Lights on the Horizon: A Socioeconomic Impact Evaluation of Rural Electrification in Tsumkwe, Namibia

Sunset reflection on the solar panels of the Tsumkwe Energy Project—photographed by Donal Boyd

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Date: May 3, 2012

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An Interactive Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

Sponsoring Agency: Desert Research Foundation of Namibia

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Abstract

This report, commissioned by the Desert Research Foundation of Namibia, presents a socioeconomic impact evaluation of the Tsumkwe Energy Project in Tsumkwe, Namibia. The Tsumkwe Energy Project implemented the largest solar-diesel hybrid system in southern Africa and is a pilot study for developing future rural electrification projects. Outlined are the methodologies and developmental steps necessary to produce an effective rural electrification assessment. We used the results of this assessment to develop a set of recommendations, opportunities, and lessons learnt for the future development of Tsumkwe.

Acknowledgements

Our team would like to thank the following individuals, organizations, and institutions for their help and support throughout the duration of our project:

- The Desert Research Foundation of Namibia (DRFN) for sponsoring our project, organizing all the logistics for our office and fieldwork, and providing us with invaluable advice throughout our project.
- Our project liaisons at the DRFN, Clarence Mazambani and Abraham Hangula, for providing us with direction and advice in the formulation of our project goals, methodology, and execution.
- Our project facilitator and translator, Jimmy Itamba, for scheduling interviews for us in Tsumkwe and translated them when necessary. Our data collection would not have been possible without his guidance and support.
- Professor Svetlana Nikitina and Professor Thomas Robertson, from Worcester Polytechnic Institute, for their guidance and advice throughout our project.
- The Polytechnic of Namibia and Worcester Polytechnic Institute for their collaboration which made our trip to Namibia and the completion of this project possible.
- Simon, for her hospitality and enthusiasm throughout our stay in Tsumkwe.

Executive Summary

Despite significant global technological advances over the last century, electricity remains a luxury that many in the developing world do not enjoy. Sub-Saharan African countries struggle to provide their residents with reliable electricity and have the lowest electrification rate by far globally. Sub-Saharan Africa has an average electrification rate of 30.5% and a rural electrification rate of only 14.2% (IEA, 2009). Governments, nongovernmental organizations (NGOs), and private companies continue to fight to electrify rural areas, but both cultural and technical factors limit their progress.

In 2006, the Desert Research Foundation of Namibia (DRFN) identified the settlement of Tsumkwe, Namibia as the site for a proposed solar-diesel hybrid energy plant that would be the largest of its kind in southern Africa. Tsumkwe is located 304 km east of Grootfontein and 735 km from Windhoek in the Otjozondjupa Region of northeastern Namibia. The settlement is home to members of the San, Kavango, Herero, Damara/Nama, Owambo, and Caprivi tribes and serves as a supply outpost to nearby villages.

The European Commission, NamPower, and the Otjozondjupa Regional Council accepted the Tsumkwe Energy Project (TEP) for funding in 2008 with a total budget of N$ 30.8 million (US$ 3.9 million).[1] As the funding for the project finishes, service providers are submitting final impact reports to the European Commission for feedback analysis. Many of these reports focus on the technical aspects of the project and provide limited insight into the project's social impact on the community.

[1] The TEP was allocated a budget of € 2,988,385. The funding has remained in euros, but for the purpose of this report, the figure will be represented in Namibian dollars. Due to currency fluctuation, this amount has ranged from around N$ 26 million to N$ 31 million. As of April 24, 2012, the currency conversion results in a budget of N$ 30.8 million.

Our report, commissioned by the DRFN, evaluates the impact of the TEP on the community with a focus on the socioeconomic development. The objectives of the assessment were to:

1. Identify the socioeconomic impacts of the expanded electrification on the residents of Tsumkwe
2. Identify the customer service relations involved in the development of the Tsumkwe Energy Project—both from a community and service provider perspective
3. Evaluate the capacity strength of the Tsumkwe Energy Project with respect to its financial and technical support structure
4. Identify technical operational challenges of the Tsumkwe Energy Project

We adapted a preexisting methodology for assessing social impact of rural electrification projects using four dimensions of sustainability: socioeconomic impact, customer service relations, capacity strength, and technical operation. We evaluated each of these dimensions using key variables. These variables helped us create interview questions for residents, businesses owners, and service providers.

Prior to our fieldwork, we conducted interviews with businesses, government organizations, and NGOs in Windhoek to understand the historical and cultural issues relating to both the TEP and the settlement of Tsumkwe. We used this information to tailor our methodology and interview questions to the Tsumkwe community.

We met with our project facilitator when we first arrived in Tsumkwe to review our interview questions and establish a plan for conducting interviews. We spent the first several days buying goods from local shops and conducting interviews with settlement officials and public service providers. We also used this time to inspect the electrical, water, and waste management infrastructure.

We conducted community interviews for eight days from all areas of the settlement, balancing respondent genders as well as interviewing residents from each location in the

community. By the end of our stay, we had conducted 73 interviews. We compiled the responses to identify patterns and to generate conclusions, recommendations, and opportunities for the DRFN's future involvement in the social, technical, and economic development of Tsumkwe.

Conclusions

The expansion of electricity in Tsumkwe affected a large part of the community in many positive ways. The 24-hour availability of electricity made the lives of residents more convenient with increased access to public services such as water, healthcare, and community education programs. The TEP has also led to the development of small businesses utilizing the expanded electricity, including a takeaway kiosk and a tailoring shop.

Despite the many positive impacts of the TEP, several problems still exist with public utilities which may limit the settlement's growth. There are serious concerns about the capacity of the Department of Works to operate and maintain the solar-diesel hybrid system. The Department of Works must significantly improve its capacity for technical support for the hybrid system to ensure operation of the system for years to come. There are also concerns about the OTRC's financial capacity to perform routine scheduled maintenance on the system. The OTRC has minimal financial support structure dedicated to the TEP. The OTRC must increase its financial support of the TEP for the project to be financially sustainable in the future.

The TEP has multifaceted impacts on not only residents, but also on all of Namibia. The project serves as a potential model that other rural settlements across Namibia and the rest of southern Africa can emulate with the help of governmental and nongovernmental organizations. The project demonstrates how a large-scale solar-diesel hybrid system can help uplift rural off-grid communities.

Recommendations

We developed recommendations to improve the development and sustainability of the TEP. The recommendations are divided into three sections to directly address organizations or governmental departments such as the Ministry of Local Government and Housing, Department of Works, Electricity Control Board, and the DRFN.

We recommend the Ministry of Local Government and Housing and the Department of Works:

1. *Create a standardized form for documenting resident concerns regarding problems with public electrical utility services*

   Interviews with residents revealed significant dissatisfaction with the Ministry of Local Government and Housing and the Ministry of Works' ability to respond to customer complaints. Creating a standardized form the residents can use to report problems to the Ministry of Local Government and Housing will improve both their organization and their communication with the Department of Works.

2. *Investigate reasons behind workers' low attendance and develop programs to increase work efficiency*

   Many of the problems with the public works infrastructure stem from low worker attendance rates. Investigating the reasons behind this low attendance will aid the Ministry of Local Government and Housing and Department of Works to understand the reasons behind worker dissatisfaction, develop programs to address these concerns, and ultimately increase worker efficiency.

3. *Increase training and equipment for the Tsumkwe Energy Project plant and ensure electrical network maintenance*

   Interviews with public officials revealed minimal training for system operators and limited access to the tools necessary to perform essential maintenance to the electrical

infrastructure. In order to maintain the TEP infrastructure effectively, the Ministry of Local Government and Housing and the Department of Works must either increase their technical training and tools or hire outside contractors to perform the necessary maintenance.

We recommend the Ministry of Local Government and Housing:

1. *Inform residents on which office to contact when there is an electrical problem in their home or area*

   During our time in Tsumkwe, it became apparent that most people did not know whom to contact when they had a problem with their electrical setup. An increased effort by the Ministry of Local Government and Housing to inform residents will increase the Ministry's ability to respond to electrical problems more effectively.

2. *Initiate an SMS program as a method of notifying the residents of a pending power outage*

   While in Tsumkwe, we had already spoken with our project liaisons, Abraham Hangula, Clarence Mazambani, and Jimmy Itamba, about initiating a SMS program to notify residents of planned power outages due to maintenance work on the system. Business owners and professionals met the SMS program with approval. Expanding this program to include all residents will increase resident satisfaction with the TEP as well as give them a sense of ownership of the project.

3. *Conduct a community meeting informing residents about the selection process involved in connecting un-electrified locations to the electrical grid*

   We observed during our time in Tsumkwe that there was significant resident confusion about why particular locations were connected to the electrical grid and others were not. The Ministry of Local Government and Housing will need to spend time and

resources to clarify these criteria, which will in turn decrease public dissatisfaction with the Ministry.

4. *Conduct a campaign educating residents on how to utilize the expanded electricity effectively with respect to business opportunities*

Educating residents of potential business opportunities utilizing electricity will aid in the development of Tsumkwe both socially and economically. Providing residents with information on how they can effectively use the electricity for financial gain, while considering system limitations, will increase the economic growth in Tsumkwe due to the electricity.

We recommend the DRFN:

1. *Conduct a follow-up evaluation of the business development, education, and public service infrastructure of Tsumkwe in 2-5 years to identify any improvements or changes from the present conditions*

During our time in Tsumkwe, we realized that in many areas it was too early to judge the true impacts that the TEP has had on the development and prosperity of the community. Repeating our evaluation in 2-5 years will allow time for the community to adapt to and take advantage of the reliable electricity.

We recommend the Electricity Control Board (ECB):

1. *Develop regulations for licensing the distribution of electricity in off-grid electrified settlements*

Currently, the ECB sets regulation standards for distribution based on the performance of the national electricity network, with end-user tariffs based on cost of electricity generation. We recommend that the ECB formalize a subsidy structure and policy for licensing the distribution of electricity in off-grid electrified settlements.

Future opportunities

We recommend the DRFN:

1. *Apply for funding to initiate an Interlocking Stabilized Soil Brick business in the settlement of Tsumkwe*

   The business will provide employment to community members, as well as subsidize construction materials for residents to construct homes that meet qualifications for a connection to the electrical grid. Appendix G: *Stabilized Soil Brick Business—Income Generating Activities* outlines the basic project proposal.

NOTE: Please refer to Appendix E: *Additional Findings, Recommendations, & Future Opportunities*—its content is out of the scope of our intended evaluation, but should be recognized and addressed accordingly.

Authorship

Brennan Ashton, Lauren Bisacky, Donal Boyd, and Jessica López all contributed to the research, writing, and execution of this report. The following is a summary of how the report was divided and compiled:

Brennan Ashton contributed to the report by drafting the Executive Summary and parts of the Background, Methodology, and Findings chapters. He also created a data entry excel file to input all data collected in the field.

Lauren Bisacky was responsible for eliminating passive voice throughout the sections of the report and contributed to the report by devising parts of the Background, Methodology, and Recommendations & Future Opportunities chapters. She also created the eight sets of interview questions used in fieldwork collection.

Donal Boyd contributed to the report by writing parts of the Introduction, Background, Findings, Conclusions, and Recommendations & Future Opportunities chapters. He also photographed the picture on the cover page.

Jessica López was responsible for the overall formatting, organization, and editing of each version of the written report. She took the initiative of being responsible for the master copy of each draft and compiled each group members' corrections in an organized and comprehensive manner. She also contributed by devising parts of the Methodology and Recommendations & Future Opportunities chapters.

In addition to the individual sections undertaken in the report, all group members worked collaboratively to establish project goals and objectives, determine findings, recommendations, and future opportunities, and edit each other's personal parts for grammar and flow.

Table of Contents

Abstract i
Acknowledgements ii
Executive Summary iii
Conclusions v
Recommendations vi
Future opportunities ix
Authorship x
List of Figures xiii
List of Abbreviations & Acronyms xiv
Chapter 1: Introduction 1
Chapter 2: Background 3
2.1 Rural Electrification Worldwide 3
2.2 Namibian Energy Policy, Regulation, and Production 5
2.3 Tsumkwe, Namibia 8
2.4 Electrical Infrastructure of Tsumkwe 13
2.5 Methodologies for Evaluating Rural Electrification Schemes around the World 20
Chapter 3: Methodology 25
3.1 Field Work Preparation 26
3.2 Field Work Collection 27
3.3 Objective 1: Socioeconomic Impacts 31
3.4 Objective 2: Customer Service Relations 34
3.5 Objective 3: Capacity Strengthening 35
3.6 Objective 4: Technical Operation 37
Chapter 4: Findings 39
4.1 Socioeconomic Impacts 39
4.2 Customer Service Relations 57
4.3 Capacity Strengthening 58
4.4 Technical Operation 62
Chapter 5: Conclusions 68
Chapter 6: Recommendations & Future Opportunities 70
6.1 Recommendations 70
6.2 Future Opportunities 76
Chapter 7: Technology & Society—Lessons Learnt 77
Works Cited 80
Appendix A: Case Studies of Previous Rural Electrification Programs 83

Appendix B: Donors, Service Providers, & Stakeholders 85
Appendix C: Images of the Solar-Diesel Hybrid Plant 87
Appendix D: Interview Questions 90
Electrified Residents 90
Un-electrified Residents 94
Business Owners 97
Clinic 99
Police Station 101
Radio Station 103
School 105
Settlement Officials 107
Appendix E: Additional Findings, Recommendations, & Future Opportunities 109
Findings 109
Recommendations 112
Future Opportunities 112
Appendix F: Expanded Solar Energy Storage Capacity Opportunity 114
Appendix G: Stabilized Soil Brick Business—Income Generating Activities 117

List of Figures

Figure 1: NamPower transmission lines and power distribution (NamPower, 2009) 6
Figure 2: Map of Namibia with marked areas of interest 9
Figure 3: Unofficial residential locations of Tsumkwe, Namibia 11
Figure 4: Original genset 1 (Hangula, [Photograph], 2011) 14
Figure 5: Original genset 2 (Hangula, [Photograph], 2011) 14
Figure 6: Property of the building that housed the two gensets (Hangula, [Photograph], 2011) 15
Figure 7: Solar diesel hybrid array—Tsumkwe, Namibia (DRFN, 2011) 17
Figure 8: Global correlation between rural electrification and education index in 2002 21
Figure 9: Ilskog's assessment method diagram (Ilskog, 2008) 24
Figure 10: Assessment dimensions for evaluating the Tsumkwe Energy Project 25
Figure 11: Key informant types for data collection 26
Figure 12: Key variables of the socioeconomic dimension 31
Figure 13: Key variables of the client relation dimension 35
Figure 14: Key variables of the capacity strengthening dimension 36
Figure 15: Key variables of the technical operation dimension 37
Figure 16: Main Street of Tsumkwe several hours after sunset before the installation of streetlights (Hangula, [Photograph], 2011) 43
Figure 17: Main Street of Tsumkwe several hours after sunset illuminated by seven of the nine originally installed streetlights (Hangula, [Photograph], 2011) 43
Figure 18: Un-electrified home in Tsumkwe North 50
Figure 19: Un-electrified home in Tsumkwe North 50
Figure 20: Electrified home in Owambo Location 52
Figure 21: Key stakeholders of the Tsumkwe Energy Project 85
Figure 22: Diesel generator room of the solar-diesel hybrid system 87
Figure 23: One of the 350 kV diesel generators 87
Figure 24: Solar-diesel hybrid system inverters 88
Figure 25: Solar-diesel battery banks 88
Figure 26: Several members of the PMU outside of the solar-diesel hybrid system facility—photograph taken 8/15/2011 (Hangula, [Photograph], 2011) 89
Figure 27: Solar kiosk installed in Tsumkwe Central at the Councilor's office (Hangula, [Photograph], 2011) 110
Figure 28: The Tsumkwe dumpsite, 3 km outside of the settlement (Diemand, Geddes, Kalauskas, & Ridley, 2010) ..... **Error! Bookmark not defined.**
Figure 29: Comparison of Scenario 1 and Scenario 2 annual diesel costs 114
Figure 30: Comparison of Scenario 1 and Scenario 2 annual profits based on an estimated revenue of N$ 360,000 per annum 115
Figure 31: Straight Double Interlocking Bock and manually operated block press (Lewis D. , 2009) 119

List of Abbreviations & Acronyms

CLDC	Community Learning and Development Centre
DRFN	Desert Research Foundation of Namibia
ECB	Electricity Control Board
EC	European Commission
IEA	International Energy Agency
ISSB	Interlocking Stabilized Soil Bricks
km	kilometer
kV	kilovolt
kVA	kilovolt ampere
kWh	kilowatt hour
kWp	kilowatt peak
LED	Light Emitting Diode
LP	Liquid Petroleum
MET	Ministry of Environment and Tourism
MME	Ministry of Mines and Energy
MTI	Materials Testing Institute
NamPost	Namibia Postal Corporation, Ltd.
NamPower	Namibia Power Corporation, Ltd.
NamWater	Namibia Water Corporation, Ltd.
NBC	Namibian Broadcasting Corporation
NGO	Nongovernmental organization
OTRC	Otjozondjupa Regional Council
PMU	Project Management Unit
TEP	Tsumkwe Energy Project
TPD	Tsumkwe Police Department
VAC	volt alternating current
WPI	Worcester Polytechnic Institute

Chapter 1: Introduction

According to a study presented by the International Energy Agency (IEA), more than one fifth of the world's population, nearly 1.4 billion people, did not have access to electricity in 2009 (IEA, 2009). Sub-Saharan Africa, in particular, suffers from the lowest overall electricity access rate with less than 31% of the region electrified (IEA, 2009). In Namibia, a mere 13% of rural households have access to electrical power (DRFN, 2011). This low percentage results from several significant challenges to rural electrification including considerably high costs of installing electricity services, the lack of appropriate incentives, and inadequate supply of electrical power from national grid services. The Namibian government, various nongovernmental organizations (NGOs), and the international community are developing strategies to implement mini-grid and off-grid electrification projects throughout Namibia. Technologies such as solar power, wind power, and diesel generators are practical options for use in alternative off-grid electrification projects (World Bank, 2010).

