LIGHTING THE WAY TO FIRE SAFETY:

REDUCING FIRE RISK IN NAMIBIA'S INFORMAL SECTOR HOUSING

OUR PROJECT TEAM WITH ONE OF OUR CONTACTS, DAVID, IN THE INFORMAL SETTLEMENT OF GOREANGAB.

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By

Connor Gillespie
Brien Hard
Casey Rota
Saloni Sachar

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Submitted to:
WPI Advisors: Holly Ault, Thomas Robertson
Sponsor: Men on the Side of the Road, Hilya Kambanda

ABSTRACT

Our group worked with Men on the Side of the Road in Windhoek, Namibia to reduce the risk of shack fires that devastate the informal settlements of Katutura. Using participatory research methods, we interviewed local community members and fire safety personnel to determine the fire safety knowledge within the community and the causes of fires. We found that candles are the most prevalent light source and are a primary cause of shack fires in Katutura. After identifying factors that contribute to the fire risk within informal housing, we developed recommendations about alternative light sources including solar, battery, and paraffin lamp options. We also identified effective methods to spread fire safety knowledge and awareness of alternative lighting in Katutura.

EXECUTIVE SUMMARY

"I was left with nothing, only the clothes I was wearing," commented a single mother of two who fell victim to a shack fire in Goreangab, an informal settlement outside Windhoek, Namibia. Twenty-five percent of Namibia's population lives in informal settlements, which the UN-Habitat defines as residential areas where the inhabitants have insecure residential status, no clean water, inadequate basic infrastructure, and overcrowding (Durand-Lasserve, 2006). Within these informal settlements, residents use candles and improper paraffin lamps[1] as major light sources because of an abundance of poverty and a lack of electricity. These open-flame light sources commonly cause fires. From July 2014 to March 2015, an average of 2.35 shack fires occurred each week in the informal region of Katutura.

Men on the Side of the Road (MSR), a non-profit organization works with men to enable them "to gain marketable skills and start on the path to self-sustainability or employment" (MSR, 2013). MSR also focuses on improving the communities of its members. Our project goal was to use participatory methods, in collaboration with Men on the Side of the Road, to identify sustainable and cost-effective lighting options to improve fire safety in Katutura.

METHODOLOGY

To complete this goal, our team developed three research questions:

1. Determine Participatory Research Partners and Informants
2. Assess Fire Causes in Katutura
3. Test and Identify Viable Alternative Lighting Sources

Our team used participatory research methods to keep the community members at the center of our project. Participatory research is a collaborative approach to research that involves the community and engages the stakeholders. The residents of Katutura are the stakeholders facing fire risk, making it important to consider their opinions and recommendations. We used the following methods to complete our objectives:

1. Interviews with 50 community members in Katutura

[1] Paraffin lamps are also known as kerosene lamps.

2. Interviews with officers of the Windhoek Fire Brigade, members of the Disaster Management Office, the Councilor of Havana, and the Entrepreneur of Uyelele – The Namibian Solar Bottle Project
3. Tests on the efficiency of candles, paraffin, and solar options
4. Pilot-tests of the solar bottle and the Pharox light
5. Observations of an MSR monthly meeting and a Disaster Management Office program

FINDINGS & ANALYSIS

Finding #1. **Candles are the most prevalent lighting source in the informal settlements of Katutura and are a primary cause of shack fires.**

Through interviews, we found that 66% of the residents used only candles as a light source. Interviews with community members and officers of the Windhoek fire brigade revealed that, in their opinions, candles were the main cause of shack fires.

Finding #2. **Contributing factors that increase fire risk in Katutura's informal settlements include:**

1. **Improper candleholders**
2. **Improper paraffin lamps**
3. **Unsupervised children**
4. **Forgetfulness**
5. **Intoxication**
6. **Clutter**

Although residents recognize the dangers of candles, they may be unaware of factors that increase fire risk.

Finding #3. **Fire safety and awareness information may not being effectively conveyed to the communities of Katutura. The Disaster Management Office (DMO) conduct fire safety and awareness programs in Katutura, but not one of the 68 community members we asked were aware of the office. The DMO thought it beneficial to collaborate between their program and other community organizations.**

The community may be unaware of programs conducted by the DMO that contain important information about fire safety techniques and awareness.

Finding #4. **Multiple lighting options are necessary to fit the needs of the various households in Katutura, which vary in income, the presence of children, and ability to invest in alternative options.**

When speaking on the issues and limitations for different households, the general manager of Men on the Side of the Road, Hilya Kambanda, stated, "one size does not fit all." No single lighting source can fit all of the needs of every community member.

Finding #5. **Small-scale solar panels and lights purchased from stores within Katutura can eliminate candle use when charged directly by sunlight. These panels and lights can also be charged inside a shack with a solar water bottle light, but charging is less efficient and will only reduce, not replace, the use of candles and paraffin lamps.**

Six of the seven solar options tested were effective based on cost, light duration, light quality, and safety.

Finding #6. **Battery powered devices can reduce or eliminate the risk of fire from open flame lighting sources.**

Although car batteries are not a viable power source for lighting, flashlights are a cost-efficient option and have a payback period of approximately one month compared to candles.

Finding #7. **According to residents, closed paraffin lamps are cost effective and may be safer than candles.**

Closed paraffin lamps are cost-efficient and may reduce the fire risk when used instead of candles.

CONCLUSIONS & RECOMMENDATIONS

After compiling our findings, we recommend that:

Recommendation #1. **The organizations Men on the Side of the Road, the Disaster Management Office, and the Windhoek Fire Brigade spread the knowledge of alternative lighting sources including solar options, battery options, and paraffin lamps as well as improved candle safety.**

Information on alternative light options and improved candle safety should be included in the above organization's programs. Additional workshops are also essential to inform the community and reduce the fire risk in Katutura.

Recommendation #2. **MSR create a new workshop regarding proper fire safety and alternative light sources. We also recommend that that the information be incorporated into their existing "Money Management" and "Life Skills" training.**

Incorporating information into new workshops and pre-existing trainings are another way to spread information to MSR members. These members can then take this knowledge and spread it to the rest of the community.

Recommendation #3. **The creation of a WPI project with the Disaster Management Office to develop and improve programs to spread fire safety knowledge to community members.**

Community members in Katutura may gain more knowledge about fire safety if the DMO improves their advertisement techniques and information distribution.

Recommendation #4. A WPI project focusing on the continuation of testing and implementation of various alternative light sources and fire safety techniques.

This project would continue to identify viable options, as well as provide a stronger evidence for the pre-existing options.

AUTHORSHIP

Chapter 1: Introduction (Connor Gillespie, Brien Hard, Casey Rota, Saloni Sachar)
Edited by Connor Gillespie, Brien Hard, Casey Rota, Saloni Sachar

Chapter 2: Background (Brien Hard, Casey Rota, Saloni Sachar)
Edited by Casey Rota, Saloni Sachar

Chapter 3: Methodology (Connor Gillespie, Brien Hard)
Edited by Casey Rota and Saloni Sachar

Chapter 4: Findings & Analysis (Connor Gillespie, Brien Hard, Casey Rota, Saloni Sachar)
Edited by Connor Gillespie, Brien Hard, Casey Rota, Saloni Sachar

Chapter 5: Conclusions &Recommendations (Connor Gillespie, Brien Hard, Casey Rota, Saloni Sachar)
Edited by Connor Gillespie, Brien Hard, Casey Rota, Saloni Sachar

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1. INTRODUCTION

"I was left with nothing, only the clothes I was wearing," commented a single mother of two who fell victim to a shack fire in Goreangab, an informal settlement outside Windhoek, Namibia. One day, she went to work leaving her two young daughters at home. The children left the shack with a candle burning inside. Recognizing the problem, they returned to the shack in order to extinguish the flame, but in their rush failed to put it out completely, knocking over the candle as they exited. As a result their one room shack containing all of their belongings erupted in flames. In this case the children were fortunate to have been outside the shack as the fire spread. Others are not so fortunate.

In 2013, the UN estimated that 863 million people in developing countries live in informal settlements (UN-Habitat, 2014). The UN-Habitat defines informal settlements as residential areas where the inhabitants have insecure residential status, lack of access to clean water, lack of access to sanitation, inadequate basic infrastructure, and overcrowding (Durand-Lasserve, 2006). Within informal settlements, open flame light sources commonly cause fires, resulting in loss of life and the destruction of property. Community members use candles and improper paraffin (also known as kerosene) lamps as primary light sources in informal settlements because of an abundance of poverty and a lack of electricity.

Twenty-five percent of Namibia's population lives in informal settlements (CLIP, 2009). Without access to an electric grid and a steady income, residents are forced to use the available sources of light, such as candles. From July 2014 to March 2015, an average of 2.35 shack fires occurred each week in informal settlements in Katutura. Of the determined causes of fires, candles ignited 40%.

Decreasing the use of candles and improper paraffin lamps could reduce the risk of shack fires. The MyShelter foundation in the Philippines is an organization that realized that light in informal settlements is necessary not only for development, but also for safety. Their project, Liter for Light, utilizes plastic water bottles, bleach, and energy from the sun to create a light equivalent to a 50-watt light bulb (MyShelter Foundation, 2014). These materials are easily accessible, affordable, and effective. This innovation minimizes the need for fuel-based light sources during the day, helping to reduce shack fires.

Men on the Side of the Road (MSR), a non-profit organization in Namibia, also realized the need to decrease shack fires caused by fuel-based light sources. This organization conducts projects that empower men within the informal settlements to be

self-sustaining. During a monthly meeting in October 2014, MSR members identified shack fires as a significant problem. A project emerged in which community members of Katutura and our team worked together in an attempt to reduce the risk of shack fires.

Our project used participatory methods, in collaboration with Men on the Side of the Road, to identify sustainable and cost-effective lighting options to improve fire safety in Katutura. To achieve this goal, we pursued the following objectives:

1. Determine Participatory Research Partners and Informants
2. Assess Fire Causes in Katutura
3. Test and Identify Viable Alternative Lighting Sources

This project intended to decrease the risk of fire within Katutura and potentially help mitigate problems that result from shack fires. After interviewing 50 community members and 18 MSR members, we found that candles are the most prevalent light source and are a primary cause of shack fires. Keeping in mind the compounding factors that increase fire risk, our project team tested and identified viable alternative light sources that can eliminate or reduce the use of open flame light sources.

2. BACKGROUND

To understand the origins of shack fires and possible solutions, in this chapter we examine the following topics:

1. Shack fires and the problems they cause
2. The global emergence of informal settlements, the Apartheid-era creation of Katutura, and how this history contributes to the problem of shack fires
3. Men on the Side of the Road and the benefits of participatory research
4. Fire risks in informal settlements
5. Alternative light sources and fire safety case studies

2.1 PROBLEMS CREATED BY SHACK FIRES

With the slightest bit of clumsiness or lapse of judgment, a single candle, makeshift paraffin lamp, or stove can ignite a fire that can destroy thousands of shacks and kill their inhabitants (Mills, 2012). Informal settlement shack fires cause devastating effects including loss of property, forced relocation, negative psychological effects, and health problems. South African Official Patrick Kulati, the Managing Director of the Paraffin Safety Association of Southern Africa stated,

> "There are very few things more important than having a safe place to stay. However, for many shack dwellers, their homes are places to die due to fires that regularly destroy their lives, homes and belongings. Numerous reports of shack fires punctuate our newspapers and radio shows. Media consumers express temporary shock, debates abound, but sustainable solutions are in short supply" (Kulati, 2011).

In the already unforgiving challenge of living in a shack, disasters such as shack fires can affect the resident's quality of life and cause the following four problems:

Problem #1: Loss of Property. For the inhabitants of informal settlements whose average income is about 12 Namibian dollars (1 US dollar) per day, any impact on a day-to-day schedule, let alone the loss of a home and its contents, can upset the balance between life and death (Raphela, 2011). Shack fires exacerbate the poverty the residents live in, especially for a family who has lost their few possessions. Those surrounding the area of a shack fire are also affected because neighboring families may offer their own home and assets for temporary assistance if a victim family is unable to afford or find

temporary housing. As long as shack fires occur, the economic state within the informal settlements will be further hindered from growing. This perpetuates the problem of informal settlements around the globe (Raphela, 2011; Huchzermeyer, 2006).

In addition, the cultural practices and traditions of those affected are often disrupted. For example, in most African countries residents have a section of their residence that is used to perform sacred rituals. Because of shack fires, the items and space used in such rituals will be lost (Raphela, 2011).

Problem #2: Forced Relocation. Living on low wages, those evicted by shack fires are often forced to accept temporary housing as permanent dwellings. Victims recognize that in their situation, homes can take years to rebuild and can be costly. Makili Kilian, an MSR member and our participatory research partner, explained that it takes only a day or two to rebuild a shack that had succumbed to fire, assuming that the victim had sufficient money to pay for materials. During the period of relocation the ability of victims to maintain or find work is hindered. When the victim's uniform has been lost or damaged by fire does they cannot return to work for some period and valuable wages are lost (Raphela, 2011).

Problem #3: Psychological Effects of Shack Fires. After losing their home, personal belongings and, sometimes, loved ones, victims of shack fires are left physiologically devastated. Behavioral problems and substance abuse are two of the psychological side effects of fear that are created by fire disasters whether it stem from personal trauma or the loss of a loved one (Raphela, 2011). David Makgone, an officer of the Windhoek Fire Brigade stated that their investigations often determine that the inhabitant of the shack were intoxicated during the time of ignition. Inebriated individuals are more likely to knock over, disregard, fall asleep and neglect a fuel-based lighting source. In this scenario a viscous circle is formed in which a past experience with shack fires may be an underlying cause of substance abuse (Raphela, 2011).

A resident of Katutura stated that it took him almost four months to rebuild his home following a shack fire. He pointed out that he had to overcome the psychological state he was left in after he lost his home and belongings. He stated that he had difficulty finding the drive to work and save money to reconstruct his home.

Problem #4: Health Problems. Aside from fatalities that take place during the fire, the burns that result from high temperatures during shack fires are also deadly. Because of their economic and social status, inhabitants of informal settlements are

removed from medical treatment and do not have access to the required sanitation and disinfecting materials. As a result, infections of fire-based burns are unavoidable and deadly. Over 95 percent of all deaths that occur from fire or burns take place in the developing world, resulting in a mortality rate from fires that is 5 times higher in Africa compared to that of Europe (Mills, 2012).

2.2 INFORMAL SETTLEMENTS: THE HISTORICAL ROOTS OF KATUTURA'S FIRES

A popular misconception is that low-income people use fuel-based light sources because they cannot afford electricity. However, compared to more developed countries, impoverished people who use fuel-based light sources pay a higher proportion of their daily income for lighting (Raphela, 2011). Impoverished people often use fuel-based sources for light because electricity is not available. The use of open flame light sources stems from unemployment and poverty. The apartheid laws previously imposed on the residents of Katutura under South African (SA) rule restricted the population's access to education, which also contributes to the current unemployment and poverty. Unemployment and poverty leads to the use of candles, the most affordable and available lighting source, within Katutura.

Origins of Informal Settlements. The emergence of slums throughout the world began with colonization by the European powers. Stripping indigenous peoples of their freedom, wages, and rights, European colonization created unskilled, low-wage workers, many of whom ended up in urban slums. The Europeans benefitted greatly from cheap labor and large returns while the indigenous peoples fell into a culture of poverty. Over time this divide became increasingly dramatic. As technology advanced, the wealthy desired to spatially separate from the poor. For example, the invention of trains in the late nineteenth century allowed elites to increase their distance from indigenous peoples and concentrate the poor in designated areas (United Nations Human Settlements Programme Staff, 2003).

Namibia, a former colony of SA, suffered a history of slavery and apartheid, leading to the forced movement of non-white Namibians into Katutura. Apartheid is defined as "a policy that governed relations between South Africa's white minority and nonwhite majority and sanctioned racial segregation and political and economic discrimination against nonwhites" (Encylopaedia Britannica, 2015). This policy was implemented through the Population Registration Act of 1950. Apartheid prevented non-

white Namibians from receiving proper education and contributed to their poverty and mistreatment. Katutura differs from global informal settlements as it was constructed because of apartheid.

