1998 White Paper on Energy Policy suggests electrification targets of 90% and 25%, respectively, by 2010 (Power Firms Join Hands to Light up Continent, 2004).

NamPower has left these rural areas and informal settlements un-electrified because there are not enough paying customers within these communities to justify the expenditure of extending the transmission lines, which would cost millions of dollars. The addition of these settlements to the grid would also contribute to the already overloaded power grid.

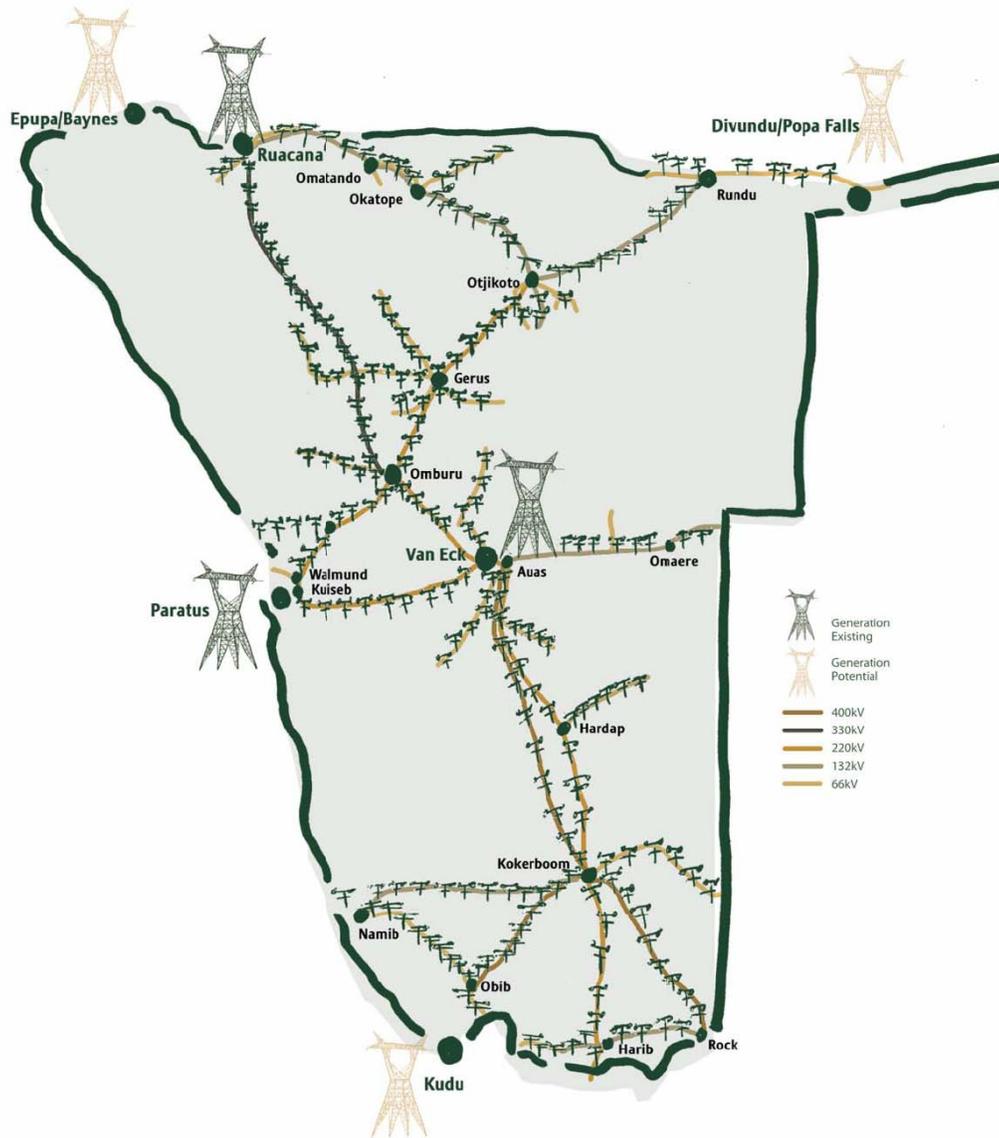


Figure 1 – NamPower Transmission Network
 Source: <http://www.nampower.com.na/2005/docs/transmission%20network.pdf>

Residential Use of Wood and Fossil Fuels

Some of the most common energy sources used in Namibia are wood, kerosene, charcoal, propane, and paraffin. Of these fuels, wood is the only source that can be considered a renewable resource; however, all these fuels are expendable and their consumption has negative effects on the community and environment.

Wood is a commonly used fuel for the cooking and heating needs of people in informal settlements and rural areas, and it can cost a family up to N\$300 per month for cooking purposes alone (Poor Can Now Warm Up Their Shacks, 2004). The widespread use of wood is creating deforestation, which may lead to additional desertification of Namibia. At the current rate trees are falling, it has been estimated that by 2045 there will be no trees left in all of Namibia (Terrasol, 2005).

There are many disadvantages to traditional fuels other than the high costs to Namibians. Wood, paraffin, candles, and kerosene, which are all used as heat and light sources, are the leading cause of shack fires (Poor Can Now Warm Up Their Shacks, 2004). Using wood, charcoal, kerosene, or liquefied petroleum gas (LPG) as fuel for cookstoves, as done in many developing countries, results in the production of carcinogenic hydrocarbons (Zhang & Smith, 1996). Studies have been conducted concluding that the use of kerosene and gas for cooking in the home also has a direct association with allergic symptoms (Venn et al., 2001).

Renewable Energy

It may not be feasible to reduce the energy demand in Namibia; however, with the use of renewable energy (RE) technologies, the strain on the earth's resources could be lessened. RE is energy obtained from sources that are essentially inexhaustible, such as wind, photovoltaic, solar thermal energy, and, in some cases, wood (Natsource, 2006).

An unending potential resource available to Namibia is solar power. With nearly 300 days of sunlight, people in Namibia can harness these sun rays through many different solar energy processes (Getaway Africa, 2005). Photovoltaic energy, solar water pumps, solar water heating, and solar cooking are some of the ways in which solar energy can be used.

One way of capturing solar energy is to use photovoltaic (PV) panels. These panels convert light to electricity that can be stored in specially designed deep-cycle batteries and used during periods with little or no sunlight. The batteries are connected to an inverter and a collector which houses sockets for appliances, as seen in Figure 2. These sockets can then provide energy for lights, radio, and other electrical appliances.

Using energy efficient electronic devices can maximize the use of this energy. These solar home systems (SHS) range in capacity from 50W to 800W. Suitable appliances that can be utilized through a SHS are florescent light bulbs, cell phone chargers, fans, radios, and televisions. A SHS is not suitable for appliances such as stoves, irons, kettles, geysers, or body insulated refrigerators and freezers (Schultz, 2005).



Figure 2 - Solar Home System

Source: <http://astralsolar.ebigchina.com/sdp/340604/4/pd-1519698/1607295-762069.html>

Solar home systems can be relatively expensive, and this cost may be too much for Namibians living in low-income areas, such as informal settlements. Solar power also requires more education to operate and maintain than other RE methods (Wormsbaecher, 2006). These drawbacks may make it improbable to implement the systems into many homes, but small businesses which use low energy devices may profit from these systems.

An efficient application for photovoltaic panels is providing electricity for solar water pumps. These pumps can be used to draw water from boreholes, wells, rivers or dams. These pumps are wired directly to photovoltaic panels and can provide steadily pumping water throughout the day. There are limitations to the depth at which these pumps can operate and the liters of water per day that can be extracted. This information can be seen in the table in Appendix J.

Solar water heating uses radiant energy to warm a liquid and can replace electric or gas water heaters (National Center for Appropriate Technology, n.d.). Solar water heating is an efficient use of solar energy and the only requirement for installing a purchased solar water heating system is a 20 degree angle roof facing north (Wormsbaecher, 2006). Solar water heaters store the water heated throughout the day in an insulated tank so that it can be used at anytime. The typical price for a solar water heating system in Windhoek is approximately N\$18,000, and the break even point for purchasing a system is approximately 4.9 years (Ministry of Mines and Energy, 2005). A solar water heating system can be seen in Figure 3.



Figure 3 - Solar Water Heater

Wind power is also a viable resource for Namibia, but just as solar power can only be collected when there is sunlight, wind power can only be collected when there is ample wind. The coastal regions of Namibia receive a South Atlantic breeze, but for other areas in Namibia, wind power may not be a reasonable option. Wind chargers are similar to solar home systems, but rather than a solar panel and an inverter, a wind turbine and a wind generator are used. Wind chargers can be purchased for homes or to power wind water pumps. The size of a wind charger indicates how much electricity it can produce, and chargers typically range between 100W to 6 kW. The advantage of wind chargers is their efficiency over PV cells' (Schultz, 2005), but wind chargers are still relatively expensive.

Biomass, in the form of invader bush, is considered a renewable energy due to its rapid growth throughout Namibia (Wormsbaecher, 2006). Invader bush species are rapidly taking over open spaces and are negatively impacting the environment by destroying many species' habitats. Bush encroachment is "the suppression of palatable grasses and herbs by encroaching woody species often unpalatable to domestic livestock" (Saltz, Ward, & Wirgand, n.d.). The excess biomass is being harvested and processed into compact logs, known as Bushblok, which can be used for cooking or home heating fuel (USAID, 2005).

There is also a vast potential for the use of biogas in Namibia due to the large number of livestock communities (Ngatjizeko, n.d.). A biogas digester can be installed in the home, reducing the amount of smoke emitted when compared to the use of paraffin, LPG, or wood stoves (New Age, 2005). A biogas digester is a spherical container that holds biological matter, such as animal manure. As the biological matter breaks down, methane gas is emitted. The methane is then burned and converted to carbon dioxide. The energy produced from burning methane can be utilized for cooking, lighting, and heating (EECA, n.d.).

Energy Efficient Technologies

Like renewable energy technologies, energy efficient techniques can reduce the amount of fossil fuels consumed. EE technologies refer to products or systems that do the same or better job than conventional products or systems while using less energy. According to the United States Environmental Protection Agency: "Energy efficiency saves energy, saves money on utility bills, and helps protect the environment by reducing the amount of electricity that needs to be generated" (EPA, 2006). EE technologies that may be appropriate for Namibia are wood-efficient stoves, solar cookers, and energy efficient lighting.

Efficient wood stoves and solar powered cookers can reduce fuel costs for consumers. A Vesto Stove, found in Figure 4, requires 70% less fire wood than traditional wood stoves by protecting the fire from wind and focusing heat directly onto

the pot. These stoves cost approximately N\$380, which is relatively inexpensive when compared to some RE technologies (Desert Research Foundation of Namibian, 2005).

The Tsotso stove is another wood-efficient stove that reduces the amount of wood needed for cooking. This stove can reduce wood consumption by up to 60% when compared to the use of a traditional wood stove. These stoves typically cost about N\$150 (Desert Research Foundation of Namibia, 2005). The stove is convenient for cooking and providing warmth when outside, as it can be moved while a fire is lit. A Tsotso stove can be seen in Figure 5.



Figure 4 - Vesto Stove



Figure 5 - Tsotso Stove

Solar cookers require no wood at all; they harness the sun's radiant energy and convert it to heat to cook food (Solar Cookers International, 2005). Examples of solar cookers can be seen in Figure 6 and Figure 7. A solar box cooker can be purchased for approximately N\$600 and can cook a chicken in 2 to 3 hours. The temperature inside the solar box cooker can reach up to 90°C (Schultz, 2005). The advantages of solar box cookers versus other RE technologies are their affordability and ease of use. A parabolic solar cooker can be purchased for approximately N\$450, and temperatures at the center of the cooker can reach over 100°C. These energy efficient products reduce the emissions of harmful gases that are produced in most communities that use clay or paraffin stoves (Pemberton-Pigott, n.d.).



Figure 6 - Solar Box Cooker



Figure 7 - Parabolic Solar Cooker

Energy efficient lighting is another affordable EE technology that can reduce costs in homes. These compact fluorescent lights, such as that shown in Figure 8, use 80% of the electricity they consume to produce light, unlike incandescent bulbs which can waste up to 78% of electricity consumed to produce unwanted heat (Schultz, 2006). Lowered power consumption can lower electricity costs if homes receive electricity from a utility provider. These lights also work well in conjunction with solar home systems, saving energy that can be used for other home appliances.



Figure 8 - Energy Efficient Light Bulb

If utilized, RE and EE technologies could help to alleviate the strains of Namibia's energy crisis. Even the simple solutions, like the solar box cookers, could lower the demand for electricity and fossil fuels; but they may not be taken advantage of if the public is not informed of the current energy shortage, available energy options, and means of purchasing these technologies.

Energy Technology Financing

The cost of renewable energy and energy efficient technologies puts them out of reach for many Namibians. In Namibia there is a network of dealers that sell renewable energy technologies such as solar water heaters and solar home systems. This network

has made arrangements with local financial institutions to provide financing for these rather expensive devices. Both the Bank of Windhoek and Konga Investments issue loans for the purchase of these items.

Konga Investment's purpose is to administer the Solar Revolving Fund (SRF). The SRF is a loan financing scheme formed to stimulate the demand for renewable energy technologies in Namibia. Konga's goal is to provide energy solution payment options to off-grid communities so they no longer have to rely as heavily on expensive fuels (Konga Investments, 2006). Qualifying Namibians who intend to purchase renewable energy technologies are eligible for Konga Investments' five year loan with five percent interest per year.

The Namibian government is now involved in financing schemes for renewable energy technologies. The government has an arrangement with Bank Windhoek to provide funding to emerging small and medium enterprises and end users in the renewable energy segment (Katswara, 2006). The agreement intends to help small and medium enterprises to do business. The conditions of the arrangement make these loans available at prime rate minus three to five percent (Katswara, 2006).

Community Outreach Initiatives Promoting Renewable Energy

Educational initiatives are commonly used to spread awareness about the limitations of fossil fuels and the potential financial and environmental benefits associated with RE and EE technologies. Examining past renewable energy projects in other developing countries can aid in determining what lessons can be taken advantage of. Technological community education has proven important when introducing financing education. Children have also been found to play an important role in spreading awareness in communities. This information was determined in studies conducted in Bangladesh, Costa Rica, and the United States.

Bangladesh is a small country struggling to provide energy, employment, food, and water to its people (Biswas, 2002). As in Namibia, a large part of the country lives in rural areas. A group of scientists from the Islamic University of Technology has recently performed a study on effective renewable energy activities in Bangladesh, which could

be applicable to other countries, like Namibia, with similar challenges. Currently 30% of Bangladesh is connected to a power grid. After evaluating several possibilities of improvement methods, it was determined that solar and biomass options would be best for the population off the grid (Islam, Islam, & Rahman, 2005). Many organizations agree that using solar energy in Bangladesh homes is feasible, but also that biomass options are not environmentally friendly or as easily accepted (Biswas, 2002).

Different organizations have conducted projects creating central solar photovoltaic (PV) charging stations in Bangladesh. Some researchers have concluded, however, that these stations have been largely ineffective because of the high costs, absence of national policy, lack of understanding of the technologies and shortage of information and trained personnel (Awal, 2000). Charging stations may not be feasible without proper education. Users in Bangladesh undercharged the batteries and eventually overused them (ARMCO, 1997). This example suggests that education can be important when introducing new power technologies.

Another factor that could hinder the acceptance of RE and EE technologies is the high initial cost. Prokaushali Sangsad, a Non-governmental Organization, conducted a survey finding that only 8.8% of households in Bangladesh were interested in buying solar home systems (SHS) either with cash or on credit at the current financing rates (Biswas, 2002). To address this cost issue, Grameen Shakti, a non-profit company created by Grameen Bank, sells SHSs on credit in Bangladesh with a low financing rate (Grameen Shakti, 2000).

Children can play a valuable role in community education programs. An intergenerational and intercommunity learning study was conducted in the town of Quebrada Ganado, Costa Rica. The study was conducted to advocate environmental education and stimulate resource management (Gack, Ray, Solorazano, & Vaughan, 1999). A conservation questionnaire was given to children in a school before, immediately after, and 8 months following an environmental education course. The same three tests were given to the parents of the students and other adults (the control group) who did not have children involved with the course. Students showed an average score increase of 67% when comparing the final test to the initial test. Parents of these students showed an average of 52% increase when comparing the same two tests. Adults without

children, though not showing much improvement on the second test, experienced an average 29% increase when comparing the third to the first test. These results can be found in Table 2. The study concluded that learning transferred from students to parents and later to other adults of the community (Gack, et al., 1999). This study illustrates the importance of including children in community education programs. RE and EE courses conducted in schools can affect a community's knowledge and willingness to adopt the new technologies.

| Group taught | Immediate (1 vs. 2) | Retained (1 vs. 3) | Retained (2. vs. 3) |
|---------------------|------------------------|-----------------------|------------------------|
| Students | 71 | 67 | 5 ^b |
| Parents of students | 38 | 52 | 10 |
| Control adults | 0 | 29 | 33 |

^a*n* = 21.

^bFour questions had correct answers that significantly decreased.