Situated just south of the Tropic of Capricorn, Namibia receives more than 3,300 hours of sunshine yearly (Total Solar Energy, 2010). The availability of solar radiation and the recent decrease in solar panel prices make the incorporation of solar power in rural electrification projects a viable means for providing electricity to the 87% of Namibians living in off-grid settlements (Laskow, 2011).

In March 2008, the Desert Research Foundation of Namibia (DRFN) initiated the Tsumkwe Energy Project (TEP) in collaboration with the European Commission (EC), NamPower, and the Otjozondjupa Regional Council (OTRC). Tsumkwe, the largest off-grid settlement in Namibia, is now home to southern Africa's largest solar-diesel hybrid system. The

hybrid system is a significant improvement over the previous system, which consisted of two diesel generators that only provided 10 to 14 hours of electricity access per day. The system provides 24-hour electricity access to approximately 43% of the residents in the settlement via 918 polycrystalline solar cells, a 766 kWh battery storage field, and three diesel generators with a combined capacity of 630 kVA (Hangula, Brief, 2012).[2]

Tsumkwe is currently home to approximately 3,800 people, most of whom are San (Vialle, 2012). Access to electricity 24 hours a day has led to the improvement of public services and general enhancement of life for all residents of the settlement. Today, streetlights illuminate the main roads, water pumps provide 24-hour water access, and the clinic can resolve medical emergencies at night with more than just candlelight (DRFN, 2011).

Our project aims to evaluate the TEP and identify ways in which the expansion of electricity has affected the lives of residents in Tsumkwe. In order to obtain current information to perform an off-grid electrification assessment, we traveled to Tsumkwe and interviewed residents, settlement officials, service providers, and institutions. This report presents our fieldwork methodologies, data, and analysis of the information gathered while in Tsumkwe. This report provides the DRFN and similar organizations with knowledge that can be used to formulate future off-grid and mini-grid electrification frameworks based on the TEP pilot study, along with potential energy and non-energy related project opportunities to benefit the community of Tsumkwe (DRFN, 2011).

[2] The percentage of electrified residents in Tsumkwe based off 107 households and 250 total households.

Chapter 2: Background

The purpose of this chapter is to provide a comprehensive understanding of the complexities and importance of rural electrification, the key stakeholders involved in Namibian electricity generation and regulation, and the demographics and history of Tsumkwe. In this chapter, we will examine the following five aspects:

1. Rural electrification worldwide
2. Namibian energy policy, regulation, and production relating to rural electrification
3. The settlement of Tsumkwe
4. History of electricity in Tsumkwe
5. The evaluation of rural energy initiatives

2.1 Rural Electrification Worldwide

Despite significant technological advances over the last century, electricity remains a luxury that many in the developing world do not enjoy. Sub-Saharan African countries struggle to provide their residents with reliable, accessible, and affordable electricity. The overall average rate of electrification in these countries is 30.5% with only 14.2% of the rural communities electrified (IEA, 2009).[3] While governments, NGOs, and private companies are working to develop strategies to electrify communities, several barriers exist that impede their progress, particularly in rural areas.

First, the gap between urban and rural electrification rates worldwide is caused in part by the complexity of rural electrification programs, which are often more expensive per connection and more technically involved than their urban counterparts (Zomers, 2003). The investment cost per connection for a rural electrification project averages N$ 9,200 and can be as expensive

[3] Electrification: to be equipped with electrical power or to supply a region or community with electrical power; in contrast, un-electrified means to be without electrical power

as N$ 765,500. In comparison, an industrial or urban supply area costs less than N$ 3,800 per connection on average (Zomers, 2003).

Second, social and cultural dissimilarities within communities and between communities and service providers further complicate rural electrification projects (Zomers, 2003). Local groups within villages and governments must collectively finance, operate, and maintain a technically complicated infrastructure with more limited technical and financial resources than in urban areas (Thompson & Laufman, 1996). Of these challenges, maintenance is the most complex issue in rural communities. In rural areas, it is difficult to maintain electrical infrastructures because funding is often limited and technically trained workers are scarce for long-term, on-site management (Zomers, 2003).

Finally, rural communities in underdeveloped areas tend to be poorer than their urban counterparts (Mwabu & Thorbecke, 2004). The limited ability of community members to pay for electricity strains the relationship between the community and the service provider. These factors, among others, inhibit the economic and social growth that often accompanies electrification projects (Zomers, 2003). Understanding the complexities of rural electrification projects worldwide is crucial to understanding the challenges facing the settlement of Tsumkwe as the TEP ends.

A detailed review of several relevant rural electrification projects in South Africa, Kenya, and India is included in Appendix A: *Case Studies of Previous Rural Electrification Programs*. These case studies highlight examples of successful and failed rural electrification programs and provide specific areas of sustainability to investigate in our assessment. Outlined below are several statements from these case studies.

One of the major problems implementers of rural energy production facilities face is the inability of the local community to maintain the system. This often occurs because community members never develop a sense of ownership of the system and the infrastructure deteriorates as a result. In India, programs to educate and train young community members on the system's technology have shown initial success in solidifying the local capacity to maintain the infrastructure (Dinesh, 2007). Many projects also do not have adequate financial support, which is another common reason for failure. An example of this type of project is the Lucingweni mini-grid in the Eastern Cape Province of South Africa. Project organizers installed a solar panel field in the village of Lucingweni, but did not plan for long-term funding for system maintenance, resulting in a failed system (Brent, 2010).

Financially sustainable electrification programs have multifaceted impacts on the receiving communities, including possible expanded access to water. Increased access to natural resources like water can have long-term negative impacts on the community and environment if effective monitoring and management practices are not in place. In Zambia, experts raise concerns that the water extraction rate after an electrification project is not sustainable and that the water table is being depleted (Oetzen, 2008).

2.2 Namibian Energy Policy, Regulation, and Production

Namibia struggles alongside the rest of the world to electrify its rural communities. Currently, the national power utility company of Namibia, NamPower, supplies less than 40% of the nation's population with electricity. (MME, 2012). Figure 1 below illustrates the locations of major electrical supply lines and power plants of Namibia's national electrical infrastructure. The power plants do not meet the nation's electricity demands and as a result, NamPower imports more than 50% of its electricity from South Africa, Zambia, and Zimbabwe (Ihuhua,

2012). Furthermore, NamPower electricity is almost entirely limited to major cities and surrounding urban areas with only 12.9% of the electrical framework extending to rural communities as of 2006 (De Vita, Endresen, & Hunt, 2006). Most rural communities are far from the nation's major supply lines, making it expensive to extend power lines to these areas. Installing new service lines to rural communities is rarely economical due to low demand from small population densities.

Figure 1: NamPower transmission lines and power distribution (NamPower, 2009)

While Namibia's overall electrification rate of 34% is higher than the Sub-Saharan Africa average of 28.5%, it is still much lower than the global electrification rate of 78.2% (World

Bank, 2010). The Namibian government established several organizations to regulate and develop the growing electrical framework. The high-level budgeting and decision-making process for the Namibian electrical infrastructure is managed by the Ministry of Mines and Energy (MME), which was established after Namibia's independence from South Africa in 1990 (MME, 2012). In 2000, the Namibian government created the Electricity Control Board (ECB) to regulate electricity generation, transmission, and distribution effectively and equitably. (ECB, 2006). The ECB achieves this mandate primarily by setting and regulating tariffs and issuing licenses. The ECB is not actively involved in improving electrical infrastructure, but is solely responsible for the regulation and licensure of new, updated, and preexisting sources of electricity generation, transmission, and distribution.

The South African Government formed NamPower in 1964 as the South West Africa Water and Electricity Corporation. NamPower is responsible for the production and distribution of electricity as well as development of electrical infrastructure for the entire nation (NamPower, 2010). Currently, the MME and ECB control and regulate NamPower. These three organizations work together to administrate, regulate, generate, and distribute Namibia's electricity.

In 1991, the MME initiated the *Rural Electrification Programme*, which aims "to connect previously off-grid rural towns, villages, and settlements to the national electricity grid (Consulting Service Africa, 2005)." The MME revisited rural electrification in 2000 in their *Study of the Restructuring of the Namibian Electricity Supply Industry*, which outlines barriers to and goals for rural electrification in Namibia (Ministry of Mines and Energy, 2000). By 2004, NamPower and the MME had electrified more than 80 villages and informal settlements, and plans to continue electrifying remaining un-electrified regions.

Namibia's *Vision 2030*, announced in 2004, outlines Namibia's aspirations to develop as an industrialized nation with a natural resource based export sector. The vision places an emphasis on the necessity to expand Namibia's electrical infrastructure to promote rapid industrialization. This goal is complicated and subject to the same factors limiting rural electrification projects outlined above in Section 2.1 *Rural Electrification Worldwide*. However, it also presents numerous opportunities for the development of small-scale decentralized power generation facilities, such as the solar-diesel hybrid system in Tsumkwe (Republic of Namibia, 2004).

2.3 Tsumkwe, Namibia

The settlement of Tsumkwe is located at the center of the Tsumkwe Constituency of the Otjozondjupa Region in northeastern Namibia. The settlement is 735 km from Windhoek and 304 km from Grootfontein, the closest major city. The route from Grootfontein to Tsumkwe is 50 km of paved road, followed by 254 km of loose gravel and sand. Figure 2 illustrates the relative distance between Grootfontein, Tsumkwe, and Windhoek: [4]

[4] The 254 km stretch is especially difficult to drive on and very dangerous during the rainy season when the loose gravel and sand becomes extremely slick. The safe speed of travel on a dry day is typically less than 80 km/h and often non-drivable when it is raining or the road is wet.

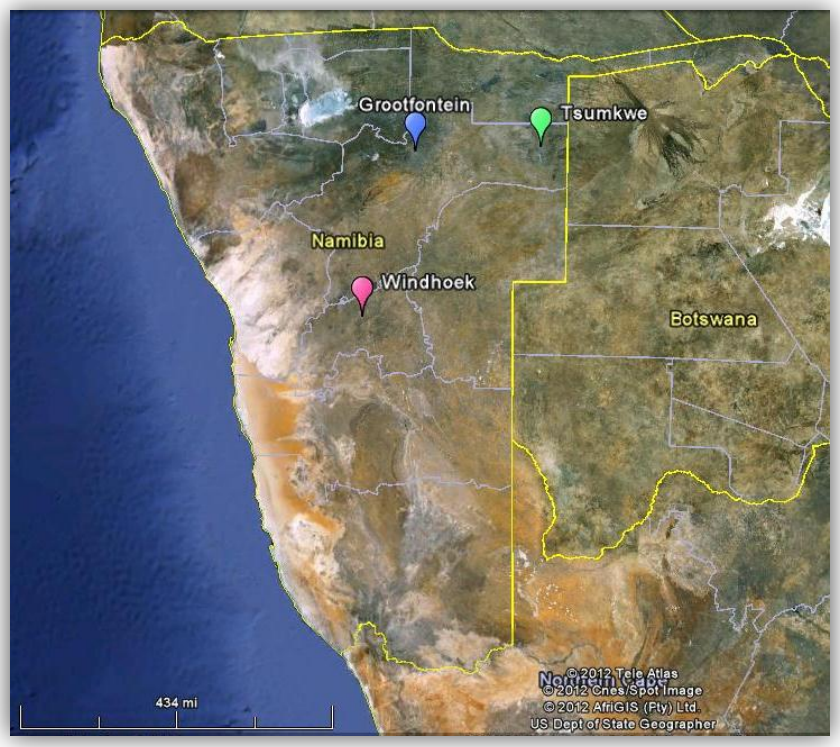

Figure 2: Map of Namibia with marked areas of interest

The Tsumkwe settlement serves as a supply outpost, providing basic goods and refueling services to the surrounding 37 villages within the constituency, and to travelers passing through on their way to or from Grootfontein.

According to the 2001 *Namibia Population and Housing Census* report, approximately 9,000 people live in the Tsumkwe Constituency and an estimated 3,800 live within the Tsumkwe settlement (National Planning Commission, 2001).[5] Tsumkwe is a diverse settlement and home to members of the San, Kavango, Herero, Damara/Nama, Owambo, and Caprivi ethnic groups. Several unofficially recognized areas called "locations" or "lokasies" divide the settlement. Figure 3 below shows the relative size and position of each location.

[5] Tsumkwe refers to the "Tsumkwe settlement" throughout the rest of this publication unless otherwise noted.

In total, there are an estimated 250 households and homesteads separated amongst the different locations. Tsumkwe North is a mix of Kavango, Herero, and Owambo people that live in large traditionally constructed homesteads of 10-30 people. Tsumkwe North also contains the primary and secondary schools. Damara, ǁharas, and Gauteng Locations contain predominately San families with a mix of other ethnic groups. Tsumkwe Central contains mostly businesses, institutions, and very few homes.[6] Owambo Location, also known as Kolbooi Lokasie, contains 16 wooden households, which are home to mostly Owambo residents. The Settlement Office employees live in the 15 households next to the Local Government offices in the Local Government Location. Similarly, the Ministry of Environment and Tourism (MET) provides housing for its employees adjacent to the Local Government Location. The Sewe Huise (Seven Houses) Location, contrary to the name, contains 19 homes.[7] Lastly, the oxidation pond, Tsumkwe Lodge, and power plant are all located in Tsumkwe South.

[6] Tsumkwe Central consists of the General Dealer, Savanna II, the craft center, NamPost, Community Learning and Development Centre (CLDC), the police station, clinic, bakery, Ministry of Gender Equality and Child Welfare office, Health Unlimited, and the Nyae Nyae Conservancy Center.

[7] Originally, there were seven houses built in this location for San traditional authority. The number of houses has since expanded to nineteen.

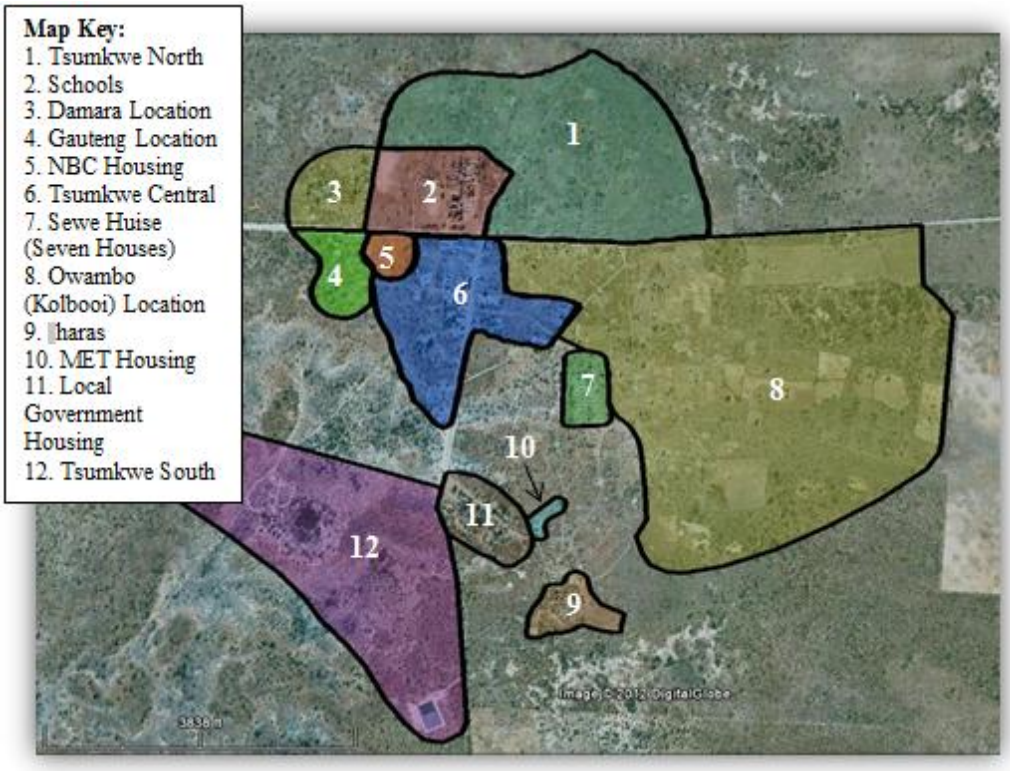

Figure 3: Unofficial residential locations of Tsumkwe, Namibia

Of the ethnic groups residing in Tsumkwe, Kavango, Herero, Damara/Nama, Owambo, and Caprivi are not native to the area. Tsumkwe's population is primarily composed of San, who has historically lived in the Tsumkwe Constituency the longest. Additionally, the vast majority of surrounding villages are San, many of whom rely on Tsumkwe for basic services such as medical care and law enforcement.

The San are widely considered to be the most marginalized and vulnerable groups in Namibia (Kanyenze & Lapeyne, 2012). They are a nomadic hunter-gatherer society whose culture is ill adapted to the challenges of modern society. As a result, they suffer from malnutrition and widespread unemployment. They are also underrepresented at a community and a national level (Kanyenze & Lapeyne, 2012). Traditionally, the San relied on hunting wild animals as their main source of food; however, when Namibia instituted a new environmental policy prohibiting this tradition without major restrictions and licenses, the San could not sustain

themselves. Despite efforts to enfranchise the San into Namibian society, they continue to have the highest rate of extreme poverty of all the ethnic groups in Namibia (Republic of Namibia, 2008).

In 2007, the Office of the Deputy Prime Minister initiated a developmental initiative to alleviate poverty and provide income-generating opportunities for the San. The initiative, proposed in the *National Development Programme 3*, has experienced some success in the development of income-generating opportunities, largely focusing on craft making. In Tsumkwe, the San are extensively involved in craft making (Republic of Namibia, 2008).

As the San capital of Namibia, Tsumkwe is on the receiving end of many initiatives aimed at improving the lives of the San. One initiative gave San communities in Tsumkwe and other settlements throughout Namibia draught animals to give them an opportunity to learn about agriculture (Vialle, 2012). Additionally, employers give San preference for jobs in a form of affirmative action.[8] This initiative assisted many San to successfully seek employment, but alienated other ethnic groups that did not receive jobs for which they believed they were better qualified. This program causes minor ethnic disagreements in Tsumkwe, which effects how different ethnicities perceive settlement leadership and by extension, the TEP, as the settlement leaders are responsible for overseeing the TEP. The initial expansion of electrical infrastructure in Tsumkwe, which targeted areas with larger San presence, has increased ethnic tensions.