Before the formation of Katutura, non-white Namibians lived in an area known as the Main Location. It was home to both locals and migrants who journeyed from the north to Windhoek in search of employment. During the 1960s, the Windhoek Municipality, in accordance with the SA government, built another segregated neighborhood location northwest of Windhoek. Wishing to increase the distance between white and non-white Namibians, the Municipality forced the non-white Namibians farther north to what is now Katutura to utilize the land in the Main Location for white housing (Wallace, 2011). The Municipality considered the relocation necessary because Windhoek had expanded westward, reaching the edge of the Main Location. Most residents opposed moving to Katutura because they considered the Main Location home. The residents protested, refusing relocation. During confrontations, the police killed eleven people and wounded forty-four. Although Katutura was not completely built, fearing military action, many residents of the Main Location moved to Katutura (Pendleton, 1996). The incompletion of Katutura resulted in a lack of power lines. Without access to electricity and no income when arriving in Katutura, residents were forced to use candles for light because of their low cost and availability.

Informal Settlements After Independence. Katutura remains unfinished, with only some communities receiving electricity. Currently, Namibia does not have its own power plant and relies on neighboring countries for electricity, a costly method. The lack of availability causes many residents of Katutura to use candles for light while some residents illegally tapped into the electric grids. Martin David, the Councilor of Havana, an informal settlement in Katutura, informed us, "…the problem is the candle."

Migration to Katutura continues today because of the constant search for employment. Many residents, including our research partner, David, migrated from the north to Windhoek for job opportunities. High rates of natural population growth and significant migration from rural areas contribute to a high unemployment rate of 40 percent (Frayne, 2004). This unemployment makes it difficult for residents in Katutura to move out of informal sector housing. Hendrik Ehlers, the entrepreneur of Uyelele – The Namibian Solar Bottle Project, explained that people from northern villages travel to Windhoek with plans to work. These migrants expect to make enough money to return

home and support their families within a few short years. Residents typically never make enough money to return home.

The lack of a steady income dictates how residents of Katutura allocate their money. Residents allocate most of their earnings towards food and other basic necessities. The average household in Katutura consists of five people (Pendleton, 1996). Speaking with the residents, household sizes can have as little as one person to more than ten people. One resident explained that she did not have a permanent job and completed odd jobs for money. She stated that she was unable to save money because she spends what she earns on food and candles. The high unemployment rate and lack of a steady income forces residents to stay in Katutura and continue utilizing candles for light.

An anonymous senior government official mentioned that the government does not want to encourage informal settlement housing and therefore does not want to encourage migration from the north. The official explained that in his opinion, the governments of the regions in the north should work to provide basic necessities and jobs for their residents so they would not have to relocate to Katutura. This could contribute to the reasons why the government has not added power lines to Katutura. Adding power lines could further encourage migration and therefore increase the number of people living in informal dwellings.

Namibia is currently working to eradicate informal settlement housing in Katutura as informal settlements deprive residents of basic necessities. Martin David explained that the National Housing Enterprise (NHE) is working on a Mass Housing Scheme project. This project aims to provide residents of informal settlements throughout Namibia with proper housing and electricity. This project has not yet begun in Katutura because with a majority of Namibia’s population living in rural communities and finite government funds, it could take decades for the NHE to construct these homes for Katutura’s residents

Migration, unemployment and lack of education are the root causes of candle use. The fires caused by candles consume families' homes, destroy personal belongings and sometimes cause death. Organizations, such as Men on the Side of the Road, realize the effects of shack fires and are working with our project group to reduce the fire risk caused by open flame lighting sources.

2.3 MEN ON THE SIDE OF THE ROAD (MSR) AND COMMUNITY-BASED PARTICIPATORY RESEARCH

Men on the Side of the Road aims "to create a platform where members can take ownership of their lives and their working future." This section explores how MSR strides to better the lives of their members. This section also provides an introduction to participatory research and its benefits.

In 2007, MSR was launched in Katutura with the goal of supplying men with the necessary skills to find employment and become self-sustainable. Members of MSR are trained in carpentry, truck driving, plumbing, and management. MSR also has a "Drop-in Centre" that gives members access to phones, printers and other tools to assist members in their search for employment. In 2013, MSR gained 79 new members, while helping to employ 252 members (MSR, 2013). MSR often partners with employers that are interested in reducing the unemployment rate in Namibia, such as the government, local businesses, and individuals. The overarching goal of MSR is to empower its members to lead self-sustaining lives, as well as improve the lives of the residents of Katutura. MSR conducts monthly meetings with their members, where members share their opinions on problems within the community. In a meeting earlier this year, the members identified shack fires caused by candles to be one the major problems. MSR chose to make alternative lighting for community members a project for this reason. This problem was also within the community's power to change. MSR strongly believes in treating each of their members with respect and therefore strongly believes in community participation when confronting an issue. These ideals made participatory research integral to our project.

Community-based participatory research (CBPR) is a collaborative approach to research that involves the community throughout all aspects of the research process, allowing each party to contribute equally (Holkup, 2004). Participatory research empowers the stakeholders to take control of the situation, encouraging them to solve their problems. It also promotes a mutual learning between the researchers and community members. The community members, as our co-researchers, participate in the entire research process, including defining the problem, gathering data, and dispersing findings (Chilisa, 2012).

Research shows that CBPR has many benefits and that it is difficult to create an effective program without the community's participation (Chilisa, 2012). Benefits of

participatory research include the more efficient use of resources, the formation of trust, and sustainability. The community members also feel as though they are contributing rather than feeling like subjects in an experiment, which makes the program more likely to be accepted (Chilisa, 2012). This method shows community members that their knowledge and input are both significant and vital. The most important benefit of participatory research, relative to our project, is that, “involving local people as participants in research and planning has been shown both to enhance effectiveness and save time...” (Cornwall, 1995). Participatory research aligns with MSR’s mission statement in that it furthers the knowledge and skills of the community.

2.4 FIRE RISKS IN INFORMAL SETTLEMENTS

Around the world, those living in poverty use fuel-based sources for cooking, heating, and lighting. These sources include candles, paraffin, wood, gas, and oil. With the absence of an electric grid, electricity is not an option for many residents of informal settlements in Namibia. Forced by their economic status and situation to adopt fuel-based sources of lighting, heating, and cooking, poverty stricken communities are also forced to accept the associated safety risks. The most destructive of these safety risks are shack fires.

Throughout informal settlements, such as Katutura, materials used for cooking, heating, or lighting can be effective fire starters. The most effective of these fire starters are candles and improper paraffin lamps. Because there has been no relevant data collected in the township of Katutura, the data collected from low-income households in South Africa can be considered relevant. Namibia and SA have very similar economical and apartheid backgrounds.

Figure 1 shows the frequency of fuel sources in low-income South African households. Among the materials used for lighting, candles are the highest at 46 percent. This provided our project group with a starting point to investigate further if Katutura's residents use candles for light and their correlation, if any, to shack fires.

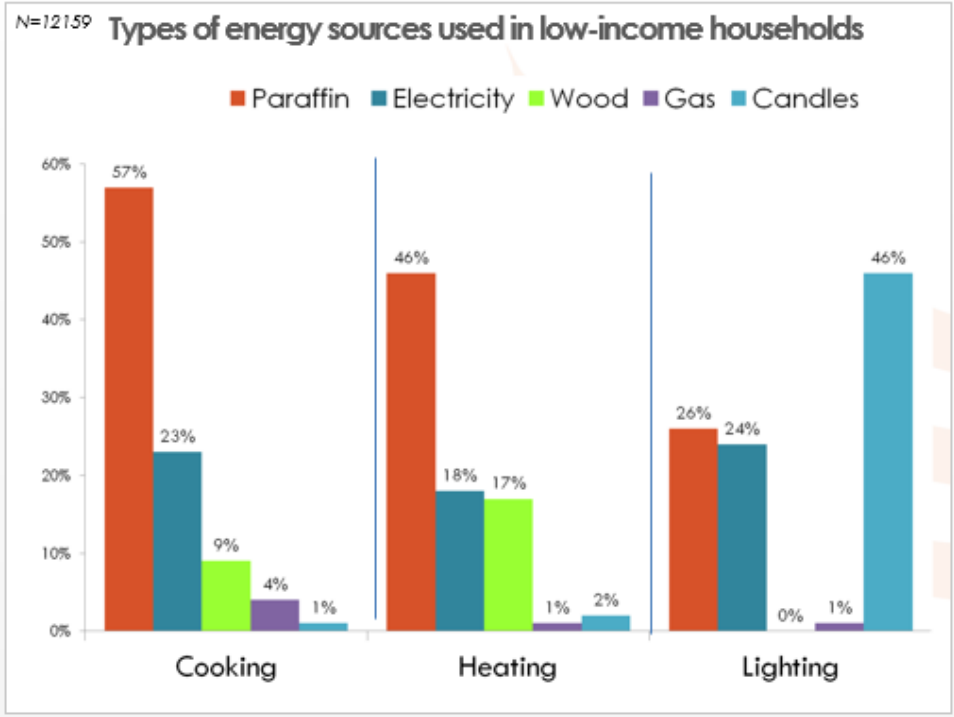

FIGURE 1. TYPES OF ENERGY SOURCES USED IN LOW-INCOME HOUSEHOLDS IN SOUTH AFRICA (PARAFFIN SAFETY ASSOCIATION, 2012)

Figure 2, from the South African Paraffin Safety Association, shows the percentages of each fuel-based source and its contribution to starting shack fires in SA. It is important to note that the section of "candle falling" also includes paraffin lamps or other products that employ an open flame to provide light.

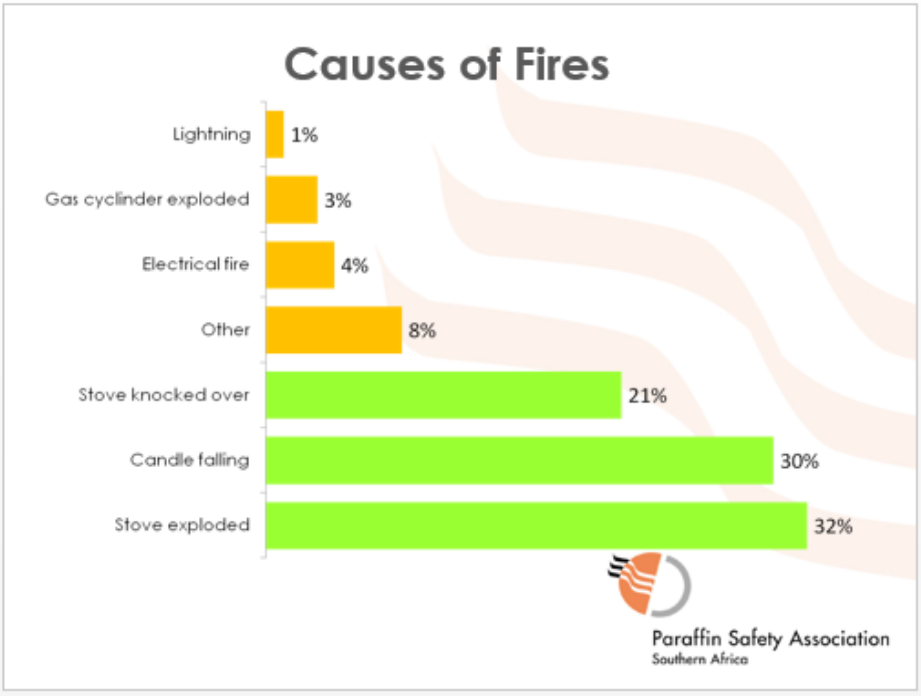

FIGURE 2. IGNITION SOURCES FOR FIRES IN LOW-INCOME HOUSEHOLDS IN SOUTH AFRICA (PARAFFIN SAFETY ASSOCIATION, 2012)

Figure 1 and Figure 2 show two important observations: 46 percent of low-income residents use candles for light and 30 percent of shack fires in SA are caused by candles falling.

The design of each lighting product and the role they play on the intensity and quickness of spreading fire is significant. For example, a candle is a fire risk because of its open flame and unstable base. Katutura residents mostly use wine and beer bottles or mugs filled with sand as candleholders. Few use store-bought candleholders. See Figure 3. These makeshift candleholders are unsteady and when knocked over, the candle can cause a fire. Because the flame is not enclosed, it allows for curtains and other flammable materials to easily catch on fire.

FIGURE 3. TYPICAL CANDLEHOLDERS IN KATUTURA; A WINE BOTTLE (LEFT), A MUG OF SAND (CENTER), AND A STORE-BOUGHT CANDLEHOLDER (RIGHT)

Furthermore, a paraffin lamp, depending on its design, can also be an open flame hazard. Residents will use makeshift paraffin lamps composed of a glass liquor bottle, paraffin, and a wick. Store-bought paraffin lamps are safer than a candle because of the flame guard. Store-bought paraffin lamps have the benefit of keeping the flame enclosed and away from curtains and flammable materials, they can be dangerous because they utilize a highly flammable fuel source. Figure 4 shows two store-bought paraffin lamps and a makeshift paraffin lamp.

FIGURE 4. VARIOUS PARAFFIN LAMPS THAT RESIDENTS OF KATUTURA USE. GLASS PARAFFIN LAMPS (LEFT, CENTER) AND A MAKESHIFT PARAFFIN LAMP (RIGHT).

2.5 GLOBAL LESSONS LEARNED: ALTERNATIVE LIGHT SOURCES & FIRE SAFETY CASE STUDIES

This section examines the technical and social features of alternative light sources. These alternative light sources could replace candles and makeshift paraffin lamps.

Lesson #1: In a study in India, people invested in solar lanterns if they were able to make monthly payments. Solar lanterns are sustainable and function at night, but the lanterns can be easily stolen and may be too expensive.

In India, a study was performed where solar photovoltaic lanterns were given to rural villagers who lacked access to grid energy (Agoramoorthy, 2009). The villagers used an installment plan to purchase the lanterns, paying 12.50 USD per month for seven months. These solar lanterns provided 6 hours of light after a full day's charge. A major benefit of these lanterns functioning after dark is that they nearly doubled the number of study hours for school children, something Men on the Side of the Road is looking for in Katutura. However, these lanterns can be easily stolen because they are solar and need to be left outside to charge.

Lesson #2: In a study in Kenya, LED lamps saved money for community members and are brighter, safer and more sustainable than kerosene lamps. Also, if people can experience a product, they are more likely to invest in it.

The Lumina Project, an initiative by the U.S. Department of Energy, distributed LED lamps for purchase to market businesses in Kenya. Six months after distribution and purchase, the researchers offered to buy back the lamps for the full price. No one accepted the offer. Business owners attested to the lamps drawing in more customers and increasing sales by illuminating their market stands. Not only were these lamps perceived to help small businesses, but also people agreed that they were much safer than kerosene lamps, especially around children (Johnstone, 2009). One of the business owners explained that, "The [LED] lamp saves money for me because I charge it once and use for three days, and if [I were still using] kerosene I would purchase [kerosene] every day. It is brighter than the kerosene lamp" (Johnstone, 2009).

The Lumina Project proves that business owners were willing to invest when shown the product and were able to witness its effects. In Figure 5, an LED lamp lights the left kiosk, while a kerosene lamp lights the kiosk on the right. The LED lamp provides a much brighter and more efficient light.

FIGURE 5. A MARKET STAND IN KENYA ILLUMINATED BY AN LED LAMP (JOHNSTONE, 2009).

Lesson #3: In a study in Malawi, community participation yielded many benefits, including the creation of jobs, the formation of trust, and the decreased use of a dangerous light source. If the community understands the benefits of the light source, they are more likely to use it.

In another project conducted in Malawi, LED lanterns were sold to rural villagers. This project aimed to train villagers to become vendors of LED lanterns. Villagers were taught how to set a price for products, how to market the lanterns to potential customers, and how to draw up contracts (Adkins, 2010). This project implemented participatory research and community participation to maximize the benefits. Before beginning work with the village, a meeting was conducted with the village chiefs to inform them about the project. Then, group meetings were held with various men and women of the village to discuss lighting issues and preferences of purchase. They also reviewed charts explaining the cost of LED lanterns compared to kerosene lanterns and performed lighting tests with the LED lanterns. Some of the benefits of the community participation include community members were more willing to sell and purchase lanterns, the community was educated about the benefits and technical features of the LED lanterns, and most importantly, the community perceived the lanterns and vendors as trustworthy. After the LED lanterns were sold, the use of kerosene and other inefficient lighting sources decreased significantly. Figure 6 shows that the percentage of households using

kerosene decreased from almost 100 percent to 30 percent just weeks after the implementation of this program.