Note. 1 = Test 1, which was given before the course began (July 1–4, 2001). 2 = Test 2, which was given immediately after the course ended (July 31–August 3, 2001). 3 = Test 3, which was given 8 months after the course ended (March 15–17, 2002).

Table 2 - Improvement in Correct Responses to Questionnaire

Source: http://www.icomvis.una.ac.cr/publ_pdfs/vaughanenvironeducat_1999.pdf

According to the Community and Energy Workbook, another step toward a successful education program is to set up a committee consisting of community leaders who believe RE and EE can positively affect their community (Hubbard & Fong, 1995). These ideas were based on American communities but were designed to achieve the same goal of meeting energy needs. This study found that researchers attempting to implement ideas in a community may face problems because they are not members of the community. A supportive local committee can help spread the ideas to other members of the community.

The Energy Demonstration Trailer

The Energy Demonstration Trailer is a community outreach initiative intended to travel to rural and urban communities and schools to educate Namibians about available

RE and EE technologies and encourage their use in attempt to address Namibia's energy problems. The trailer was funded by the Desert Research Foundation of Namibia (DRFN) as an educational tool and was overseen by the Habitat Research and Development Centre (HRDC) (Birmingham et al., 2005).

The HRDC is a non-governmental organization that addresses housing and related energy issues in Namibia. The HRDC provides its research and resources to its partners, including the City of Windhoek and the National Housing Enterprise. The HRDC works with these partners to make homes safer, environmentally friendly, and energy efficient (Habitat Research and Development Centre, n.d.). For a more complete profile of the HRDC refer to Appendix A.

Many Namibians cannot travel to the HRDC to learn of alternative energy options, so the Energy Demonstration Trailer will bring the centre's resources to various communities. In 2005, the HRDC involved a team of Worcester Polytechnic Institute (WPI) students in the design of the trailer and its contents. The student team conducted research and interviews to determine available products that could be used for instructional demonstrations. Formal quotes from suppliers were obtained by the team to determine which exact products should be included in the trailer design. Some appliances include solar cookers, solar panels, a voltage converter, a wind generator, and a wood-efficient stove. The complete list of demonstration materials compiled by the team can be found in Appendix B.

The team's design was complete in May 2005, construction of the trailer began, and a training manual was completed. The trailer was completed in early 2006 but did not yet have a complete educational program and had not been tested.

Funding is available to construct additional trailers, but this will be done only after the evaluation of the first in order to make possible improvements. Improvements may be helpful to enhance the effectiveness of the trailer demonstrations and activities in various communities.

CHAPTER 3: METHODOLOGY

The goal of this project was to deliver recommendations to the Habitat Research and Development Centre (HRDC) to enhance the Energy Demonstration Trailer's ability to encourage Namibians' use of energy efficient (EE) techniques and renewable energy (RE) technologies. In attempt to accomplish our goal, we devised and executed four objectives. First, we assessed energy uses and constraints in various types of communities in order to better understand peoples' energy needs. We then used that knowledge to expand the educational capacity of the trailer, making some additions and modifications before the first visits. Our third objective was to perform and assess demonstrations we conducted. Our experiences during these demonstrations were used to make improvements to the trailer and its contents in the form of a user manual, structural change to the trailer, and renovations to demonstration models. In this chapter we present details on the specific methods we used to accomplish these objectives.

Assessing Energy Use and Constraints in Communities

The goal of the Energy Demonstration Trailer is to encourage the use of RE and EE technologies throughout Namibia, and we aimed to develop recommendations for accomplishing this goal in different types of communities throughout the country. When selecting sites to bring the trailer for its first demonstrations, we intended to choose different types of communities that were familiar with presentations of new ideas from research organizations. By doing so, we hoped to receive constructive feedback and information during these inaugural trials. To tailor demonstrations for various communities based on their energy needs, we assessed the energy use in electrified and un-electrified rural areas and electrified and un-electrified urban areas.

We conducted preliminary visits to rural and urban communities in order to gather information regarding current energy needs, uses, and constraints. We visited electrified and un-electrified areas of Okondjatu, a rural town approximately 200 km northeast of Windhoek, which was involved in a range-management project with the Desert Research Foundation of Namibia (DRFN). To understand energy use and needs in an urban, un-

electrified community, we visited Barcelona, which is an informal settlement on the outskirts of Windhoek, previously involved in projects with the HRDC. This was an important objective in order to determine what would be emphasized on the Energy Demonstration Trailer during demonstrations. By determining the energy uses and constraints, we focused on the technologies and information that could possibly be most beneficial or relevant to the particular community.

During these preliminary visits, we met with community leaders who could give us a better understanding of the community, such as how it operates or what its primary concerns are. During these visits we introduced ourselves, the goal of our project, and what we would like to do in the community. We also asked community leaders and representatives about energy needs, common fuel sources, how these fuel sources are used, and how much they are currently spending on these fuels. We explained the materials on the trailer and discussed the feasibility of the adoption of these technologies.

To compile the data received during the preliminary visits, we constructed profiles of individual communities. Each profile contains data concerning energy needs, the amount of money spent on energy per household, and the types of energy sources used. This profile template can be seen in Appendix C. By analyzing these profiles we could see the differences in communities' ways of life and how these affect their energy needs. We then determined which activities and technologies should be included and emphasized during an actual visit with the trailer. By doing so we hoped to better tailor the Energy Demonstration Trailer so that visits would be more engaging and useful for each community.

To determine energy use and constraints for urban electrified communities, we conducted informal interviews with residents of electrified areas of Windhoek. We asked how much money was typically spent on electricity monthly, what appliances were used in the home, and if any fuels were used to provide energy. We used this information to provide recommendations regarding how to modify trailer demonstrations when visiting an urban, electrified community.

Expanding the Educational Capacity of the Trailer

Once we assessed communities' different energy needs, we set out to gather materials to address those needs and include the material on the trailer. Product and environmental information was collected to be included on the trailer in order to increase awareness by educating people on the various energy options that are available. Models and additional demonstrations were also created in order to visually explain some of the information that was being presented.

We were provided with a list of local contacts which our liaison, Robert Schultz, believed could be helpful in supplying information and educational materials. Many of these local companies and organizations, listed in Appendix G, are stakeholders in the Energy Demonstration Trailer project, having provided technologies for the demonstrations. We set up and conducted meetings with business representatives during which we explained how and why we intended to distribute the information and materials we sought. Several of these representatives provided us with brochures, business cards, and/or posters regarding RE and EE products and information.

In addition, we compared the energy needs in various types of communities with the types of technologies currently available on the trailer. Where there were gaps we decided on additional models and activities to provide education in those areas. These models were created by the team in the Terrasol workshop owned and operated by Werner Schultz.

We also collected financial materials, such as loan applications, to present steps that may be taken in order for RE and EE technologies to be purchased and implemented. We met with a representative of Konga Investments, a local financial institution involved in the Solar Revolving Fund, to obtain detailed instructions for their loan application process. By relaying the provided application instructions in a simple manner, we hoped to encourage the use of RE and EE technologies by simplifying the purchasing process.

Performing and Assessing Demonstrations at Selected Sites

We took the trailer for inaugural visits to test its performance and assess demonstrations and activities. Several demonstration sites, including a school and rural

and urban communities, were recommended by our liaison, Robert Schultz, an Energy Researcher at the HRDC, and Nils Wormsbaecher, our Technical Advisor.

We selected the Science and Environmental Club from the A. Shipena Secondary School for a practice demonstration because of the school's close proximity to the HRDC. Because the trailer was not complete at the time the demonstration was scheduled, a contingency plan was to allow the students to visit the HRDC and take part in demonstrations similar to the ones that were on the trailer.

During the demonstration two team members presented, set up, and explained various RE and EE technologies while the other two team members documented the students' reactions to the demonstrations. Following an explanation of the RE and EE technologies, we gave the students time to freely ask questions about the technologies that interested them. The two team members that recorded reactions looked for which demonstrations attracted the students' attention by observing which demonstrations provoked questions and discussion.

The rural community of Okondjatu was selected for our first demonstration with the trailer. This demonstration site was divided into two separate demonstrations. During a morning and afternoon session we demonstrated for the rural electrified village, and into the evening we conducted another demonstration with the members of the rural un-electrified area. By doing so we had the opportunity to present the trailer in different settings as well as with different audiences.

During our visit to the electrified village of Okondjatu, we set up the demonstrations behind the local secondary school principal's home, where people were invited to participate. Community members were greeted by one of our four team members or our liaison, Robert Schultz, and taken around in groups to the different demonstrations, where we explained the technologies and models in detail. Following the demonstrations, we met with our liaison to discuss which demonstrations attracted the most and least interest from the community. We discussed questions about the demonstrations, such as:

- Did we have difficulty explaining any demonstrations? If so, what materials would be needed to make explanations simpler?

- Did any questions from participants recur throughout the demonstration? If so, what were they?
- Did any of the models fail to fulfill their purpose? If so, how can they be improved?
- Which demonstration received the most attention in the community? Which tended to initiate questions and physical or tactile interaction? Which demonstrations did people return to?

At this time, we also assessed the trailer and demonstration materials to determine the structural improvements we could make to perform future demonstrations more smoothly.

Our visit to the Okondjatu farming community, located approximately twenty kilometers west of the village, took place during the late afternoon and into the night. Community members convened around the trailer's computer monitor to watch a PowerPoint presentation our team and our liaison gave. The presentation included a question and answer session to ensure that everyone's questions on the particular technologies of interest were answered. We set up some of the technologies on the trailer, such as the Tsotso stove, and explained them to young adults of the community. In order to analyze which technologies and demonstrations should be emphasized in this community, we noted which technologies received the most questions during the PowerPoint presentation and which technologies attracted the most interest based on our informal conversations with community members. Many of these informal conversations took place while a movie was played on the trailer's computer following the presentation.

Following the four hour drive on unpaved roads from Okondjatu, we unpacked and cleaned the trailer. We checked all the equipment for damage sustained due to travel. We recorded any damage or problems that we noticed to develop recommendations for changes to the trailer.

The Habitat Research and Development Centre's Open Day was the site for our final trailer visit. The director of the HRDC, Jacques Korrubel, invited us to demonstrate at the Open Day so that RE and EE technologies on the trailer could be viewed and explained. The HRDC is located in an urban area of Windhoek where it can be easily reached by citizens of electrified and un-electrified urban areas. We informed people gathered around the trailer about the various technologies and information the trailer has

to offer. Following this demonstration, we met with our liaison and assessed the demonstration and trailer materials. We discussed the same questions we had after concluding our Okondjatu village demonstration.

Improving the Trailer and its Contents

Our final objective was comprised of three parts: developing recommendations, implementing recommendations that were feasible within our time constraints, and creating a user manual to aid in the use of the trailer. These three deliverables were intended to help our liaison further develop the Energy Demonstration Trailer to encourage the use of RE and EE technologies.

We made recommendations based on our hands-on experience with the trailer and our observations of people who interacted with it. These recommendations included emphasizing appropriate demonstrations in specific communities. We developed these recommendations after discussing which demonstrations received attention in communities. We also developed recommendations for improving demonstrations and models based on difficulties we had explaining and performing demonstrations. We made recommendations for improving the construction of the trailer and adding necessary hardware to the trailer based on our observations during the set up of the trailer and after our visits. As we developed these recommendations, we implemented many of them. We completed the changes that our team believed would make the demonstration trailer more effective and could be executed in the time available.

Finally, we created a user manual that explains how the trailer and each technology are set up and demonstration techniques we found to be effective. The manual was intended to provide recommendations for performing demonstrations in different types of communities based on our experience in the various communities we visited.

CHAPTER 4: RESULTS AND ANALYSIS

In the first part of this chapter we describe additions that we made to the trailer before its first use, based on our assessments of energy technologies that would be relevant in a variety of communities. In the second section of the chapter we describe four different demonstrations we conducted and report the assessment results from each.

We used results from each community to develop guidelines to use when preparing for demonstrations at the corresponding site types. We present the results from rural Okondjatu demonstrations, demonstrations with the students of the A. Shipena Secondary School, and demonstrations at the Habitat Research and Development Centre's (HRDC) Open Day, located in an urban area. We also present findings from a preliminary visit to the urban Barcelona community.

Trailer Hardware and Demonstration Development

Before the trailer was taken out on its first demonstration, additions were made in order to expand the trailer's educational capacity. To demonstrate renewable energy (RE) and energy efficient (EE) technologies not included on the trailer, we created several models and added them to the trailer's demonstration materials. While the models were made, special attention was placed on the need for the models to be compact and lightweight. Most of the work on the trailer and its contents was completed in the Terrasol workshop in collaboration with our liaison, Robert Schultz; the owner of Terrasol, Warner Schultz; and Terrasol employees.

The trailer was originally equipped with solar panels, an inverter, five deep cycle batteries, a wind charger, a computer monitor, and power strips. The additions we made at Terrasol were:

- Mounting and wiring of the subwoofer and 5 speaker system
- Layout of how supplies, equipment, models, and demonstration would be stored and secured on the trailer
- Creation of a solar water heater model
- Creation of a solar water pump model
- Creation of a collapsible energy efficient shack model
- Creation of a energy efficient lighting display

We created models and displays to provide interactive demonstration materials for inclusion on the trailer. The following sections describe the purposes and construction of these models.

Solar Water Heater Model

Through our preliminary visits, we found that electricity was commonly used for heating water. We believed it was important to demonstrate a water-heating technology on the trailer because solar water heaters can reduce energy consumption and save people money on electricity or fuels used for heating water. Solar water heaters are very efficient in utilizing solar energy for water heating and can reduce a household's electricity expenditure by up to 50% (Schultz, 2006). The trailer was not equipped with a solar water heating system, and, therefore, we created a model to demonstrate how solar water heaters work.

Copper piping was painted black and fastened into a black wooden box lined with aluminum foil and covered with a sheet of glass. Valves were connected to the copper piping through the wooden box so that it could be filled with water. Rubber hosing was fastened to the valves and to a black plastic jug, which stored the water. The jug was intended to be elevated above the solar water heater during demonstrations and the system to be filled with water until no air was present in the rubber and copper piping. When the model is placed in the sun, water heats up in the copper piping and rises through the rubber hose into the top of the black water jug. Cool water sinks to the bottom of the jug, flows through the piping, and the process repeats. This system, seen in Figure 9, was designed to act like a large solar water heater that can heat up to 200 liters of water and is mounted on the roof of a building or home.



Figure 9 - Solar Water Heater Model

Solar Water Pump Model

We found that people in rural and farming communities were not supplied water from a municipality. Instead, these people rely on boreholes and use diesel water pumps to supply water for themselves and livestock. A solar water pump model was not on the trailer, so we created one to represent a solar water pump that can be placed inside boreholes to pump water using electricity generated by solar panels. This model presents an alternative to purchasing costly fossil fuels for pumping water.

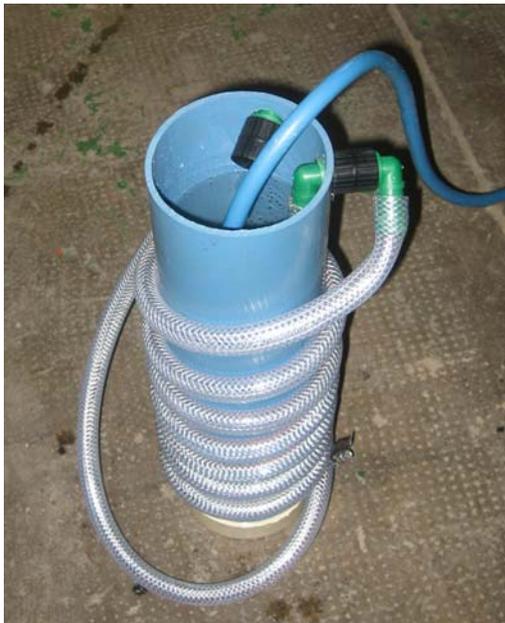


Figure 10 - Solar Water Pump Model

We placed a water pump that can be used inside actual boreholes as deep as 40 meters inside a piece of PVC pipe 50cm long and 15cm in diameter. We sealed the pipe on the bottom to ensure no water could leak out. We left the top of the PVC pipe open so that people were able to see the water flowing from the pump, through the rubber hose, then back up to the top of the pipe. The pump model, seen in Figure 10, is placed a meter away from the trailer and is plugged into a special power outlet that runs off of the solar panels.

Energy Efficient Shack Model

The United Nations Development Program's 2005 Human Development Report indicates that 34.9% of the population of Namibia earns just US\$1 per day, and 55.8% earns US\$2 per day (CIA, 2005). We found that because of these low incomes many people live in informal shacks constructed of scrap metal and various materials. These homes are often very hot during the day and cold at night. The trailer did not present information on how to improve these shacks in order to make them more energy efficient and comfortable. We created an energy efficient shack model to demonstrate relatively inexpensive and simple techniques that can be implemented to create an energy efficient shack or make existing shacks more energy efficient.

The model, seen in Figure 11, was constructed of corrugated metal, which we found is often used for roofing on full-scale shacks in both urban and rural communities. The shack we created was reversible; one side was painted white to reflect sunlight and make the inside of the model cooler, while the other side was painted a dark rust color to absorb the sunlight and heat the shack. We designed the model to be easily taken apart and folded up for storage. The model has windows on its sides to allow cross ventilation and a slanted roof which over hangs the north side, shading the doorway from the sun and allowing rain to run off.