Some of the largest employers in Tsumkwe are government organizations, including the Ministry of Regional and Local Government and Housing. This ministry, or "Local Government" as it is called by residents, serves as the settlement's administrative authority. Masheshe Likoro is the appointed director of the Local Government and works with his assistant,

[8] Namibia's Vision 2030 outlines employment initiatives for the San and suggests that employer's preference San in order to de-marginalize their society (Republic of Namibia, 2004).

Benedict Tjombuua, to oversee the operation of the settlement and the management of public services. The Department of Works office in Tsumkwe is responsible for the maintenance of public services and supervised by Andre Louw. Several other ministries, which have offices in Tsumkwe, include: Ministry of Agriculture, Ministry of Water & Forestry, Ministry of Environment & Tourism, and Ministry of Gender Equality & Child Welfare. The OTRC office in Otjiwarongo is the overseeing body of the Local Government.

2.4 Electrical Infrastructure of Tsumkwe

The South African government established Tsumkwe as a military post during South Africa's control of Namibia. When Namibia became an independent nation in 1990, the Namibian government funded the construction of a school, clinic, and police station for the members of the Tsumkwe community. Tsumkwe continued to use the two gensets, shown in Figure 4 and Figure 5, left behind by the South African Government as its primary source of electricity.[9] The OTRC assumed political control of Tsumkwe after the establishment of the Regional Government of Namibia in 2003.

The OTRC poorly maintained, managed, and operated the electricity production system. Severe pollution issues remain in the building and property that housed the gensets due to multiple diesel spills and general neglect for the environment as seen in Figure 6. Power was unreliable and the high cost of fuel limited generator operation to 10 to 14 hours per day. At times, the generators would not operate for days because the OTRC would forget to pay for diesel and have it then shipped to Tsumkwe. When there was fuel available, the generators only provided electricity to residents from 5:00 AM to 1:00 PM and 5:00 PM to 10:00 PM. The

[9] Genset: arrangement of an electrical generator and an engine fixed together to construct a single piece of equipment

interruption in power throughout the day made it difficult for residents to complete work or to utilize any electrical appliances.

Figure 4: Original genset 1 (Hangula, [Photograph], 2011)

Figure 5: Original genset 2 (Hangula, [Photograph], 2011)

Figure 6: Property of the building that housed the two gensets (Hangula, [Photograph], 2011)

In addition to the poor electrical service, residents of Tsumkwe could not afford a cost reflective tariff of N$ 6.00 per kWh.[10] The OTRC heavily subsidized the tariff, requiring residents to pay an end-user tariff of only N$ 1.00 per kWh and institutions to pay N$ 1.90 per kWh. This made the electricity much more affordable for many of the impoverished Tsumkwe residents; however, the subsidized tariff resulted in an annual deficit of N$ 1.2 million to the OTRC. In addition, very few residents paid their electricity bills, resulting in a credit meter outstanding debt of N$ 6.2 million by 2010 (Hangula, Tsumkwe Energy Project Update Powerpoint, 2012).[11] NamPower investigated the cost of connecting Tsumkwe to the national grid system to minimize the cost to the OTRC, but found that a national grid connection would cost more than N$ 150 million. The OTRC had no choice but to continue paying the subsidy for diesel.

[10] Cost reflective tariff: a tariff referring to the price charged per unit of electricity (cost/unit) that produces sufficient revenue to meet the cost per unit of electricity produced.
[11] Credit meters measured the amount of electricity used per month at each household. However, residents ignored and never paid the bills issued by the Local Government.

At the same time, the DRFN began evaluating opportunities for implementing a solar-diesel hybrid system modeled after the success of a smaller system at the Gobabeb Training and Research Center in the Namib Desert. Gobabeb is a privately owned facility, and the DRFN was anxious to test whether the hybrid system would work as a publically owned utility (Hangula, Brief, 2012). The DRFN chose Tsumkwe as the site for electrification and proposed the TEP to the EC for funding in October 2006 (Hangula, Brief, 2012). The DRFN is the implementing agency of the TEP. The specific project objective as outlined in the project proposal is to introduce a solar-diesel hybrid electricity system and energy efficient methods in Tsumkwe, Namibia's largest off-grid settlement, as a pilot project for other areas in Namibia and southern Africa (European Commission, 2006). The new 202 kWp system provides 24-hour, uninterrupted electricity to 107 households and various institutions and businesses (Hangula, Brief, 2012). The overall objective of the project is to reduce poverty in the Otjozondjupa Region by providing the physical infrastructure necessary to support the increase and diversification of socioeconomic activities amongst the San of Namibia (European Commission, 2006).

The TEP has a total budget of N$ 30.8 million that was joint-funded by the EC (75%), NamPower (14%), and the OTRC (11%) (Global Environment Facility, 2010).[12] The OTRC will assume complete ownership of the assets introduced by the DRFN when the project is completed. The DRFN put the proposal into action in March 2008 and since then has facilitated the construction of the solar-diesel hybrid system and powerhouse, exchanged all existing credit meters with pre-paid meters, and provided the community with streetlights. Additionally, the Project Management Unit (PMU) worked closely with the community to exchange 77 electric

[12] Please refer to Appendix B: *Donors, Service Providers, & Stakeholders* for an in-depth analysis of the key stakeholders involved in the project's implementation.

stoves with LP gas burners, replace 43 electric geysers with solar water heaters, distribute 700 energy efficient light bulbs to households, and install a solar charging kiosk.[13][14] The project was scheduled for completion on February 29th, 2012, however, the EC granted an extension to the DRFN until November 2012 (DRFN, 2011). Currently, the PMU is in the process of connecting 86 households in Damara Location, Gauteng Location, ǁharas Location, Tsumkwe Central, Seven Houses, and Tsumkwe North to the electrical grid. Moreover, subcontractors recently installed additional streetlights throughout the settlement and are addressing outstanding issues with the existing electrical distribution network (Hangula, Brief, 2012).

Figure 7: Solar diesel hybrid array—Tsumkwe, Namibia (DRFN, 2011)

The solar-diesel hybrid plant consists of 918 polycrystalline solar panels, shown in Figure 7, providing power to the settlement during daylight hours while charging the 766 kWh battery

[13] The PMU is responsible for the day-to-day execution of the project and includes the project coordinator and project assistant. The project manager and field facilitator also facilitate the project's implementation.
[14] The PMU distributed over 52 rechargeable lamps to residents that are chargeable at the solar charging kiosk.

storage field.[15] The battery field remains charged to 100% capacity throughout the day. Ideally, when the output to the settlement exceeds the input from the solar panels, such as during the night or during overcast days, the hybrid control system automatically switches to draw power directly from the battery bank. However, due to unknown technical difficulties, the hybrid control system does not automatically switch over from solar to diesel and system operators must manually perform the switchover every morning and night (Hangula, Brief, 2012).

The system has three gensets, two 150 kV generators and one 350 kV generator. When the batteries reach 50% of their total capacity, the hybrid control system turns on either the one 350 kV genset or the 150 kV pair. On a typical sunny day with no overcast, the solar panel array produces over 50% of the daily electricity demanded and the gensets compensate for the energy deficit. (Hangula, Brief, 2012).

The project manager projected the average electricity demand per annum in Tsumkwe to be approximately 580,350 kWh. The storage capacity of the battery field is presently limiting 100% utilization of solar energy, which has an annual production capacity of 353,904 kWh. The current battery field can only provide 68,438 kWh per year to the settlement, assuming an average output capacity of 2.5 hours per 24-hour period and excluding overcast periods. However, there currently are no plans to expand the battery field to meet the output capacity of the solar panels (Hangula, Brief, 2012).

The reduction of electricity production costs to N$ 3.50 per kWh is one of the most notable immediate outcomes of the project. Despite this reduction, tariffs remained similar to previous rates at N$ 1.00 for residents and N$ 1.90 per kWh for government institutions and businesses. The change in production costs significantly reduced the annual cost to the OTRC,

[15] Please refer to Appendix C: *Images of the Solar-Diesel Hybrid Plant* for additional images of the solar-diesel hybrid system and plant.

which continues to subsidize the tariffs. Currently, the projected yearly operation cost of N$ 963,900 stems from an average of N$ 10.64 per liter of diesel. The projected annual revenue collected from tariffs amounts to N$ 360,000 resulting in an N$ 603,900 deficit absorbed by the OTRC (Hangula, Brief, 2012). The expanded electrical system also provides power to government institutions, the schools, the clinic, the electrical water pumps, a fueling station, the police station, a tourist lodge, and numerous other businesses and institutions (Bryant Eisenbach, 2009).

For nearly two decades, two diesel generators provided electricity to residents in Tsumkwe. The power supplied was irregular, unreliable, and only available for 10 to 14 hours per day. The settlement now has 24-hour access to electricity, which the DRFN and OTRC hope will improve the livelihoods of the Tsumkwe residents. The solar-diesel hybrid system in Tsumkwe is the first off-grid power production facility of its size and complexity in Namibia and as such is a key player in the electricity supply industry of Namibia.

Namibia's *Vision 2030* outlines Namibia's aspirations to develop as an industrialized nation, placing specific emphasis on the development of Namibia's electricity supply industry as an essential element of industrialization (Republic of Namibia, 2004). The vision acknowledges that the transformation will occur with the decentralization of power generation stemming from the development of small-scale power production plants such as the TEP.

The TEP is a model for the creation of operational and regulatory requirements for similarly scaled independent power producers (Hangula, Brief, 2012). It is important to assess the impacts of the TEP in an effort to identify lessons learnt for implementation of similar project in Namibia and throughout all of southern Africa.

2.5 Methodologies for Evaluating Rural Electrification Schemes around the World

Organizations such as the World Bank have financed projects in rural electrification since the 1980's. The Bank believes economic growth opportunities to rural communities can be provided by removing the largest barrier to economic growth—the lack of electricity (World Bank, 2008). Electrification not only affects economic growth, but the entire socioeconomic condition of a region or country. Researchers categorize these impacts into four categories: health, education, environment, and income (Kanagawa & Nakata, 2008).

A lack of electricity has several lasting health and environmental effects. The traditional source of energy for cooking, heating, and lighting for 2.5 billion people around the world is biomass from wood and agricultural byproducts. Burning biomass raises the potential for long-term exposure to hazardous pollutants, contributing to both environmental and health concerns (Kanagawa & Nakata, 2008). Not only does using biomass fuels for cooking and heating produce more CO_2 emissions linked to global warming, but it is also producing products of incomplete combustion which include fine and ultrafine particles with an even higher global warming potential (Miah, Rashid, & Shin, 2009). Gathering biomass fuels is not only time consuming but negatively affects the individual's heath. Most of these negative health and wellness effects harm women and children. Additionally, the lack of reliable refrigeration limits perishable food storage and the amount and types of vaccinations and medications that can be stored in clinics and households. In some cases, the lack of refrigeration significantly affects a community's ability to provide sufficient healthcare for its residents (Kanagawa & Nakata, 2008).

Another key component of assessing the socioeconomic impact of new rural electrification schemes is the effect of electrification on education. In addition to increasing

employment opportunities, access to reliable electricity enfranchises members of poor settlements and encourages them to take an active role within their community (Kanagawa & Nakata, 2008). A 2005 IEA report highlighted the relationship between electrification and education, as seen in Figure 8. The IEA report considers increased student attendance due to increased hours of illumination for studying at home and increased access to communication technology such as television and radio for educational purposes as sources of impact for a rural electrification project. (IEA, 2005).

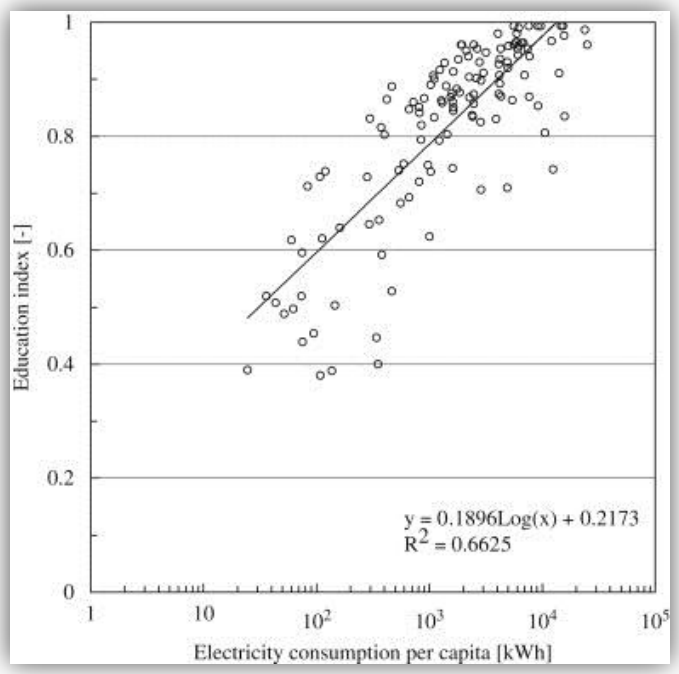

Figure 8: Global correlation between rural electrification and education index in 2002

In addition to providing increased educational, and therefore employment, opportunities, access to electricity provides opportunities for developing nonfarm-based businesses. A 2001 report on nonfarm incomes in Nicaragua published in the *Journal of World Development* states that access to electricity and drinking water connections can influence the success of nonfarm self-employment and are an integral part of a successful rural business. These nonfarm-based

businesses can generate greater income with fewer hours than a traditional farm-based income. An exhaustive evaluation of the overall effects of electricity on rural communities must include all four categories of socioeconomic impact—health, education, environment, and income.

Meaningful evaluations of rural electrification projects must also use carefully designed methods. This ensures they can both assist current ongoing projects as well as present lessons learnt for use in future development projects. A 1994 IEG report identified that the lack of thorough evaluations created misleading returns on investments. In these cases, the provider assumed the majority of the financial burden and the community received minimal benefits. In response to this report, organizations such as the World Bank developed new methods to quantify the impacts of electrification on community development. Key variables listed in this new methodology are the quality of lighting, opening hours of clinics, female health knowledge, and income from home businesses. While the World Bank used analytic assessment methods, other organizations developed evaluation styles to determine impact from rural electrification projects (World Bank, 2008). The methodology used for our evaluation of the socioeconomic impact of the TEP directly incorporates some of these key variables from the World Bank's assessment.

A 2008 study published in the *Journal of Energy Policy* identified three overarching electrification evaluation styles: descriptive study, experimental study, and analytic study. These evaluation styles range from the qualitative descriptive study to the model driven analytic study. While the highly structured and quantitative style of experimental and analytic studies provides concrete conclusions, quantitative data can be far more difficult to collect than qualitative data, which makes for the basis for a descriptive study (Kanagawa & Nakata, 2008).

Elisabeth Ilskog, Doctor of Technology and researcher at the Swedish Royal Institute of Technology, spent the last ten years performing interdisciplinary research in areas of energy and sustainable development of energy use. As part of this research, she outlines in the 2008 *Journal of Energy Policy* a methodology for rural electrification assessment incorporating components of descriptive and analytic assessment styles. Ilskog proposes that off-grid electrification assessments should begin with a broad focus of five sustainability dimensions: technical development, environmental development, social and ethical development, environmental development, and organizational and institutional development. Ilskog gives each variable set of indicators used to evaluate each variable. Figure 9 outlines these key variables.

Ilskog also stresses that the researcher must outline the methodology for collecting data in detail and identify any limitations in the indicators. The methods used for indicator data collection is a key factor in the successful implementation of Ilskog's methodology. The data should include both qualitative and quantitative measures whenever possible. Potential data sources include pre-structured interview questionnaires, direct inspection of technical equipment, logbooks, and formal technical engineering and financial reports (Ilskog, 2008). Researchers can easily tailor this methodology to any rural electrification and off-grid or mini-grid projects. This methodology was the basis for our evaluation of the TEP.