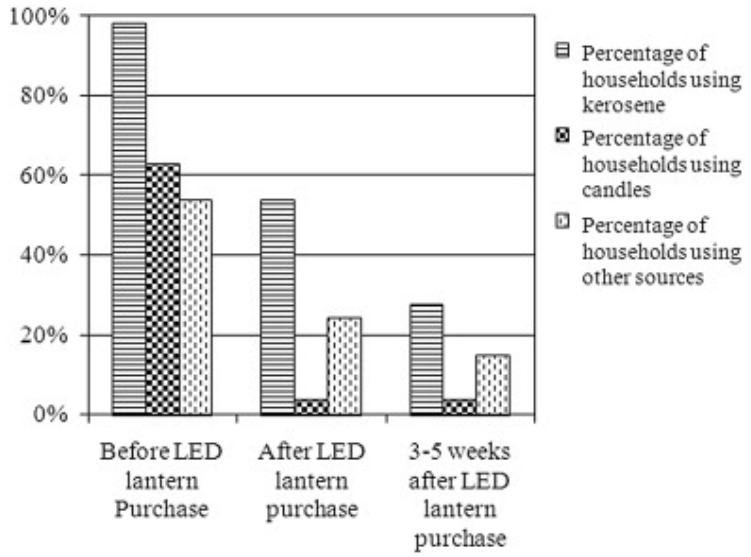

FIGURE 6. PERCENTAGES OF LIGHT SOURCES USED BY HOUSEHOLDS DURING THE LED PURCHASE PROCESS (ADKINS, 2010).

By involving the community and creating salespersons from the village, residents were more likely to buy lanterns because they knew they were coming from a reliable source.

Lesson #4: Teaching communities about fire safety and methods to prevent fires can reduce fire risk. It is helpful to teach the community safer ways to use candles. However, these programs need to be more widely implemented throughout the community as well as throughout different age groups to be more effective.

Based in South Africa, the Safer Candle Project by Childsafe aims to reduce fires in informal settlements. The "Safer Candle" is simply a glass jar with sand in the bottom that the candle is placed in. The goal of this project was to make candle protection simple and inexpensive for families. Demonstrations of how the safer candle prevents fires are given in waiting rooms at the Red Cross Children's Hospital in Cape Town (Childsafe, 2015).

In South Africa, the government has implemented a Learn Not to Burn Preschool Programme because of the vast number of children that die from burn-related injuries. The Learn Not to Burn Programme is based on a similar program from the National Fire Protection Association based in the United States. This program teaches preschool aged children fire safety awareness and skills. They are taught not to play with matches,

lighters, and paraffin, and how to escape a burning building as well as many other fire safety tips. This program has been evaluated and proven to be effective in reducing burns on preschool aged children (NFPA, 2013).

2.6 SUMMARY

Informal settlements exist throughout the world, including in Namibia. Candles and improper paraffin lamps are dangerous and prevalent lighting sources within informal settlements, including Katutura. These lighting sources often lead to shack fires, demonstrating a need for an alternative light source and fire safety awareness. Men on the Side of the Road (MSR) is working to overcome this problem of shack fires. Our project group worked alongside MSR, as well as the community, to gather information through participatory research.

3. METHODOLOGY

Our project used participatory methods, in collaboration with Men on the Side of the Road, to identify sustainable and cost-effective lighting options to improve fire safety in Katutura. To achieve this goal, we pursued the following objectives:

1. Identify Participatory Research Partners and Informants
2. Assess Fire Causes in Katutura
3. Test and Identify Viable Alternative Lighting Sources

3.1 IDENTIFY PARTICIPATORY RESEARCH PARTNERS AND INFORMANTS

Knowledge sought. Research partners, community members, and experts that our team could collaborate with to keep the residents at the center of the project.

Method. Our findings and final suggestions relied on participatory research and the informant's expertise. Our project team worked with:

1. **Research Partners –**Our project group worked alongside Men on the Side of the Road employees Janet Wicks, Hilya Kambanda, Tomas Shilongo and their consultant, Tessa, a student from the Polytechnic of Namibia. MSR members David Mupandeki, Makili Kilian, and Johannes Haimene acted as our contacts and sources of information in Katutura.
2. **Community Members –** These were individuals our project group interviewed during our visits to the informal settlements of Goreangab, Havana, and One Nation.

Our project team collaborated with Men on the Side of the Road, resulting in connections to MSR members within Katutura. At a monthly MSR member meeting, our project was discussed, from which four members volunteered to become our research partners. They guided us through the areas of Katutura and brought us to our community members who gave us information on their interactions with different lighting sources.

Justification. It was vital to our project to have community members as research partners because they helped us build trust within the community. Having David, Makili, and Johannes guide us through the community allowed the residents of Katutura to trust us. This trust led to residents allowing us to interview them. Makili expressed that it was vital for our group to interview residents of Katutura alongside a local because many

residents would be hesitant to communicate with us. Before our group began our interviews, our consultant and contacts were the first to greet and speak to potential interviewees. It was also important to have community participants because they are living within Katutura and are affected by the struggles with open flame light sources and the risk that these lighting sources pose.

Limitations. First, our team could not choose our contacts. We did not meet all the potential members and did not give suggestions on the qualities we considered relevant. For example, our participatory research partner Makili was not fluent in English, causing us to rely on our consultant's translation when interviewing residents and communicating with him.

Analysis. Each contact was from a different region of Katutura, allowing our team to identify a wide range of community members with different household profiles

3.2 ASSESS FIRE CAUSES IN KATUTURA

Knowledge Sought. The fire risk and causes of fire in Katutura. Assessing the causes of fires was vital to developing criteria for alternative lighting suggestions.

Method. To gather this information, our project team conducted interviews with residents of Katutura and observed the interior of their homes. The interview questions can be seen in Appendix A. We also interviewed various experts around Windhoek that had knowledge on shack fires. These experts were Damien Makgone and Abe Van Vuuren of the Windhoek Fire Brigade, Mekondjo Shanyengange of the Disaster Management Office, the Councilor of Havana Martin David, and the entrepreneur of the Namibian Solar Bottle Project, Hendrik Ehlers. These interviews were intended to gather information on the fire risk present and the causes of shack fires within Katutura. The interview questions for each can be seen in Appendix B, C, D, and E respectively.

Justification. By interviewing community members, our project group obtained first-hand knowledge of candle use in Katutura. Gathering information from stakeholders was important because they have personal experience with different lighting sources. Our project group also gathered information from the community members such as their primary lighting source, if they had been victims of shack fires, and their methods of combating the dangers of candles. With the permission of the household owner, our project team observed the interior of some residents' homes. This allowed us to visually see the fire risks that were both mentioned and unmentioned by the community members.

Interviewing members of the Windhoek Fire Brigade, employees of the Disaster Management Office, the Councilor of Havana, and Hendrik Ehlers also gave our project group information as we were able to obtain a municipality and managerial point of view on shack fires. The Windhoek Fire Brigade's database included investigations and statistics on the causes of shack fires. Damien Makgone, Station Officer of Operations at the Maxwilili Fire Station, identified common trends that firefighters had noticed through their experience. Their views on residents from an authority's point of view showed us other factors that cause shack fires and the resulting damage, such as intoxication and the inability to inform the Fire Brigade of fires. Mekondjo Shanyengange, of the Training and Information Division in the Disaster Management Office, informed us on the different fire safety programs they conduct within Katutura and the fire safety information that they spread. Martin David, the Councilor of Havana, gave a another municipality's view on shack fires and the damage they cause, as he is part of the government. Finally, Henrik Ehlers, the entrepreneur of the Namibian Solar Bottle Project, for his past efforts in reducing fire risk in Katutura. Through his project work within informal settlements Hendrik had a wealth of knowledge on economic, cultural, and logistical challenges our team could have faced during our time in Namibia. He also gave us insight on how to overcome these challenges as he had faced similar problems.

Limitations. Cultural and language barriers proved to be a limitation during every interaction with community members. Based upon our interactions with Tessa, David, Makili, and Johannes as well as the community members, it was clear that residents of Katutura had preconceived notions about our group. These notions sometimes contributed to the resident's hesitation to communicate with us. When communicating, translation proved to be a limitation as many of the interviewees spoke limited English. Our interviews were conducted through translation from our consultant, Tessa, who was able to ask our questions to the community members in the Oshiwambo language. For those community members who spoke Afrikaans, Tessa had to ask our contact David the question in Oshiwambo, who then translated questions in Afrikaans. Two main problems resulted from utilizing translators. The first challenge was that Tessa could not provide our group or the interviewee with an exact translation. The second was that Tessa's interpretation of the question on the participant's answer might not have been completely accurate. The participant's honesty may have also affected our data because it was impossible to determine the validity of their claims.

Tessa informed us that certain questions, although useful, were culturally inappropriate to ask. These questions included the interviewee's average income and

occupation. Therefore alternative ways of producing this information had to be considered. We also faced the constraint of time. Men and women in Katutura work or complete chores throughout the day, making it difficult to schedule meeting times with our research partners and interviewees. This factor also affected the sampling method used to select our interviewees. We could only interview the residents who were present in the townships when we were and those selected by our research partners, possibly causing the results to be biased.

To obtain information from households that utilized different lighting sources such as electricity and solar power, our project team expressed these interests to our contacts. Because of this, our contacts were influenced in different ways. For example, our contact David was under the impression that our group was only interested in observing shack fire sites and interviewing those who had been victims to fires and therefore only led us to shack fire locations. Makili, however, asked our team whom we needed to interview, in which case we were able to steer his efforts to contact households with solar panels and those who utilize electricity. Because our contacts led us to neighbors they thought would fit our needs, our sample was not random. Because our sample was not random, it did not give an accurate representation of the community Therefore, we did not draw conclusions based on information from the entire community, only on those we interviewed. We hypothesized that certain criteria did fit the community. Furthermore, our project group found it difficult to find and interview those who were victims of shack fires since many of the individuals had relocated or were not present at the time of interviewing. Lastly, a difficulty was that no shack fire or situation in which a shack fire occurred was the same. Each shack is unique in its own way, meaning that the fire or risk varies from household to household.

Analysis. The information from the interviews was compiled into excel documents in which patterns and discrepancies could be identified through visual representations. After analyzing the assessment of the fire risk and fire causes, our team identified possible alternative light sources.

3.3 TEST AND IDENTIFY VIABLE ALTERNATIVE LIGHTING SOURCES

Knowledge Sought. Alternative lighting sources that meet the needs of community members of Katutura.

Method. Following the development of criteria, our project group traveled to shops in China Town and local building stores to identify alternative lighting sources. Our project

team was able to test and assess five small-scale solar options in two ways. The first was in direct sunlight. The second utilized Hendrik Ehlers' mobile shack that accurately simulated conditions of a shack in Katutura. The solar options are as follow:

1. Solar Battery Hybrid
2. Solar Energy Kit
3. LED w/ panel
4. Garden Light
5. Solar Winding Hybrid

Our project team identified community members that volunteered to pilot test our other two solar options, the Pharox Anti-theft Solar Roof Light and the Uyelele Solar Bottle. One community member tested the Pharox light and two tested the solar bottle. Feedback from the pilot testers, the MSR community meeting, and our own findings were compiled in an excel document to compare them to each other as well as with candles and paraffin lamps. Our team analyzed this information to determine various household profiles and the most viable options for each one.

Justification. A set list of criteria allowed our project group to accurately assess how viable any suggestion or alternative was according to its target audience. For example, an alternative lighting source that is very cheap, easy to install, but only works during the day may have been a strong option for a single mother whose children often stay behind in the household and need light while kept inside the shack. This option may not be of use to a single person who is rarely home during the daylight hours and does not require an extra light source to see inside his or her shack. This is also the reason for the development of several alternatives, which could ultimately address the issue of shack fires across several sub-groups of informal settlement households. The purpose of testing and pilot testing was to continue to evaluate alternatives based on the criteria. Testing in the mobile shack supplied us with the information needed to understand strengths and weaknesses as well as determine which options are the most viable. Pilot testing resulted in equally important information directly from the community members. Feedback from the pilot tester was considered the most accurate information we could obtain. This is also true for the community discussions that our project team took part in. Despite our knowledge of Katutura and its inhabitants we could never accurately gauge their opinions on certain alternatives that we suggested. By using participatory research in this sense, our project group avoided a situation in which time was wasted on an alternative that community members did not feel confident supporting. This strategy also allowed our

team to receive feedback on suggestions, increasing the valuable information we collected.

Limitations. The limitations of language barriers, translations, and response bias are the same as in section 3.2. Further limitations were that our team had only three pilot testers that were all volunteers and not a random sample. Because of this we did not receive a large amount of first hand data back from the community members based on their different economic status, household, and lifestyle. Therefore commonalities or discrepancies were harder to identify and less reliable for making generalizations. Small showings at the community discussion also hindered our project team's information gathering. For an area as large as Katutura, a large amount of data is needed in order to better understand the overall tendencies of support or dislikes in respect to alternatives, but getting a large amount of data proved to be difficult.

Analysis. From this evidence we identified the most viable option for different household profiles within Katutura, such as a single mother with children compared to a single man. This information was crucial to the success and implementation of alternatives because the appropriate option must be paired with the appropriate household in order to help improve lighting and decrease the risk of fire in Katutura.

4. FINDINGS & ANALYSIS

Through participatory research methods, interviews, and experimentation, our project team identified viable alternative lighting options that reduced the fire risk compared to open flame light sources in informal settlements within Katutura. This chapter presents the benefits and limitations of our findings on, as well as the limitations in the development of, these alternative lighting options. Also included is our team's analysis of feedback from potential users, pilot testers, and current users of several alternative lighting options. This chapter is divided into three parts:

1. Fire Risk in Katutura
2. Fire Safety Awareness in Katutura
3. Testing of Alternative Lighting Options

FIRE RISK IN KATUTURA

Finding #1. **Candles are the most prevalent lighting source in the informal settlements of Katutura and are a primary cause of shack fires.**

Summary of Evidence. Interviews and observations conducted with 50 residents of Katutura, three employees of the Disaster Management Office, and two officers the Windhoek Fire Brigade revealed the following information:

1. Out of the 50 households and 18 MSR members our team interviewed, 45 currently use candles as a light source. See Figure 7. Note that out of the 68 interviewees, 66% use only candles. Another 16% use paraffin lamps, either proper or makeshift, and 9% do not use an open flame light source.
2. Only 2 out of the 50 households have never used candles.
3. From July 2014 to March 2015 there was 1 fire per 900 people in informal dwellings compared to 1 fire per 3800 people in formal dwellings.
4. Fires in informal settlements in Windhoek have increased in the past 3 years (2012, 2013, 2014).
5. Candles are the primary cause of shack fires.