There are two means of insulation that can be used underneath the roof of the model shack: store-bought insulation and collected reeds. We mounted each of these on cardboard that could easily be placed over or removed from the shack. We also fitted cardboard insulation for the walls of the shack model.

The temperature inside the model could be measured before any energy efficient techniques were applied, with the rust side of the shack outward. The temperature could then be measured again with the energy efficient techniques implemented to demonstrate the temperature difference.



Figure 11 - Energy Efficient Shack Model

Energy Efficient Lighting Demonstration

We found, during our preliminary visits to electrified communities, that most people were using incandescent light bulbs throughout their homes for lighting. These bulbs are between 40-100W, have 12% efficiency, last an average of 6 months, and can cost \$30-60 per month on electricity bills (Schultz, 2006). The trailer did not present any efficient lighting displays, so we created an energy efficient lighting display, as seen in Figure 12, to demonstrate the efficiency and advantage of fluorescent lighting versus standard incandescent lighting. These lights are between 7-20W, have 80% efficiency, can last about 3 years, and only cost between \$8-15 dollars per month to power (Schultz, 2006). We found energy efficient lights were simple technologies to implement compared to other more expensive technologies on the trailer, such as solar home systems. We also found that these lights are readily available in most hardware stores for people to purchase.

We inserted various fluorescent light bulbs ranging from 7W to 15W in sockets on 14 gauge wire roughly seven meters long and hung this on the frame of the trailer's collapsible gazebo. The lights are different shapes and colors and are displayed so that people can not only see their brightness but also feel the amount of energy that is given off as heat instead of light. We also added a 60W incandescent light bulb to the strand in order for people to feel and see the differences in the fluorescent and incandescent light bulbs. When the incandescent light bulb was lit, the amperage meter on the trailer showed an increase of current being drawn compared to the reading of current drawn only by the fluorescent bulbs. We intended for this demonstration to illustrate how people can make use of several fluorescent lights using the same amount of power that a single incandescent light would consume.



Figure 12 - Energy Efficient Light Display

Community Visits and Demonstration Results

Each community we visited with the trailer provided us with different information to analyze in order to make site-specific recommendations. The types of communities we visited were: a rural, electrified community; a rural, un-electrified farming community; an urban school; an urban, electrified community; and an urban, un-electrified community. The demonstrations and technologies emphasized in each of the areas differed due to the financial and energy resources available to its people; therefore, different results were found in each of these communities.

Rural, Electrified Community

We conducted a preliminary visit to Okondjatu, a village located in the Otjozondjupa Region of Namibia, approximately 200km northeast of Windhoek, in order to determine the people's energy sources, uses of energy, and what technologies to emphasize during our visit with the trailer. During this preliminary visit, we found that only public buildings, stores, and community members with formal homes had access to electricity. Wood was found to be the main fuel used for cooking and heating purposes for those without electricity. Most homes did not use any fuel for heating water. Very few solar or wind systems were found to be used in the community, and these were owned by the wealthiest members. Expensive technologies, such as solar home systems, were not found to be practical for a majority of the main village community. We found that people did not have access to banking, excluding them from loan possibilities for these technologies. A complete community profile can be found in Appendix D. Based on our findings we decided to emphasize cooking technologies in the subsequent trailer demonstration visits because cooking is the primary use of energy in this community.

We traveled to Okondjatu with the trailer and spent one day in the village. This was the first time the trailer was set up for a demonstration, and during set-up we noticed several things that could be improved upon in regards to its structure and amount of hardware, including:

- Insufficient support for the tongue of the trailer once it was removed from the vehicle.
- Too much dust collected inside the trailer during travel.

- Access to the computer wiring was difficult.
- No ratchet or socket set in tool kit made setting up the wind charger and solar panels difficult.
- Side door supports were not brightly colored and were a hazard.
- The nuts and bolts that fastened the solar panel to the trailer had fallen off and had no sealant around them.
- The solar panels and pin boards/whiteboards were in the way of the parabolic cooker mounted on the back of the trailer.

Once the trailer was set up demonstrations took place throughout the morning and afternoon, for approximately five hours. Community members came and went during this period of time, and the audience size was generally around 60 people. A majority of these participants were children and educators, though young adults and elders of the community were also present. With such a large number of participants, we found that all four team members and our liaison were constantly presenting to community members. The method we found most appropriate was to systematically walk groups of people through each demonstration station we had set up.

We designated eight separate demonstration stations for the technologies we were presenting. These sites consisted of: the Tsotso stove, the solar box cooker, the energy efficient shack model, the solar water heater model, the parabolic cooker, the solar water pump, the energy efficient lighting display, and the solar panels and wind charger.

To demonstrate the Tsotso stove, we placed a log of Bushblok in the center of the stove and described how it concentrated heat to burn less wood than traditional wood stoves. We did not find lighting a fire in the stove practical due to the large volume of people present during the demonstrations. A fire could not be watched and attended to and therefore would not have been safe. Even without a fire lit, people were still interested in the stove and asked questions regarding its design. Questions were also asked about where Bushblok could be purchased and how it was made.

To demonstrate the solar box cooker, we placed a carton of eggs in the cooker in the morning and described how the cooker worked to each group of participants. When the eggs were cooked, we distributed them to participants to demonstrate the cooker's abilities. Afterwards we allowed people to place their hands inside the cooker to feel the heat contained inside. This interactive method of demonstrating proved very effective, especially for children who requested to feel inside the box repeatedly.

We first assembled the energy efficient shack model in its most inefficient construction. This involved covering the windows, removing all insulation, and facing the dark surface of the shack outward. The temperature inside the shack was then taken, but this took some time as the shack needed to heat up and the thermometers did not take instant readings. Once a participant took a reading, we assembled the shack in its most efficient construction to demonstrate the temperature difference. This also took an inconvenient amount of time, as the air needed to circulate inside the shack and the thermometers did not read instantly. This model did not attract as much interest as other demonstrations as the temperature difference measured was small, at most five degrees Centigrade.

We set up the solar water heater model on the side of the trailer, facing the sun. An initial temperature was taken and recorded on the whiteboard next to the model. When demonstrating to the community, we explained how home water heating systems work and referred to a fact-sheet on the pegboard next to the model. Temperature readings were taken approximately every hour and recorded on the whiteboard to demonstrate how the sun heats water. The temperature change was not dramatic over short periods of time, and the water temperature increased just six degrees Centigrade over the course of the five hour demonstration. This demonstration was not particularly impressive, and people did not see substantial benefits of solar water heating systems. We also found that this technology was not appropriate for most of the community since energy was often not used for home water heating due to its high costs.

We set the parabolic cooker up at the front of the trailer because its position at the rear of the trailer did not face the sun. It would have been difficult to move the trailer once it was set up so the cooker was removed and simply rested against the trailer's hitch. Without a proper stand, the cooker was difficult to position, and the water in the pot placed on the cooker never reached a full boil. When the water steamed and people could feel the heat concentrated at the center of the cooker, people at the demonstration were interested and asked more questions about how it worked. Questions were also asked about how long food typically takes to cook, but the intense heat the parabolic cooker can create could not be shown.

We allowed the solar water pump model to run continuously, and the running water attracted people to the display. During demonstrations, we explained how the pumps worked and referred to a fact-sheet that was displayed on the pegboard next to the model. When explaining at what depths and for what volumes of water a diesel pump would actually be more cost efficient, a chart would have been helpful but was not available. The solar water pumps attracted much interest from the community and generated many questions. The community was concerned with providing water to its many cattle, and the solar water pumps presented an alternative to pumps that used costly fossil fuels.

We wrapped the energy efficient lighting display around the frame of the gazebos, which were placed in front of the trailer's monitor and speaker system. When performing this demonstration, we encouraged people to touch the fluorescent bulbs to emphasize that electricity is not used to create heat as with incandescent lighting. An incandescent bulb was also set up for comparison. We explained how using the efficient lighting could save money on electricity bills and presented the prices of each bulb to demonstrate the quick payback period. People showed interest in the lighting, but local stores did not carry the bulbs and traveling to buy them did not seem realistic.

When showing people the slide show on the computer's monitor, we demonstrated the use of electricity from the solar panels and wind charger on the trailer. We explained the process of storing energy from the sun and wind and referred to fact-sheets on the trailer's pegboards. People asked many questions about how the technologies worked, but they seemed to lose interest once we told them the price. Therefore, we found these technologies to be too expensive to be implemented by most people in this community.

During demonstrations at the stations for each model, a recurring question was the price of the presented technology. We were able to verbally provide the answer to this question and write the prices down into notepads if requested. Many people also asked for contact information of suppliers of the technologies. We were able to verbally answer this question, but we only had supplier pamphlets or business cards to distribute for a few technologies presented.

Once young English-speaking adults of the community had been brought to every demonstration, they began giving the demonstrations to non-English speaking elders. We interpreted this to mean that they understood the technologies and our education techniques were effective. This was helpful during our demonstrations, as we did not have a translator present that spoke Herrero, the community's native language. A young adult performing a Tsootso stove demonstration can be seen in Figure 13.



Figure 13 - Young Adult of Okondjatu Demonstrating Use of a Tsootso Stove

Based on our observations during our demonstrations in the village community of Okondjatu, we found that cooking technologies, energy efficient housing techniques, efficient lighting, and solar water pumps were the most relevant technologies to emphasize in similar rural communities. Based on this visit, we also identified opportunities for improvements in the shack and water heating models, and peoples' interest in purchasing information for energy-efficient stoves.

Rural, Un-electrified Farming Community

The Okondjatu un-electrified community is comprised of farmers who live several kilometers west of the main village of Okondjatu. Much like the main village, wood is collected for cooking and heating, and very few solar or wind systems were being used. Unlike the main village, there is no electricity provided to any buildings in this area. Again, we decided to emphasize cooking technologies during our visit with the trailer.

During this visit, we believed that the solar water pump model should also be emphasized based on our visit to the village of Okondjatu.

We spent one night in the farming community of Okondjatu and our demonstrations were performed at night without sunlight. This was made possible because the batteries on the trailer had been charging throughout the day while the village demonstration took place. Approximately sixty people, consisting of elders and young adults, gathered for our demonstrations. We found that only the young adults gathered around the technologies and models, while the elders remained seated around the trailer expecting a formal presentation.

Due to the expectation of a formal presentation, not all demonstration stations were set up for this community. The solar box cooker, Tsotso stove, solar water pump, solar panels and wind generator, and energy efficient lighting display were presented to the young adults who were interested in the technologies. The trailer's computer was used to present a slide show, and during this show questions from the elders were answered with the aid of a translator from the DRFN.

We set up the solar box cooker, but since it was dark by this time we were unable to perform a cooking demonstration. We explained how the cooker worked and discussed example cooking times for different foods. Due to the price of the technology and lack of local suppliers, many of the young adults were interested in how to construct the box cooker themselves. We provided general advice on the construction and provided those interested with a pamphlet that illustrated a cooker, but we did not have pamphlets explaining the box cooker's construction.

The Tsotso stove attracted young adults' interest because it used wood, which is part of their congregational cooking style. Bushblok, a fuel log made from invader bush, was used in a cooking demonstration to prepare our dinner, and during this demonstration questions were asked regarding the stove's construction. This stove has a more straightforward design than the solar box cooker, and our explanations were sufficient. During the presentation, some men picked up the stove, brought it to their sitting area, and used it for warmth. We found that Bushblok was a popular product with this community because it is made from bush, much like that encroaching their farmland. We

received many question regarding where Bushblok could be purchased, and we found that people were disappointed that we did not have any for sale.

We set up the solar water pump model as we had in the village community of Okondjatu, but the model was not presented until our formal presentation had begun. During this presentation, many questions were asked regarding whether the solar water pumps were appropriate for the boreholes the community currently used. It was decided that too much water was pumped from the boreholes for the solar water pumps to be more efficient than diesel pumps, but we explained that with the use of smaller boreholes the pumps could be implemented.

We explained that electricity to run the slideshow presentation on the computer had been collected using solar panels and a wind generator. The community asked many questions regarding solar and wind energy, such as which would be more efficient in their community. The lighting display was presented in conjunction with the solar home system to emphasize the need to conserve electricity with the system. This demonstration set-up can be seen in Figure 14. As electricity was not being used in the community for lighting, the display did not attract much interest or provoke many questions.



Figure 14 - Okondjatu Farming Community Presentation

After the presentation, we showed a movie on the trailer's monitor, and we found that this was considered a luxury for this community because people did not have television sets. Most of the people present during the presentation stayed for the movie, and we used this gathering time to answer any final questions.

Based on our observations during the brief demonstrations and the presentation in the farming community of Okondjatu, we found that purchasing large technologies such as solar water pumps and solar home systems was of interest to the elders of the community. We found that constructing cooking technologies, such as the Tsotso stove and box cooker was of interest to the community as well.

School Community

When we presented renewable energy and energy efficient technologies to the students of the A. Shipena Secondary School, the Energy Demonstration Trailer was not complete so it was unavailable. We brought the students to the Habitat Research and Development Centre to demonstrate various technologies. The student group we presented to was the Science and Environmental Club, consisting of 15 students, approximately 15- 17 years old. Our findings were based on students' interactions with technologies that are included on the trailer, such as the solar box cooker, parabolic cooker, and Vesto stove. We did not conduct a preliminary visit with the students because they would have to be removed from class time, so as a result we collected home energy use data during demonstrations.

Since most students at the A. Shipena Secondary School Demonstration lived around the school in low-income housing, we considered that a financial priority of the students' families may not be to purchase expensive solar power equipment, such as solar home systems. We found that most of the students' homes receive water from the city, so solar water pumps may not be practical. We found these housing details through informal interviews with the students during demonstrations, and students also freely answered questions about their home energy use.

We found that electricity from NamPower was used in most students' homes, with the exception of one student who said his family had a solar home system on their farm. Most students said their family's electric bill was between N\$200 and N\$300 per month. A community profile for the A. Shipena Secondary School can be found in Appendix E.

We set up the parabolic cooker and boiled water, in order for the students to see the high heat the cooker generates. We placed several eggs in this water and later distributed the cooked eggs to the students. We also encouraged the students to place their hands where the sunlight was concentrated so they could feel the heat directed on the pot. This interactive approach prompted many questions from the students about how the parabolic cooker worked and how they could construct their own.

We set up the solar box cooker and placed a carton of eggs inside intending to hand them out when they were cooked. When presenting the cooker we opened the lid and encouraged the students to feel the heat inside. Students asked many questions about the construction of the box cooker and how it worked. Students were interested in developing solar cookers for school science projects. Because we repeatedly opened the box cooker so that students could feel the heat, the eggs did not fully cook before the end of our demonstration, and we were unable to distribute them.

We cooked sausages and onions on the Vesto stove to show students how the energy efficient wood stove worked. We explained the design of the stove and how much wood it can save compared to traditional wood stoves. This demonstration included the use of Bushblok, which prompted many questions about how it is made. We found that the students did not show much interest in the wood stoves, which may be because their families rarely use wood for cooking purposes.

Handouts prompted detailed questions about how each technology worked. We could not take an interactive approach to demonstrate a solar home system, solar water pump, and wind charger because the trailer was not complete, so we placed handouts on a bulletin board and then we discussed them with the students. After we answered questions, students took the handouts with them as inspiration for science project ideas.

Urban, Electrified Community

We performed demonstrations with the trailer at the Habitat Research and Development Centre's Open Day. Advertising for the event attracted people from different income levels of Windhoek. The trailer had approximately 10 people gathered around the demonstrations during the four hours they were set up. The demonstrations

presented at this site consisted of a redesigned energy efficient shack model, a Vesto stove, a Tsotso stove, a parabolic cooker, a solar box cooker, an energy efficient lighting display, a redesigned solar water heater model, a solar water pump model, and solar panels and a wind charger.

We presented a renovated shack model that showed a temperature difference of at least 10 degrees Centigrade between the energy efficient shack and the inefficient shack. We found that people from Katutura were interested in the demonstration and asked many questions about the techniques that could be implemented in their own homes. We also found that people living outside of Katutura were not as interested in and did not spend as much time at this demonstration.

We lit a fire in the Vesto stove using Bushblok and explained how the design of the Vesto stove is more efficient than a traditional wood stove. We cooked sausage and onions on the Vesto stove to demonstrate how quickly it can cook a meal. Distributing the food attracted more people to the demonstration and prompted more questions. Many people told us they planned on purchasing a Vesto stove in the immediate future.

We also lit a fire in the Tsotso stove using Bushblok and explained how it is more efficient than a traditional wood stove. We placed a pot of water on the Tsotso to demonstrate how quickly it could be brought to a boil. During the demonstration, we picked up and moved the Tsotso stove to demonstrate its convenience and mobility. People asked many questions about the Tsotso stove but asked more questions about purchasing the Vesto stove.

We set up the parabolic cooker on a stand with a pot of water to demonstrate how the sun can quickly bring the water to a boil. We encouraged people to feel the heat concentrated on the pot, and we found that people were generally surprised to see the water boiling. Approximately ten people were interested in purchasing the parabolic cooker, and we were able to direct them to a local supplier.