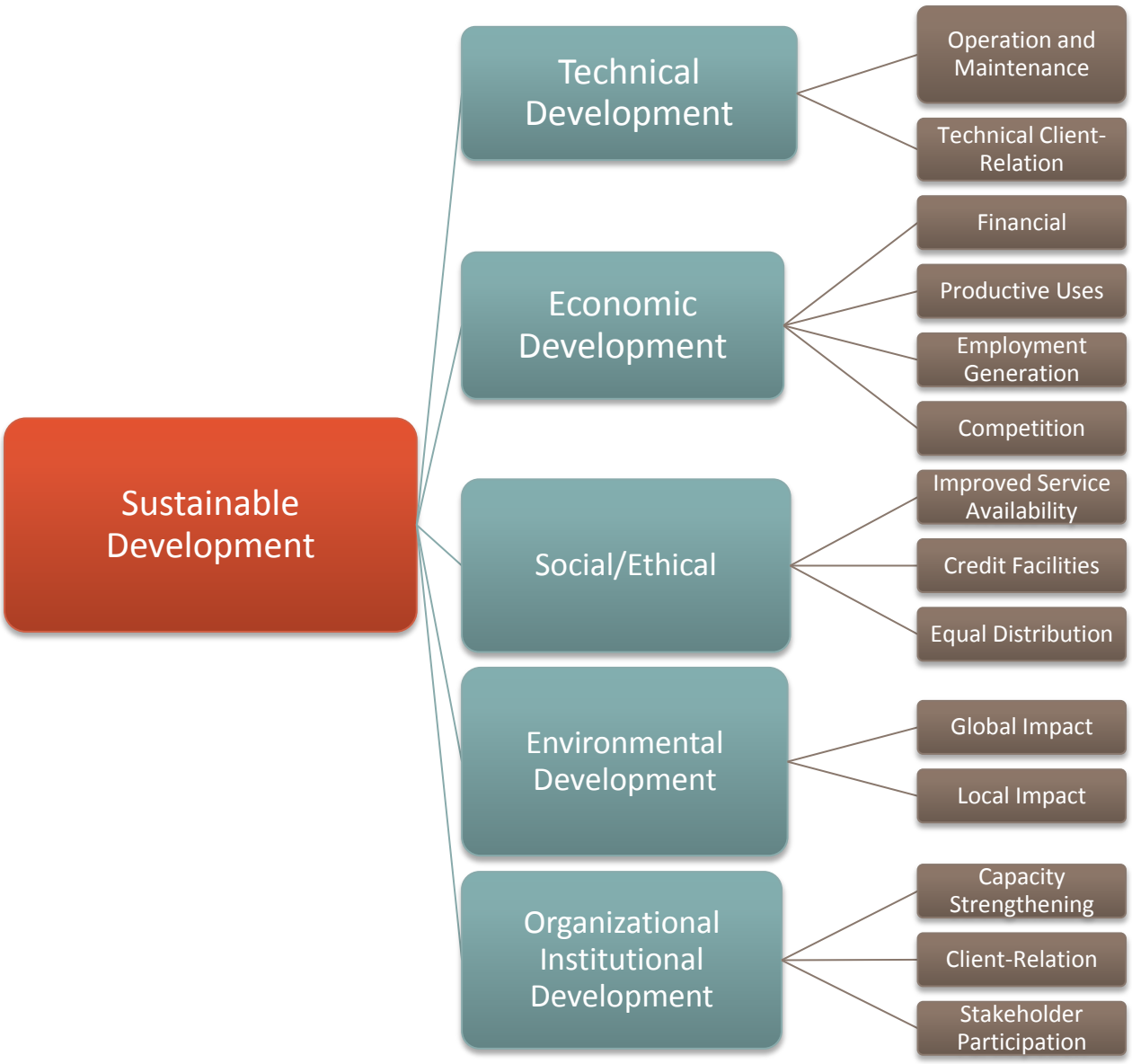

Figure 9: Ilskog's assessment method diagram (Ilskog, 2008)

Chapter 3: Methodology

The goal of this project was to assess the socioeconomic impacts of the TEP as well as identify further opportunities for development in the settlement. To achieve this goal, we developed an assessment structure based on the format proposed by Elisabeth Ilskog, which explored four *dimensions* of sustainability (Figure 10). These four dimensions formed the basis of the project objectives:

1. Identify the socioeconomic impacts of the expanded electrification on the residents of Tsumkwe
2. Identify the customer service relations involved in the development of the Tsumkwe Energy Project—both from a community and service provider perspective
3. Evaluate the capacity strength of the Tsumkwe Energy Project with respect to its financial and technical support structure
4. Identify technical operational challenges of the Tsumkwe Energy Project

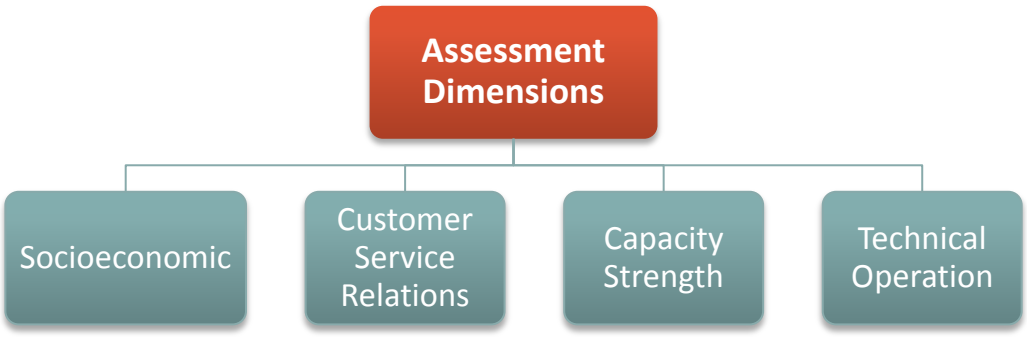

Figure 10: Assessment dimensions for evaluating the Tsumkwe Energy Project

For each dimension of the assessment, we developed major key variables and subsequent indicators with which we evaluated the TEP. In the following sections, the methods for collecting data on the key variables and indicators are expanded and outlined.

3.1 Field Work Preparation

We collaborated with our DRFN project liaisons, Clarence Mazambani, Abraham Hangula, and Caroline Coulson, to set project goals, develop understanding of the project and region, and solidify the logistics of our fieldwork prior to visiting Tsumkwe. We created questionnaires for residents, key stakeholders, and service providers in Tsumkwe. The end goal of conducting interviews was to understand the impacts of the TEP from the perspectives of the local residents and service providers. Both electrified and un-electrified residents were interviewed. Key stakeholders included business owners and public service employees. The main service providers included NamPower, the OTRC, and settlement officials. Figure 11 below outlines the five kinds of interviews we conducted based on the type of respondent:

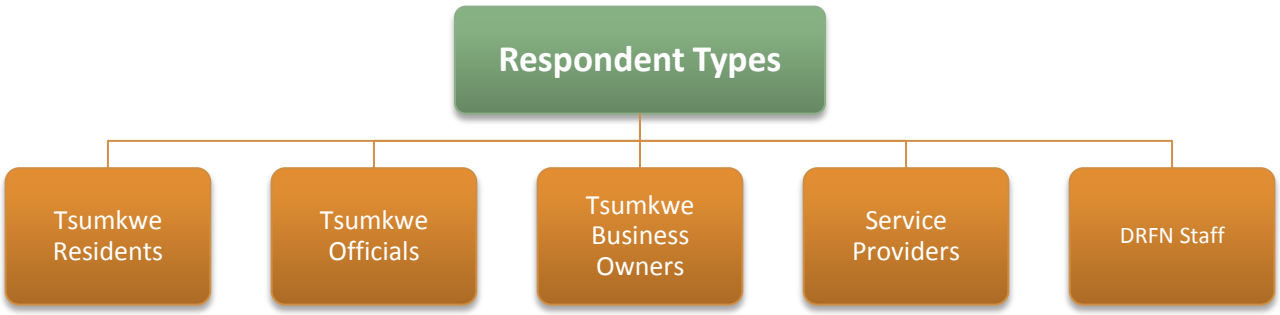

Figure 11: Key informant types for data collection

Ms. Mazambani reviewed our proposed questions multiple times and made suggestions to the overall question organization and structure of our interview questions. This review ensured open-endedness and limited leading questions. We met with companies as well as governmental and nongovernmental organizations to develop our understanding of the TEP, public service operations in Namibia, and the local culture of Tsumkwe. We interviewed companies and organizations involved with the implementation of the TEP, including EMCON, the ECB,

NamPower, SolarAge, and the Nyae Nyae Conservancy. We further shaped our interview questions from the information gathered in these meetings.

Appendix D: *Interview Questions* details the finalized sets of interview questions. There are eight sets of questions tailored to gather data from various sources: electrified residents, un-electrified residents, business owners, clinic, police station, radio station, school administrators, and settlement officials.

Despite these precautions, we had limited knowledge about the culture and people of Tsumkwe as we developed our interview questions while in Windhoek. It was difficult to determine question appropriateness and anticipate respondents' reactions to the interview questions. We found out quickly once in Tsumkwe that this factor was a major limitation affecting our data collection. We also had a limited understanding of the settlement's public services, which required us to adjust and expand interview questions once in Tsumkwe.

3.2 Field Work Collection

We met with our project facilitator and translator, Jimmy Itamba, upon arrival in Tsumkwe. During this meeting, we explained the scope and objectives of our project to ensure that he understood the intentions for our data collection. We also reviewed each set of our interview questions with Mr. Itamba to gain his feedback on wording and to develop an optimal procedure for collecting the data. We involved Ms. Mazambani, Mr. Hangula, and NamPower's TEP project supervisor, David Jarrett, in the discussion as well. We concluded the meeting with a tentative schedule for conducting the interviews throughout our time in Tsumkwe. We agreed to begin with interviewing settlement officials and business owners for the first two days allowing residents to become aware of and adjust to our presence. After our discussion, Mr.

Jarrett gave us an introductory tour of the energy plant, which greatly expanded our understanding of the system and its upkeep.

During our first two days in Tsumkwe, we interacted with the residents on an informal basis so they could familiarize themselves with us without feeling as though we were in Tsumkwe purely to survey them.[16] This allowed our team to form relationships with potential respondents so they could feel that they could open up to us about their perspectives on the TEP at later date. We formed relationships by exploring the settlement, buying from local vendors, and playing friendly games of volleyball with the officers of the police station. We also met with Honorable Councilor Moses !Coma and the settlement clerk, Benedict Tjombuua, to introduce ourselves and explain the purpose of our visit to Tsumkwe.

Mr. Itamba served as our main connection to the Tsumkwe community—arranging meetings with settlement officials, business owners, and residents, as well as serving as one of our translators. Arranging interviews with respondents was often difficult and at times limited our progress. Several residents did not feel comfortable with the language barrier, others did not want to risk making public their views about the TEP, and some were away on leave for either work or personal reasons. Mr. Hangula and Mr. Itamba translated interviews when community members felt uncomfortable speaking in English or when the language barrier would likely affect the community member's ability to express themselves fully.

We divided Mr. Hangula and Mr. Itamba between each of our two interviewing teams to translate interviews. We used English whenever possible to prevent miscommunications. Ms. Mazambani aided when there was a communication problem with residents in English. Her

[16] This tactic is especially important as they are considered one of the most over-surveyed populations in the country (Hangula, Brief, 2012).

regional accent and word choice allowed her to rephrase questions in English in a way that respondents would understand and be able to answer appropriately.

This inevitable language barrier hindered our goal of conducting consistent, uniform interviews with every respondent. We asked all respondents the same questions, but the inconsistency in phrasing may have affected respondent's answers. The difference between Mr. Hangula and Mr. Itamba's translation styles also limited the uniformity of our data collection. Mr. Hangula and Mr. Itamba had different methods of approaching the interviews, which led to differing lengths of responses.

Our translators' relation to the residents of Tsumkwe also influenced how respondents reacted to particular questions. Mr. Hangula serves as the project manager of the TEP and his presence in some interviews may have made respondents hesitant to express negative feelings towards the TEP. When we needed Mr. Hangula to translate, we asked him to make it clear to the respondents not to let his presence influence their responses. However, if we did not need his translating services, he would excuse himself from the interview after a short introduction of our project purpose. Mr. Itamba is a local resident of Tsumkwe and the field facilitator of the PMU. He is on friendly terms with most of the residents, but residents still connect him to the DRFN and the TEP.

The language barrier made it difficult for respondents to answer scale-rating questions, as they did not understand what was being asked. Respondents often would neglect our request for a rating between one and five and instead give in depth answers to the questions involving the rating system. In order to acquire a rating, we had to probe respondents by rephrasing the question and explain the rating system. Upon reflection, we decided not to use the ratings

gathered during interviews because the rephrasing of questions to residents was not consistent between interviews.

We considered these impacts of the language barrier when drawing conclusions about the respondents' viewpoints in Chapter 4: *Findings*.

Our team split into two groups of two, excluding the translator, to maximize the number of interviews conducted and to minimize uneasiness of the respondents. Ms. Mazambani split her time between the groups. We split into groups by gender, which may have affected some of the responses. For example, each group received different responses when asking residents to describe the common crimes experienced in Tsumkwe. The female group received several reports of rape as a type of crime in Tsumkwe, whereas the male group received more crime reports pertaining to fighting and theft.

While conducting interviews, we actively sought out an even number of males and females to interview to avoid generating a bias in the data; in the end, we had interviewed 41 females and 33 males. We also balanced the number of interviews conducted per location to ensure we gave each group equal representation in the findings and analysis; these groups included both electrified and un-electrified residents and ethnic groups. Table 1 provides a summary of the final interview count we were able to achieve while in Tsumkwe. Overall, we were able to conduct 73 interviews with residents, stakeholders, and service providers associated with the TEP.

Table 1: Final interview count

Respondent types	Number of interviews conducted	Number of males interviewed	Number of females interviewed
Settlement officials	8	4	4
Business owners	5	3	4
Public services	7	2	5
Un-electrified residents	16	9	7
Electrified residents	36	15	21
Focus group	1	-	-
TOTAL	**73**	**33**	**41**

The following sections detail the approach we used to evaluate the four dimensions of impact from the TEP on the community and development of Tsumkwe.

3.3 Objective 1: Socioeconomic Impacts

We evaluated the socioeconomic effects of the TEP on business operations, public service operations, and the day-to-day lives and chores of residents. Figure 12 illustrates these key variables of the socioeconomic dimension:

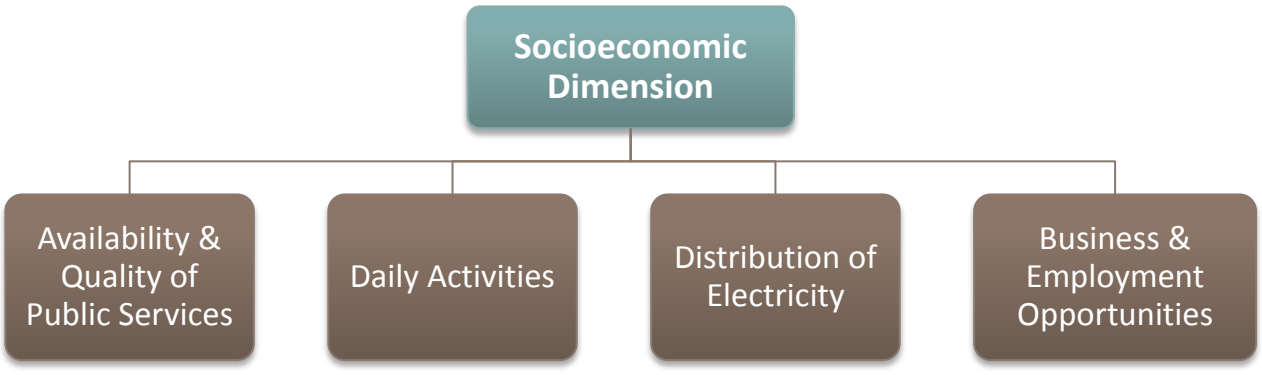

Figure 12: Key variables of the socioeconomic dimension

The first variable we evaluated was the availability and quality of public services. We aimed to determine if and how the public services in the settlement changed since the installation of the TEP. These public services included the clinic, the Community Learning and

Development Centre (CLDC), NamPost, the police station, the radio station, and the schools. We evaluated the public services because these services affect all residents of the settlement, both electrified and un-electrified. We assessed this key variable by interviewing both public service providers and residents. By interviewing both providers and residents, we obtained not only the official changes, such as the changes in study hours of the school, but also how the community perceived and made use of these changes. Interviewing public service providers before residents helped us formulate more questions for the residents regarding their interactions with the public services.

Once in Tsumkwe, we identified both NamPost and the CLDC as highly important services to the community; our limited knowledge of Tsumkwe before arriving in the settlement caused us to overlook the post office and CLDC when we designed our interview questions. Not only did we interview employees of these public services, but we also integrated questions about the services in our residential questionnaires. After several residents commented on how power outages affected the water supply, we added a question about the amount of time it takes for the water supply to stop and resume. Despite our review of interview questions prior to fieldwork, residents consistently had difficulty understanding the question asking them to evaluate their satisfaction of public services.[17] Respondents misunderstood the question because they were unsure what was classified as a public service. We clarified the question by suggesting specific public services which could have been impacted by the TEP.

The second variable we evaluated was the changes in daily activities in both electrified and un-electrified residents. This included any changes in daily schedules, chores, and activities since the expansion of electricity to 24-hours in August 2011. This allowed us to assess the minor day-to-day effects of the TEP on residents. We evaluated this variable by interviewing

[17] How satisfied are you with public services now that there is 24-hour power compared to before?

electrified and un-electrified residents, focusing our questions on their appliance use and changes to their routines. We conducted interviews to compare electrified residents to un-electrified residents and to determine if there were any changes in the daily lives and schedules of the un-electrified residents. In some cases, residents of un-electrified areas accessed electricity with a generator or an illegal connection.[18] In these cases, we interviewed them as electrified residents. When un-electrified residents identified that they used electric appliances in other areas as part of their daily routine, relevant questions about daily routine from the electrified resident survey were included. Additionally, we interviewed professional workers in ministry offices, schools and public service offices in order to determine the effect of the TEP on their workday.

The third key variable we evaluated in the socioeconomic dimension was the distribution of electricity across the community of Tsumkwe. We evaluated this key variable by first reviewing a map created by the International Development Consultancy outlining settlement development plans including electrification. We used the information from this map to determine which locations in Tsumkwe had service line connections to the electrical grid prior to our fieldwork.

Once in Tsumkwe, we worked to understand the criteria used to connect households to the electrical grid by interviewing Mr. Tjombuua. We also interviewed community members in un-electrified locations to gain their perspectives on why there were not electrified. We created a list of points to discuss with Mr. Tjombuua before we left Tsumkwe to discuss these perspectives.

The fourth and final key variable assessed under the socioeconomic dimension was the changes in business and employment opportunities. We evaluated the impacts of the TEP based

[18] Illegal connection: the distribution of electricity from an electrified household to an un-electrified household using methods that violate ECB distribution health and safety codes

on the hours, employment, and services provided by local businesses. This was primarily to describe the economic changes in Tsumkwe after the establishment of 24-hour power and to predict any upcoming changes to business operation, including the establishment of new businesses. We evaluated this key variable by interviewing business owners and operators and residents. By interviewing the business owners and operators, we were able to identify changes in business practices and plans for expansion. Interviewing residents allowed us to determine their perception of the changes to local business opportunities. We identified several limitations during the interview process. First, residents interpreted questions regarding "markets" differently—some included shebeens or unofficial businesses run out of homes, while others identified as markets solely businesses similar to the General Dealer and Savanna II.[19] Second, respondents interpreted employment opportunities differently—some residents included only opportunities to work for registered businesses, while others included self-employment such as making crafts at home or temporary work. We clarified these terms when necessary while trying to minimize leading responses.