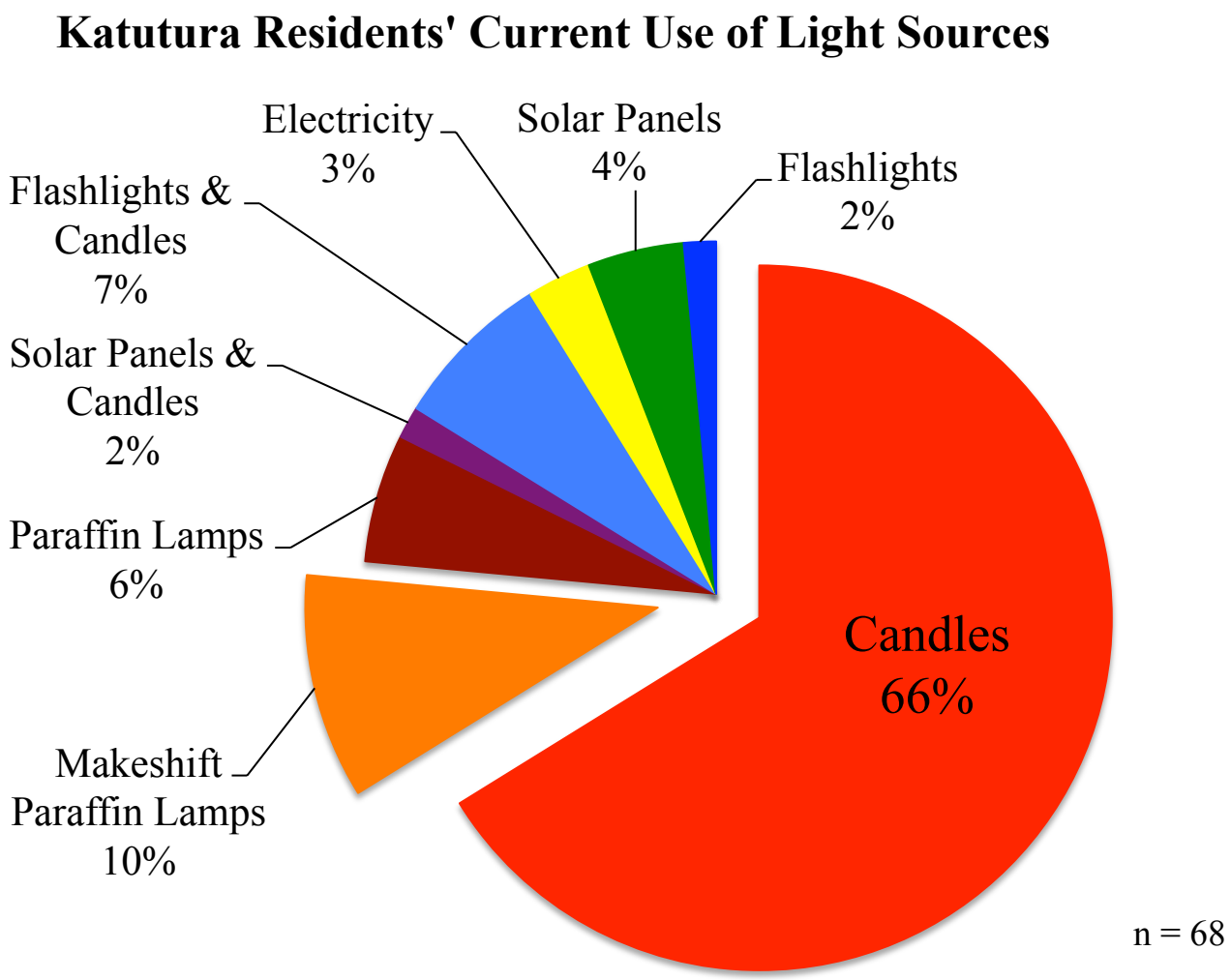

FIGURE 7. THE USE OF LIGHT SOURCES BY RESIDENTS OF KATUTURA

Explanation. Residents of Katutura use candles because of their low-cost and convenience. Upon purchase, candles are the least expensive lighting source. They are also the most accessible. Candles are sold at small shops within the informal settlements as well as in grocery and building supply stores. Another benefit of candles is that if they are stolen, misplaced, or broken; it is not financially devastating. They are a consumable product and there is no initial investment associated with their use. Makeshift paraffin lamps are similar to candles because they are also dangerous open flame light sources.

Open flame light sources are the primary causes of shack fires within Katutura. Of the six shack fire victims we interviewed, candles caused four of the fires. Mekondjo Shanyengange, an employee of the Disaster Management Office, explained that candles are the main cause of fires stating, “Until everyone has proper housing there will always

be problems, but we must do something…it is a sad situation when people are losing their lives for a little light…" Station Officer of Operations, Damian Makgone, of the Windhoek Fire Brigade explained that, in his opinion, candles are the primary source of shack fires. According to the Annual Statistics Report by the Windhoek Fire Brigade, candles are the most frequent determined cause of shack fires. See Figure 8. Causes are typically reported to the fire brigade by the victims themselves or neighbors who witnessed the fire. Although a large amount of fire causes are undetermined, the most determined cause is candles.

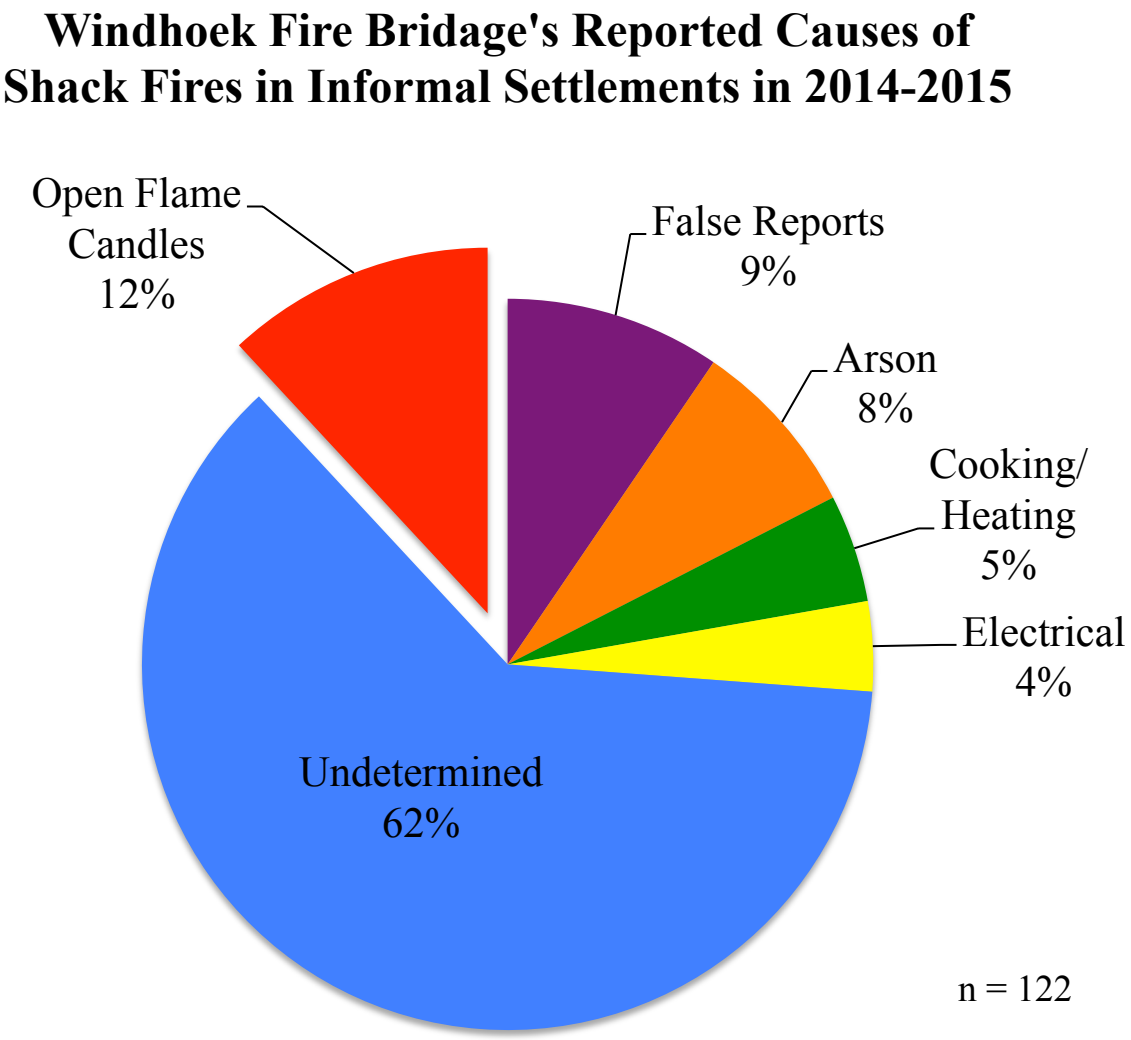

FIGURE 8. FIRE CAUSES FROM INVESTIGATIONS CONDUCTED BY THE CITY OF WINDHOEK EMERGENCY MANAGEMENT DIVISION (WINDHOEK FIRE BRIGADE, 2015).

Of Windhoek's population of 326,858, roughly a third live in informal settlements (Namibia's Statistics Agency, 2011). From July 2014 to March 2015, there was 1 fire per 900 people in informal settlements compared to the 1 fire per 3800 people in formal dwellings of Windhoek. Informal dwellings had a total of 122 fires compared to 57 formal dwelling fires. Katutura contains a majority of the informal dwellings in Windhoek.

Fires have continued to increase within informal settlements through the last 3 years. See Figure 9. A possible explanation for the apparent trend of Figure 9 is that fire risk in informal housing is continuing to grow as the informal settlement populations grow. The population in Katutura increases as more people migrate from the North to find employment. The population increased from 233,529 in 2001 to 325,858 in 2011. Typically, people who migrate from the North use candles as a light source because they are looking for employment and are financially unstable.

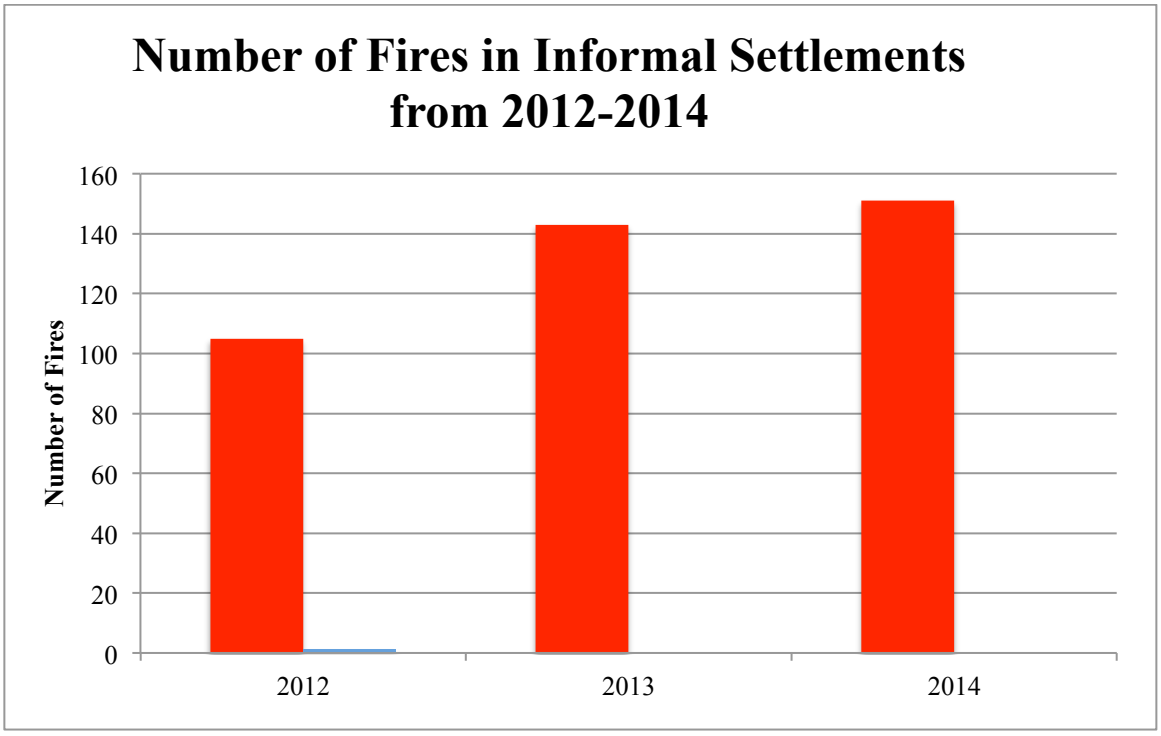

FIGURE 9. COMPARISON OF INFORMAL STRUCTURE FIRES DURING THE YEARS OF 2012, 2013, AND 2014 (WINDHOEK FIRE BRIGADE, 2015).

Analysis. After gathering opinions from experts and interviewing the residents of Katutura, there is evidence to support the hypothesis that candles are the primary cause of shack fires. These findings reveal that there is a need in Katutura for safer candle use or alternative light sources.

Finding #2. **Contributing factors that increase fire risk in Katutura's informal settlements include:**

1. **Improper candleholders**
2. **Improper paraffin lamps**
3. **Unsupervised children**
4. **Forgetfulness**
5. **Intoxication**
6. **Clutter**

Summary of Evidence. After interviewing 50 residents in Katutura, two employees of the Windhoek Fire Brigade and three employees of the Disaster Management Office, we found that the following six compounding factors contribute to the occurrence of shack fires.

1. Residents who use candles utilize improper candleholders.
2. Residents who use "improper paraffin lamps" composed of an alcohol bottle, paraffin and a wick.
3. Unattended children who either play with flame based sources or use them improperly for light.
4. Intoxicated residents who are at risk of knocking over, mishandling, and forgetting about a lit candle.
5. Residents who forget to extinguish a lit candle before leaving their shacks or going to bed.
6. The shacks can be compact and contain residents' personal belongings in a small area. With limited space, the shacks are cluttered with those personal belongings and present a fire risk. Residents also use flammable, cloth curtains to separate rooms or for decoration in their shacks.

Explanation. When factors including improper candleholders, improper paraffin lamps, unsupervised children, intoxication, forgetfulness, and clutter are combined with candle use, they can attribute to shack fires. Residents often use what is most available to them to hold candles. These devices include wine bottles, beer bottles, tin cans and cups with sand. These makeshift candleholders are unstable and can be easily knocked over. They also do not protect the flame from the materials in the shack, adding to the fire risk.

Residents also utilize makeshift paraffin lamps, but may have the misconception that they are a safer alternative to candles. Residents using these lamps claimed that they

made the switch from candles to these lamps because they thought candles were more dangerous. An example of a makeshift paraffin lamp is shown in Figure 4 in the background chapter. These lamps are usually composed of a liquor bottle, paraffin, and a wick. These makeshift lamps have a liquid fuel source and an unprotected flame. If the lamp accidently falls, it can create a disastrous fire.

Children, on occasion, are left at home when the parents go to work or have to leave the shack. The children can light candles to see in the dark or play with them, sometimes leaving them unattended or accidently dropping them. Children who are locked in shacks are at risk of injury or death if a fire occurs and they are unable to escape. Of the six shack fire victims we interviewed, two informed us that their children caused the fire while their parents were absent from the residence.

Forgetfulness, when combined with candle use, is a fire risk. Community members will either leave their home or fall asleep without extinguishing the flame. A victim our project group interviewed explained that he left the candle burning when he left to collect water. When he returned, he was shocked that his home had burned to the ground. The mentality that it is safe to leave for a short period of time or take a brief nap while a candle is left unattended is detrimental. Officer Makgone of the Windhoek Fire Brigade expressed that in his experiences, forgetting to extinguish a candle is a common occurrence. Makgone stated “the bodies are most often found by the door because the inhabitants cannot find the exit by the time they are aware there is a fire.”

Intoxication combined with candle use can have equally deleterious consequences. Officer Makgone, as well as Mekondjo of the DMO, explained that many fires occur when inebriated residents forget to extinguish their candle before bed. Inebriated residents also have a larger risk of mishandling the candle.

Finally, shacks in Katutura range in size, but are often over-filled with the residents' personal belongings. The clutter poses a fire risk because if a candle were to fall, it could easily ignite the belongings and cause a fire. The clutter also decreases the residents’ mobility in their home, increasing the chances for the residents to trip with a lit candle. These residents also use flammable cloth curtains to separate rooms or for decoration in their shacks. One victim informed us that when the flame of a candle came into contact with a curtain, it caused a shack fire that burned her home. The residents practice unsafe fire safety by not using weights to hold down the curtains for stability. Figure 10 shows the inside of two shacks in Katutura. On the left, curtains are used to separate rooms. On the right, curtains are used to decorate the walls.

FIGURE 10. TWO SHACKS, ONE THAT USES CURTAINS TO SEPARATE ROOMS (LEFT) AND ONE THAT USES CURTAINS FOR DECORATION (RIGHT)

Analysis: Although Katutura's residents may be aware of the fire risks associated with candles, some may be unaware of how compounding factors combined with candles can increase fire risk. Some of Katutura's community members are unaware of cost-effective alternative lighting options. Many alternatives are dismissed because residents believe that alternatives to candles are too expensive. In addition, men and women will often spend the day looking for work or completing chores, limiting their time to find newer and more cost-effective alternatives.

FIRE SAFETY AWARENESS IN KATUTURA

Finding #3. **Fire safety and awareness information may not being effectively conveyed to the communities of Katutura. The Disaster Management Office (DMO) conduct fire safety and awareness programs in Katutura, but not one of the 68 community members we asked were aware of the office. The DMO thought it**

beneficial to collaborate between their program and other community organizations.