We set up the solar box cooker, but were not able to perform a cooking demonstration with it as we needed to attend to the fires in the Vesto and Tsotso stoves. When presenting the cooker we opened the lid and encouraged people to feel the heat inside. Approximately fifteen people asked us where they could purchase the cookers, and we told them to contact the HRDC.

We set up the energy efficient lighting display with only the incandescent bulb not completely inserted in the socket. We advised people to watch the amperage consumption meter on the side of the trailer as we inserted the bulb, and the meter showed a large increase in consumption. We then unscrewed the bulb again to show the consumption decrease. This method prompted many people to ask where to purchase these fluorescent light bulbs. We also encouraged them to feel the fluorescent light bulbs and explained that electricity was not consumed to create heat. We addressed people's concerns about the ambiance of these bulbs by describing lighting fixtures that can be placed over the bulbs to create lighting similar to an incandescent bulb.

We placed the renovated solar water heater model in sunlight and recorded the initial temperature of the water on the whiteboard next to the model. During demonstrations we explained how the model represented home solar water heaters and referred to fact sheets placed on pegboards near the model. Few questions were asked, perhaps because a solar water heating company was explaining the same technology at the Open Day.

We put the solar water pump model at the front of the trailer and allowed it to continuously run throughout the day. People at the demonstration received water from the city and therefore did not ask many questions about the pump.

We explained to people that all the electrical appliances on the trailer were being powered by electricity from the solar panels and wind charger. We had many appliances available to demonstrate the abilities of these electrical systems, such as a fan, hair clippers, an air compressor, and a television. We received at least twenty questions regarding the size of the solar home system needed to power the appliances people used in their homes. We also received many questions about the feasibility of using wind chargers in Windhoek, as well as their availability.

Some recurring questions we received throughout the day included what financing options were available for purchasing renewable energy technologies and where to purchase the cooking technologies presented. We found that our research into loan programs prepared us to answer these finance questions. We were able to direct people to suppliers of the cooking technologies that were also at the Open Day.

Urban, Un-electrified Community

Upon our initial visit to the Barcelona community, we assessed the community's energy sources and uses to determine what technologies should be emphasized during a later visit. We found that the community was not electrified and was relying on costly fuels, such as wood and propane. We were told that community members were spending approximately N\$130 every two weeks on propane used for cooking three meals a day for five to six people. No energy was used specifically for heating in the homes. Most of the homes in this community were shacks made from metal, tin, and other gathered materials. The community profile created using data collected from this visit can be found in Appendix F.

From our findings, we believe that cooking technologies and small solar home systems may be options for this community. Since this is a residential area, the majority of energy consumed goes towards cooking and lighting. Community members also expressed interest in having appliances, such as a refrigerator and a television, which indicates that the homeowners may be interested in solar home systems. While these individuals may not have a lump sum of money to purchase these technologies, they should be presented in tandem with financing options. Energy technology financing loans may be an option for people in Barcelona because the community members revealed that they have bank accounts. Although we are not able to return to the site to perform a demonstration with the trailer, the information we have collected could be useful for future demonstrations.

New User Demonstration

After we compiled the user manual and we implemented some recommendations, the trailer was taken by representatives of the Namibia Renewable Energy Programmes (NAMREP) to a trade show in Ondangwa, Namibia. This demonstration was performed by members of NAMREP without the assistance of our liaison or our team members. We gave a training session to NAMREP before they took the trailer to ensure they knew how to use all of the equipment, a copy of the user manual was also supplied.

Upon returning from the trade show, NAMREP informed us that all demonstrations went smoothly and there were no technical problems. The user manual we gave them helped in setting up the trailer and performing demonstrations with the technologies. Overall, NAMREP was very pleased with the trailer's performance and returned it to our liaison in its original condition.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Based on our findings we have concluded that the Energy Demonstration Trailer has significant potential to accomplish its goals of raising awareness and encouraging the use of renewable energy (RE) and energy efficient (EE) technologies. The recommendations presented in this chapter are intended to help our sponsor advance the trailer's capabilities and effectiveness. Our recommendations focus on the creation of a user manual as well as recommendations specific to demonstrations, the trailer operations, and trailer modifications. We have implemented several recommendations which are described in this chapter. We will also describe recommendations we believe can enhance the trailer's effectiveness if implemented in the future.

Project Outcomes

After performing our initial demonstrations with the Energy Demonstration Trailer, we implemented many of our own preliminary recommendations for improvement that we found would be useful before future trips with the trailer. We have:

- *Constructed a more durable energy efficient shack model.* Participants were interested in hearing about ways in which they can keep their homes cool in the summer and warm in the winter. The model did not need to be reversible; simply showing an efficient shack versus an inefficient shack next to each other was found to be more effective. Taking the model apart and reversing it to show what an inefficient shack construction was not useful in presenting new information, and the new model is easier to demonstrate. The new model is able to show larger temperature differences between the efficient and inefficient shacks. On hot days, the model can demonstrate a temperature difference of at least 10 degrees Centigrade.
- *Arranged for construction of a collapsible stand for the parabolic cooker.* The parabolic cooker may attract more participants if taken off its mounted hinged frame and placed on the collapsible stand so that it can be properly aligned with the sun. Based on the interest shown in the cooker while on a proper stand during our demonstration with the school audience, we believe the parabolic cooker will attract more attention if properly aligned with the sun for cooking or water boiling demonstrations. While attached to the trailer in Okondjatu, the parabolic cooker was not properly aligned, unable to boil water, and did not attract as much attention as during the demonstration with the children of the A. Shipena Secondary School.

- *Improved the solar water heater model.* The original solar water heater model produced hot water only after several hours and did not insulate the water that was eventually heated. The heater was also too large to store on the trailer and was quite difficult for demonstrators to fill and use. The new model is smaller and heats water more quickly.
- *Painted warning stripes on extruding poles for safety.* The poles were previously painted an inconspicuous black and were a hazard because if someone walked into them, the doors of the trailer could collapse and cause injury. We painted yellow stripes on these poles as a caution.
- *Added a diesel versus solar water pump chart.* Solar water pumps are only appropriate for a certain combination of water volume and borehole depth. This chart, seen in Appendix K, explains when diesel or solar power would be more efficient for pumping water. Since the prices of solar water pumps vary with the depth of the boreholes, farmers who require large amounts water from deep boreholes may find this chart useful if contemplating the purchase of a solar water pumping system.
- *Installed DVD software onto the trailer's computer.* We found that DVD software should be installed on the trailer's computer to increase the ease of use during demonstrations. The computer did not have the proper DVD software to play movies, which was found to be enjoyable after demonstrations and an opportunity to collect feedback from the community.
- *Improved trailer's structure and made hardware additions.* Improvements to the trailer were made, such as strengthening the jockey pulley and sealing the screws for the solar array. Hardware additions consisted of two bayonet fitting light bulbs for the lighting display, a ratchet, a jack, and a tire iron. We also added rubber plugs for the ends of extruding poles for safety purposes and labeled all keys for the trailer. The plank under the trailer's monitor was made removable in order to access the back of the computer. A venting system was added to reduce the overpressure created inside of the trailer during travel.

User Manual

We created a user manual to instruct future demonstrators how to set up the trailer and demonstration materials when visiting a community. Though our team was familiar with the trailer because we were involved in its completion, future demonstrators may find an instruction manual useful when performing their first demonstration. The manual,

which can be found in Appendix B, may need to be translated to different languages in the future in order to increase its effectiveness. The manual includes sections on:

- *Setting up the trailer.* This section describes how to unhitch the trailer, set up the wind charger and solar panels, open the trailer display doors, and turn the power on.
- *Setting up camping equipment.* This section explains how to set up the gazebos, the table, the chairs, and the tent.
- *Setting up and using the demonstrations.* This section explains how to prepare each model on the trailer for demonstrations and recommendations for how to perform these demonstrations. We make recommendations to:
 - *Cook food in the solar box cooker.* While demonstrating the solar box cooker, we recommend that food be cooked throughout the day so that participants can sample the food and witness the cooker working. Hardboiled eggs seemed to be a popular food, are inexpensive, and only take about an hour to cook with uninterrupted sun.
 - *Cook with the Vesto or Tsotso for small audiences.* We concluded that for small audiences or night demonstrations, a fire in a Vesto or Tsotso stove with a pot of boiling water or cooking food attracts people. During cooking demonstrations, participants can immediately see that they can save money and time by using these low-cost, wood-efficient stoves. However, if a large audience is present, we found that it is difficult and unsafe to maintain a fire while performing other demonstrations.
 - *Use Bushblok in the wood-efficient stoves.* Using Bushblok in the stoves was an informative addition to the cooking demonstrations because farmers were interested once they knew where the Bushblok came from. With the rapid spread of bush encroachment in Namibia, Bushblok can be demonstrated as a renewable energy which benefits the environment.
 - *Boil water with the parabolic cooker.* By boiling water, participants can actually see the parabolic cooker working. This is typically a popular demonstration due to its aesthetic characteristics and its high heat generation capability.
 - *Use food coloring in the water of the solar water pump model.* We found that the solar water pump model attracted people because they saw and heard the water flowing from the hosing. We concluded that using food coloring in the water during the demonstration will enhance the model's aesthetics and show the water flowing through the piping more clearly.

- *Site-specific recommendations.* This section makes recommendations for visits to different types of communities, including:
 - *Schools or groups of children.* We recommend hands-on, interactive demonstrations to keep the children's attention. Asking simple questions about energy kept the children engaged during demonstrations. Hand-outs are recommended for the children to take home to think about the demonstrations later or show to their parents. We also encourage demonstrators to emphasize simple techniques, such as painting a house a light color.
 - *Rural, electrified communities.* We recommend emphasizing cooking technologies because we found wood and propane were common fuels for cooking even in communities with electricity. We found that RE and EE suppliers may not be located in rural communities, so readily available contact information will be helpful. We also found that many rural communities consist of farmers, so solar water pumps used to draw water for livestock was of interest. Energy efficient lighting was an inexpensive technology that people in electrified rural communities may be able to use to save money on electricity.
 - *Rural, un-electrified communities.* In communities where elders and/or community leaders play an important role in decision making, we found that a presentation was expected in addition to our demonstrations. As in rural, electrified communities, RE and EE suppliers may not be local and supplier information will be helpful. Movies are of special interest in un-electrified communities since television sets are not likely to be used at home. Gatherings to watch movies are a good opportunity to get feedback from the community or allow people to ask further questions.
 - *Urban, electrified communities.* We concluded that emphasizing cooking technologies was effective because wood and propane were common fuels for cooking even in communities with electricity. Energy efficiency in the home tended to be of interest when a temperature difference could be seen in the shack model. We recommend emphasizing simple techniques, such as painting a house a light color. We also recommend demonstrators to emphasize solar water heaters because water heating can be a large portion of an electricity bill. Since banking is available in most urban communities, low-interest loans for technologies may be possible, and instructions for obtaining these loans will be helpful during visits.
 - *Urban, un-electrified communities.* Like urban, electrified communities, cooking technologies and energy efficiency in the home are likely to be effective demonstrations. Banking is also available in most urban, un-electrified areas, and we concluded that solar home systems may be of

interest in these communities. Presenting loan information during these demonstrations will be useful.

Recommendations for Trailer Operations and Support

Based on our experiences with the Energy Demonstration Trailer in different communities, we developed recommendations for the operations and long-term financial support of the trailer. These recommendations consist of:

- *Conducting visits to demonstration sites before bringing the trailer.* We found initial visits to communities to be useful in determining their energy uses and constraints. This knowledge assists demonstrators in determining which technologies to emphasize during demonstrations. The visits were also useful in making contacts in the communities to be sure an audience would be present when we conducted demonstrations. This initial visit also allows the demonstrators to create demonstration tactics that suite the communities' expectations. For example, in the farming community of Okondjatu, the elders expected a presentation during our preliminary visit, so we were prepared to present one when visiting with the trailer.
- *Showing movies at night after demonstrations.* To entertain people at night while they linger around the trailer after demonstrations, movies can be shown. The loud speaker system and the action on the screen attracted attention during our visit to Okondjatu. While people are gathered before a movie, there is an opportunity for discussion in order to receive feedback about demonstrations.
- *Showing a picture slideshow with music during demonstrations.* We concluded that showing a picture slideshow with a variety of music playing on the computer can be used to attract people to the side of the trailer that has the computer monitor, wind charger output display, and solar panels' output display. The pictures that were displayed were of RE and EE technologies, and some of them were located at local communities and businesses. We found this created a welcoming atmosphere during our demonstrations and the children enjoyed dancing to the music.
- *Providing a way for people to order cooking technologies.* Another significant recommendation for the trailer is to provide a way for people to order the solar cookers and efficient wood stoves from the trailer. Orders could be places after demonstrations with a down payment, and a second trip could be made to the community to deliver and explain the products. This recommendation is based on our visit to Okondjatu, during which we were asked numerous times if people could purchase the demonstration cookers.

- *Conducting demonstrations with four (possibly multilingual) demonstrators for groups of more than thirty people.* The trailer is equipped for two demonstrators to travel to communities for overnight visits. We recommend that the trailer be equipped for four demonstrators when presenting to groups of more than thirty people. After conducting demonstrations we found that two demonstrators were inadequate to handle large crowds, whereas with four we could handle approximately sixty people. Multilingual demonstrators could also be an advantage when traveling with the trailer. We struggled to communicate with some people and believe that demonstrators familiar with many languages could be more effective.
- *Charging product suppliers a fee for advertising.* Charging suppliers advertising fees could provide financing for implementing some recommendations and future trips with the Energy Demonstration Trailer. During our trips with the trailer, we found that many people were interested in where to purchase presented technologies. We distributed many specific suppliers' contact information, and our sponsor could be compensated for this service. We recommend that further research be conducted on this topic, such as how to provide suppliers with evidence that the trailer advertising works.

Recommendations for Additional Modifications to the Trailer

We recommend that further additions and modifications be made to the trailer and its demonstration material to enhance its design and make demonstrations more interactive and informative. These additions and modifications include:

- *Constructing a solar water heater model using a washing stand.* We recommend that a solar water heater model be created using a dish washing stand to store water so participants can feel the warm water. Participants cannot actually use or feel the water that gets heated in the black jug currently used for storage, and we believe this is the reason for their lack of interest. We also recommend showing a small scale cross section poster or model of how home solar water heating systems work. Since the model is not an exact replica of the actual system, we found that a direct reference would be helpful when explaining how the system works.
- *Designing a hand-out on how to construct a solar box cooker.* Solar box cookers are easy to use and have a simple design. People were interested in constructing their own solar box cooker during our visit to Okondjatu, so we provided an example, found in Appendix K, to use as a reference in the design of an instructional hand-out.

- *Downloading music onto the computer's hard drive.* Downloading music to the computer's hard drive eliminates the need for a separate source of music on the trailer. With music installed on the trailer's computer, demonstrators will not need to rewire speakers to play music.
- *Laminating all posters and paper display materials.* We recommend that all posters and paper display materials be laminated for future demonstrations. Having experienced rain during a demonstration we came to the conclusion that all materials will be protected and last longer if laminated. This will reduce the cost of replacing posters and other materials that may be destroyed by water or that will be handled frequently.
- *Include a pamphlet that includes purchasing information about all technologies presented.* Konga Investments may be willing to provide such a pamphlet which they have already compiled. We believe this pamphlet could be a helpful tool to be included on the Energy Demonstration Trailer. The business cards and pamphlets that we passed around were helpful, but because we only had a limited number we had to write the information on pieces of paper and hand them out when asked for supplier contact information. This pamphlet will also reduce the overall number of pamphlets to keep stocked on the trailer.
- *Constructing a biogas demonstration model.* Another addition to the Energy Demonstration Trailer we recommend is a biogas demonstration model. Included on the trailer are educational biogas posters to be distributed to communities, but there is not a model to demonstrate the value or efficiency of biogas. Based on our conclusion that interactive demonstrations attract interest and are found most convincing, a biogas model and demonstration may prove more valuable than distributing posters alone. A feasible biogas demonstration to be included on the trailer can be seen in Appendix L.
- *Altering the trailer's structure and making hardware and supply additions.* Through use of the Energy Demonstration Trailer during demonstrations, we found additions and alterations that we believe should be implemented to the hardware of the trailer. These supply additions include food coloring for the solar water pump display and trash bags. We also recommend dust covers for the computer and refrigerator as these electronics gathered large amounts of dust during travel.

To determine whether the trailer is effective in spreading the use of RE and EE technologies, either with or without implementing all of our recommendations, we recommend further studies be carried out. Additional visits to the demonstration sites some time after demonstrations are conducted will determine if any of the demonstrated

technologies or techniques have been purchased or employed once the Energy Demonstration Trailer has left.

The intention of our recommendations is to enhance the Energy Demonstration Trailer's ability to encourage Namibians' use of renewable energy technologies and energy efficient techniques. The adoption of the technologies the Energy Demonstration Trailer presents could decrease the use of current energy sources, including electricity from power plants, wood, and propane. Decreased reliance on current energy sources may potentially result in lower rates of desertification, fewer health problems in Namibia due to burning fossil fuels, and reduced demand from power plants.