3.4 Objective 2: Customer Service Relations

This objective evaluated the interactions between the electrical service providers and the community as well as determined the goals of both electrical service providers and community members for the TEP. Figure 13 illustrates the two key variables associated with the customer service relations assessment dimension:

[19] Shebeen: an informal establishment selling alcohol without a license

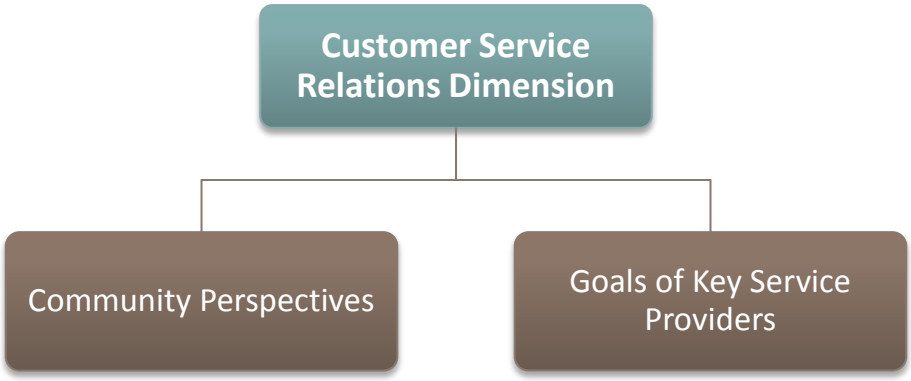

Figure 13: Key variables of the customer service relation dimension

The first key variable assessed the various perspectives of community members regarding their understanding and viewpoints of the TEP. This was expected to provide a baseline for resident expectations for the TEP from which we could compare goals of the PMU. We interviewed both community members and business owners because residents and business owners were likely to have different ideas of what types of electrical and customer service is appropriate. We left these questions moderately open-ended to avoid limiting the responses.

The second key variable identified the goals of key service providers such as NamPower, the DRFN, and the OTRC. We evaluated this key variable by interviewing the service providers, focusing on the OTRC and other government offices. We focused on the OTRC because they are the acting administrators of the TEP and are responsible for future regulation of the electricity produced by the TEP as well as addressing customer concerns.

3.5 Objective 3: Capacity Strengthening

The third objective, capacity strengthening, is the ability of the PMU to build financial and technical support structures to ensure the sustainability of TEP infrastructure. Figure 14 below illustrates the two key variables associated with the capacity strengthening dimension:

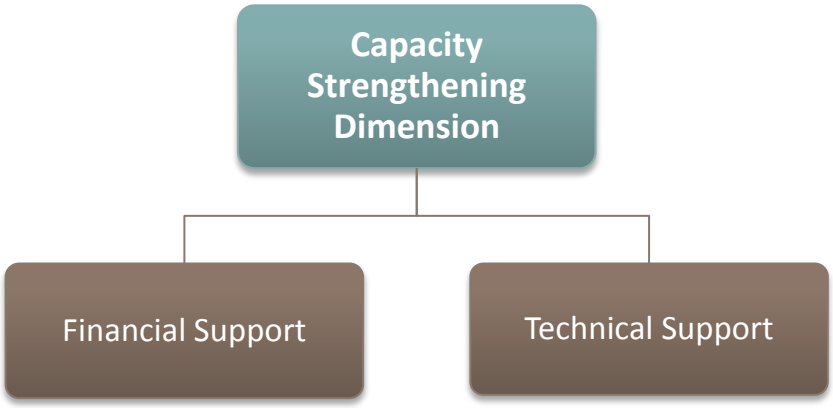

Figure 14: Key variables of the capacity strengthening dimension

The first key variable assessed the financial support structure and the OTRC's capacity to provide funding for maintenance and unexpected expenses. This assessment allowed us to gauge the financial sustainability of the TEP. We evaluated this objective by interviewing Mr. Hangula and Mr. Tjombuua. This allowed us to develop an understanding of both the project's initial financial plan as well as the OTRC's plans to continue development, expansion, and maintenance of the system. Questions in regards to the OTRC were as direct as possible to determine if they had established plans for funding maintenance of the hybrid system.

The second key variable under the capacity strengthening objective was technical support. We focused on the current level of technical support of the system and plans for future support. When evaluating this key variable, we concentrated on training opportunities, repair services, and the current system hardware.

As with financial support, we evaluated the technical support by interviewing Mr. Hangula as well as council members at the OTRC to gain their insight as the previous and current administrators of the TEP. We were unable to interview anyone from the Department of Works who may have been able to give more detailed information on the system's technical problems. We developed an understanding of contractor responsibilities and issues relating to

coordination of overall system plans and contractual deadlines by working closely with Mr. Hangula. This information provided insight for recommendations about the structure and planning of future projects of similar scale to the TEP.

3.6 Objective 4: Technical Operation

The fourth and final assessment dimension identified the fundamental strengths and weaknesses of the TEP's technical operation. We broke the evaluation of this assessment dimension down into the key variables outlined in Figure 15 below:

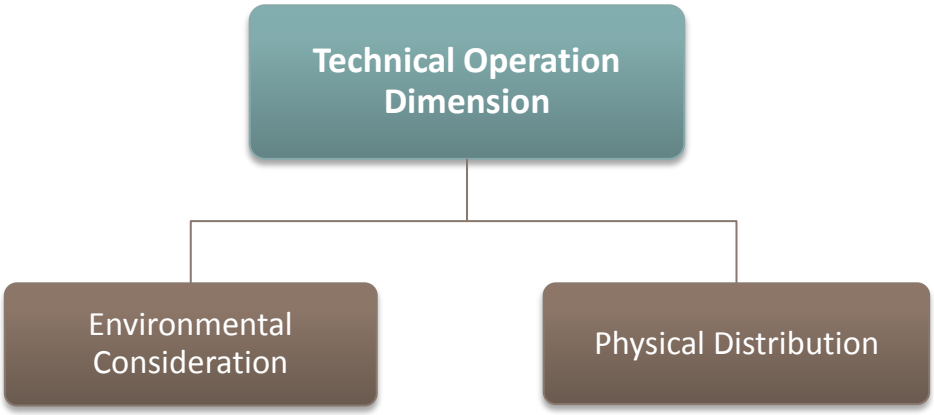

Figure 15: Key variables of the technical operation dimension

The first key variable under the technical operation dimension was the environmental impacts of the TEP, specifically, the effect of the expanded electrification on the water usage in Tsumkwe. Water pumps currently provide residents with 24-hour access to running water in comparison to the previous 10 to 14 hours, which raised concerns about the capacity of the water table. We intended to compare the current borehole flow rates to the flow rates when running water was only available for 10 to 14 hours a day to determine the initial effects of increased

water access. We worked with NamWater to establish the water levels in the boreholes and the water table as well as water flow rates. However, it was difficult to quantify the impact of the TEP on the water table due to the limited historical data and recent inception of the TEP. We therefore relied on qualitative data gathered from interviews with residents, business owners, and public service providers. We used their responses to determine how their water usage changed since the installation of the TEP and identify possible future concerns for the sustainability of Tsumkwe's water supply.

The second key variable was an evaluation of the physical condition of the distribution lines and power production facilities. We assessed the condition of metering devices, distribution lines, diesel generators, and other facility items to determine the Department of Works' ability to perform maintenance to the system. We assessed this key variable through direct observation of the electrical infrastructure as well as by interviewing Mr. Hangula, Mr. Jarrett, and Mr. Tjombuua. Interviewing system administrators allowed us to obtain an expert's perspective on current problems, while inspecting the infrastructure permitted us to identify any new or unaddressed problems with the physical distribution.

After several respondents noted equipment damage that they associated with the TEP, we started collecting information on damaged equipment at Mr. Hangula's request. This information was difficult to collect because some respondents included information from before the TEP and commented on damage to other people's equipment that they had heard about.

Chapter 4: Findings

During our eight-day stay in Tsumkwe, we conducted 73 interviews with various settlement officials, business owners, service providers, and residents. We performed 52 resident interviews, surpassing our target of 50 resident responses. Detailed in the following sections are the findings and analysis of our data collection both in Tsumkwe and in Windhoek. While the TEP is well received in the community with the majority of the impacts positive, there are still several problems standing between the current implementation and a fully-functioning system.

4.1 Socioeconomic Impacts

Availability & Quality of Public Services

Residents now have 24-hour access to the water supply.

NamWater owns the four boreholes supplying the settlement of Tsumkwe with water. NamWater pumps the water directly from the ground and into six 60 cubic meter storage tanks. The water becomes the property of the Local Government as soon as it passes through the NamWater meters.

The electrical grid expansion has significantly increased the hours water is available to residents. In the past, water was only available when electricity was available, which was approximately 10 to 14 hours per day. When the power went off at 10:00 PM, water would only be available for 30 additional minutes.[20] When the power would come back on at 5:00 AM in the morning, water was still unavailable until about 6:00 or 7:00 AM until enough water to pump was pumped from the boreholes to the storage tanks. This forced residents to store water at night for morning chores like bathing and cooking. Several community members also recalled times

[20] The water in the storage tanks is only enough to supply the settlement with approximately 30 minutes of water when the borehole pumps are not operational.

in which electricity was unavailable for days at a time because of diesel shortages. Residents and their crops and livestock suffered from dehydration due to the unreliable water services.

Now water is available for 24 hours a day barring extended electrical outages. Power interruptions lasting longer than 30 minutes will disrupt the water supply to the community for one to two hours after the power returns. However, these interruptions are infrequent.

The CLDC library and computer services are more accessible to community members due to 24-hour access to electricity.

The CLDC offers community members a public library, an internet café, and printing services. Before the expansion of electricity, the library operated from 8:00 AM to 1:00 PM on weekdays. After the TEP, the CLDC expanded its normal hours of operation by three hours and is now open from 8:00 AM to 1:00 PM and from 2:00 PM to 5:00 PM on weekdays. The additional hours allows community members to access the CLDC's resources in the afternoon without rushing to complete other work in the morning. Additionally, CLDC staff now host special wellness workshops covering topics such as self-education, health and sanitation, and the environment.[21] There are also plans to host special programs for learners after 5:00 PM to give them afterschool access to computers and books. All community members can utilize these programs free of charge. The CLDC does, however, charge for unlimited internet, printing, and copying access for N$ 50 a month.

The expanded access to CLDC education services has led to the employment of at least two community members.

The increased access to CLDC services gives residents the opportunity to learn new skills by reading books, using the internet, and attending special wellness programs. In an interview, the director of the CLDC stated, "[t]wo adult learners from Tsumkwe have learned to read and

[21] Self-education refers to the use of the computer and other CLDC to teach oneself a new skill.

write through using the computer and now one works at the primary school and the other works in the secondary school." The director also stated that there are members of the community applying for jobs at the Local Government office and ministries in Tsumkwe and in Grootfontein, all of which require computer literacy skills. Many community members learn computer skills by attending computer classes at the CLDC, making them more desirable to employers.

The Tsumkwe clinic can now address medical emergencies at night using electric lighting and medical equipment.

The most notable impact of the expanded electricity on the clinic is that the nurses can now attend to emergencies during the night using electrical lighting. In the past, nurses struggled to address childbirth and other nighttime emergencies appropriately due to insufficient lighting from candles, flashlights, and kerosene lamps. One resident recalled when residents "used to direct the headlights of cars into the clinic windows to increase the nurse's lighting while stitching animal attack wounds." Moreover, nurses can now operate intravenous pumps, heart rate monitors, and other medical equipment at night. Another resident stated that, "I feel much more cared for knowing that if I had an emergency, I will be safe. I am so grateful for the electricity. Everyone should be grateful."

The Tsumkwe clinic can now store refrigerated medication and bodily fluid samples for extended periods.

Previously, refrigerators could not keep medication from spoiling for extended periods. Nurses can now store blood and mucus samples in the refrigerator for the doctor from Mangeti, who comes once a month, to test for tuberculosis and malaria.[22] Before 24-hour electricity was available, the nurses could not keep samples for more than a few days. Now the nurses can

[22] Mangeti is a village 100 km west of Tsumkwe.

collect fluid samples at the patients' convenience and store them until the doctor can arrive to conduct laboratory testing.

Residents expressed that they feel safer at night due to the installation of streetlights along the main roads and side roads.

The TEP includes the installation of streetlights on the main street and in Gauteng, Damara, Sewe Huise, and ǁharas Locations. G&S, the contractor responsible for installing the streetlights, fixed the existing streetlights on the main road and installed additional streetlights on the road from Grootfontein to Botswana and to the ǁharas Location. Many residents, primarily residing in locations other than Gauteng, Sewe Huise, and ǁharas Locations, commented that they felt safer with streetlights on the main road, but would like more. The streetlights allow residents to see other people and animals such as snakes and hyenas at night. Streetlights also deter hyenas, which frequent Tsumkwe and occasionally attack livestock.

Figure 16 shows the main street of Tsumkwe before the installation of streetlights while Figure 17 shows the main street illuminated several hours after sunset by seven out of the nine originally installed streetlights. G&S has completed installation of streetlights on the existing power poles throughout the settlement; however, the installations were months behind schedule.

Figure 16: Main Street of Tsumkwe several hours after sunset before the installation of streetlights (Hangula, [Photograph], 2011)

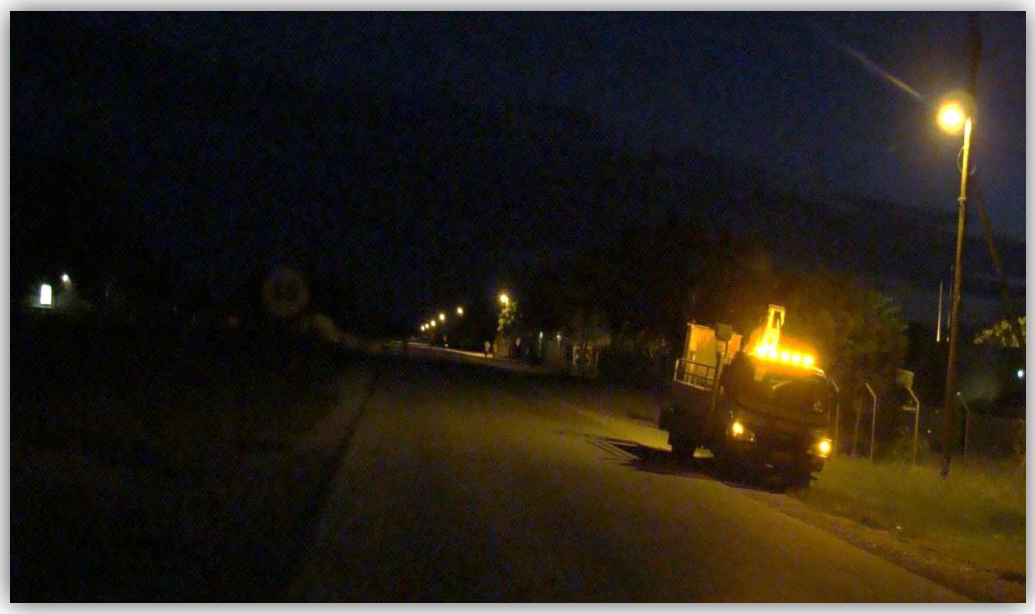

Figure 17: Main Street of Tsumkwe several hours after sunset illuminated by seven of the nine originally installed streetlights (Hangula, [Photograph], 2011)

Illumination at night in the primary school hostels prevents trespassers from sleeping in the dormitory halls.

The Tsumkwe Police Department (TPD) inspector cited that before the expansion of electricity, adults would trespass into the primary school hostel and sleep in the learners' dormitory halls. Now that there are lights in the hostel buildings, school officials have not reported any cases of trespassers. The inspector believes that the perpetrators have not returned because they are afraid to be seen by the TPD. As a result, the hostel is much safer for both the learners and teachers staying in the facility.

TPD officers can communicate more reliably because of the 24-hour access to electricity.

Officers at the TPD can now charge their two-way radios whenever needed. In the past, the radios frequently ran out of power and police officers could not recharge them unless the electricity was on. One officer cited that, "One time I was out on patrol alone and I came across a group of men fighting, but my radio was dead and I could not call for backup. Earlier that day I forgot to charge my radio before the electricity turned off at 1:00 PM and I went on patrol at 4:00 PM, one hour before the electricity came back on." Now, electricity is available to charge their radios 24-hours a day, which has greatly improved officer communication. Officers can go out on patrol and not have to worry about the next time the electricity will be available to charge their radios.

Residents have increased access to banking services through NamPost because of 24-hour electricity.

The Tsumkwe NamPost branch acts both as a post office and a bank where clients can deposit, withdraw, and send money. The banking service requires electricity to operate the card machine, the fingerprint identification scanner, and the computer system. NamPost can now remain open for banking services past 1:00 PM allowing the office to operate during the normal

business hours of 8:00 AM to 5:00 PM. Community members explained that before the expansion of electricity, they would rush to complete tasks and chores in order to get to NamPost by 1:00 PM. Other community members could not use the banking service because their working hours conflicted with NamPosts' hours of operation. Since the expanded hours of service, approximately 20 new residential customers have opened banking accounts at NamPost. The expansion of electricity allows more residents to utilize NamPost's services.

The Tsumkwe Namibia Broadcasting Corporation (NBC) has been able to increase its broadcasting from 15 to 24 hours per day.

The NBC has an office stationed in Tsumkwe and a radio tower providing around-the-clock radio programming to the community in several different languages. Previously, the NBC offered programming from 6:00 AM to 9:00 PM, but now offers it 24 hours a day. Two additional hours of local programming is broadcasted in Ju|'hoansi language from 9:00 PM to 11:00 PM and then national programming is broadcasted for the remainder of the night until 6:00 AM. We were not able to quantify if the number of listeners has increased because of the expanded hours of programming as the director of the NBC station did not have this data. However, several San residents reported that they do listen to the radio more often since electricity is available 24 hours a day.

The NBC broadcasting tower has decreased broadcasting costs by N$ 6,050 per month.

The station now saves a significant amount of money on diesel fuel as a direct result of 24-hour access to public utility electricity. In the past, the NBC operated a company generator to ensure continuous broadcasting from 6:00 AM to 9:00 PM. The generator would run when the electricity was not available from 1:00 PM to 5:00 PM and use eight 200 L drums of diesel every two months (N$ 8,800 a month). Since the expansion of electricity, the amount of diesel fuel consumed has decreased significantly to five 200 L drums over four months (N$ 2,750 per

month).[23] The NBC still uses its own generator to compensate for any unplanned outages or to provide the broadcasting tower equipment with extra power. The expansion of electricity has allowed the NBC to reduce the cost of operating the broadcasting tower significantly despite longer broadcasting hours.