Summary of Evidence. Our project team found that the need for a change goes beyond the community members because the Disaster Management Office and Emergency Services also focus on fire risk reduction. During an interview with Mekondjo Shanyengange of the Training and Information Division of the DMO, we learned that their office and Emergency Services conduct programs twice a month to spread knowledge on fires, floods, and other potential disasters. To spread this information to the greatest number of residents possible, these programs are conducted around Windhoek at locations that are frequented by large numbers of people. The DMO believes they are getting the safety information across to the public, however, when asking our interviewees about the office, none had heard of the DMO and the information they are spreading. Based on the information obtained from interviews, the DMO may be spreading information mostly to those who want it, and not those who need it.

Explanation. The Disaster Management Office and Emergency Services can only accomplish so much as they are limited in number and funding. When our team presented our project to the DMO and what we aimed to do, they eagerly wanted to join forces. This could be because MSR has connections with the communities of Katutura and over 1000 members.

Based on the program our team attended, the DMO and Emergency Services appears to lack proper methods of passing fire safety information to the residents whom truly need it. Very few people attended this meeting and none of those people had previously heard of the DMO. With few attending, we can hypothesize that the information spread by the DMO and Emergency Services may not be properly distributed to the correct household profiles. These claims are based on one program and may not accurately represent the organizations' efforts.

The Disaster Management Office also expressed interest in pairing with Hendrik Ehlers of the Solar Bottle Project. The DMO saw the Solar Bottle as a viable option to reduce any use of candles during the day, thus getting candles and matches out of the hands of children. They, however, need an installation guide for community members.

Analysis. It was critical we identified other organizations trying to reduce fire risk in Katutura because it gave our team, the Disaster Management Office, and Emergency Services different sets of ideas. To further help the implementation of the solar water

bottle, we designed an installation guide that can be distributed at the bi-monthly Disaster Management programs, as well as at the monthly MSR meeting. This allows the DMO to quickly and easily spread information about the solar water bottle project and other fire safety information. See Appendix H.

TESTING OF ALTERNATIVE LIGHT OPTIONS

Finding #4. **Multiple lighting options are necessary to fit the needs of the various households in Katutura, which vary in income, the presence of children, and ability to invest in alternative options.**

Summary of Evidence. When speaking on the issues and limitations for different households, the general manager of Men on the Side of the Road, Hilya Kambanda, stated, “One size does not fit all.” This view has been supported by the 50 interviews conducted, input of community members, and discussion with MSR members.

Explanation. Household income is the most important factor that affects the choice of an alternative light source. A household consisting of a single parent is limited to the amount of income earned by that individual. With kids to take care of, and only one source of income, the parent may not be able to afford more expensive alternatives such as solar panels. Compared to a single parent household, a single male or female household may allocate less income towards necessities for a family. Assuming that this single individual works a regular job, they may have the opportunity to invest in more expensive lighting options.

Not only do children affect the household’s ability to invest in alternative lighting options, but also they are an important consideration when choosing one. Based on our research and interviews, children are the cause of some shack fires. Therefore a household with children should invest in a light source that eliminates all flamed-based light sources and is child-friendly.

The last problem is community members' willingness or ability to invest in more expensive alternative lighting sources. In some cases a household’s income does not allow for saving whether it be because of necessary expenses or a lack of work. However, Hilya, the general manager of Men on the Side of the Road and the instructor of money management skills training mentioned, “residents do not think to save". They receive their pay and spend it, without the mentality to allocate their money towards more important aspects of their lives. Residents in Katutra often migrate from the north in

hopes of finding employment and expect to stay only a few years. Therefore, they may not consider investing in alternative lighting options. According to our 50 interviews with residents, the average residency time was approximately nine years.

Analysis. There are multiple profiles of households within Katutura. These households have varying situations that contribute to the need for multiple alternative light sources in order to reduce the fire risk within Katutura.

Finding #5. **Small-scale solar panels and lights purchased from stores within Katutura can eliminate candle use when charged directly by sunlight. These panels and lights can also be charged inside a shack with a solar water bottle light, but charging is less efficient and will only reduce, not replace, the use of candles and paraffin lamps.**

Summary of Evidence. Our project team tested five solar options and pilot tested two options that can be seen in Appendix I. When solar testing each light our team placed the solar panels in direct sunlight. When charged by sunlight, all but one solar option exceeded community members' need for light quality and duration. The solar panels were also tested against a 4-year-old solar water bottle within a mobile shack. To ensure that the age of the bottle did not affect solar charging capabilities the panels were also tested against a brand new solar water bottle in a simulated shack. Charged by a solar bottle, none of the solar options met the needs of the community members. However, two of the three pilot test households eliminated their use of candles following the installation of an alternative light source.

Explanation. Figure 11 shows the length of time each solar option lasted after being charged for 420 minutes, excluding the Pharox anti-theft solar roof light and the solar water bottle. A lighting source was considered expended when everyday actions such as navigating through a room, reading, and writing could not be performed effectively. During our interviews, the longest time period in which community members used candles on an everyday basis was four hours, or 240 minutes. Four out of the five solar options, including the solar energy kit, LED light with panel, garden light, and solar-winding hybrid light lasted longer than 240 minutes when charged in the sunlight. The solar-battery hybrid light lasted 30 minutes. When charged with the 4-year-old bottle the length of time each solar option lasted decreased dramatically. The solar battery hybrid, solar energy kit, LED light with panel, and garden light all lasted less than 1/10 the time compared to its daylight performance. The solar-winding hybrid light lasted

approximately 1/4 of the time compared to the daylight charge. Using a new solar water bottle did not increase performances.

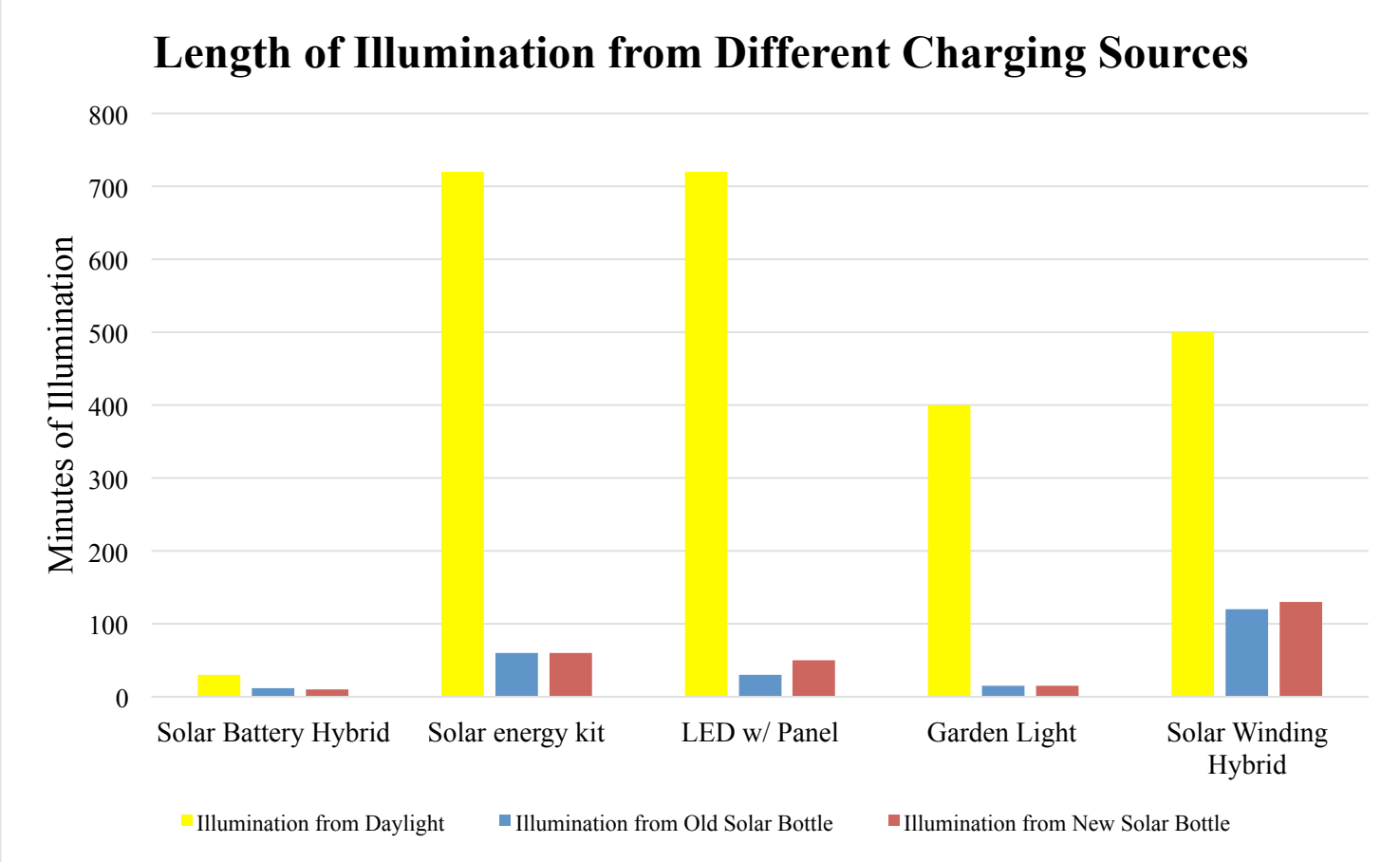

FIGURE 11. THE LENGTH OF ILLUMINATION FROM DIFFERENT CHARGING SOURCES

Figure 12 shows the overall cost of the solar options, as well as candles, over a time period of 10 months. The garden light starts off as a cheaper alternative light source at one month, but its light is limited and is used more as a flashlight. The solar-winding hybrid light and LED w/ panel, solar battery hybrid light, the solar light kit, and the Pharox anti-theft solar roof light pay off in approximately 2, 2.5, 4.5, and 6.25 months respectively. As a reference point for costs, one of the largest solar panels we observed within Katutura was 80 watts and was used to power lights, radios, and a television. This costs approximately N$1000 and takes around 18 months to pay off compared to using candles for four hours a night.

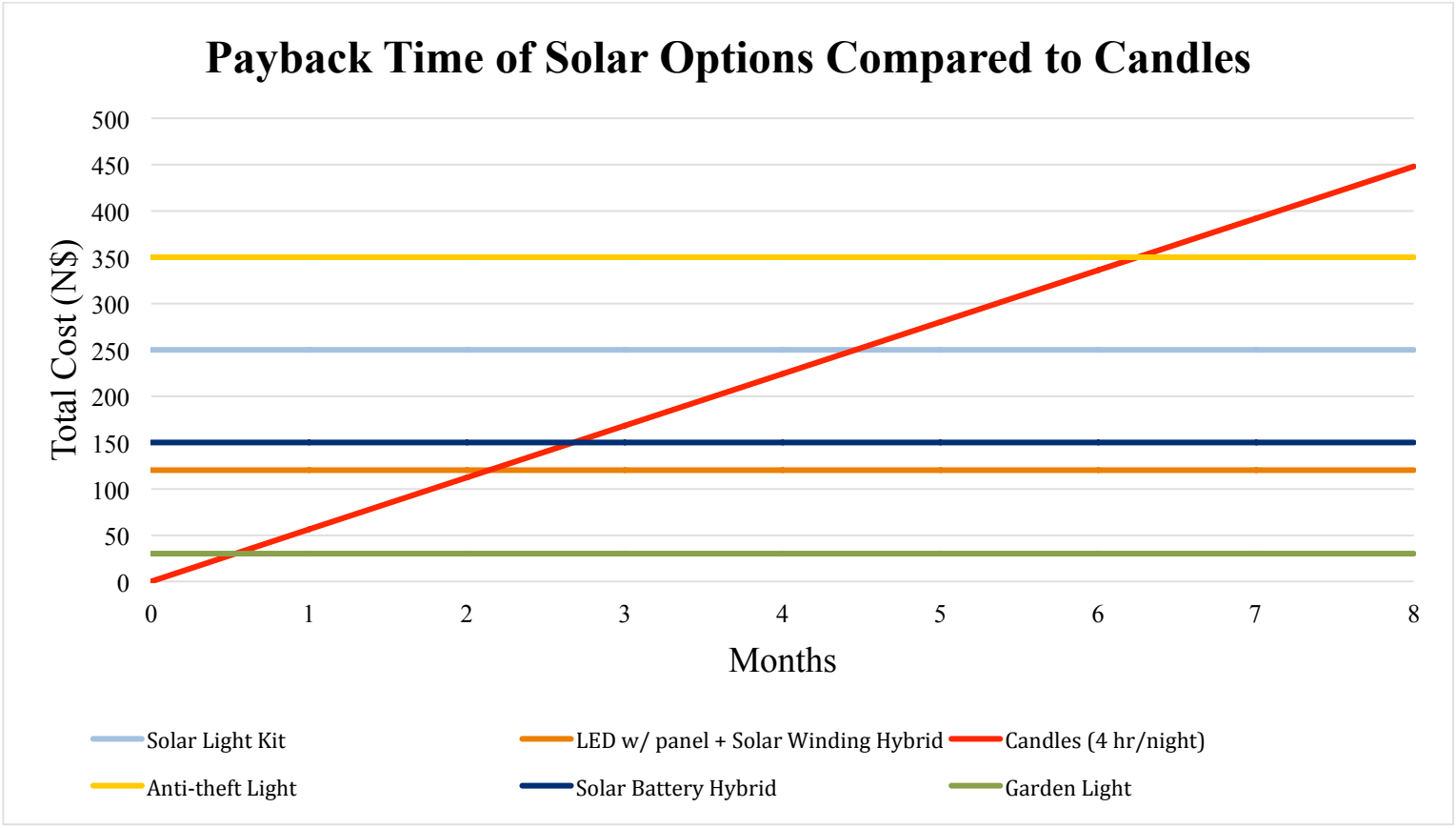

FIGURE 12. PAYBACK TIME OF SOLAR OPTIONS COMPARED TO CANDLES

The Pharox Anti-Theft Solar Roof Light could not be tested under the solar bottle because, similar to the solar bottle, it too requires installation on the roof and therefore acquires its charge directly from the sun. Because we could not test this option by charging via the solar bottle, our team had to develop another way to test this alternative. Our team decided to pilot test this option by installing it in a shack in One Nation. Information on the packaging of the light claimed that a full day charge under the sun would enable the battery approximately 5-6 hours of use. When our team checked in with the pilot tester, we found that the residents were pleased with the light's performance. The light was installed in the bedroom section of the house that was separated by plywood walls and a curtain door so it remained dark during daylight and nighttime hours. The residents explained that on a sunny day there were no problems using the light sporadically throughout the day and night.

Previous to the installation of the anti-theft roof light the household used a small battery powered light bulb in the separate bedroom, but still relied on candles to illuminate the rest of the residence. Following the installation the family stated that they

had completely stopped using candles as they now used the small light for the rest of their house. It is important to note that in households with separate rooms, multiple solar lights would be needed to eliminate the use of candles for the entire residence.

The solar water bottle was pilot tested in two households, one in One Nation and one in Goreangab. The pilot tester in One Nation, a single male, reported that the solar water bottle was convenient for light when cooking and moving around his residence, but did not reduce his candle use. Because he separated his residence into sections using curtains he showed our team that he did not need to close the door to gain privacy and therefore his shack did not get very dark during the day. He did, however, explain that he recommended it to nearby households that he knew used candles during the day because their shack was consistently dark.

The second pilot tester, a single mother with 2 children, found the solar water bottler very useful during the day. This residence did not have separate rooms within the shack and could not close the door for privacy without having to use a light source to see. More importantly, the mother explained that for the past week and a half she had not used candles, stating that the moon had created enough light through the solar bottle for the family to see at night. Lastly, she mentioned that the solar bottle was much safer than using candles, especially when children were present and unsupervised.

Analysis. All of the solar options, excluding the solar-battery hybrid, are viable light sources for the community members of Katutura. Each, assuming that they are charged by daylight for at least 7 hours, provide more than enough light for one night's average use of 4 hours. According to two of the three pilot testers, the solar water bottle and the Pharox Anti-Theft Roof Light can reduce or eliminate candle use based on daily weather or household size. Based on these tests, we created the following criteria to assess each solar option:

1. Cost – Will be based on what the resident can afford. There are different classes of people in Katutura that can afford different alternatives.
2. Light Duration – Should be able to sustain its light for the length of at least a candle to completely eliminate the use of candles.
3. Light Quality – Although it is up to personal preference, the base light quality our team identified was that of a candle.
4. Safety – Must be safer than candles to help reduce the risk of fire within households.