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APPENDIX A: Habitat Research and Development Centre Profile

The Habitat Research and Development Centre (HRDC) is a Non-Governmental Organization that addresses housing issues in Namibia. As stated by the HRDC, the mission of the organization is “to promote the use of indigenous building materials and designs, to engage multi-disciplinary teams in the basic research, the adaptation of existing knowledge and applied research to achieve a holistic approach to problem solving in the field of housing and related issues” (Habitat Research and Development Centre, n.d.).

The HRDC is comprised of several departments that come together for one common interest. The partners involved with this organization include the Ministry of Regional, Local Government and Housing and Rural Development (MRLGH), the National Housing Enterprise (NHE), and the City of Windhoek. The Director oversees the internal workings of the HRDC which are broken into four departments: Research Department, Public Relations Department, Technical Training and Support Department, and Financial and Administrative Department. All parties work closely to educate Namibians in energy conservation and renewable energy (INFORSE, n.d.).

The Habitat Research and Development Centre is the only institution of its kind in Namibia. The HRDC provides its research and resources to its partners in the public and private sectors, first being the City of Windhoek. Windhoek utilizes research made by the HRDC in order to accommodate the city’s development. The NHE is a publicly chartered business that provides home loans and other financial services to Namibians in order to make the housing market more fair and equitable. It is then the HRDC’s goal to make these homes safer, environmentally friendly and energy efficient (Habitat Research and Development Centre, n.d.).

The problem that Windhoek is faced with is not something that one person can solve alone. The importance of energy conservation and education in informal settlements is an issue that our sponsor wants to address. The HRDC aims to find a way, with the use of the demonstration trailer, to convey the importance, convenience, and ease of using alternate forms of energy. Part of the HRDC’s mission is problem solving

in the field of housing. Since many informal residency fires are caused by the use of kerosene and other inefficient fuels, renewable energy provides a safe and economic alternative. By educating villagers of informal settlements the HRDC can improve housing conditions.

Located in Windhoek, the HRDC can observe the needs of the villagers, including energy needs, first hand. Information can also be obtained from the HRDC's partners: the MRLGH, the NHE, and the City of Windhoek. The centre includes a library to conduct necessary research, as well as on-site training facilities, such as those to train the demonstrators travelling with the energy trailer. Laboratory and testing facilities are located at the centre so that much needed information can be obtained first hand. The site provides a display area for visitors to view beneficial products. Visitors can also learn methods developed by the centre using available materials, such as solar panels and cookers (Habitat Research and Development Centre, n.d.).

APPENDIX B: Trailer Demonstration Materials

- One radio
- One television and VCR
- One 40L refrigerator
- One solar water pump
- One fan
- One 12V mini tire compressor
- One set electric hair clippers
- Five 75W solar panels
- Five 12V deep-cycle batteries
- One voltage inverter
- One non-electric iron
- One solar box cooker
- One solar parabolic cooker
- One Vesto stove
- One Tsotso stove
- One 9kg wind generator
- Models of a shack, a solar water heater, and energy efficient lighting

APPENDIX C: Community Profile Form

1) Location of Community _____

2) Common types of residences/buildings? (i.e. tin shacks, apartments, modern houses, etc.) _____

3) What types of energy sources are the residents currently relying on the most?
Wood Propane Kerosene Solar Electricity Other

4) How much is spent on individual fuels and what percentage of income is this?

5) Which members of the community (all, business owners, farmers, etc.) are involved in banking? _____

6) Which technologies seemed feasible for the community?

7) Which technologies did NOT seem feasible for the community?

APPENDIX D: Okondjatu Community Profile

- 1) Location of Community Rural community approximately 300km from Windhoek

- 2) Common types of residences/buildings? (i.e. tin shacks, apartments, modern houses, etc.) Some of the homes that were near the center of town and the school were one room buildings made of concrete block. Further out from the center of town, homes were generally shacks made of various materials such as tin roofing and wood planks.

- 3) What types of energy sources are the residents currently relying on the most?
Wood Propane Kerosene Solar Electricity Other
Some of the businesses and homes in the center of town were electrified, most relied heavily on wood for cooking and heating.

- 4) How much is spent on individual fuels and what percentage of income is this?
The cost of using wood comes from the expense of fuel used in vehicles to gather it.

- 5) Which members of the community (all, business owners, farmers, etc.) are involved in banking? No members of the community have available banking.

- 6) Which technologies seemed feasible for the community?
Efficient wood stoves, solar box cookers, and parabolic cookers seemed to be feasible options for this community due to their ease of use and low cost.

- 7) Which technologies did NOT seem feasible for the community?
Solar home systems and solar water heaters did not seem feasible for the average community member mainly because their low income and lack of banking would make it difficult to apply for a loan for these products.

APPENDIX E: A. Shipena Secondary School Profile

- 1) Location of Community Secondary school located in Katutura
-
- 2) Common types of residences/buildings? (i.e. tin shacks, apartments, modern houses, etc.) Most students live in local low-income housing. The school is a large cement, modern building complex.
-
- 3) What types of energy sources are the residents currently relying on the most?
Wood Propane Kerosene Solar **Electricity** Other
-
- 4) How much is spent on individual fuels and what percentage of income is this?
Students and the teacher said N\$200-300 was spent on electricity each month. We do not know what percentage of their income this is.
-
- 5) Which members of the community (all, business owners, farmers, etc.) are involved in banking? n/a
-
- 6) Which technologies seemed feasible for the community?
Students showed a lot of interest in the parabolic cooker and talked about making their own as well as inquiring about the price. They seemed interested in adapting fluorescent lights and convincing their parents to do so, which is not too expensive. Bushblok was also feasibility.
-
- 7) Which technologies did NOT seem feasible for the community?
The children were educated about the RE and EE products. Feasibility in the homes was not determined.

APPENDIX F: Barcelona Community Profile

- 1) Location of Community Urban settlement in Katutura

- 2) Common types of residences/buildings? (i.e. tin shacks, apartments, modern houses, etc.) Most homes were tin shacks and shacks made from other various gathered materials. There were a few concrete one to two room homes, however.

- 3) What types of energy sources are the residents currently relying on the most?
Wood **Propane** Kerosene Solar Electricity Other
There is no electricity to the settlement. Gas stoves are used for much of the cooking and sometimes wood. Paraffin is used for lighting, but since it is so expensive candles are sometimes used. Nothing is generally used for heating in the homes at night. Batteries are used for radios.

- 4) How much is spent on individual fuels and what percentage of income is this?
A 9kg gas bottle costs about N\$130 with transport and lasts about 2 weeks when cooking 3 meals a day for 5-6 people. Wood costs N\$5 per bundle, and the bundle lasts about 2 days. Paraffin costs N\$5 per liter and lasts for just 2 nights for lighting. Batteries for the radio cost N\$15 and last for about one month.

- 5) Which members of the community (all, business owners, farmers, etc.) are involved in banking? All members of the settlement are involved in banking or at least have access to it.

- 6) Which technologies seemed feasible for the community?
Efficient wood stoves, solar box cookers, and parabolic cookers seemed to be feasible options for this community due to their ease of use and low cost when compared to current energy source costs. People seemed somewhat interested in the box cookers when brought up. Shack insulation should also be emphasized.

- 7) Which technologies did not seem feasible for the community?

Solar home systems and solar water heaters did not seem feasible for the average community members mainly because the high cost of the systems. _____

APPENDIX G: Contacts

Organisations

For energy and environment brochures, business cards, DVDs or VHS, posters

| | | |
|---|---|---|
| <p>Ministry of Mines and Energy Private Bag 13297, Windhoek Tel: 061 2848111 Fax: 061 2848363 Contact: Mr Noddy Hipangebwa</p> | <p>Namibia Renewable Energy Programme Private Bag 13297, Windhoek Tel: 061 2848111 Fax: 061 2848173 Contact: Mr Shimwefileni Hamutwe</p> | |
| <p>UNDP Namibia Private Bag 133290, Windhoek Tel: 061 2046111 Fax: 061 2046203 Contact: Ms Martha Mwandangi</p> | <p>Desert Research Foundation of Namibia PO Box 20232, Windhoek Tel: 061 377500 Fax: 061 230172 Contact: Mr John Palet, Arnold, Lucky or Boois</p> | <p>Habitat Research & Development Centre PO Box 63036, Windhoek Tel: 061 268200 Fax: 061 268 201 Contact: Mr Jacques Korubel</p> |
| UNDP is funder of the Energy Trailer | DRFN will be part of the Trailer Field Tests | HRD C is part of the Trailer Project |

Renewable Energy Suppliers

For company and product brochures, business cards, DVDs or VHS, posters

| | | |
|--|--|---|
| <p>ConServ cc PO Box 6422, Windhoek Tel: 061 236336 Fax: 061 256726 SWH, SHS, PVP</p> | <p>Excelair PO Box 11, Omaruru Tel: 064 570328 Fax: 064 570452 SWH, PVP</p> | <p>Namibia Engineering Corporation PO Box 5052, Windhoek Tel: 061 236720 Fax: 061 232375 SWH, SHS, PVP</p> |
| <p>Solar Age Namibia PO Box 9987, Windhoek Tel: 061 215809 Fax: 061 215793 SHS, PVP</p> | <p>Solar Stove Project Private Bag 5516, Oshakati Tel: 065 231463 Fax: 065 231463 SBC</p> | <p>SolTec cc PO Box 315, Windhoek Tel: 061 235646 Fax: 061 250460 SWH, SHS, PVP</p> |
| <p>TERRASOL PO Box 6036, Windhoek Tel: 061 239454 Fax: 061 239454 PVP, SWH</p> | <p>K&K Solar cc PO Box 2837, Swakopmund Tel: 0812275645 SWH chkostrzewa@hotmail.com</p> | <p>Free Energy Europe / Free Energy Foundation freeenergyeurope@gmail.com Contact: Arnelies Withofs</p> |
| SPONSOR | | SPONSOR |
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Tel: 0812793438
Solar Technician

Willen Kweyo
PO Box 1594, Oshakati
Tel: 0811290291
Solar Technician

Josty Lubinda
PO.Box 258, Katima Mulilo
Tel: 0812459086
Solar Technician

Richard Khachab
PO.Box 29, Otjivwarongo
Tel: 0812422826
Solar Technician

Mateus Nyambali
PO.Box 2333, Ondangwa
Tel: 0812432192
Solar Technician

Prescott Tjamburo
PO.Box 8987, Windhoek
Tel: 0811287168
Solar Technician

Renewable Energy Financing

For company brochures, business cards, application forms

Bank Windhoek
PO Box 15, Windhoek
Tel: 061 2990380
Fax: 061 2991282
Contact: Ms Kama Ndihla

Konga Investments
PO Box 40303, Windhoek
Tel: 61 25 9961
Fax: 61 25 9962
Contact: Ms Loide Kalompo

Useful Contacts

For company brochures, business cards, Application Forms

SchoolNet Namibia
Tel: 0811244200
Contact: Mr Joris Komen
School data

APPENDIX H: Project Implementation Plan

| | <u>Activities</u> | <u>Outputs</u> | <u>Time</u> |
|-----------|---|---------------------------------------|-------------|
| 1. | Finalize trailer hardware | | |
| | 1.1. Check status | Meeting conducted | 2d |
| | 1.2. Identify missing components | List of missing components | 1h |
| | 1.3. Finalize components | Components acquired | 5d |
| | 1.4. Pack components | Trailer is packed | 1d |
| 2. | Finalize training and demonstration contents | | |
| | 2.1. Check status | List of materials | 1d |
| | 2.2. Identify missing contents | List of materials | 1h |
| | 2.3. Finalize contents | Materials acquired and compiled | 5d |
| | 2.4. Pack contents | Materials packed | 1d |
| | 2.5. Provide content inventory | Inventory list | 1d |
| 3. | Arrange demonstrations | | |
| | 3.1. Identify sites | List of sites, contact details | 3d |
| | 3.2. Conduct pre-visit | Pre-visit conducted | 3d |
| | 3.3. Community profile | Profile compiled | 3d |
| | 3.4. Customised awareness approach | Completed recommendations in profile | 3d |
| | 3.5. Finalize demonstration schedule | Itinerary | 2d |
| 4. | Arrange training session | | |
| | 4.1. Contact DRFN | Meeting with DRFN | 1d |
| | 4.2. Finalize training date | Training date | 1d |
| | 4.3. Conduct training | Training conducted | 3w |
| | 4.4. Finalize demonstration procedure | Written procedure | 2d |
| | 4.5. Update contents | Updated contents | 1w |
| 5. | Prepare for demonstrations | | |
| | 5.1. Arrange transportation | Confirmed transportation | 3h |
| | 5.2. Purchase supplies | Supplies | 3d |
| | 5.3. Pack trailer | Trailer packed | 2d |
| 6. | Perform demonstration | | |
| | 6.1. Individual informal interviews | Interviews complete | 3d |
| | 6.2. Erect trailer displays | Displays erected | 6h |
| | 6.3. Conduct demonstrations | Demonstrations complete | 3d |
| | 6.4. Conduct community interview | Interview complete | 3d |
| | 6.5. Energy entertainment | Community interaction with trailer | 2d |
| | 6.6. Record feedback | Feedback recorded | 3d |
| 7. | Review trailer and contents | | |
| | 7.1. Arrange internal feedback session | Session complete | 1w |
| | 7.2. Make recommendations | Recommendations | 1w |
| | 7.3. Finalize user manual | Completed user manual | 3d |
| | 7.4. Implement recommendations | Changes made to trailer and materials | 1w |

APPENDIX I: User Manual

Energy Demonstration Trailer



User Manual



Compiled by WPI students:

Tarra Epstein
Steven Feroli
Andrew Kennedy
Sara Praschak

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1. Initial Trailer Set-up

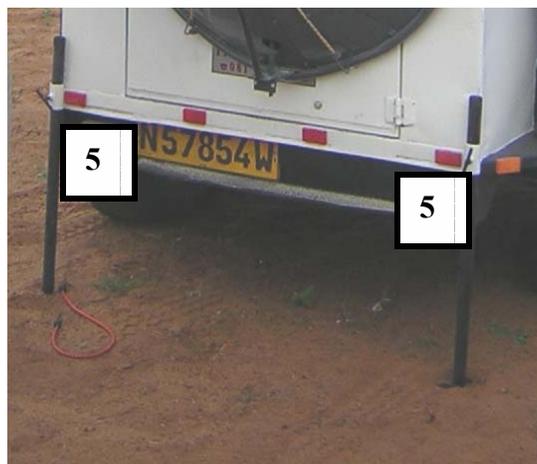
This section is intended to assist with the initial set-up of the trailer upon arrival at a demonstration site. This process may take approximately 30 minutes.

Unhitching the Trailer

1. Park the trailer on hard level ground.
2. Lower the front wheel of the trailer onto a hard level surface.
3. Lower safety bar and tighten wing bolt.

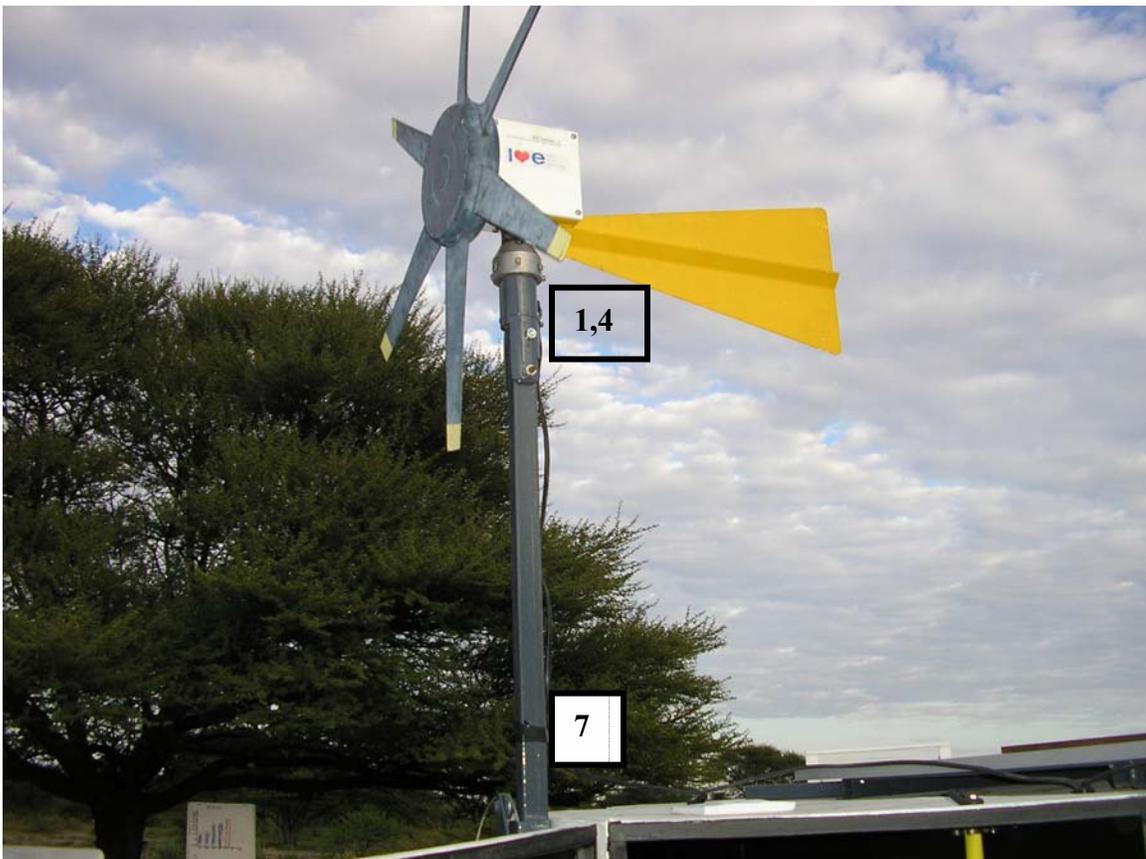


4. Disconnect hitch, unplug electrical wires, and move the vehicle out of the demonstration area.
5. Lower rear supports and tighten wing bolts.