The primary and secondary school administrators have not yet identified the impacts of 24-hour access to electricity through the marks of learners.

Administrators at the primary and secondary school cited that they have not noticed an increase in the overall marks of learners since the expansion of 24-hour electricity, so it is concluded that it is too early to identify the benefits. We were unable to gather the appropriate information to formulate a valid analysis of the TEP's impact on the community concerning education.

All residents of Tsumkwe have benefit from the expanded hours of public services. The increase in access to water, community learning, healthcare, and banking services has positively affected the lives of the community. The services provided by these institutions have also improved as a direct result of the TEP.

Daily Activities

Professional workers at ministry offices, schools, and public service offices can work more efficiently during workdays because of 24-hour access to electricity.

Professional workers at ministry offices, schools, and public service offices can now work a standard workday of 8:00 AM to 5:00 PM without interruptions to their electricity access. Before the expansion of electricity, professionals only had access to electricity from 8:00 AM to 1:00 PM, which limited their ability to work efficiently. Professional workers would have to

[23] A diesel fuel price of N$ 10.64 per liter was used to estimate the monthly cost for NBC.

rush to complete any work before 1:00 PM that required the use of a computer, printer, copy machine, or fax machine. Some workers would end their day at lunchtime.

For example, one teacher at the primary school commented that she had to rush to print and copy class materials for the next day before 1:00 PM. and sometimes would not have the chance to print everything she needed. The inspector of the TPD also noticed an increase in her productivity because of the reliable electricity. She mentioned that, "Now I can complete my reports quicker using the computer, without having to rush to get them done before 1:00 PM. It used to take me so much longer to write reports because I could only work until 1:00 PM, but now I can take my time."

Electrified residents make use of household electrical appliances throughout the day to make their daily tasks and chores easier.

Electrified residents use many appliances throughout a typical day and own a wide range of electrical appliances including refrigerators, toasters, coffee makers, blenders, televisions, DVD players, radios, washing machines, and computers. Residents with refrigerators now do not have to worry about wasting perishable food. In the past, long periods of unplanned power outages resulted in large quantities of spoiled food.

Most un-electrified residents have access to some electrical device or appliance. Un-electrified residents without refrigerators often store their perishable foods in neighbors' or family members' refrigerators and freezers. Moreover, several un-electrified residents have their own mini-generator, which they use to power refrigerators.

Several un-electrified residents in ǁharas and Gauteng Locations also have bought or plan to buy electrical appliances in anticipation of receiving electricity in the future. Before the expansion of electricity, electrified residents could not use electric appliances and devices throughout the entire day. Now, electrified residents can do their laundry, use their computers,

or watch television at their leisure. The expansion of electricity to 24 hours a day has made the lives of electrified residents more convenient.

Electrified residents are now able to go to sleep later due to the access of 24-hour electricity.

We discovered through interviews that electrified residents spent more of their time in the evening watching television, studying, or performing work-related activities and consequently stayed up later than they did before the implementation of the TEP. Previously, residents had to use their daylight and electrified hours preparing for bed before the power turned off at 10:00 PM. Now, with 24-hour electricity, residents can spend their daylight hours doing other productive activities such as chores or fieldwork and prepare for bed at any time.

Residents without 24-hour access to electricity in their homes often explained that they could not stay up much later than 8:00 or 9:00 PM because they must prepare for bed before it was too dark. Un-electrified residents spend more of their daylight hours preparing for bed, and are therefore have less productive hours during the day. Despite the differences in bedtimes, both electrified and un-electrified residents woke up on average between 5:00 and 6:00 AM.

Distribution of Electricity

Electricity is not distributed equally to community members because the Local Government did not publicize their standards for household electrification.

There are 107 households currently connected to the electrical infrastructure in Tsumkwe. The PMU plans to connect over 86 households in Damara Location, Gauteng Location, ǁharas Location, Tsumkwe Central, Sewe Huise, and Tsumkwe North to the electrical grid. However, there remain many homes throughout the settlement that the Local Government has not given approval for connection to the electrical infrastructure. Residents have been applying for a connection in Tsumkwe North for several years, but the Local Government repeatedly did not

fulfill their requests. Recently, an additional 86 homes have been selected for connection to the electrical grid including 25 households in Tsumkwe North.[24] However, there are still numerous homes in this location that will remain un-electrified.

To justify not electrifying the remaining homes in Tsumkwe North, the settlement clerk, Benedict Tjombuua, remarked that the houses are not permanent structures and therefore cannot be connected to the electrical grid. He defined permanent structures as: "[a] home or building that is not just made of mud, but of brick or cement; a home that will be able to support the electrical infrastructure. We need something to attach the meter box to, not just stones and mud." Figure 18 and Figure 19 show typical homes in Tsumkwe North. The traditional household in Figure 18 is made of mud, tree branches, and reeds for roofing. The home in Figure 19 is made of mud and stones, with a steel corrugated sheet roof supported by thick wooden supports. He explained that, "if they build permanent structures, we will connect them." Most of Tsumkwe North's residents feel that that their homes fit Mr. Tjombuua's criteria, and argue that, "[t]he homes we live in are permanent structures; I have lived here for eight years, in the same home. I have applied to the town office for electricity several times, everyone here has. But we continue to be ignored." Nearly every resident we interviewed in this location expressed similar dissatisfaction. It is also important to note that Mr. Tjombuua did mention, "There are homes in Tsumkwe North that could be classified as permanent structures, but not the majority."

[24] There were no plans to connect homes in Tsumkwe North at the time of our interviews.

Figure 18: Un-electrified home in Tsumkwe North

Figure 19: Un-electrified home in Tsumkwe North

The Local Government would consider funding the construction of electrical lines and additional infrastructure if more of the homes in the location fit the description of permanent structures.

Despite Mr. Tjombuua's description of a permanent structure, there are electrified homes in Tsumkwe that do not meet the stated criteria. These homes are made primarily of wood and lack any stone, brick, or concrete structure for support as seen in Figure 20.

The community members in Tsumkwe North took additional steps in their pursuit of a connection to the electrical grid by signing a joint petition letter and sending it to the OTRC in Otjiwarongo. The letter expressed the community's desire to be connected to the electrical grid and included accusations against the Local Government office leader, Masheshe Likoro. The petitioners claimed that Mr. Likoro's decision to leave homes in Tsumkwe North un-electrified stems from tribal discrimination. Petitioners allege that Mr. Likoro chose not to approve funding to electrify this location because he is of San descent and there are no San living in Tsumkwe North. We were unable to interview Mr. Likoro directly as he was on leave for the entirety of our stay in Tsumkwe.

After discussing the topic with Mr. Tjombuua and the local residents, it became apparent that the Local Government did not have a standardized definition of permanent structures resulting in community tensions and charges of tribalism.

Figure 20: Electrified home in Owambo Location

Business and Employment Opportunities

Access to 24-hour electricity has led to the development and expansion of small businesses in Tsumkwe.

Several small businesses in Tsumkwe, such as the OK Shop, have developed as a direct result of the TEP. The OK Shop was only a small market before the expansion of electricity, but the shop owner opened a shebeen adjacent to the original marketplace building after the expansion. The OK Shop Shebeen now has several refrigerators that keep the alcohol cold all day long.

A takeaway kiosk also opened in the Tsumkwe Craft Center selling chips, sausages, and fried dough during lunch hours. The owner prepares the food at home, stores it in a refrigerator in the Craft Center, and heats it up in a microwave for customers. Before the expansion of electricity, the power would shut off at 1:00 PM, making a lunch kiosk impossible to operate.

Now that electricity is available at lunchtime, the owner can make a profit by selling food to workers who take their break for lunch at 1:00 PM.

Another resident in ǁharas Location plans to open a small tailoring shop in the near future. The resident explains that she will make clothing and repair damaged clothes using an electric sewing machine. She can now use the sewing machine between 1:00 PM and 5:00 PM and work in the field in the mornings. She commented that, "I could not open a tailoring shop in the past because I would not have the time. I have to wake the children up in the morning for school, tend to the field, and prepare food for the evening. I would have no time left over to do anything before the power would turn off, but now I have an extra four hours in the afternoon for my tailoring business."

There are additional small businesses developing all across the settlement such as china shops, small food shops, arts and crafts shops, catering businesses, and shebeens.[25] Mr. Tjombuua cited that there is an increase in the number of residents filing business applications at the Local Government office.

Access to 24-hour electricity has not yet led to a discernible increase in employment opportunities.

There has been no quantifiable increase in the number of jobs available to residents by preexisting businesses since the expansion of electricity in Tsumkwe. When we asked community members about job employment opportunities in Tsumkwe, the most common response we received was that, "There are no employment opportunities in Tsumkwe." While many residents of Tsumkwe are technically unemployed, most have some source of income, usually selling crops, herding cattle, making crafts, or receiving pension checks.

[25] China shop: a shop that sells inexpensive knickknacks

There are very limited wage and salary jobs available in Tsumkwe. The Tsumkwe Lodge employs approximately 40 community members and is the largest employer in the settlement. The lodge has not increased the number of jobs available to residents since the expansion of electricity. In addition to the lodge, residents also hold jobs at the primary and secondary schools as well as the local ministries. However, we were not able to identify any new employment opportunities in Tsumkwe since the expansion of electricity.

Mr. Tjombuua affirmed our observations by stating that, "employment in Tsumkwe is unique, most residents are some form of self-employed or craft makers. Some residents have jobs working construction when there is work available, but work is not often available. Most residents tend cattle and small stock or cultivate small farms [..] the Tsumkwe Energy Project has not yet had an effect on the number of jobs available in Tsumkwe, but we are expecting new businesses to develop and for more jobs to be available."

Community members are dissatisfied with the availability of perishable goods and other general goods in Tsumkwe markets.

Tsumkwe is home to several small markets and small private businesses, including the General Dealer, Savanna II, and OK Shop. There are additional, smaller service shops selling a minimal selection of goods. The General Dealer is the largest market in Tsumkwe and offers goods such as assorted cool drinks, sugar, toilet paper, and canned foods. Since the expansion of electricity, shop owners have not expanded their selection of dry or perishable goods. Even though the shop owners can now refrigerate perishable goods 24 hours a day without the risk of spoilage, they do not carry large quantities of these items in their markets.

The owner of one shop stated that it would be far too expensive to ship perishable goods to Tsumkwe in large quantities and resell them. She remarked, "I cannot make money selling perishable goods because I have to first travel to Grootfontein to buy the goods, and then I have

to sell them in my shop at a higher price. Residents would realize that they could buy the same goods in Grootfontein for less." The shop owner also mentioned that she does not have the capital to invest in purchasing a large amount of perishable goods with the hope that she can sell them all to the local community. Both electrified and un-electrified residents still rely on traveling to Grootfontein to buy their perishable goods.

Community members expressed their dissatisfaction with the availability of perishable goods and other foods available in Tsumkwe. The only perishable goods available in Tsumkwe shops are the limited meats and fresh milk at the General Dealer and beef from a freshly slaughtered cattle hanging from a tree. As a result, residents have to spend between N$ 110 to N$ 150 each way for a ride to Grootfontein to shop for supplies.

Access to 24-hour electricity has not led to the establishment of large commercial companies in Tsumkwe.

From our discussion with community members, it is obvious that there is a great demand for a reliable source of dry and perishable goods. Community members expressed that they would save time and money if there was a business in Tsumkwe that sold all of the goods a store in Grootfontein would sell. Large commercial markets such as Pick'n Pay and Fruit & Veg did not have any interest in establishing a store in Tsumkwe in the past when the electricity was only available for 10-14 hours a day. Mr. Tjombuua positively expressed, "Now that there is 24-hour power, big businesses will want to come to Tsumkwe, there is a demand for them to come here. They can make money here." It is now possible for commercial markets and "big businesses" to establish storefronts in Tsumkwe because they will have the access to the appropriate electrical infrastructure. The original implementers of the TEP stated in the project proposal that one of the expected outcomes of the project is the development of large and small businesses and expansion of existing businesses in Tsumkwe (European Commission, 2006).

The hybrid system has only been online since August of 2011 and operated smoothly for several months afterwards. However, in the past few months, the reliability of the electricity supply has decreased as operation problems begin to emerge.[26] The system has been operating at nearly 24-hour power since December 2011, with the electricity being unavailable for at least twice a day in the morning and night for several minutes. This daily interruption of power may be one of the reasons why outside businesses have not shown the expected interest in Tsumkwe development. Commercial companies may see that Tsumkwe has potential to be a marketable location, but the current technical instability of the system could be preventing them from investing. The PMU and G&S are working to improve system stability and Local Government officials believe that a smoothly operating system will motivate large businesses to invest in Tsumkwe. At this point, it may be too early to expect development of large commercial storefronts.

We were unable to quantify the economic development in Tsumkwe resulting from the TEP.

The information gathered on economic development from existing businesses, newly developed businesses, residents, and Mr. Tjombuua was purely qualitative. We did not obtain information regarding income or revenue generated by businesses we interviewed and therefore, we cannot form a quantitatively substantiated statement regarding the economic development in Tsumkwe.

[26] Please refer to Section 4.4 *Technical Operation* for specific information on the current unreliability of the system.

4.2 Customer Service Relations

The goal of the DRFN was to determine the feasibility of replicating the Gobabeb solar-diesel hybrid system on a larger scale as a public utility.

The DRFN jointly runs a solar-diesel hybrid system with the Ministry of Environment and Tourism for the Gobabeb Training and Research Center in the Namib Desert. For the DRFN, the TEP serves as a pilot venture to determine if a larger scale version of the system in Gobabeb could be used to further electrify off-grid rural communities around Namibia. The DRFN does not want to remain in the capacity of providing management or maintenance for the TEP, and believes that the responsibility for that resides with the OTRC, Local Government, and Department of Works. As part of the DRFN's research, the foundation may continue to be involved in development projects in the Tsumkwe settlement.

NamPower's support of the TEP stems from the corporation's social responsibility to assist rural off-grid communities.

As a public utility provider, NamPower sees their support of the TEP primarily a social responsibility. The corporation also sees the TEP as a possible model for the development of rural electrification initiatives in other parts of Namibia; however, NamPower wants to identify lessons learned and see substantial long-term technical and financial capacity building by the OTRC, Local Government, and Department of Works before using the TEP as a model for other regions.

The OTRC supports the TEP as a way to reduce their operational costs and increase the community's access to electricity.

The OTRC pledges in their mission statement to "provide basic social and physical infrastructure, equability distributed throughout the region, and to reduce poverty." They intend for the TEP to stimulate economic growth, decrease poverty, and improve heath, sanitation, and education in Tsumkwe. The OTRC supports the TEP as an initiative for increasing the

utilization of decentralized renewable energy to complement national rural electrification initiatives.

Questionnaires designed to understand the goal of community members were not effective in yielding quantifiable results.

We developed the customer service relations objective to understand how the community members' needs from the TEP aligned with the objectives of the organizations involved in the design, implementation, and operation of the TEP. We interviewed the DRFN, NamPower, and Local Government to determine their long-term goals for the project and their motivations to support the project. However, we were unable to build an understanding of the community's goals for project. We avoided directly asking community members what they wanted from the project to evade creating expectations. We did not want them to expect that we would be acting upon comments that we gather pertaining to future development in Tsumkwe. While it may have given residents false hopes, directly asking community members about their goals for the TEP may have been a more effective approach to determine whether the TEP is addressing community concerns.

4.3 Capacity Strengthening

Financial Support

The OTRC's plan for funding the continued maintenance and operation of the TEP is unclear.

We discovered several critical problems with the funding for maintenance and operation of the solar-diesel hybrid system from our interviews with the DRFN and the Local Government. It was unclear which maintenance and repair issues fell under the responsibility of the ORTC or the responsibility of the Department of Works. While normal repair costs to public utilities such as water are the responsibility of the Department of Works, the OTRC has paid maintenance

costs for the electrical infrastructure in the past such as replacing a transformer that was struck by lightning. The OTRC must establish a clear division of financial responsibility to budget funds for the TEP properly.

The second major financial concern is the OTRC's budgeting process. All requests for funding come from a single account, which provides funding for the entire settlement. Organizations send requests to the OTRC, which decides whether to fulfill the request based on the amount of money in their account. The OTRC performs minimal long-term budget planning—this makes planning to replace TEP assets such as the battery bank difficult. By not setting aside sufficient funds into a dedicated account on a yearly basis, there is no guarantee that the OTRC will have sufficient funds to replace the battery bank, which requires replacement every seven years. The final evaluation of the TEP suggests that the OTRC create a separate legal entity to manage both the liability and finances of the TEP. (Capoco, Pigaht, & van der Plas, 2012) This entity would manage its own budget to ensure sufficient funds are available for maintenance, as well as ensure ECB compliance. In order for the ECB to license the current OTRC distribution cost reflective tariff structure, a portion of revenue from tariffs must be allocated for the maintenance and operation costs of the electricity generation plant.

The OTRC and ECB are still negotiating the tariff structure for the distribution licensing, but reaching a truly cost reflective tariff is not possible in Tsumkwe. The ECB bases the regulations for distribution licensing on national utility tariffs. Unfortunately, there is currently no policy developed for regulating the distribution of electricity through tariffs in rural communities where the residents cannot pay high cost reflective tariffs. In Tsumkwe, residents are much less likely to be able to pay high enough tariffs for the OTRC to obtain a distribution license without heavily subsidizing the tariff. The OTRC will continue paying a high subsidy in

order to retain a distribution license once the ECB approves their current end-user tariff structure.

Technical Support

The Department of Works office in Tsumkwe does not appear to have the capacity to support the maintenance and expansion of water utilities.

We quickly discovered that there were serious issues with the technical support of Tsumkwe public utilities, water in particular. In comparison to the TEP, the water supply infrastructure, which is also under the management of Local Government, is simple. During our site visit to Tsumkwe, we observed leaking water taps, pipes leaking at main valves, and homemade unofficial hookups throughout the settlement. In the ǁharas, Gauteng, and Local Government Locations, residents complained of low water pressure, especially during peak use times. Across from the Department of Works office is a leaking connection to a main water line that must be shut off when water to the house is not in use or the front yard floods. The homeowner reported the leaking valve several months ago, but the Department of Works has not yet addressed the problem. This was not an isolated incident—in the time that we were in Tsumkwe, we did not see a single instance of a Department of Works employee perform maintenance on any sort of infrastructure.