Finding #6. **Battery powered devices can reduce or eliminate the risk of fire from open flame lighting sources.**

Summary of Evidence. Our team investigated the use of 12 Volt car batteries as a lighting source as well as flashlights and the solar battery powered lanterns. Because these alternatives do not use a flame for a light source, and are generally reliable, battery powered devices are a much safer alternative to candles. Although car batteries are not a cost effective option, flashlights and battery-powered lanterns can be cost effective after one month and three months respectively.

Explanation. Standard car batteries can power a 12 Volt light, or can connect to an inverter to power normal 220-volt light bulbs and appliances. However, these batteries cannot continuously be discharged and recharged before the batteries fail to hold the necessary voltage. Deep cycle batteries, most often used in large trucks or marine engines, can be discharged and recharged multiple times, but similar to the car batteries, will lose efficiency over time. As a result, using one battery for a long period of time requires a large upfront investment to purchase, and it is recommended that the battery be connected to a recharging source each day, much like an alternator in a car. This can be either a trickling system that requires electricity to operate, or a solar panel. If a solar panel is used, then the car battery serves the same purpose as batteries that are sold with the solar panels. Using car battery costs more than using the batteries sold with the solar panels.

Other battery options include flashlights and battery powered lanterns. Figure 13 shows the pay off period for both options according to candle use of three, four, and five hours per night. A flashlight, with the initial investment of N$50 and the additional investment of N$32 per month for batteries, pays off in less than one month, one month, and three months according to three, four, and five hours of candle use, respectively. The solar-battery hybrid light, powered by three AA batteries, pays off in three and a half and 14 months according to five and four hours of candle use respectively. This option does not pay off at 3 hours of candle use.

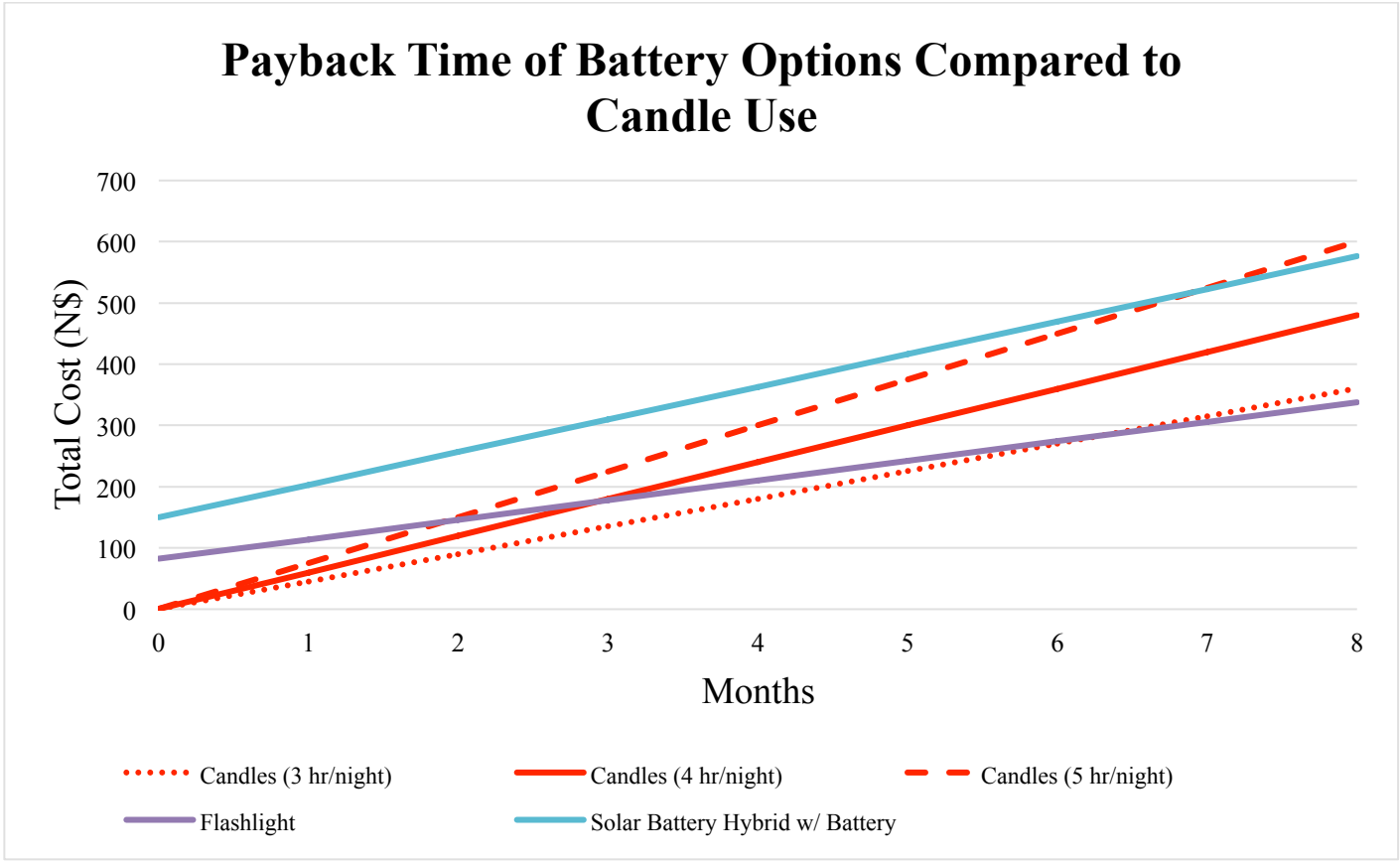

FIGURE 13. PAYBACK TIME OF BATTERY LIGHT SOURCES COMPARED TO CANDLES

Analysis. Because car batteries are not sustainable without a charging source each day, require a large upfront investment, and are not as cost effective as batteries sold with solar panels they are not a viable lighting source. Flashlights are very cost effective, paying off within three months for the least amount of candle use, but do not illuminate an entire household. Lastly, battery powered lanterns such as the solar-battery hybrid light, require a large upfront cost and will realistically not pay off before the lantern stops operating. These do however provide a bright light in all directions and are easily portable. Criteria for these alternatives are the same as that of solar panel alternatives and can be seen in the Analysis section of Finding 5.

Finding #7. **According to residents, closed paraffin lamps are cost effective and may be safer than candles.**

Summary of Evidence. Currently, over three fifths of the 68 residents our team talked to use candles as a lighting source. Although residents view candles as the primary ignition source for shack fires, they still continue to use them for light. Over 15% of residents we talked to use paraffin lamps as a lighting source, arguing that they are safer than candles.

Our team then looked into the cost effectiveness of both options, and found that our specific paraffin lamp, a N$30 lamp with a ½" wick, pays for itself in approximately one month. This was both the cheapest lamp and the smallest wick that we could find. We wanted to identify an affordable option that produced a slower burn rate compared to a 1" wick that most paraffin users own.

Explanation. Residents see the danger that coincides with candles but few act to mitigate the risk present in their home. When asked why they have not made the switch to a safer alternative such as proper paraffin lamps, many responded that alternatives were too expensive. After completing a cost analysis of candles compared to paraffin, our team learned that even by purchasing an inexpensive closed lamp, paraffin can begin to save money after about a month. The cost analysis was performed using the following factors and can be seen in Figure 14.

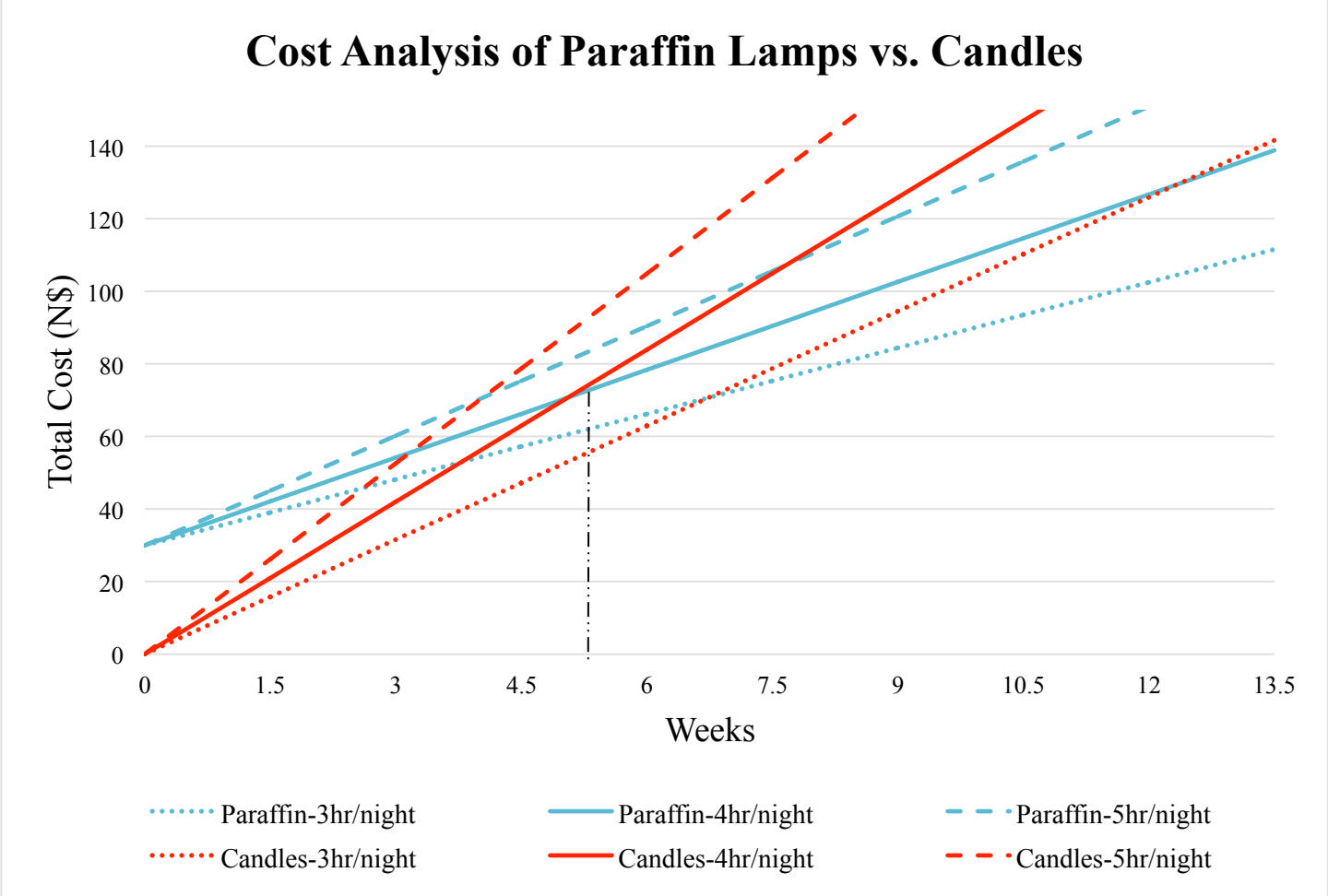

FIGURE 14. COST ANALYSIS BETWEEN PARAFFIN LAMPS AND CANDLES

1. Through interviews, our team discovered that community members use light between three and five hours per night. For this cost analysis, we used three, four, and five hours per night as constants to produce different scenarios for different usage.
2. A typical candle life averages just over seven hours. Using three hours per night as a minimum time, we found that a household uses about three candles per week. Utilizing three candles a week and at a minimum cost of N$3.50, we found that there is a baseline cost of N$15.75 for candles per week and a half. Using four hours per night as an average time, we found that a home would use about four candles per week. Multiplying four candles by the minimum cost, we found that there is a baseline cost of N$21.00 for candles per week and a half. Finally, using five hours per night as a maximum time, we found that a home would use roughly five candles per week. Multiplying five candles by the minimum cost we found a candle to be, we found there to be a baseline cost of N$26.25 for candles per week.
3. A paraffin lamp with a ½'' inch wick was purchased for N$30 at Build-It, a local building store. Residents who use paraffin purchase a liter of paraffin fuel for N$15 within their communities. After completing tests with the ½'' wide wick-paraffin lamp our team purchased, we found that 250mL of paraffin would take about 13 hours to burn out, or 19.2mL/hr. At three hours a night, residents would burn approximately 57.6mL per night, or N$9.10 for a week and a half of use. At four hours a night, residents would burn approximately 76.8mL per night, or N$12.10 for a week and a half of use. Finally, at five hours a night, residents would burn approximately 96mL per night, or N$15.10 for a week and a half of use.

   A full liter would then burn for about 52 hour. At three hours a night a liter of paraffin would last about 17 days, at four hours a night a liter of paraffin would last about 13 days, and at five hours a night a liter of paraffin would last about 10.5 days.
4. We then began to compare candles with different usages of paraffin based on a week and a half time scale, because that is the length of time a liter of paraffin burns at an average of 4 hours of use per night. Through one and a half weeks, candles prove to be the cheaper option at 3, 4, and 5 hours of usage, mainly because there is the initial investment on the paraffin lamp.
5. After four and a half weeks, paraffin shows itself to be cheaper when using the fuel for five hours a night. Paraffin takes about five weeks to pay itself off when

using the fuel for 4 hours a night, and takes about seven weeks to pay itself off when using the fuel for 3 hours a night.

Analysis. With residents believing that paraffin is safer and our cost analysis showing that paraffin pays itself off after about a month, we have found that a closed paraffin lamp has proven itself to be a more efficient option compared to candles. Using a closed paraffin lamp will reduce fire risk, as curtains cannot blow into the flame. A paraffin lamp could also enable residents to possibly save and eventually invest in a solar panel, thus completely eliminating the use of fire for lighting.

5. CONCLUSIONS & RECOMMENDATIONS

Our team conducted over 50 household interviews within 3 different informal settlements, took part in two community discussions and tested 6 alternative lighting sources and techniques in order to reduce the risk of fire within Katutura, Namibia. We developed the following 7 findings:

Finding #1. **Candles are the most prevalent lighting source in the informal settlements of Katutura and are a primary cause of shack fires.**

Through interviews, we found that 66% of the residents used only candles. Interviews with the community and officers of the Windhoek fire brigade revealed that, in their opinions, candles were the main cause of shack fires.

Finding #2. **Contributing factors that increase fire risk in Katutura's informal settlements include:**

1. **Improper candleholders**
2. **Improper paraffin lamps**
3. **Unsupervised children**
4. **Forgetfulness**
5. **Intoxication**
6. **Clutter**

Although residents recognize the dangers of candles, residents may be unaware of factors that contribute to fire risk.

Finding #3. **Fire safety and awareness information may not being effectively conveyed to the communities of Katutura. The Disaster Management Office (DMO) conduct fire safety and awareness programs in Katutura, but not one of the 68 community members we asked were aware of the office. The DMO thought it beneficial to collaborate between their program and other community organizations.**

The community is unaware of programs conducted by the DMO that contain important information about fire safety techniques and awareness.

Finding #4. **Multiple lighting options are necessary to fit the needs of the various households in Katutura, which vary in income, the presence of children, and ability to invest in alternative options.**

Income, the presence of children, and the willingness or ability to invest in alternatives affect which alternative will be most beneficial to the household.

Finding #5. **Small-scale solar panels and lights purchased from stores within Katutura can eliminate candle use when charged directly by sunlight. These panels and lights can also be charged inside a shack with a solar water bottle light, but charging is less efficient and will only reduce, not replace, the use of candles and paraffin lamps.**

Four of the 5 small-scale solar panels and lights tested were effective alternatives for residents of Katutura. These alternatives were tested on four criteria including cost, light duration, light quality, and safety.

Finding #6. **Battery powered devices can reduce or eliminate the risk of fire from open flame lighting sources.**

Car batteries are not an effective power source for lights, but flashlights are a cost-efficient option and have a payback period of approximately one month compared to candles.

Finding #7. **According to residents, closed paraffin lamps are cost effective and may be safer than candles.**

Closed paraffin lamps are cost-efficient and reduce the fire risk compared to candles.

RECOMMENDATIONS

After compiling our findings we made 4 recommendations that are organized into the following two categories:

1. Techniques to Reduce Fire Risk through Alternative Lighting Sources
2. Proposed Future WPI Projects

This chapter also includes a section on program design principles that we have learned through our project.