Setting up the Wind Charger

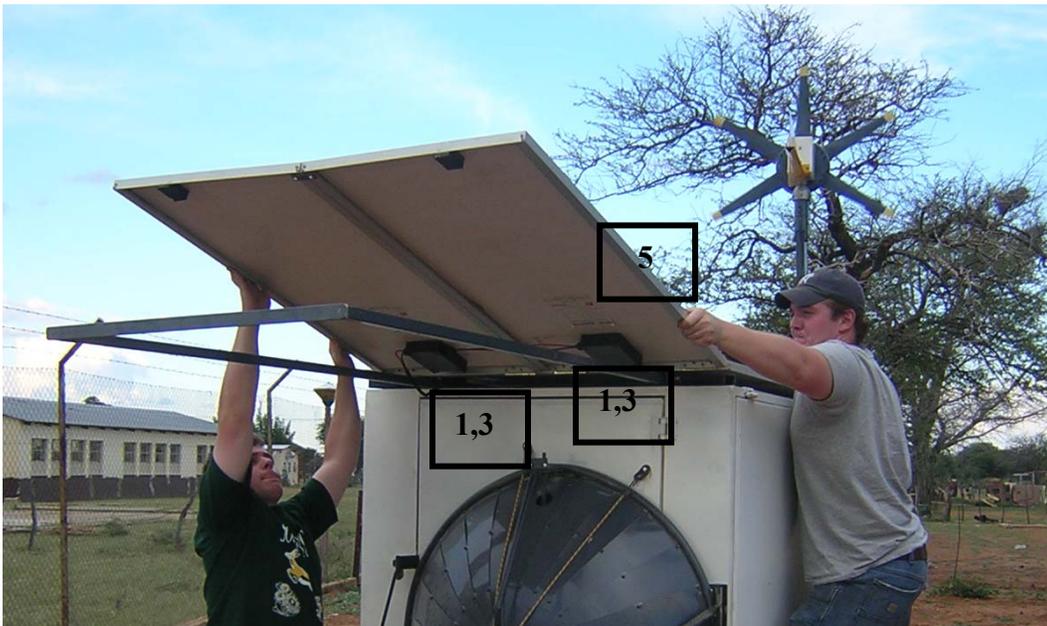
1. Remove the top bolt while charger is folded down.
2. Remove bungee cords.
3. Lift wind charger up with yellow handle until it is perpendicular to the top of the trailer.
4. Insert and tighten top bolt.
5. Bolt tail onto back of wind charger.
6. Raise charger with yellow handle until warning line is reached (about 1m above top of trailer) and firmly tighten yellow wing bolt.
7. Attach power cord to pole of charger.



Setting up the Solar Panels

Note: This step requires at least two people.

1. Loosen bolts at the top, back end of the trailer keeping the solar panel support rails in place.
2. Pull the solar support rails out to the indicating lines.
3. Tighten the bolts to keep the rails in place.
4. Remove bungee cord over solar panel.
5. Slowly and carefully flip solar panel on the hinge so it rests on the rails.



Preparing the Trailer

1. Remove bungee cords from parabolic cooker.



2. Rotate parabolic cooker away from the trailer to access the rear door and remove the cooker from the trailer.
3. Unlock all trailer doors.
4. Use the four (4) thin black and yellow poles in front compartment to support the sides of the trailer that flip up.



5. Turn power inverter on.



6. Close circuit breakers if not already closed.



7. Insert the four (4) larger, square black and yellow poles at each corner of the trailer.
8. Hang a whiteboard/corkboard on each of the poles at the corners of the trailer.



9. Use air compressor to clean dust out of the trailer, paying special attention to the computer area.



10. Turn on the computer and fridge, if not already on.
11. Take green storage bins out of trailer.

12. Insert TV tray onto arm that held the parabolic cooker.



13. Place VCR and TV onto the TV tray and secure with a bungee cord.



14. Take out and plug in all display appliances, such as the fan, hair clippers, and radio.

2. Setting up Camping Equipment

This section is intended to help in setting up all camping equipment, including the collapsible gazebos that may be used even if not spending the night at a demonstration.

Setting up the Gazebos

1. Remove gazebo from top shelf of trailer.
2. Take the gazebo out of the outer green bag.
3. Pull the legs of the gazebo outward until fully extended.



4. Raise the center of the gazebo until level.



5. Raise legs until snapped into place.
6. Attach elastics in center of each side to the rods of the gazebo.

Setting up the Table and Chairs

1. Remove table and chairs from the bottom shelf of the trailer.
2. Unfold the table top-side toward the ground.
3. Lift legs until vertical.
4. Insert bottom half of legs that were attached by magnets.
5. Slide rings to ends of table to keep legs sturdy.



6. Unfold chairs and place on even surface.

Setting up the Tent

1. Rake away rocks and sticks from area where tent will be placed.
2. Remove tent from outer bag.
3. Unroll tent and remove polls from bag.
4. Face tent entrance in desired direction.
5. Untie black rods and place center X at center of tent.
6. Insert rod ends to connect into four poles.



7. Tie the rods center X at the center of the tent.
8. Bend the rods to fit ends into holes at each corner of the tent.
9. Attach hooks along the sides of the tent to the rods.
10. Hammer stakes into the ground through the holes in the cloth on the sides and corners of the tent.



11. Lay tan rain cover over the top of the tent and attach hooks to the open holes on the tent.



3. Setting up and Performing Demonstrations

This section is intended to assist in the setup of all demonstration materials included on the Energy Demonstration Trailer. It also provides recommendations on how to perform demonstrations using the materials.

Display Boards

1. Determine where each demonstration model will be placed for demonstrations.
2. Divide laminated posters and sheets among the four display boards, placing relevant information sheets near technologies being demonstrated. For example, the Solar Versus Diesel Water Pump chart should be placed near the water pump model demonstration area.
3. Pin the posters and sheets onto the boards using push pins.
4. Remove all posters and sheets from the boards before packing back onto the trailer.



Energy Efficient Lighting Display

1. Disentangle the lighting display if it was disturbed during travel.
2. String the lights around the sides of the set up gazebos.



3. Insert light bulbs into sockets, putting the incandescent light bulb last on the strand.
4. Plug in the string of lights to the trailer and make sure the power strip is on.



5. Begin demonstrations with the incandescent light bulb slightly out of the socket, so it is not lit.
6. Advise the audience to watch the consumption meter on the side of the trailer while completely inserting the incandescent bulb so it is lit. The meter will show a higher current being drawn.
7. Again slightly remove the incandescent bulb to show the changing consumption meter.
8. Touch and invite people to touch the fluorescent lights to show how cool they are. Emphasize that electricity is not wasted to produce heat; only light is produced by the bulbs.
9. When taking down the light display, remove bulbs before unstringing the display from the gazebo.

Water Pump Model

1. Fill the blue PVC pipe of the water pump model with water.
2. Plug the pump into the energy trailer in its designated outlet.



3. Add water into the blue PVC pipe until clear tubing and PVC pipe are full of water and water is flowing freely.



4. Refer to the Solar Versus Diesel Water Pump chart (which should be placed on the display board near the pump model) during demonstrations.
5. Empty all water from the model before packing back onto the trailer.

Water Heater Model

1. Fill black container with water.
2. Position heater facing the sun.
3. Place container on surface above the water heater.



4. Refill black container until tubing, container, and piping inside the heater are filled with water, assuring all air is removed from the heater.
5. Record initial water temperature and post using dry erase markers on the white board closest to the model.



6. Record black container water temperature every hour or two on whiteboard adjacent to display.
7. Empty all water from the model before packing back into the trailer.

Solar Box Cooker

1. Remove solar box cooker from middle shelf of the trailer from the back.
2. Place box cooker on level ground in direct sunlight.
3. Position the angled side of the cooker toward the sun.
4. Lift blue lid to reveal Plexiglas and position so the reflected sunlight is concentrated in the center of the box.
5. Use the black stick stored under the lid to keep it in this position.
6. Tighten the drawstring attached to the lid.
7. Lift the metal latch at the back of the cooker.
8. Lift the yellow lid so the inside of the box is accessible.
9. If desired, place food or liquid to be cooked or heated inside the box cooker in a black pot or pan. An open carton of eggs can be placed in the cooker to cook and hand out during demonstrations. If not cooking food, people can reach in the box cooker to feel the heat inside.



10. Close the yellow lid of the box cooker and latch.
11. Reposition the cooker and/or lid every hour to keep the reflected sunlight concentrated in the center of the box.



Parabolic Cooker

1. Remove bungee cords from the parabolic cooker if not already removed.
2. Remove nuts and bolts holding the cooker onto the doorframe.



3. Fold out legs of parabolic cooker stand and tighten wing bolts.
4. Place parabolic cooker on stand and tighten.



5. Position the cooker facing the sun, tilted so the reflected sunlight is concentrated in the center of the cooker. This is easier to align with a black pot on the cooker.



6. Put food or water in the pot to demonstrate how the parabolic cooker works. Keep the lid on the pot if boiling water to speed up the process. Remove the lid to show people that the water is boiling, but use a towel or pot holder as the lid will be hot.
7. Reposition the cooker every half hour to keep the reflected sunlight concentrated on the pot.
8. Take the pot off the cooker and dismantle the stand when finished at the demonstration site. Put the stand back into the cabinet at the front of the trailer, and attach the cooker to the back of the trailer.

Vesto Stove

1. Remove the Vesto stove from the trailer and place on level ground.
2. Start fire in the center of the stove, if desired for demonstration. If available, use Bushblok and explain the fuel during demonstrations.



3. Place grate or pot supports on rim of the stove.
4. Place pot or pan on the grate or supports.



5. If cooking food for a demonstration, which may attract people to the stove, put it onto the pan or in the pot. Distribute the food to people around the stove.
6. Allow the stove to cool completely before cleaning and storing in the trailer.

Tsotso Stove

1. Remove the Tsotso stove from the trailer and place on level ground.
2. Place pot supports on rim of stove.



3. Start a small fire and continue feeding the fire through the opening at the bottom of the stove if a fire is desired for the demonstration.
4. Place a pot or pan on the supports.



5. If cooking food for a demonstration, which may attract people to the stove, put it onto the pan or in the pot. Distribute the food to people around the stove.
6. Allow the stove to cool completely before cleaning and storing in the trailer.

Note: The Tsotso stove can be moved while a fire is lit using the handles on either side of the stove.

Energy Efficient Shack Model

1. Remove the energy efficient shack models from the trailer and place in direct sunlight on a green bin.
2. Insert thermometers inside shacks to monitor internal temperature.



3. Monitor the temperature inside each of the shacks throughout the day to demonstrate the effectiveness of the energy efficient shack. When demonstrating temperature difference to an audience, lift the lid of the efficient shack to show insulation, overhang, and windows for cross ventilation.

4. Site-Specific Recommendations

This section provides recommendations for performing demonstrations in different types of communities. A visit to demonstration sites before bringing the Energy Demonstration Trailer is recommended in order to determine exactly what is expected during demonstrations.

Performing Demonstrations for Schools or Groups of Children

- Hands-on and interactive demonstrations should be emphasized, such as letting the children check the shack model temperatures themselves or allowing them to feel the heat concentrated in the parabolic cooker.
- Simple energy questions should be asked in order to keep children involved. For example:
 - What is the purpose of the reeds in the energy efficient shack? (insulation)
 - How does a solar home system provide electricity at night? (batteries)
- Cooking food on the various solar and wood-efficient cookers and distributing it is a good way to draw children's attention to these technologies. Eggs are a simple food to cook and distribute.
- Children enjoy watching movies, and gathering for this purpose may be an opportunity to present technologies again and ask more energy questions.
- Children appreciate informational hand-outs that can be taken with them after the demonstrations.
- Energy efficiency in the home, demonstrated by the shack model, tends to be of interest to children. Do not assume simple techniques, such as painting a house a light color, are already known.



Performing Demonstrations for a Rural, Electrified Community

- Wood and/or propane may still be a common fuel for cooking in rural communities where there is electricity. For this reason, emphasis should be placed on cooking technologies that can save people money on these fuels. Food can be cooked and distributed if demonstrating for a small crowd.
- People in rural communities may not have RE and EE suppliers locally, so contact information for suppliers should be readily available.
- Many rural communities are farmlands, and providing water to livestock is a daily concern. For this reason, solar water pumps to be used in boreholes may be of interest to the community. Point out the chart showing the solar water pump's capabilities.
- Energy efficient lighting is a relatively inexpensive technology that can be adopted in communities that have electricity and should be emphasized and explained during demonstrations.
- Energy efficiency in the home, demonstrated by the shack model, tends to be of interest when temperature differences can be seen. Do not assume simple techniques, such as painting a house a light color, are already known.
- Hands-on, interactive demonstrations should be emphasized, especially when children attend the demonstrations.
- People enjoy gathering to watch a movie on the trailer, and this gathering is an opportunity for them to ask more questions and to present technologies again.



Performing Demonstrations for a Rural, Un-electrified Farming Community

- Wood and/or propane are commonly used cooking fuels for communities without electricity. Solar and wood-efficient stoves should be emphasized because they will reduce daily costs or efforts for obtaining these fuels.
- Providing water to livestock is important in farming communities, and solar water pumps may be of particular interest in these rural communities. Information on solar water pumping capabilities should be provided to clarify what size or type of system is needed for particular farms.
- Local RE and EE technology suppliers may not exist in rural, farming communities. Contact information for suppliers should be readily available.
- Movies are of special interest to rural, un-electrified communities since television sets are not likely to be used in homes.
- In communities where elders and/or community leaders play an important role in decision making, presentations may be expected in addition to standard demonstrations. A PowerPoint presentation on the trailer's computer may aid in this process.



Performing Demonstrations in an Urban, Electrified Community

- Wood and/or propane may still be a common fuel for cooking in urban communities where there is electricity. For this reason, emphasis should be placed on cooking technologies that can save people money on these fuels.
- Energy efficient lighting is a relatively inexpensive technology that can be adopted in communities that have electricity and should be emphasized and explained during demonstrations.
- Energy efficiency in the home, demonstrated by the shack model, tends to be of interest when a temperature difference can be seen. Do not assume simple techniques, such as painting a house a light color, are already known.
- Solar water heaters should be emphasized due to the fact that water heating can be a large portion of an electricity bill. Since banking is available in urban communities, obtaining low-interest loans for this technology may be possible.
- Loan opportunities should be presented to urban communities to demonstrate the feasibility of obtaining larger, expensive technologies.

Performing Demonstrations in an Urban, Un-electrified Community

- Wood and/or propane are commonly used cooking fuels for communities without electricity. Solar and wood-efficient stoves should be emphasized because they will reduce daily costs or efforts for obtaining these fuels.
- Energy efficiency in the home, demonstrated by the shack model, tends to be of interest when a temperature difference can be seen. Do not assume simple techniques, such as painting a house a light color, are already known.
- Solar water heaters should be emphasized since banking is available in urban communities, and obtaining low-interest loans for this technology may be possible.
- Solar home systems should be presented along with emphasis on the use of efficient appliances and lighting to maximize the potential of the system.
- Loan opportunities should be presented to urban communities to demonstrate the feasibility of obtaining larger, expensive technologies, like solar home systems.