Additionally, the Local Government meters less than 5% of the water consumed by the community. In the ǁharas Location, residents reported that Local Government promised residents' meters after the Department of Works upgraded the locations' water pipes. The Local Government has not followed through with the request, which was filed several months ago. If the Local Government gives residents meters, they will have a significant opportunity to collect revenue while simultaneously improving service.

The basic water infrastructure of Tsumkwe is in dire need of repair in nearly every location of the settlement. The capacity of the Department of Works to maintain the water infrastructure does not positively indicate their capacity to maintain any other infrastructure.

The Local Government office does not yet have the capacity to operate the solar-diesel hybrid system.

Currently, the PMU and David Jarrett from NamPower perform necessary operation and maintenance on solar-diesel hybrid system with little involvement from the OTRC. The OTRC took legal ownership of the TEP at the end of January 2012, but do not currently have the capacity to perform the necessary system operations or maintenance. The OTRC appointed Andre Louw from the Ministry of Public Works and Mr. Tjombuua to maintain and operate the system. However, neither have the necessary technical experience. Mr. Louw has experience in generator maintenance, but has no experience in solar-diesel hybrid systems. Mr. Tjombuua has minimal experience in electrical generation, but is increasing his technical knowledge of solar panel systems by attending workshops and seminars. He has attended a training workshop in Windhoek on solar panels and plans to receive further training pertain to the hybrid system.

Presently, the DRFN project manager, Abraham Hangula, and Mr. Jarrett address tasks such as programming meters for homes, dealing with customer complaints about malfunctioning equipment, and negotiating with contractors. These tasks are supposed to be the responsibility of Mr. Louw, Mr. Tjombuua, and the OTRC. The OTRC's inattention to these duties is extending the ownership transition period unnecessarily and runs the risk of increasing operational difficulties in the future.

Mr. Tjombuua also emphasized that employees of the Department of Works do not have access to necessary tools and supplies to maintain public works. The OTRC needs to develop a

concrete plan for increasing their local capacity for maintaining all systems, including water and electricity.

A properly operating system will ease the technical burden on the OTRC. To achieve this, the OTRC and DRFN must address all outstanding issues with contractors before the DRFN further removes itself from the project at the end of May. The DRFN developed operation and maintenance documentation to assist this transition.

Holding contractors to a strict deadline is also desired for the sustainability of the TEP. G&S, the contractors responsible for installing power lines and connecting homes, is consistently late and unreliable, contributing to delays in the project's end date. The sustainability of the system depends on the OTRC's ability to develop a strategy for managing the operation and maintenance of the hybrid system.

4.4 Technical Operation

Environmental Considerations

Water consumption in Tsumkwe may be greater since the expansion of 24-hour electricity.

NamWater was only able to provide us with one year of rate data from the boreholes in Tsumkwe. This data was insufficient to quantify the effect that the TEP has had on water consumption rates in Tsumkwe. The data may still exist with NamWater; however, records of consumption rates and borehole depths are recorded by hand and are not available in an electronic database. We were able to assess how the TEP has affected the consumption rates of residents using qualitative data from interviews.

During community interviews, residents stated that they use more water due to 24-hour availability. A 2010 WPI evaluation of the water system in Tsumkwe noted that the settlement already exceeded the NamWater's recommended water extraction rates at the four boreholes

(Diemand, Geddes, Kalauskas, & Ridley, 2010). Additionally, the majority of water taps and pipes in Tsumkwe leak profusely, which is contributing to the over-extraction of boreholes. Much of the water "consumed" by the settlement is actually attributed to water wasted by the leaky infrastructure. Even if residents do not use water at night, the leaks in the pipes contribute to even more wasted water now that water is accessible 24 hours. If water consumption rates have increased, water extraction rates will have increased, and the current water management system in Tsumkwe may not be sustainable. Over extraction may lead to water shortages in the future, but we cannot say for sure without quantitative borehole data.

Physical Distribution

The electrical infrastructure in the Owambo Location has been hazardous and potentially deadly to the residents of this location since 2007.

Several severe issues remain with the distribution of electricity throughout Tsumkwe, especially in the Owambo Location. In the Owambo Location, residents have been reporting serious electrical shocks from appliances in their households when it rains since 2007. While the root cause is unknown, residents believe the connection from the Government Housing Location to the main distribution box in the center of the Owambo Location is at fault. Residents reported the issue several times to both the Local Government and the PMU. G & S inspected the transformer in the Government Housing Location approximately one year ago, but never performed follow-up testing and left the issue unresolved. Both the Local Government and PMU believed that the contractors had investigated and resolved the issue.

During our site visit, we informed the Local Government that the issue had still not been resolved. The contractors investigated the electrical distribution box in Owambo Location, but could not address the issue because they did not have the appropriate tools or equipment. The problem has yet to be unresolved.

The Department of Works and Local Government ignore illegal connections.

Illegal connections are prevalent on the edges of electrified locations, providing electricity to un-electrified households. The majority of observed illegal connections consisted of a heavy extension cord running from the wall outlet of an electrified home to an un-electrified household. Mr. Hangula described a case in which he observed an extension cord with frayed wires and exposed splices running to separate households.

Another illegal connection consists of several lines of thin wire stemming from one household's wall outlet and connects six homes to the electrical grid. The electrified household's wall outlet is ripped out and completely rewired to the thin extension cords. Trees hold up a number of the wires extending electricity to homes, while others run through standing bodies of water on the ground close to where children play.

Illegal connections present a serious health and safety risk to residents. The Local Government and Department of Works are fully aware that these connections exist throughout the settlement, but do not publically acknowledge them.

Electrical distribution boxes are not secure throughout the settlement, which presents a hazard to the health and safety of community members and risks damage to the electrical infrastructure.

While in Tsumkwe, we observed several distribution boxes unlocked and open. On the main street across from the police station, we observed a distribution box wide open with the electrical breaker covers removed. Another distribution box near the NBC radio tower that was left open with two stones holding the fiberglass shell box surrounding the sensitive electrical components.

Unsecured distribution boxes allow residents to gain unauthorized access to the grid infrastructure. Mr. Hangula mentioned that some residents might try to tamper with the boxes in

the hope that they could rewire them to receive unmetered electricity to their homes. However, residents risk electrocution and could cause serious damage to the electrical grid infrastructure by tampering with the boxes.

The solar-diesel hybrid system is not running autonomously and as a result, residents experience short interruptions in service twice a day.

The hybrid system still suffers from several technical issues—the most significant of which is the failed automatic switchover between the gensets and the solar panels. Currently, operators shut off the supply of electricity to the settlement for several minutes each morning between 6:00 and 7:00 AM. During the short time that the grid is off, operators manually operate the large lever-arm of the manual override to switch the source of electricity to the settlement from genset to solar panels. The process reverses again between 5:00 and 6:00 PM.

The disruption causes unnecessary stress to the grid infrastructure as well as damages sensitive appliances such as televisions and refrigerators. Moreover, the manual override is designed for limited operation and has broken several times due to overuse, causing additional unplanned extended power outages. The switchover issue stems from the system incompatibility between the solar panel field and genset operating systems.

Juwi is the contractor responsible for the installation of the solar panel field and control system. The contractor is in the process of working with the DRFN and NamPower to resolve the switchover issue. However, Juwi is based in Germany and the DRFN has had trouble negotiating with the company to send an engineer to Tsumkwe to resolve the switchover issue.

Community members, business owners, and service providers in Tsumkwe have had electrical equipment damaged because of unplanned power interruptions.

The failed switchover between the diesel generators and the solar panels causes several minutes of interrupted electricity service to the settlement twice a day. Many residents, business

owners, and service providers have cited that switchovers damage their electrical equipment if they leave it plugged in to the outlet during the switchover. Residents reported televisions, refrigerators, and radios received extensive damage during switchovers and in many instances, the electronic equipment was unrecoverable. Business owners and service providers also reported irreparable damaged sensitive equipment such as computers, fax machines, and copy machines. Many residents are not aware that the Local Government office has an established program subsidized by the OTRC to refund their electronic equipment losses. The OTRC will provide a refund for damaged equipment if residents file an incident report in the Local Government office and provide a receipt of the damaged equipment.

Business owners and service providers responded positively to SMS notifications of planned power outages.

During our stay in Tsumkwe, we worked with Mr. Hangula to establish a protocol for notifying public service offices and businesses of a planned switchover. Each day, Mr. Hangula sent an SMS to approximately fifteen individuals twenty minutes before the switchover in the morning and the evening. Those notified were then able to save computer work and disconnect sensitive electronic equipment before power went out. Business owners and workers in public offices approved of the program and were very appreciative. While the program does not compensate for the improper operation of the hybrid system, it is a way to mitigate the impacts of the switchover on the community until Juwi resolves the system problem.

One of the twelve battery banks of the solar-diesel hybrid system is not functioning due to a malfunctioning inverter.

The inverter box of one battery bank is not synchronizing with the system properly. The nonfunctioning battery bank decreases the capacity of the battery bank field to store energy from the solar panels. As a result, the deficit of energy demanded by the settlement at night must be

provided by operating the genset, which is very costly. Juwi is responsible for replacing the inverter and is aware of the issue, but the problem remains unresolved.

The meter at the General Dealer was not functioning properly, resulting in 30% overcharge for electricity usage.

The final problem that we observed with the technical operation of the electrical infrastructure in Tsumkwe was the incorrect programming of meters. Some residents reported issues with the speed at which their prepaid meters were running, but most customers were just miscalculating their electricity usage. However, in one case, the manager of the General Dealer reported that the meter at her storefront was functioning improperly and consuming units at a rate comparable to that of the lodge. The manager stressed that the Lodge operates 25 guest rooms, pool pumps, several refrigerators, two deep freezers, and several computers. She remarked that it is impossible that the General Dealer, which only has four refrigerators, could be using more energy than the Lodge. Mr. Hangula conducted an energy audit and compared it to the readings from the meter. He found that the meter was registering 30% higher energy usage than the audited amount. The manager also mentioned that the meter had been overcharging her for several months. The manager reported the issue to the Local Government office, but the problem went unresolved until Mr. Hangula addressed the situation directly during our site visits.

Chapter 5: Conclusions

The expansion of electricity in Tsumkwe affected a large part of the community in many positive ways. The 24-hour availability of electricity made the lives of residents more convenient with increased access to public services such as water, healthcare, and community education programs. For example, residents do not have to store water the night before for cooking and bathing in the morning and nurses can address medical emergencies quickly and efficiently at all hours of the night. Professional workers can work efficiently throughout the entire workday without prolonged interruptions in electricity access, and residents do not have to rush to NamPost by 1:00 PM. The TEP has also led to the development of small businesses utilizing the expanded electricity, including a takeaway kiosk and a tailoring shop.

Despite the many positive impacts of the TEP, several problems still exist with public utilities, including electricity and water, which may limit the settlement's growth. During our visit to Tsumkwe, we observed several serious problems with the water infrastructure. The Department of Works made no effort to repair these problems during our stay, which brings into question the Department of Work's technical capacity to perform maintenance to the water infrastructure. Accordingly, there are serious concerns about the capacity of the Department of Works to operate and maintain the solar-diesel hybrid system, which is significantly more complicated than Tsumkwe's water infrastructure. The Department of Works must significantly improve its capacity for technical support for the solar-diesel hybrid system to ensure operation of the system for years to come. There are also concerns about the OTRC's financial capacity to perform routine scheduled maintenance on the system. The OTRC has minimal financial support

structure dedicated to the TEP. The OTRC must increase its financial support of the TEP for the project to be financially viable in the future.

The TEP has multifaceted impacts on not only residents but also on all of Namibia. The project serves as a potential model that other rural settlements across Namibia and the rest of southern Africa can emulate with the help of governmental and non-governmental organizations. The project demonstrates how a large-scale solar-diesel hybrid system can help uplift rural off-grid communities.

Chapter 6: Recommendations & Future Opportunities

We developed three sets of recommendations directed towards governmental and nongovernment organizations such as the Ministry of Local Government and Housing, Department of Works, the DRFN, and the ECB. The recommendations were formulated using our findings reported in Chapter 4: *Findings*. We also constructed a future development opportunity for the community of Tsumkwe.

6.1 Recommendations

We recommend the Ministry of Local Government and Housing and the Department of Works:

1. *Create a standardized form for documenting resident concerns regarding problems with public electrical utility services*

   Interviews with residents revealed many were unaware of the procedure for reporting problems regarding electrical infrastructure. Of the residents who did make complaints, many stated that the Ministry of Local Government and Housing did not follow up on their reports. Creating a standardized form with which residents can report malfunctioning equipment will make it easier for customers to describe their concerns effectively and for the Ministry of Local Government and Housing to organize and follow up on complaints. Involving the Department of Works with creating the form will further streamline the reporting process and increase the likelihood of its successful implementation. We further recommend the Local Government office to assign a single individual responsible for receiving and organizing customer service reports. This individual should have strong communication and customer service skills.

2. *Investigate reasons behind workers' low attendance and develop programs to increase work efficiency*

Many of the problems with public works infrastructure stem from low worker attendance rates. As with the previous recommendation, these infrastructural issues include a repeated failure to move diesel for the generators from one storage tank to another, leaving transformers unsecured and unlocked throughout the settlement, and neglecting to fix damaged transformers and water pipes. We recommend the Department of Works begin by investigating the availability of tools and training to workers and take steps to acquire tools and increase training as necessary. We further recommend the Department of Works examine employee motivation and introduce initiatives as necessary to increase motivation and efficiency. These initiatives can include supervisor training, employee recognition and reward programs, and monthly worker satisfaction meetings.

3. *Increase training and equipment for the Tsumkwe Energy Project plant and ensure electrical network maintenance*

Interviews with public officials revealed minimal training for system operators and limited access to the tools necessary to perform essential maintenance to the electrical infrastructure. We recommend the Department of Works purchase tools necessary to complete basic maintenance to minimize disruption of service. There was also significant resident concern about the potential inability of the system operators to maintain the complex solar generators. Mandating training in solar energy systems for system operators will maximize their ability to perform basic maintenance on the system and alleviate resident concerns about the capacity of the Ministry of Local Government and Housing and Department of Works to operate the system. Finally, the system is not currently operating as designed due to a contractor who has failed contractual obligations.

When the Department of Works needs to perform maintenance outside of its capacity, it must hold contractors responsible for all contract stipulations to avoid unnecessary delays.

We recommend the Ministry of Local Government and Housing:

1. *Inform residents on which office to contact when there is an electrical problem in their home or area*

   During our time in Tsumkwe, it became apparent that most people did not know whom to contact when they had a problem with their electrical setup. The Ministry of Local Government and Housing currently displays posters in businesses and the Tsumkwe Settlement Office to inform residents of their policies, however, most residents do not read these posters. The Ministry of Local Government and Housing can instead inform residents of these procedures when residents buy electricity at the Settlement Office or over the radio. Finding new ways to communicate with residents will minimize confusion and allow for the Ministry of Local Government and Housing to handle directly both simple and complex problems. This program would include informing residents which office is in charge of the maintenance of the system and who to contact from within that office if they have a problem. In addition to establishing a point of contact, the campaign would include instructing residents on the reporting process created to ensure that the Ministry of Local Government and Housing knows and accounts for all electrical issues.

2. *Initiate an SMS program as a method of notifying the residents of a pending power outage*

   While in Tsumkwe, we had already spoken with our project liaisons, Abraham Hangula, Clarence Mazambani, and Jimmy Itamba, about initiating a SMS program to

notify residents of planned power outages due to maintenance work on the system. We started by creating a list of the major public service and business owners to test the response rate of the devised approach. We notified the owners 20-30 minutes in advance of a planned power outage and stated specifically how long the electricity would be out. The SMS program was well received. Warning the owners of a system repair allowed them to shut off their appliances in preparation for the outage and prevent irreparable damage to company equipment.

For the short-term, we recommend the system administrators continue sending SMS messages to public service providers and business owners until the solar-diesel synchronization problem is fixed. For the long-term, we recommend setting up a program in which residents can sign up to have an SMS notification sent to their phones whenever the system is offline for maintenance. This will allow residents to prepare for power outages and avoid damage to their appliances.

3. *Conduct a community meeting informing residents about the selection process involved in connecting un-electrified locations to the electrical grid*

We observed during our time in Tsumkwe that there was significant resident confusion about why particular locations were connected to the electrical grid and others were not. Premature accusations regarding the reason for the division have circulated throughout the settlement. Giving residents a clear and concise understanding about the selection process required for connection to the grid will minimize confusion and unfounded accusations. There are a couple ways administrators can inform residents of these criteria, including town meetings, radio announcements, or a combination of the two. This process would benefit both TEP administrators and residents by limiting speculation about the administrator's priorities when choosing locations to electrify.

4. *Conduct a campaign educating residents on how to utilize the expanded electricity effectively with respect to business opportunities*

Educating residents of potential business opportunities utilizing electricity will aid Tsumkwe's social and economic development. The campaign would present business ventures compatible with the system's current capacity level for residents to consider. Informing residents of business opportunities would allow them to significantly expand Tsumkwe's business sector as well as improve existing businesses. Some business options could include butcher shops, produce shops, tailor shops, appliance repair shops, restaurants, carpentry stores, home improvement stores, and cafés. The operation would also identify and explain the application process to open a business venture to ensure all residents understand the steps required to realize their idea.

Another aspect of the campaign is the possibility of instituting an open market for local residents to sell their produce and promote their trade to the community as well as the surrounding villages. An open market will make it easier for residents to benefit from their hard labor as well as feel pride in their work. This also helps keep local money in the community, building the local economy. If enough interest is gathered, an open market should be reviewed and initiated with the support of Ministry of Local Government and Housing.