***Recommendation #1*. The organizations Men on the Side of the Road, the Disaster Management Office, and the Windhoek Fire Brigade spread the knowledge of alternative lighting sources including solar options, battery options, and paraffin lamps as well as improved candle safety.**

Explanation. The alternative lighting sources include:

1. Small solar lighting devices under 5 Watts
2. Uyelele Solar Bottle independently or in combination with small solar panels
3. Battery Options
4. Medium solar panels, 5 to 30 Watt
5. Large solar panels, 30 to 120 Watt
6. Proper paraffin lamps

Small Solar Options. In order to reduce, or even eliminate, fire risk from lighting sources within Katutura, the use of all flame based lighting sources must be stopped. The safest, most practical, and cost effective options are small solar lighting devices rated fewer than 5 Watts. These lights include the five solar options that our team tested, the Pharox anti-theft solar roof light, and the solar bottle. See Appendix I. The most expensive, but arguably safest investment in terms of reliability and longevity, is the Pharox anti-theft solar roof light. It is a tested and researched product unlike its counter parts from the china store, and according to its packaging, will last for five years. This product is ideal for households with at least one person working, and is convenient if the residence must be left unattended as it is permanently installed. Solar lighting devices are also recommended to households with at least one person working because of their affordability. These options are especially useful if there will be a person at the residence during the daylight hours so that the solar option can charge by sunlight but under close watch in case of attempted theft. If charged for approximately seven hours, excluding the solar battery hybrid, all of the six options last long enough to eliminate the use of candle or paraffin lamps.

Uyelele Solar Bottle. The least costly solar option is the solar bottle. This option is used to provide light inside a household during the day, but does not work at night. Therefore this option is recommend to those that use candles at any point during daylight hours because their shack remains dark. This also helps with privacy, allowing residents to

close their door now that the inside is illuminated. It is also recommended to parents that on occasion must leave their children at home. With the installation of a solar bottle, the children will not require another light source such as candles when left inside the shack. Although the solar bottle cannot eliminate the use of flame based lighting sources it does have the potential to limit it, this goes for the combination of solar panels and the solar bottle as well. In order to protect from theft a small solar panel can be attached to solar bottle inside the shack. Although the bottle and panel can charge any of the six options we tested, they do not last nearly as long as they did when charged in the sunlight. The six solar options can last anywhere from 10 to 90 minutes when charged with the solar bottle.

Battery Options. We recommend the use of battery powered flashlight or spotlights if the overall illumination of a room is not a priority. These light sources have a realistic payoff time with the longest being approximately 4 months. Battery powered lanterns are also very effective lighting sources. However, including the price of batteries many of these lanterns will not pay off when compared to using candles. If a flashlight or lantern does fit the need of a household we recommend that they have LED's, these bulbs are the most efficient and reliable. We do not recommend using a car battery or deep cycle battery independently. Instead of using a car battery we recommend that a community member invest in a solar panel and the battery that is specifically paired to it.

Medium Solar Panels. The next solar options are medium sized panels, 5 Watt to 30 Watt. Community members can expect to pay N$200 to N$500 not including a light source, which can cost N$30 to N$120 depending if it has a built in battery or not. These panels also have the capability to power other electronic devices but in a small capacity. Similar to the larger solar panels there are installation costs if the owner decides to place them permanently on the roof, but will be generally be cheaper because of the smaller size and less materials needed. These panels are best purchased by households with one or two members working consistently. These households must not have a large need to power several other electronic devices.

Large Solar Panels. Large solar panels, as seen in Figure 15 are the last solar option. Not only will solar panels like these power multiple light bulbs, but they are also able to power radios, television, and other devices. For solar panels similar to the ones shown in Figure 15, 60 Watt to 120 Watt, community members can expect to pay anywhere from N$700 to N$1300. If the solar panel is located on the roof however, according to our interviews, a theft proof installation can cost up to another N$1000. If the owner chooses

to install the panels independently, the installation cost would only be the materials he or she uses. These solar panels are best suited for households with multiple members working consistently. These panels are also appropriate for those that are interested in more than light, but powering other electronic devices. It is important to keep in mind that a battery cell may or may not be included in the price of the solar panel. If it is not, one should expect to pay anywhere from N$100 to N$700 on top of the solar panel and installation costs.

FIGURE 15. LARGE SOLAR PANELS ON THE ROOFS OF HOMES IN GOREANGAB

Lastly, we recommend that any of these techniques can be used by any of the household profiles we have identified. Although we recommend that a larger household with many residents working invest in a large solar panel, it is also perfectly appropriate for the household to invest in several of the less expensive solar options that our team tested. Because “one size does not fit all” the choices of implementing any of these options are based on personal preference.

Paraffin Lamps. For the households with no members working and cannot afford or access the alternative lighting sources listed above, we recommend that they invest in an inexpensive paraffin lamp with no larger wick than half an inch. See Figure 16. By using a smaller paraffin lamp with a smaller wick the cost of using these lamps decrease. Although the initial investment costs more than using candles, these lamps will pay off in approximately a month and are safer than open flame candles, especially if some of the residents are children.

FIGURE 16. PARAFFIN LAMP

Proper Candle Holders and Flame Guards. If a paraffin lamp is not feasible we recommend the use of a proper candleholder. An ideal candleholder would secure the candle tightly, include a base that would contain the wax and flame if burned all the way down, and is not easily knocked over. Once the candle is placed in a proper candleholder we also recommend the use of a flame guard. There are a variety of ways to do this, however the most ergonomic and friendly design is to first cut the candle in half as to decrease the area that must be covered. Then, cheap and available materials such as chicken wire are manipulated in such a way that surround the candles flame, paying

special attention that the flame guard is large enough that the flame cannot go outside the guard. If flammable materials cannot reach the flame the risk of fire is decreased.

Recommendation #2. **MSR create a new workshop regarding proper fire safety and alternative light sources. We also recommend that that the information be incorporated into their existing "Money Management" and "Life Skills" training.**

Explanation. MSR employees Hilya and Tomas currently conduct two training workshops a month. Both of these workshops are required by MSR applicants to become a member. The two workshops are "Life Skills" and "Money Management." We recommend that they include information on fire safety techniques as well as various alternative light sources in both workshops. Awareness of the feasibility of alternative light sources is important for the residents of Katutura. Many residents are aware of alternatives, but do not realize that some alternatives are affordable. For example, during the "Money Management" workshop, a section would focus on techniques to save money for safer lighting options and how to identify the best lighting options based on their budget. The "Life Skills" workshop would include fire safety techniques, awareness, and how to properly use alternative light sources. We also recommend MSR to conduct specific workshops for alternative lighting sources and fire safety. The workshop would include the information from the both the "Money Management" and "Life Skills" workshops as well as information on how to construct, use, apply and implement alternative light sources. For example, physically constructing, practicing installing, and understanding the solar bottle project would be the most efficient and beneficial workshop for community members that are interested. Construction of the water bottle can also become an employment opportunity for MSR members or other members of the community. The most effective techniques of gathering and spreading information use interactive discussions and meetings involving the community members. MSR members can spread the fire safety and alternative light source knowledge that they have gained from the workshops to the rest of the community.

Limitations. A major limitation of MSR is that it is difficult to get members to come to meetings and workshops. Workshops and meetings are not mandatory if you are a current member of MSR. Funding and time are also necessary for MSR to conduct these workshops.

Recommendation #3. **The creation of a WPI project with the Disaster Management Office to develop and improve programs to spread fire safety knowledge to community members.**

Explanation. After meeting with representatives of the Disaster Management Office (DMO), sitting in on a monthly MSR meeting, and conducting 50 interviews with community members of Katutura, it was clear that:

1. There is a lack of fire safety knowledge within Katutura.
2. Residents within Katutura do not know of the Disaster Management Office and what they do in the communities.
3. Efforts to reduce fire risks within Katutura are not being effectively conveyed to those who need it most.
4. The Disaster Management Office has great fire safety information, but do not practice effective tactics to spread this information.

The valuable fire safety information from the DMO would be beneficial to the residents of Katutura as it can help reduce fire risk and the resulting damage. The DMO holds biweekly programs for community members. When our team attended one of these programs, three other offices were present: the Department of Infrastructure, Water & Technical Services; Emergency Services; and Solid Waste Management. All four offices were trying to get their information across, presenting an overwhelming atmosphere for those who do attend. As a result, tactical techniques for spreading fire safety information are needed as the DMO lacks adequate advertising and appearance. The DMO advertises their programs through the radio and the newspapers. This leaves a large gap in awareness, as many Katutura residents do not have access to these media outlets. Therefore, we recommend the creation of a WPI project in which the students will research, identify, and develop more effective ways to spread fire safety knowledge throughout Katutura.

Limitations. This recommendation is based on a program our team attended in which we determined it would be more effective if it was implemented at other locations in Windhoek. However, we can hypothesize that other programs are conducted in a similar fashion as not one of our interviewees had heard of the DMO and only a few knew information such as the emergency services phone number.

Recommendation #4. A WPI project focusing on the continuation of testing and implementation of various alternative light sources and fire safety techniques.

Explanation. Our team identified alternatives that could be used instead of candles and other flame sources. With limited time, our team was not able to test and implement as many alternatives as we would have liked. However, further control testing and pilot testing is needed for alternative lighting options. There is still valuable information this project needs to produce and new alternatives that could permanently replace candles. More research and testing are needed to develop stronger and more viable alternatives. We recommend that there is a continuation of this project to resume the testing and implementation processes. After more alternatives have been established, control tested by the project team, and a greater number of options have been pilot tested within Katutura, a better essence of which options will succeed and which will fail will be developed. Future control and pilot testing in Katutura is necessary, as it will allow for the community members voices to be heard. This would enable the future team to effectively identify light sources that are economically and practically suitable.

Limitations. The community members chose our project during an MSR monthly meeting when they discussed problems within Katutura that had to be addressed. Other problems could arise, taking the residents focus off the fire risk and on to a different problem at the present time. This would remove the attention from the continuation of developing safer and more viable options, ending all progress

PROGRAM DESIGN PRINCIPLES

The following are lessons we learned about the relationship between technology, society, and project design:

1. Participatory research is effective because it empowers stakeholders to take control of their problems and encourages them to work towards a solution. This method also helps researchers obtain the stakeholder's point of view and provides a better understanding of the situation at hand.

Our contacts in Katutura assisted in interviewing and pilot testing by bringing us to the homes of their neighbors and friends. After we arrived at a residency, they explained our project to the residents. They then assisted us in interviewing by either explaining questions in further detail or asking the questions themselves. This empowered them to take matters into their hands. They were passionate about reducing

fire risk within Katutura and wanted to have a positive change in their community. Both David and Johannes, two of our contacts, helped our project group to install the solar bottle in two households. They were eager to learn, help install, give input, and explain the product to the two households.

Having a contact with us eliminated the initial skepticism of the residents. The contact made the residents feel more comfortable. Once we were introduced, the people of Katutura were welcoming and eager to answer our questions. Using participatory research and contacts we achieved trust within the community, allowing us to obtain essential information from residents. Without contacts, it would be very difficult for our team to approach and speak to residents.

2. Solutions that seem the most efficient and reasonable to foreigners may not be the most efficient and reasonable to stakeholders. It is important for researchers to acknowledge and keep in mind the cultural and social impacts of their work

Globally, people value different things. This makes it challenging for outsiders to recommend suggestions. Not only do people have different values, but also in different countries there are various economic constraints. For example, saving money and investing in a solar panel that would solve the lighting challenge seems to be the most reasonable option for Katutura's residents. The situation is more complicated than that. Because of low-income rates, it is nearly impossible for many residents to invest in a more expensive option than candles. The general manager of MSR, Hilya, explained that many residents of Katutura do not have money management skills, which prevents them from being able to invest.

Also, as outsiders, we don't understand the culture of Namibia making it difficult to find solutions and recommendations that fit the needs of the community members of Katutura. Obtaining the community’s input on criteria for these solutions and recommendations helps make this challenge more feasible.

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APPENDICES

APPENDIX A – QUESTIONS FOR COMMUNITY MEMBERS OF KATUTURA

Good Morning/Afternoon, we are University students from the United States working with Men on the Side of the Road focusing on reducing the risk of fire in Katutura. We hope you have a few minutes and would participate in an interview so that we can learn about what you use and how you interact with your lighting sources. Any information you share with us will be viewed as confidential and anonymous.

What lighting sources are they using?

a. *If candles/paraffin:*
   i. How much do candles cost?
   ii. How many candles do you use in a week?
   iii. How do you put the candle out?
   iv. What times of the day do you use candles?
   v. How long do you use candles for?
   vi. How long do the candles last?
   vii. What methods do they use to make candles safer? (Candle stands, making them last longer, etc.)
   viii. Do they use candles for religious reasons?
   ix. Why do you use candles as opposed to another source of light?
   x. Are you a victim of a shack fire? If so what is your story?
   xi. If you are a victim of a shack fire, or if you have seen one, how do you handle the situation? Do you call the fire brigade? How do you/people put the fire out?
b. *If electricity:*
   i. Where are they getting it?
   ii. How much does it cost?
c. *If car batteries*
   i. How long does a car battery usually last for? (How many lights is it powering?)
   ii. How did they hook the lights up?

iii. Is there any way to recharge them?
iv. Why do you use car batteries?
v. Where did you obtain car batteries?
vi. Why do you use car batteries to power light as opposed another light source?

d. *If Solar Panel?*
i. How much does it cost?
ii. How did you get it? How is it setup?
iii. How much does it cost to maintain?
iv. Has anyone ever attempted to steal it? How do you prevent theft?
v. Why do you use a solar panel as opposed to another source of light?

Questions Regarding Children

a. Do you have children? If so, how many?
b. Does anyone in the household work? Do you spend the day looking for work or activities that require not being home? If so, where do you leave the children during that time?
c. If you lock your children at home, how long do you lock them for? How often?

In general

a. What recommendations or ideas do you have?
b. How long have you been in this community? (Do you plan on leaving?)
c. Do you use curtains in your homes to separate the house?
d. On average, what is your weekly income?
e. Is portability a factor when looking for an alternate light source?
f. What fire safety knowledge do you already have?

APPENDIX B – INTERVIEW QUESTIONS FOR MEMBERS OF THE WINDHOEK FIRE BRIGADE

Good Morning/Afternoon, we are University students from the United States working with Men on the Side of the Road focusing on reducing the risk of fire in Katutura. Thank you for taking time to speak with us about shack fires in Katutura. We are interested in fire safety knowledge and techniques specific to the informal settlements. With your permission, we would like to be able to use the knowledge you share with us in our report. You will be able to review our paper and have the opportunity to veto any quote of yours that you feel might hurt your standing. You will also have the opportunity to remain anonymous, as we would like to respect your privacy.

1. Does the Windhoek Fire Brigade respond to shack fires within Katutura?

2. Is there a specific branch or section of the Windhoek Fire Brigade whose jurisdiction is Katutura?

3. Is there currently a database that compiles information on fires in informal settlements? Are there reports filed after each fire? If so, what specifics does these contain? Can we access them under supervision?

4. What seems to be the main cause of these fires?

5. What economic and physical resources are used in order to extinguish and prevent shack fires?

6. Have any fire safety education programs been implemented in the past? If so, what knowledge was shared and why this particular set of information?

7. If programs have been attempted, what methods were used? What methods were the most successful and what methods were the least successful? How do you know that the results you obtained were successful/unsuccessful?

8. According to your knowledge and experiences, what recommendations do you have in developing and implementing community education programs for fire safety? Why?

9. Do you charge the residents of Katutura to out a fire?

APPENDIX C – QUESTIONS FOR DISASTER MANAGEMENT OFFICE

Good Morning/Afternoon, we are University students from the United States working with Men on the Side of the Road focusing on reducing the risk of fire in Katutura. Thank you for taking time to speak with us about shack fires in Katutura. We are interested in fire safety knowledge and techniques specific to the informal settlements. With your permission, we would like to be able to use the knowledge you share with us in our report. You will be able to review our paper and have the opportunity to veto any quote of yours that you feel might hurt your standing. You will also have the opportunity to remain anonymous, as we would like to respect your privacy.