Inventory

Camping Equipment

- 1-Folding plastic table (60X60X10 cm folded)
- 2-Folding chairs
- 1-Camping Tent (4 person max.)
- 3-Folding gazebo tents
- 1-Cast iron pot
- 1-Double sided frying pan
- 1-Dishwashing Stand
- 1-Ground mat (3X3m)
- 1-20 liter water can
- 1-Braai set
- 2-Canvis water bags
- 1-Grilling rack w/ handle

General Equipment

- 4-Plastic storage bins (40X50X30 cm)
- 1-Fire extinguisher (1.5kg dry chemical)
- 1-Refrigerator
- 1-4.5kg propane bottle with burner attachment
- 1-20 liter petrol can
- 1-First aid kit
- 1-Tool set

Demonstration Equipment

- 1-Vesto stove
- 1-Tsotso stove
- 1-Solar box cooker
- 1-Parabolic cooker w/ stand
- 4-Pinboard/whiteboard (60X90cm)
- 10-Flourescent light bulb
- 1-Incandescent light bulb
- 1-Light bulb strand (+/- 5m)
- 1-Light bulb strand (1m)
- 1-Computer w/ monitor and 5 speaker sound system
- 1-Television set
- 1-VCR
- 1-Hair clipper set
- 1-Fan
- 1-AM/FM Radio

APPENDIX J: Diesel Versus Solar Water Pump Chart

Ministry of Mines and Energy Study, 2005
Cost Benefit Analysis between Diesel and PVP Water Pumps
At 100 m water level depth and 7,000 litres per day

PVP: N\$ 4 for every m³ (1,000 litres) pumped by Year 5

Diesel: N\$ 13 every m³ (1,000 litres) pumped by Year 5 (at N\$ 3,96 per litre Diesel)

Borehole water levels and daily water deliveries where
PVP is most optimally suited

| | | Total Pumping Head | | |
|----------------|--------|--------------------|--------|--------|
| | | 50 m | 100 m | 150 m |
| Litres per day | 5.000 | Solar | Solar | Solar |
| | 8.000 | Solar | Solar | Solar |
| | 12.000 | Solar | Solar | Diesel |
| | 16.000 | Solar | Solar | Diesel |
| | 24.000 | Solar | Diesel | Diesel |
| | 40.000 | Solar | Diesel | Diesel |
| | 50.000 | Diesel | Diesel | Diesel |
| | 80.000 | Diesel | Diesel | Diesel |

APPENDIX K: Building a Solar Box Cooker

Source: http://www.exoticblades.com/tamara/sol_cook/instruct.html

Supplies and Equipment

Gathering the supplies and equipment required to build a solar oven is a time-consuming aspect of the whole project. The insulation and aluminum foil tape are items you may not have worked with before. They are found in the insulation section of larger hardware or home supply stores. The cardboard is a common material, but it may take a few weeks to find the boxes of the right size. All the other items are readily available at most hardware or grocery stores.

Supplies

A solar box cooker is constructed mainly of cardboard and aluminum foil. Building a solar box cooker made requires the items on this list:

- Cardboard for reflectors -- heavy-duty two-ply corrugated cardboard, such as two computer monitor boxes, 14 feet by 3 feet total
- Cardboard for inner box -- lid of a standard 10 ream office paper box, 11 1/2" by 18"
- Cardboard for inner box lid -- enough to make a strip 5" wide and 62" long
- Cardboard for outer box -- box approximately 16" by 22" and at least 6" deep
- Heavy-duty aluminum foil, one 75 square feet roll
- Plate glass, 12 " by 18 1/2"
- Foil-backed foam board insulation, about 1/2" inch thick, sold in 4' by 8' sheets. (The whole 4' by 8' sheet is not used for one cooker. You may be able to find discarded scraps of insulation to use for the project.)
- Aluminum foil tape, available where insulation is sold -- 2" by 50 yard roll
- 6' roll of 1/2" wide adhesive-backed foam weatherstripping
- One quart white glue, such as Elmer's

Equipment

These tools will not be used up in the process of making the solar cooker, and can be reused.

- Box knife and sharp blades
- Measuring tape or yardstick
- T-square and protractor
- Marking pen
- Brushes and rollers to spread glue
- Containers to hold glue and water mixture, such as empty cans or wide-mouth jars

The following items are needed to use the solar oven once it is complete:

- Sunglasses -- one pair for everyone looking at the solar box cooker while it is in the full sun
- Oven mitts
- Leather gloves
- Oven thermometer to measure temperature of oven
- Candy or meat thermometer to measure temperature of food
- Two ten-inch bungee cords
- Clothespins and heavy string
- Three bricks

Instructions for Building a Solar Box Cooker

Read the instructions in the previous section, Supplies and Equipment, for information about the materials. After all the supplies are gathered, the first step in constructing the solar box cooker is cutting the cardboard and foil-backed foam board insulation into the correct sizes.

Once the cardboard and foil-backed foam board insulation are cut into the correct sizes, the actual construction begins. The box knife is used to score the cardboard to make neat folds. Elmer's glue adheres the foil to the cardboard. Aluminum foil tape holds all the pieces together.

Components in completed solar oven:

- Inner box lid constructed from a five inch strip of cardboard
- Inner box bottom constructed using the lid of an office paper box
- Cardboard and foil reflector made of two large boxes
- Plate glass, 12 1/4" by 18 3/4"
- Outer box, approximately 15" by 22" and at least 6" deep

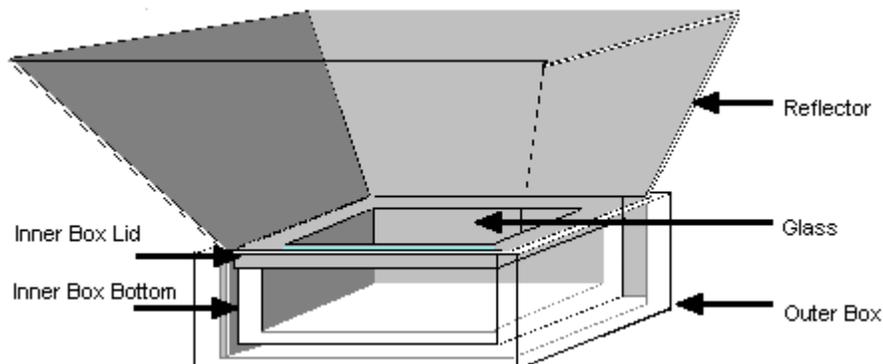
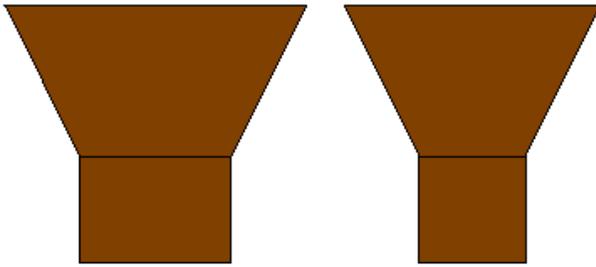


Figure 6: Diagram of complete solar oven.

The instructions cover constructing the three-part inner box, which is insulated to trap the heat used for cooking. The reflector, four pieces of sturdy cardboard covered with foil, is constructed next. The last stage is to use the outer box and bungee cords to hold the reflector and inner box together. Use Figure 6, a diagram of the complete solar oven, to help identify the parts.



Preparing Supplies by Cutting Them to the Correct Sizes

Instructions for cutting the cardboard and insulation for the inner box are first. The cardboard for the reflectors is next. The reflectors are an odd shape, and big, but the illustration for them is carefully made to scale.

Cutting cardboard for the inner box. This first piece is the easiest! Cut on a protected surface, and use the straight edge and T-square to make strips of even widths. (I suggest using aluminum foil tape to tape pieces together throughout the project, as all other tapes dry and crack when exposed to high temperatures.)

1. Cut 5” wide strips of cardboard until you have 62” when they are placed end to end
2. Use the aluminum foil tape to tape the pieces together to create the 5” wide and 62” long strip.

Cutting insulation for the inner box. Now that you have practiced cutting 5” wide rectangles on cardboard, cutting the pieces of foil-backed foam board insulation will be easier. I prefer to wear leather gloves when handling insulation to avoid itchy hands.

1. Cut two strips that are 5” wide by 18” long and two strips 5” wide by 12 1/2” long.
2. Next cut a rectangular piece 12 1/2” by 19”.
3. Check the fit; the five pieces should fit around the office paper box lid as shown in Figure 8 in the next section.

Cutting cardboard for the reflectors. The hardest cutting was saved for last. The four trapezoid shaped reflectors form

the reflector illustrated Figure 6 when fastened together. The inner box is rectangular, so two of the reflectors that surround it are wider than the other two. The illustration in Figure 7 shows one of the wider reflectors, with a width of 20” at the narrow base, on the left. The reflector on the right is one of the two narrower reflectors, with a width of 14” at the narrow base. The instructions will cover cutting each size separately. Figure 7. Cutting cardboard for the reflectors. Cut two of each size.

To create the two wider reflectors, as shown on the left:

1. Cut a rectangle 40" by 35". Mark one of the 40" sides as the top of the reflector.
2. Measure and mark a horizontal line, parallel to the top, 20" from the top of the reflector. Make a mark 10" from each side along this line. This marks where the next line should intersect.
3. Turn the cardboard so the top is facing towards you. Use the protractor to measure and mark a 22 1/2 degree angle at each end of the 40" width. Make the resulting lines long enough to intersect the horizontal line at the marks drawn in step two.
4. Check the measurements. You should have a trapezoid with a long side of 40" marked as the top, a short side of 20" and a height of 20" drawn on the cardboard.
5. Mark the bottom rectangle shown under the trapezoidal shape in Figure 7. Draw a straight line from the short side of the trapezoid to the bottom of the reflector. The rectangle should have two sides of 20", and two 15" sides.
6. Cut along the outlines marked on the cardboard and shown in Figure 7. Do not cut along the solid line that connects the trapezoid and the rectangle.
7. Repeat steps 1 through 6 to create the second wide reflector.

The instructions for the two narrower reflectors are very similar, but the entire set of instructions is repeated to avoid confusion. To create the two narrower reflectors, as shown on the right:

1. Cut a rectangle 34" by 35". Mark one of the 34" sides as the top of the reflector.
2. Measure and mark a horizontal line, parallel to the top, 20" from the top of the reflector. Make a mark 10" from each side along this line. This marks where the next line should intersect.
3. Turn the cardboard so the top is facing towards you. Use the protractor to measure and mark a 22 1/2 degree angle at each end of the 34" width. Make the resulting lines long enough to intersect the horizontal line at the marks drawn in step two.
4. Check the measurements. You should have a trapezoid with a long side of 34" marked as the top, a short side of 14" and a height of 20" drawn on the cardboard.
5. Mark the bottom rectangle shown under the trapezoidal shape in Figure 7. Draw a straight line from the short side of the trapezoid to the bottom of the reflector. The rectangle should have two sides of 14", and two 15" sides.

6. Cut along the outlines marked on the cardboard and shown in Figure 7. Do not cut along the solid line that connects the trapezoid and the rectangle.

7. Repeat steps one through six to create the second narrow reflector.

You have now cut the pieces necessary to construct the solar box cooker. The next three stages of the construction will not require extensive cutting, but you will need the box knife to score the cardboard so it folds easily.

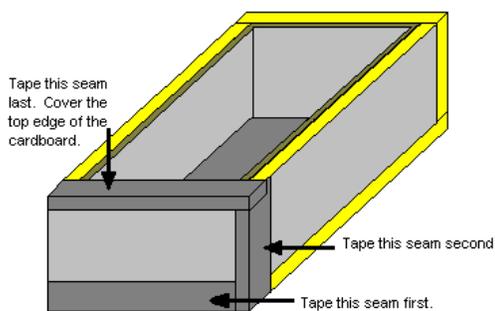
Constructing the Inner Box

The inner box of the solar box cooker traps the heat used for cooking. The food to be cooked is placed inside the inner box, which is covered with the piece of glass. The sun's rays enter through the glass top. The heat from the sun's rays is trapped, heating the inside to temperatures over 200 degrees. It is important that the inner box be very well-insulated and constructed of material that withstand high heat.

The inner box has three parts: the bottom, the glass cover, and the lid. The bottom is constructed by insulating the lid from an office paper box. The glass is checked for fit and strips of adhesive-backed foam insulation are applied to the edges. The inner box lid is constructed by scoring the 5" wide strip of cardboard so it will fold easily, lining it with foil, then folding and taping it in place.

Constructing the inner box bottom. The bottom of the inner box is constructed by insulating the lid of the office paper

box with aluminum foil and foil-backed sheathing. Follow these four steps to create a well-insulated inner box bottom:



1. Line the inside of the box with aluminum foil. Glue the foil to the inside of the box following the instructions in the Skill Tip: Gluing Foil to Cardboard below.

2. Fold any foil that extends above the top edge of the box to the outside.

3. Fit the 5 pieces of foil-backed sheathing to the outside of the box. Figure 8 illustrates how the five pieces fit around the box. Use a few dabs of unthinned white glue to hold them in place temporarily.

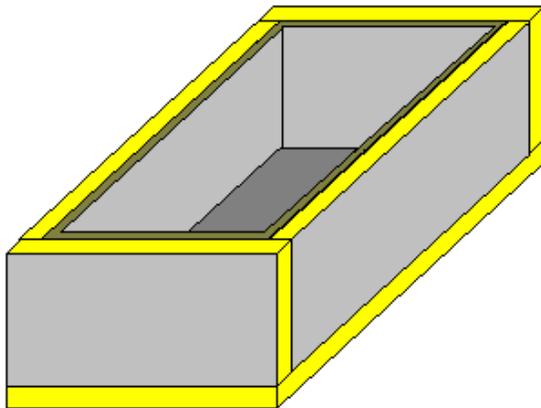
Figure 8. Fit the five pieces of sheathing to the bottom and sides of the box.

4. Permanently attach the sheathing to the outside of the box by taping in place with the aluminum foil tape. Figure 9 illustrates where to tape the pieces in place.

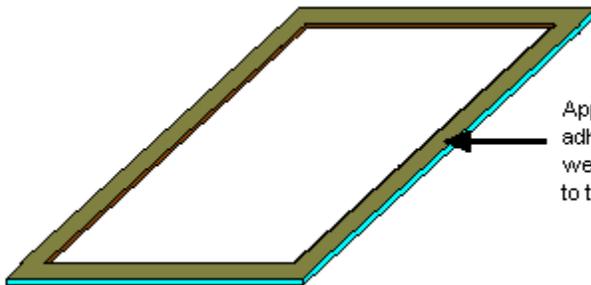
Note: The sheathing has friable fiberglass that will flake away over time. Cover all exposed edges with the aluminum foil tape.

Skill Tip: Gluing Foil to Cardboard

Follow these steps to glue foil to cardboard neatly:



1. Mix 1/3 part water to 2/3 parts glue.
2. Wet the brush with glue.
3. Apply a thin even coating of glue to the cardboard.
4. Lay a sheet of foil in place.
5. Use a damp paper towel to smooth the foil out. Start in the middle and work out to the edges. Gently press foil into folds
6. Repeat steps 2 through 5 until all surfaces are covered.
7. Wipe up any glue that seeps out at seams.



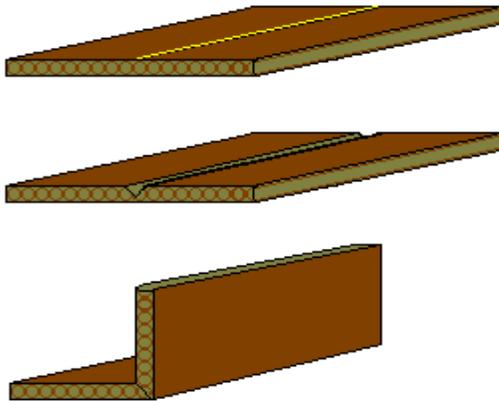
Preparing the glass. The piece of glass lays on top of the inner box bottom constructed in the last phase. There are two steps to preparing the glass to use in the inner box: (1) check the fit, and (2) apply weatherstripping.

Figure 9. Tape the sheathing in place with aluminum foil tape.

1. The glass which covers the top is 12" by 18 1/2". Now that the 1/2" thick sheathing has been attached to all four sides of the box, lay the glass on the inner box bottom and check the fit. It should cover the inner box bottom completely. If it does not fit, carefully measure the outside length and width of the inner box bottom and get a piece of glass to fit those measurements.

2. Once you have checked that the that the piece of glass is the right size, apply the 1/2" wide adhesive-backed foam weatherstripping. Place it along the four edges on one side of the glass where the glass rests on the top edge of the inner box bottom, as shown in Figure 10. The weatherstripping seals the gap between the inner box bottom and the glass and keeps the glass from sliding around. The weatherstripping also makes the glass easier to hold on to when lifting it off the inner box bottom so you can get your hot food out of the oven.

Constructing the inner box lid. The cardboard lid for the inner box holds the inner box bottom and glass together. The open center allows the sun's rays to enter the oven. The 5" wide strip of cardboard is first cut and scored. Then foil is applied to the cardboard, which adds extra insulation to the outside of the inner box. Finally, it is folded into a rectangle and taped in place. Follow these five steps to cut and score the cardboard for the inner lid:



1. Use the straight edge, T-square and marking pen to mark a line the length of the cardboard and 1" from one of the long edges of the 5" wide strip of cardboard.

2. The 62" length of cardboard is divided into 4 sections. Mark a line the width of the cardboard $12 \frac{1}{4}$ " from one end. Mark a second line $18 \frac{3}{4}$ " from the first. Mark the third line $12 \frac{1}{4}$ " from the last line. This last line should be $18 \frac{3}{4}$ " from the end.

3. Use the box knife to cut through the cardboard at black lines shown in Figure 11.

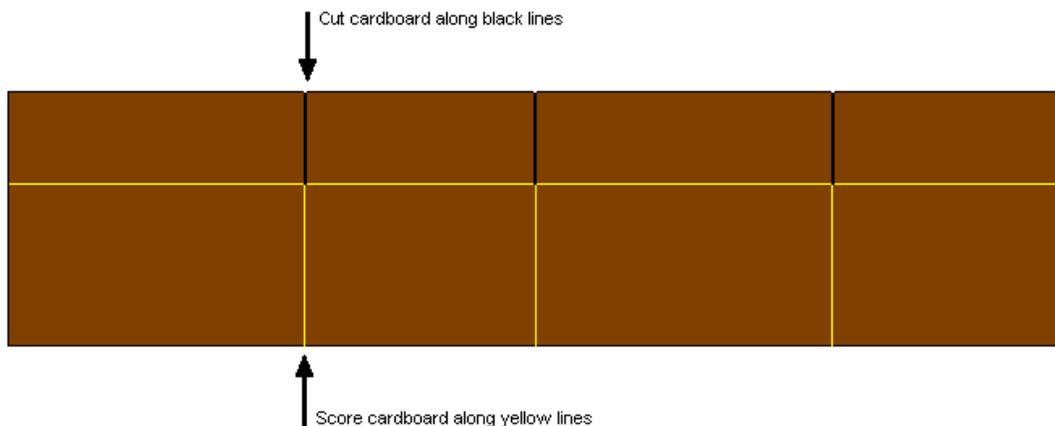


Figure 11. Cut and score the 5" strip of cardboard for the inner box lid.

4. Score cardboard along the yellow lines indicated in Figure 11. Refer to the hints in the Skill Tip: Scoring and Folding Cardboard below to score the cardboard for neat folds.

5. Check the fit of the inner box lid. Fold it into a rectangle, and slide it over the inner box bottom. It should slide over the bottom easily, but without too much extra space.

Skill Tip: Scoring and Folding Cardboard

Follow these steps, demonstrated in Figure 12, to make neat folds in cardboard:

1. Cut through one layer of the corrugated cardboard with the box knife

2. Completely retract the box knife blade. Use the blade end of the closed box knife to make a channel along the cut surface of the cardboard.
3. Place a straight edge along the channel and gently fold.

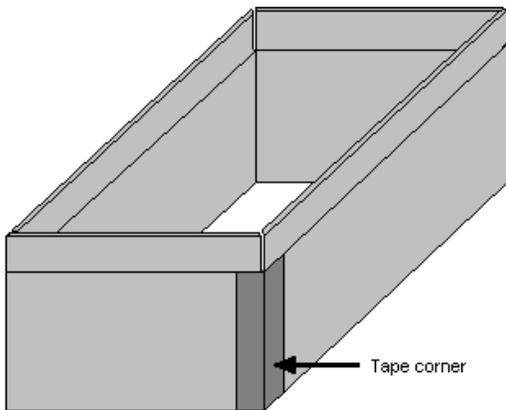
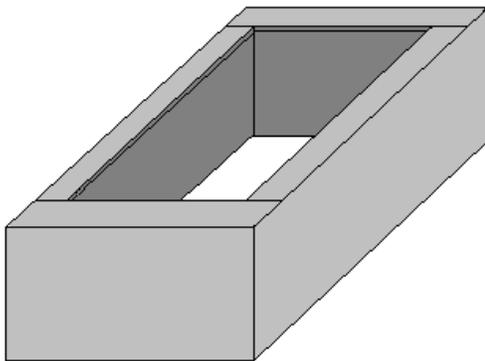


Figure 12. Score cardboard for neat folds.

Insulating and taping the inner box lid. Now that the piece of cardboard used for the inner box lid is cut and scored, you can cover it with foil, tape it into a rectangle, and apply a strip of weatherstripping. Follow these steps, using the illustrations for more information:

1. Lay the cardboard out flat, and glue aluminum foil to both sides. Press the foil gently into the score lines.



2. Use aluminum foil tape to seal the top and bottom edges. Cut through the tape at the three 1" deep cuts along the top edge.

3. Fold into a rectangle, and tape as illustrated in Figure 13.

Figure 13. Fold the 5" wide strip of cardboard into a rectangle. Tape the ends together.

4. Fold the top flaps down, and tape into place. Figure 14 shows the completed inner box lid with its open center, which will allow the sunlight into the oven.

Figure 14. Fold the flaps down to make a box lid with open center.

5. Turn the lid so the folded-in flaps are face down on the table. Apply a strip of the 1/2" adhesive-backed foam insulation to the inside corner of the box lid.

Congratulations! Figure 15, from top to bottom, shows the inner box lid, the piece of glass, and the inner box bottom. Check the fit of the three pieces you have made which fit together to create the inner box of the solar box cooker.

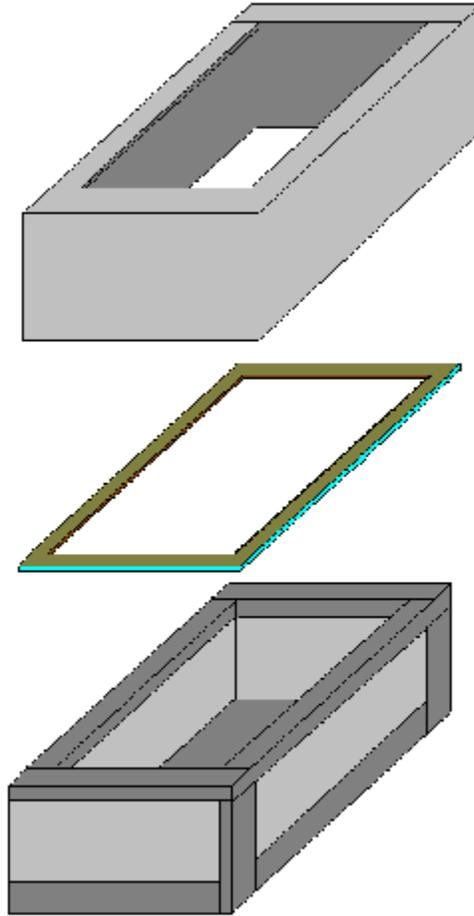


Figure 15. The inner box lid, the glass, and the inner box bottom pieces fit together to create the inner box.

If the sun is straight overhead, this inner box alone will heat to temperatures of about 180 degrees in twenty minutes. The reflector, which is built next, increases the amount of sunlight which strikes the box.

Constructing the Reflector

The reflector is easy to finish, though a bit cumbersome. The final step of constructing the reflector requires a very large flat space to lay the four pieces out before taping them together. A clear space on the floor is probably best for this last part.

1. Get the four pieces cut for the reflector, and lay them out.

2. Glue aluminum foil to the top trapezoidal shaped parts of the cardboard reflectors, as illustrated by the gray areas in Figure 16. Refer back to the Skill Tip: Gluing Foil to Cardboard for tips.

3. Mark a line 5" below the base of the foiled trapezoid, as illustrated by the yellow line in Figure 16. Score and fold the cardboard along this line. Refer back to the Skill Tip: Scoring and Folding Cardboard if necessary.

4. Lay the four reflectors out, alternating wide and narrow, in the shape shown in Figure 17. Using aluminum foil tape, tape the reflectors together along three of the angled sides.

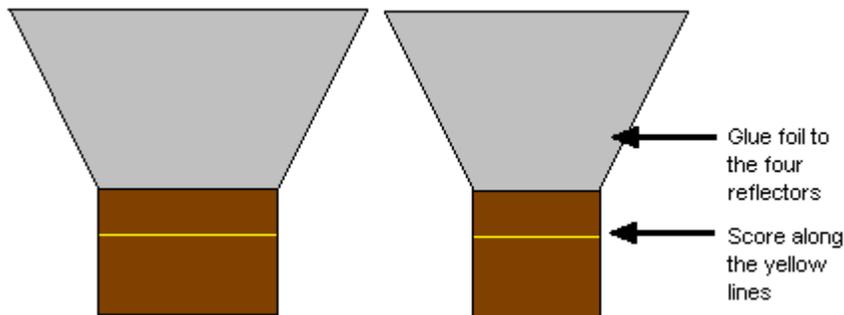


Figure 16. Glue foil to the four reflectors. Score the cardboard along the yellow line, 5" below the base of the trapezoid.

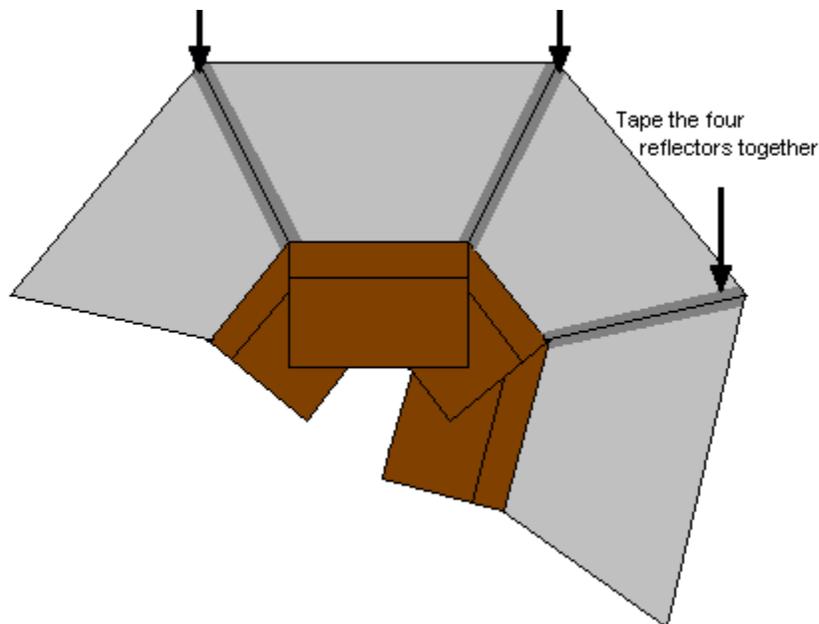


Figure 17. Tape the four reflector pieces together.

The reflector is now completed. The final step of folding it into the rectangular funnel shape that reflects light down into the solar oven is included in the last stage of

construction, assembling the oven. Follow these four steps to assemble the solar box cooker:

Assembling the Solar Box Cooker

The inner box and the reflector are now completed. The outer box does not require any construction. If it is bigger than 16" by 22" or deeper than 6" you may need to use some wadded up newspaper or scrap cardboard to hold the inner box and reflector in place. The bungee cords and clothespins are used to hold the reflector closed around the inner box.

1. Fold the reflector along the taped seams to form a rectangular funnel shape, as illustrated in Figure 18.

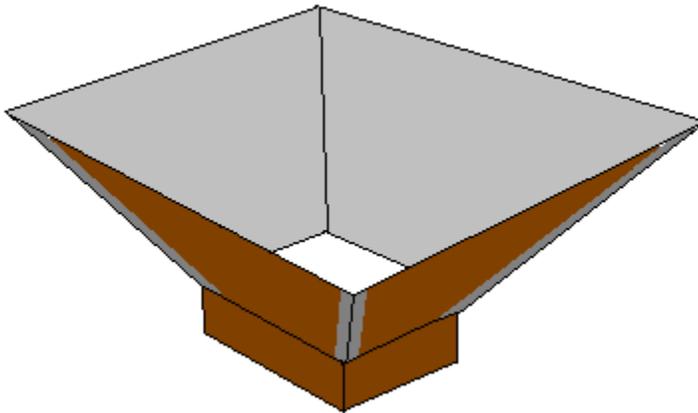


Figure 18. The reflector folded into a rectangular shape.

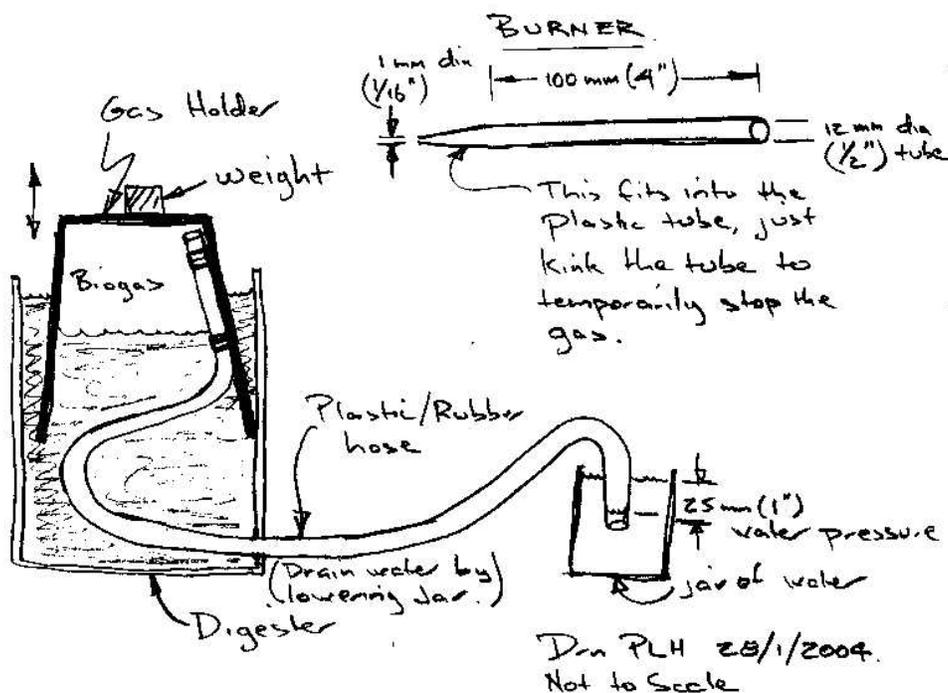
2. Fold the bottom of the reflectors along the score line to form a base.
3. Place the reflector in the outer box and ask someone to hold it in place.
4. Place the inner box into the center of the reflector. It is heavy enough that it will anchor the reflector in place. Fasten the reflector closed with bungee cords at the base and clothespins and string along the top edge.

The construction of the solar box cooker is now complete. The next section, Tips for Use, will guide you through the first heating of the oven in the sun, which will drive off any fumes from the construction materials, and allow you to check the oven's performance. After the box cooker's first heating, it is time to cook and experiment.

APPENDIX L: Biogas Model Design

Source: <http://www.ees.adelaide.edu.au/pharris/biogas/SciFair.html>

There are plenty of options for anaerobic digesters as all you need is a gas tight container and some organic waste. I think the simplest method is if you can find two buckets/containers such that one will fit upside down inside the other with some clearance (not that easy to do in spite of the proliferation of plastic containers). The bottom container holds the digesting liquid and the inverted one becomes the gas holder - it may need some guides so it does not topple over as it rises with gas. To avoid the possibility of a gas leak I would use waterproof tape/glue/silicon sealant to hold a plastic tube from the top of the gas space running out through the side of the digester bucket (you will notice a liquid leak!) with enough slack to allow the gas holder to rise (See sketch below, 2004 version, guides not shown - a challenge for you!).



I hope by this stage you have read and understood the safety page <http://www.ees.adelaide.edu.au/pharris/biogas/safety.html> although it is written with larger digesters in mind - for example you do not have to have the flame 20 m from the digester or have a flame trap, as in the most unlikely event of the flame burning back to the digester you will not get much more of a bang than when lighting a gas stove with such a small digester!

Can you get some cow manure (make sure NO antibiotics are given to the animals) - enough to quarter fill the digester container? I have found that dog manure does not work on its own, like poultry manure or food waste you may still need some cow manure as a starter. Fill the rest of the digester with water and mix it up, then place the gas holder on top and let all the air out (some weight on the gas holder will help). The digester needs to

be placed somewhere warm (15-20 C or 60-70 F) and gas production should start in a day or so. Put the free end of the plastic tube in a jar of water to seal it. If you are in a hurry 35-40 C (95-105 F) will give quicker response. Let the gas holder fill up (the volume will probably be a bit less than the volume of liquid, I hope) and discard this gas, as the first gas will be mainly carbon dioxide (CO₂) and won't burn (it will actually extinguish a match, but don't allow smoking as there may be some methane present - all being well).

To make a burner you need a small hole for the jet into a larger tube as a mixer, a bit like a bunsen burner as used in chemistry labs, but I do not worry about the air holes. I use a 1 mm hole into 12 mm tube, so a 1/16" jet opening into 1/2" tube (this should be metal) would work well with enough weight to make about 25 mm (1") water pressure - more weight may blow out the flame and less may not give enough gas. About 20 litres (I think that's 5 gallons) of gas will normally boil a cup of water.

You may find that you get a bluish flame when the match is held there, but the flame goes out without the match - that means you have less than 50% methane in the biogas or the pressure is too high, just remove some weight and if the flame still goes out burn off the gas and try again in a few days. As methane is a greenhouse gas try to burn off the excess gas rather than just letting it escape to atmosphere.

You could measure how high the gas container rises each day to record the volume of gas generated and once everything is going well (maybe a week or so) add some more waste (no more than 1/20 of the liquid volume each day) to feed the digester - the overflow is good organic manure.

Here is my 2005 version, made out of soft drink bottles and containing the smell better!



It is a bit hard to see, but the smaller plastic jar inverted in the right hand container is for gas storage and the water level in the inner jar is slightly below that in the outer container. If you look carefully you will see the tube connecting the digester head space (left container) to the gas storage headspace (right container). The tube coming off to the front is the gas outlet. As gas is generated the inverted jar will rise.