1. How often does your office run programs about fire safety within Katutura?
2. How do you run these programs?
3. Where do you run these programs? Do you pick these sites for any reason?
4. Do you run these programs just within your office or is a combination of offices around the City of Windhoek?
5. What information do you spread during these programs? What information do other offices try to spread?
6. How do you advertise for these programs?
7. Do you find these programs to be effective? How do you know?
8. Do you ever go into the informal settlements to spread information?
9. Do you respond to fire scenes within Katutura? If so, what do you do?
10. Do you see any weak areas in your programs that you could improve on?
11. What do you see as the main cause of shack fires?
12. Have you ever heard of the Solar Bottle Project? Thoughts on how it works?

APPENDIX D – INTERVIEW QUESTIONS FOR MARTIN DAVID, COUNCILOR OF HAVANA

Good Morning/Afternoon Mr. David, we are University students from the United States working with Men on the Side of the Road focusing on reducing the risk of fire in Katutura. Thank you for taking time to speak with us about your community and shack fires in Katutura. We are interested in the information you have regarding the progression of your community and the issue of shack fires. With your permission, we would like to be able to use the knowledge you share with us in our report. You will be able to review our paper and have the opportunity to veto any quote of yours that you feel might hurt your standing. You will also have the opportunity to remain anonymous, as we would like to respect your privacy.

1. Do you see fires as a major problem in the Katutura?
2. What do you see as the main cause of shack fires?
3. Have there been other efforts in the past to reduce the risk of shack fires?
4. Do you know Mr. Hendrik Ehlers of the Namibian Solar Bottle Project? Has he ever been to Havana?
5. Do you see the solar bottle as a viable option?
6. Are there any plans to improve living conditions within Katutura?
7. Do you see these plans happening in the near future?

APPENDIX E – INTERVIEW QUESTIONS FOR HENDRIK EHLERS, ENTREPRENEUR OF UYELELE – THE NAMIBIAN SOLAR BOTTLE PROJECT

Good Morning/Afternoon Mr. Ehlers, we are University students from the United States working with Men on the Side of the Road focusing on reducing the risk of fire in Katutura. Thank you for taking time to speak with us about your project and shack fires in Katutura. We are interested to see how this solar bottle works and what you have done with the bottle so far. With your permission, we would like to be able to use the knowledge you share with us in our report. You will be able to review our paper and have the opportunity to veto any quote of yours that you feel might hurt your standing. You will also have the opportunity to remain anonymous, as we would like to respect your privacy.

1. How does the solar bottle work?
2. What does one need to build the bottle?
3. How do you install the solar bottle?
4. Do you install the bottles? Do you have others install it?
5. How did you get involved with this project?
6. In your opinion, how popular is the solar bottle in Katutura?
7. Is it popular around the country of Namibia?
8. Can the solar bottle charge small solar panels?
9. Where do you see this project going in the future?
10. Do you think there is a possibility that if this starts to really catch on jobs could be created for building and installing it?

Presentation. Protocol for Pilot Testing of Pharox light in Katutura, Namibia. The investigators were Brien Hard, Connor Gillespie, Casey Rota, and Saloni Sachar. Our project team first taught the pilot tester household in One Nation how to operate and install a Pharox light. The light was installed in a house owned by a married couple. After a period of one week, our team revisited the household in order to collect information on the independent pilot test.

Background and Justifications. Pilot testing of the alternative is important as our team values the input of the community members. Placing one of our alternative lighting sources into the home of a resident allowed our team to gain firsthand knowledge on how the product works and what the comparison is to other light sources such as candles. Our team used the pilot testing of the Pharox light to determine if this light is capable of replacing candles completely or not.

Objectives. The main goal from this test was to obtain firsthand information on how this light works (simple or complicated, installation, etc.), how long it lasts under a day of solar charge, and if it worth the monetary commitment.

Research Questions.

1. Did this light produce sufficient lighting for you during the night? During the day?
2. How did this light compare to that of a candle/paraffin lamp/currently used light source?
3. Did this light replace your need for candles or other lighting source? Completely, minimized usage, did not decrease usage?
4. Was purchasing this light worth the upfront investment?
5. Would you recommend this light to others in your community?
6. Have neighbors or other community members noticed the solar bottle installed on the roof? Have you shown anyone else in the community how it works?

Methods. With the help of our contact Johannes, we selected a home in One Nation to install the Pharox light. After installing the light in the roof, we obtained contact information and informed the residents that our team would return for a follow up. Around a week later, we returned to One Nation to ask the above research questions to acquire the information on how this light works.

Limitations. The limitations during the pilot tests include the following:

1. Language barrier
2. Scheduling a time to install and return to the household to collect information

Despite having a translator, the language barrier between the community members and the project team did have an effect on the pilot testing process. Teaching community members about the Pharox light was a longer process because of having to translate to another language and the information was often misunderstood as a result. Finding time that both the householders and the project team were available was also difficult. It was difficult to get in contact with the householders via a cellular phone, and their schedule was often very unpredictable.

Time Table. Our team returned to where we installed the light about a week after pilot testing began to observe the interactions the community members had with the light, this will give enough time for the resident to get an in depth understanding of how the light works.

Resources. Tessa – Our consultant and translator. Other materials needed are the Pharox light (purchased from Build-It), hammer, and nail.

Presentation. Protocol for Pilot Testing of the Uyelele Solar Bottle in One Nation, Katutura, Namibia. The investigators were Brien Hard, Connor Gillespie, Casey Rota, and Saloni Sachar. Our project team first taught the pilot tester households how to construct and then helped install two solar bottles in two separate informal settlements. The first household was a single male living in One Nation, while the second was a family of four including two small children living in Goreangab. Once the bottle was installed there was a period of one week until our team revisited the household in order to collect information on the independent pilot test.

Background and Justifications. One of the possible alternative light sources that could help limit the use of candles within informal settlements is a solar bottle. During our interviews within the informal settlements our team did not encounter community members already using this technique. By conducting a pilot test with two separate households that fit different profiles and are in different geographic locations our team collected information on the experiences community members had while using the solar bottle. This information was important to conclude whether the solar bottle reduced the risk of fire in the households it was installed in. With this information our project team could, or could not recommend the use of the solar bottle in order to reduce the fire risk within informal settlement housing.

Objectives. Determine if the use of a solar bottle reduced the risk of fire within the pilot households.

Research Questions.

1. Is the pilot tester satisfied with learning how to construct a solar bottle?
2. Does he/she understand how to install the bottle properly?
3. What are his/her overall thoughts on the solar bottle after using it?
4. What has changed since the installation for better or for worse?
5. Did the installation of the bottle affect the use of candles at any time?
6. Would he/she recommend the use of the solar bottle? If so who would they recommend it to?
7. Have neighbors or other community members noticed the solar bottle? Have you shown anyone else in the community how it works?

Methods. In order to collect this information, the pilot testers were not trained in any way other than how to make and install the solar bottle. Once installed with the help of the household's members the project team returned after a week. During the second visitation the project team used face-to-face inquiry methods such as interviews and observation to collect the required information.

Limitations. The limitations during the pilot tests include the following:

1. Language barrier
2. Knowledge on the tools required
3. Scheduling a time to install and return to the household to collect information

Despite having a translator the language barrier between the community members and the project team did have an effect on the pilot testing process. Teaching community members how to make a solar bottle was a longer process because of having to translate to another language and the information was often misunderstood as a result. Also, while making and installing the bottle some community members have never used and did not know how to use certain tools like the metal shears. This required a learning process in order to make sure that the community members were as involved in the process as possible. Finally, finding time that both the householders and the project team were availed was difficult. It was difficult to get in contact with the householders via a cellular phone, and their schedule was often very unpredictable.

Timetable. The timetable is the same as Appendix F.

Resources. For the two pilot tests we had the following resources necessary to complete the teaching, construction, and installation of the solar bottle.

1. Tessa, our translator
2. 1x4 meter corrugated sheet metal
3. Two 2 liter bottles
4. Silicone Sealant
5. Quick drying adhesive
6. 8 bolts and 8 nuts
7. 1 sheet metal shear
8. 1 hammer and 10 nails
9. 1 metal file

APPENDIX H – HOW TO CONSTRUCT THE SOLAR BOTTLE

Materials Needed:

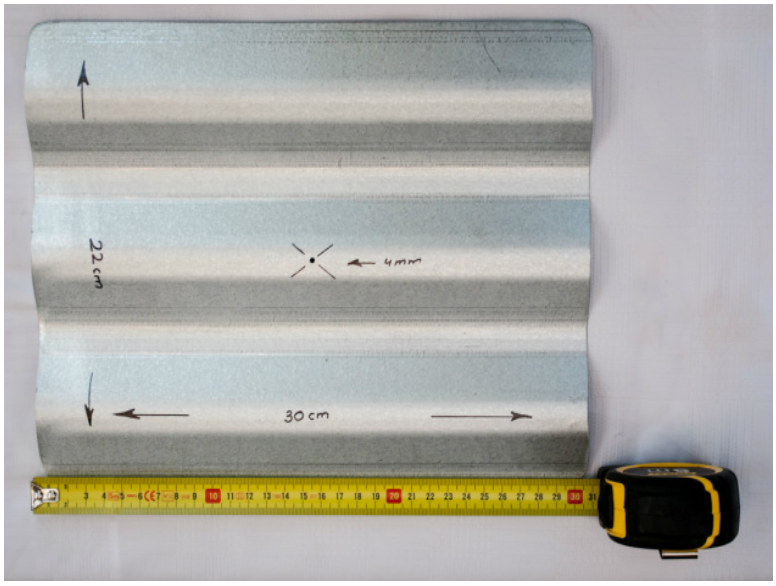
1. 2 Liter Soda Bottle*
2. 2 Caps of Bleach*
3. Corrugated Zinc Sheet*
4. Silicon*
5. Adhesive**
6. Hammer**
7. 1 Nails**
8. 4 Bolts**
9. Metal Cutters or Shears*
10. Pliers*

*Items needed for product

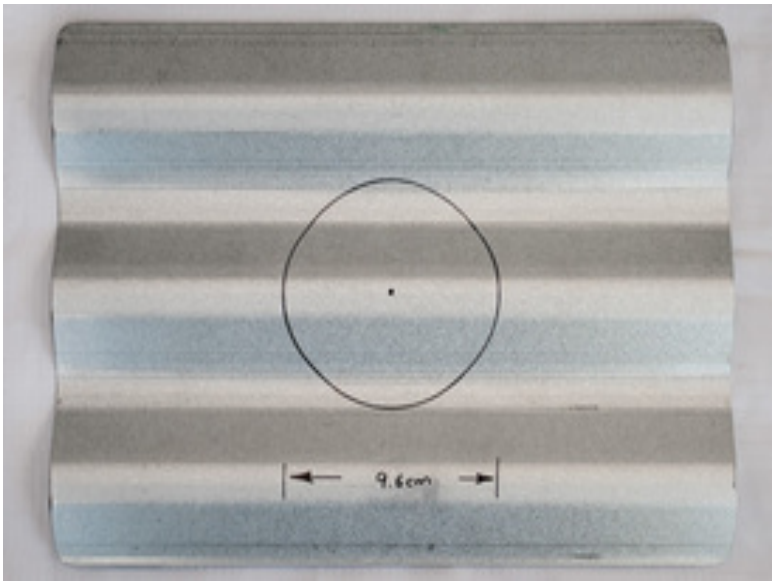
**Items Recommended for installation

INSTRUCTIONS:

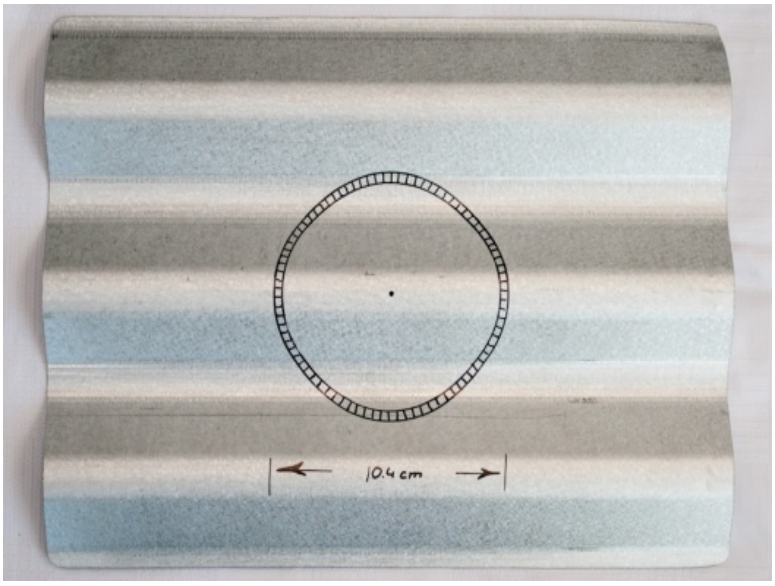
1. Cut a corrugated zinc plate with the dimensions 30 x 22 cm.



2. On the plate, draw a circle in the center to fit the size of the 2 liter bottle being used. A diameter of 9.6 cm is the general rule of thumb.



3. Then, draw another circle with a diameter of 10.4 cm around the first. As seen below, connect the two circles periodically with lines.



4. Puncture a hole in the center of the circle with the hammer and nail. Use this hole as a starting point for the metal cutters. Cut from the center out to the smallest circle in straight lines, do this multiple times creating triangles. Then, cut out the smallest circle.

5. Once the smallest circle has been removed, make a cut alone each line drawn previously. Use the pliers to bend the “teeth” upwards to a 90 degree angle.

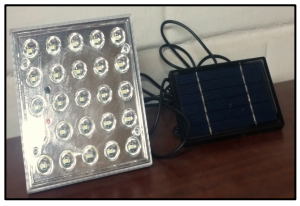
6. Stick the bottle through the hole, so it fits tightly and is held by the metal teeth. If needed, push the metal teeth into the bottle for a tighter fit.
7. Rinse the 2 liter bottle, fill with water and 2 caps of bleach. The water will diffract the light, and the bleach will keep the water clean. Seal the cap with silicon.

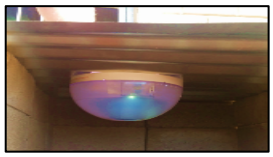
8. Use silicone to seal the bottle around the teethed hole. Give this ample time to dry.
9. Cut a hole into the roof slightly larger than the bottle in the location you want the light. Again, use the hammer and nail to make a starting hole.
10. Add silicon and to the plate and place on the roof, making sure that it is lined up properly to allow for a proper seal.
11. Bolts or adhesive can be used to secure the solar water bottle.

Most of these instructions as well as the visuals were taken from Entrepreneur Hendrik Ehler's website

Link: http://uyelele-solar-bottle.weebly.com/installation.html

APPENDIX I – SOLAR LIGHT OPTIONS

Solar Option:	Description	Panel Wattage:	Battery:	Bulb:	Dimensions:	Panel Size:	Cost (N$):
Solar Battery Hybrid 	Built in battery charged by built in solar panel. Can also be powered by 3 AA batteries.	1.2 Watt	Lithium battery or three AA batteries	8 LED	8.5 x 15.5	4.5 x 4 cm	150
Solar Energy Kit 	Built in battery charged by external solar panel.	2.5 Watt	3.7 Volt lithium battery	12 LED	10.5 x 16.5	10.25 x 15 cm	250
LED w/ Panel 	Built in battery charged by external solar panel.	1 Watt	Lithium battery	25 LED	12 x 12 cm	7 x 12	120
Garden Light 	Built in battery charged by built in solar panel.	0.5 Watt	NiMH rechargeable batteries	1 LED	5.5 cm diameter	2.5 x 2.5	30

Solar Winding Hybrid 	Built in battery charged by built in solar panel. Also charged by winding mechanism.	1.2 Watt	4 Volt rechargeable battery	15 LED	11 x 21 cm	6 x 6 cm	120
Pharox Anti-Theft Solar Roof Light 	Built in battery charged by built in solar panel. Installed on the roof with an anti-theft mechanism.	0.8 Watt	Lithium Iron Phosphate rechargeable battery	2 LED	18 cm diameter x 15 cm thick	8.5 cm x 8.5 cm	350
Solar Water Bottle 	Installed on the roof, illuminates the inside of household during daylight hours	n/a	n/a	n/a	25 x 35 cm (subject to change)	n/a	N$0 – N$150 depending on supplies available