We recommend the DRFN:

1. *Conduct a follow-up evaluation of the business development, education, and public service infrastructure of Tsumkwe in 2-5 years to identify any improvements or changes from the present conditions*

During our time in Tsumkwe, we realized that in many areas it was too early to judge the true impacts that the TEP has had on the development and prosperity of the community. Our evaluation was less effective because 24-hour power has only been

available for a short period of 8 months. For this reason, we recommend the DRFN conduct a follow up evaluation of the business development, education, and infrastructure of Tsumkwe in 2-5 years. Allowing the settlement to develop will let the residents become accustomed to, and take advantage of the reliable energy. It will also provide an understanding of how 24-hour power has affected those connected who were originally un-electrified at the beginning of the project's development.

We recommend the ECB:

1. *Develop regulations for licensing the distribution of electricity in off-grid electrified settlements.*

Currently, the ECB sets regulation standards for distribution based on the performance of the national electricity network, with end-user tariffs based on cost of electricity generation. For the TEP, the ECB is attempting to issue a distribution license using the national electricity network performance, but the regulations are not appropriate. In order to receive a license for distribution of electricity in a rural setting, where the community members often cannot pay expensive cost reflective tariffs or any tariff at all, the distributing agency is forced to pay high subsidies to receive a distribution license. We recommend that the ECB formalize a subsidy structure and policy for licensing the distribution of electricity in off-grid electrified settlements. The reformulation of the current nationally standardized regulations is important as Namibia's further investigates decentralized power generation for rural communities.

6.2 Future Opportunities

We recommend the DRFN:

1. *Apply for funding to initiate an Interlocking Stabilized Soil Brick business in the settlement of Tsumkwe*

   The business will provide employment to community members, as well as subsidize construction materials for residents to construct homes that will meet qualifications for a connection to the electrical grid. Appendix G: *Stabilized Soil Brick Business—Income Generating Activities* outlines the basic project proposal.

NOTE: Please refer to Appendix E: *Additional Findings, Recommendations, & Future Opportunities*—its content is out of the scope of our intended evaluation, but should be recognized and addressed accordingly.

Chapter 7: Technology & Society—Lessons Learnt

Rural electrification initiatives require local governing authority involvement from the beginning of the project.

The TEP serves as a pilot study for the Namibian Government. In the future, project-implementing agencies should carefully evaluate the capacity of the settlement or village's local administrative bodies. The implementing agency should work closely with the local authority to choose a designated operations unit. At a minimum, the unit should be comprise of a one individual responsible for the management and operation of the plant, supplemented by an accountant and two other technically trained standby operators. Implementing agencies must identify these key employees prior to the execution of any rural electrification project to ensure a smooth transition from the implementing to the managing agency. These actions are necessary to ensure the sustainability of future rural electrification systems.

Educating residents on energy efficiency and solar technology has lasting benefits and maximizes the technology's impact.

The implementing agency of the TEP, the DRFN, effectively educated the community on energy-efficient measures. Prior to the commissioning of the hybrid system and during its construction, the PMU and professional teams associated with the Local Government informed residents on the impacts of energy efficiency and the effects of inefficient practices on the new solar-diesel hybrid system.

Residents developed an understanding of how solar power is a reliable source of energy for powering electrical appliances through educational demonstrations. These demonstrations consisted of a solar trailer powering common household appliances. The DRFN also replaced hot plates with gas stoves, incandescent bulbs with compact florescent bulbs, and electric water heaters with solar water heaters. During the replacement, the DRFN educated residents on the

importance of choosing energy efficient appliances to ensure the system will continue to meet community demands. These educational programs gave community members an understanding and sense of ownership of the project.

The education and sense of ownership will have a long lasting impact on the sustainability of the TEP. Accordingly, the educational programs and methodologies used by the DRFN should be studied and implemented in other rural electrification programs.

When considering the installation of any form of nontraditional technology it is important to identify cultural barriers that may affect the community's acceptance of the technology.

The PMU installed two Otji toilets in two separate locations of Tsumkwe, but all four are currently unused. The PMU neither conducted a site assessment nor surveyed the community during the planning stages of the toilet installation for either location.

The San community members do not use the two toilets at an outpost 2 km outside of the settlement. The San do not feel comfortable using toilets close to households because it is unacceptable for another person to know when they are using the bathroom. If the PMU surveyed the community members prior to installing the toilets and used their input to determine a location, the toilets would be more widely used.

Community members do not use the Otji toilets in Gauteng because the individual originally responsible for emptying the drums did not receive payment for his services and therefore stopped performing his duties. The PMU wrongly assumed that the individual would continue emptying the drums without payment. As with the toilets in the San settlements, it would be more effective to first survey the community members during the planning stages to give them ownership of the project and then involve the community in the installation. The PMU should identify a community member to take ownership of the Otji toilet and be responsible for its long-term maintenance.

The Otji-toilets installed in Tsumkwe are one case of a failed project due to the neglect for community member's social and cultural practices. Identifying cultural barriers and empowering the community are viable methods for ensuring the long-term sustainability of a rural project.

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Appendix A: Case Studies of Previous Rural Electrification Programs

The electrification of regions brings opportunity for the continued development of village water supplies. In many cases, one of the limiting factors in access to water is the ability to run costly diesel pumps (Diemand, Geddes, Kalauskas, & Ridley, 2010). Researchers found that powering the pumps with small scale photovoltaic installations is effective in populations between 500 and 2000 people. The photovoltaic systems, while having a substantially higher initial cost, minimize the costs of both operation and maintenance in comparison to traditional diesel installations. In Zambia, these pumps allowed for small-scale irrigation to become profitable (Oetzen, 2008). However, experts have raised concerns about the extent to which water table is being depleted with the increased operational hours of the pumps. In the Tsumkwe settlement of Namibia, the community was overdrawing water even with only 10 to 14 hours of electricity a day. With a new lower cost photovoltaic installation, it is very possible that limited water resources will be depleted (Diemand, Geddes, Kalauskas, & Ridley, 2010).

Two majors source of failure for rural off-grid systems are the inability of the system to meet demand and the inability of the system operators to maintain the system both from an economic and technical standpoint. In India, Rural Electronic Workshops provide access to both high efficiency appliances as well as training in assembly, maintenance, and repair of the grid. These workshops have proven highly effective in regions where professional technicians are unavailable (Dinesh, 2007).

According to Adriaan Zomers, several factors determine the successful management of a mini-grid project. These include, but are not limited to, a politically and socially stable environment, international support, an appropriate electrification process, a well-developed strategy, and an appropriate utility organization (Zomers, 2003). Accordingly, numerous

corporations and organizations are interested in developing the electrical infrastructure of rural communities throughout Sub-Saharan Africa.

One example of a failed rural electrification project is the Lucingweni mini-grid in the Eastern Cape Province of South Africa. The Lucingweni mini-grid utilized renewable energy over traditional energy sources. Project implementers intended this project to be a test run in the study of rural mini-grids, but the sponsors failed to consider several factors, resulting in a failed system. Significantly, the implementers failed to correctly estimate cost evaluation of installing a mini-grid system over extending the national grid (Brent, 2010). After the project was completed, the national grid was extended into the region, which provided residents with less expensive grid power. This project served as a warning of what could happen to an improperly managed mini-grid project.

If the variables are managed correctly, rural communities stand to gain enormously from electrification projects. Residents benefit from the electricity with improved education, health care, water access, sanitation services, and business opportunities (Kirubi, 2009). The Mpeketoni Electricity Project of Kenya is an excellent example of a well-managed and subsequently successful energy project. Small businesses reported as much as a 70% increase in daily income after the electrical mini-grid was established, with as much as a 170% increase in daily productivity (Kirubi, 2009). The Mpeketoni Electricity Project serves as an example of an ideally managed rural electrification mini-grid project.

Appendix B: Donors, Service Providers, & Stakeholders

There are three types of stakeholders analyzed in this section—organizations who donated capitol (donors), organizations who provided labor (service providers), and the project's beneficiaries (stakeholders). These stakeholders can be seen in Figure 21 below:

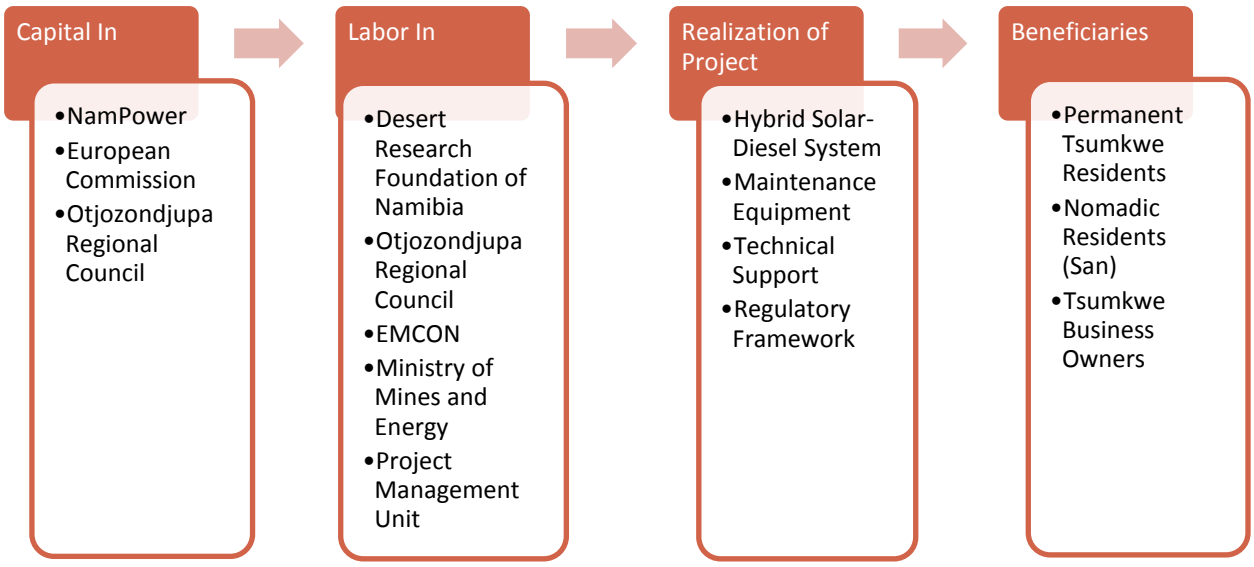

Figure 21: Key stakeholders of the Tsumkwe Energy Project

The project was joint-funded by the EC (75%), NamPower (14%), and the OTRC (11%) (Global Environment Facility, 2010). Before the TEP, the OTRC spent N$120,000 on diesel every month, a figure that will be minimized with the solar panels.

The **DRFN** is the implementing agency of the TEP. The DRFN Energy Desk provides expertise through the PMU. The **PMU** is responsible for the day-to-day execution of the project and includes the project coordinator and project assistant. The project manager and field facilitator also facilitate the project's implementation.

The **OTRC**, apart from co-funding the project, is the intended legal owner of the solar-diesel hybrid system and all other assets associated with the TEP. The OTRC operates as the

legal entity associated with the facilitation of project implementation, channeling of funds and future maintenance and operation of the installed hybrid system. The OTRC will also assume all future decision-making and liabilities associated with the operation of the hybrid system.

NamPower provided technical expertise and capacity in the construction of the solar-diesel hybrid system during the implementation stages of the project. Accordingly, NamPower still acts as a technical consultant organization during the final months of the TEP and is overseeing continued network expansion work performed by **G & S**.

Additional organizations:

- **Juwi** is the company that provided the solar panels to the TEP.
- **Pupkewtiz** is the company that provided the two 150 kV diesel generators.
- **EMCON** is the project's consultant company.
- **G & S** is the electrical contractor that is responsible for all network expansion, as well as connections to home.

Appendix C: Images of the Solar-Diesel Hybrid Plant

Figure 22: Diesel generator room of the solar-diesel hybrid system

Figure 23: One of the 350 kV diesel generators

Figure 24: Solar-diesel hybrid system inverters

Figure 25: Solar-diesel battery banks

Figure 26: Several members of the PMU outside of the solar-diesel hybrid system facility—photograph taken 8/15/2011 (Hangula, [Photograph], 2011)

Appendix D: Interview Questions

The following eight questionnaires were given orally to each specified informant type. The questionnaires are listed in the appendix as follows: Electrified Residents, Un-electrified Residents, Business Owners, Clinic, Police Station, Radio Station, School, Settlement Officials.

Electrified Residents

Date:	Time:
Respondent/Interviewee name(s):	
Highest level of education obtained:	
Estimated Age(s) of respondent(s):	
Family size:	Name of location:

1. Where do you originally come from?				
2. How long have you been living in the area?				
Now we're going to talk about electricity in Tsumkwe…or some segue like that				
3. Is the electricity always 24 hours a day?			Yes	No
4. If no, how often is electricity unavailable?				
5. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
6. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
7. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				

1	2	3	4	5
We're going to talk a little bit about your household chores.				
8. What tasks do you do on a daily basis?				
9. Which tasks do you use electricity for?				
Now we're going to talk a little bit about the types of appliances you use day to day.				
10. Do you use kerosene or wick and oil burners for lighting?			Kerosene	Wick and oil burners
11. Do you have light bulb lamps?			Yes	No
12. If yes, what kind?				
13. Do you have a radio or television?			Yes	No
14. If yes, what kind?				
15. What other types of electrical appliances do you own?				
Now we're going to discuss your daily schedule				
16. What time do you usually get up in the morning?				
17. What time do you usually go to bed at night?				
18. Has your schedule changed recently?			Yes	No
19. If yes, can you describe the changes?				
Public Services Segue				
20. In the past few months, have you visited the local clinic?			Yes	No
21. To your knowledge, are any new forms of medical services offered?			Yes	No
22. If yes, can you describe them?				
23. Does the clinic operate at night?			Yes	No
24. To your knowledge, have the hours of operation of the clinic changed?			Yes	No

25. If yes, can you describe them?		
26. Do you have access to water in your home?	Yes	No
27. Is the water supply service consistent?	Yes	No
28. Is it sufficient?	Yes	No
29. If no to any of the above, can you describe the water supply service?		
30. How does this compare to your access to water before August?		
31. Do you send your children to primary or secondary school?	Yes	No
32. If yes, do they study at home?	Yes	No
33. What time of day do they study?		
34. Do you ever go out after dark?	Yes	No
35. Do you feel safer going out after dark after the streetlights were installed?	Yes	No
36. Why or why not?		
37. Do you listen to the radio?	Yes	No
38. If yes, what do you listen to?		
39. If yes, how often do you listen to the radio?		
40. To your knowledge, what is the level of crime in Tsumkwe six months ago?		
41. To your knowledge, what is the level of crime in Tsumkwe now?		
42. What types of crime are usually committed?		
Thank you for your patience, our final set of questions are about your interactions with local businesses.		
43. What types of markets are there in Tsumkwe?		
44. Do markets provide refrigerated or perishable food?	Yes	No
45. If yes, how do markets preserve perishable foods?		
46. What are typical hours of operation? Have they changed in the last six months?		

47. Do local residents in Tsumkwe own any businesses?	Yes	No
48. If yes, can you describe the business(es)?		
49. Have new businesses developed in the past few months?	Yes	No
50. If yes, are any of them owned by local residents?		
51. Do you own a business?	Yes	No
52. If yes, can you describe the business?		
53. What employment opportunities are available to community members?		
54. What is your main source of income?		
55. (If not addressed above) Do you have a job?	Yes	No
56. Do other Tsumkwe residents travel outside the region for work?	Yes	No
57. Has this changed in the last six months?	Yes	No
58. If yes, how has it changed?		
59. Do you have any additional relevent information that I did not ask?		
60. Do you have any questions for me? (List questions, if any)		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Un-electrified Residents

Date:	Time:
Respondent/Interviewee name(s):	
Highest level of education obtained:	
Estimated Age(s) of respondent(s):	
Family size:	Name of location:

1. Where do you originally come from?		
2. How long have you been living in the area?		
We're going to talk a little bit about your household chores.		
3. What tasks do you do on a daily basis?		
4. How do you heat water for cooking and bathing?		
Now we're going to talk a little bit about the types of appliances you use day to day.		
5. Do you use kerosene or wick and oil burners for lighting?	Kerosene	Wick and oil burners
6. Do you have light bulb lamps?	Yes	No
7. If yes, what kind?		
8. Do you have a radio or television?	Yes	No
9. If yes, what kind?		
10. What other types of electrical appliances do you own?		
Now we're going to discuss your daily schedule		
11. What time do you usually get up in the morning?		
12. What time do you usually go to bed at night?		
13. Has your schedule changed recently?	Yes	No
14. If yes, can you describe the changes?		
Public Services Segue		
15. In the past few months, have you visited the local clinic?	Yes	No

16. To your knowledge, are any new forms of medical services offered?	Yes	No
17. If yes, can you describe them?		
18. Does the clinic operate at night?	Yes	No
19. To your knowledge, have the hours of operation of the clinic changed?	Yes	No
20. If yes, can you describe them?		
21. Do you have access to water in your home?	Yes	No
22. Is the water supply service consistent?	Yes	No
23. Is it sufficient?	Yes	No
24. If no to any of the above, can you describe the water supply service?		
25. Do you send your children to primary or secondary school?	Yes	No
26. If yes, do they study at home?	Yes	No
27. What time of day do they study?		
28. Do you ever go out after dark?	Yes	No
29. Do you feel safer going out after dark after the streetlights were installed?	Yes	No
30. Why or why not?		
31. Do you listen to the radio?	Yes	No
32. If yes, what do you listen to?		
33. If yes, how often do you listen to the radio?		
34. To your knowledge, what is the level of crime in Tsumkwe six months ago?		
35. To your knowledge, what is the level of crime in Tsumkwe now?		
36. What types of crime are usually committed?		
Thank you for your patience, our final set of questions are about your interactions with local businesses.		

37. What types of markets are there in Tsumkwe?		
38. Do markets provide refrigerated or perishable food?	Yes	No
39. If yes, how do markets preserve perishable foods?		
40. What are typical hours of operation? Have they changed in the last six months?		
41. Do local residents in Tsumkwe own any businesses?	Yes	No
42. If yes, can you describe the business(es)?		
43. Have new businesses developed in the past few months?	Yes	No
44. If yes, are any of them owned by local residents?		
45. Do you own a business?	Yes	No
46. If yes, can you describe the business?		
47. What employment opportunities are available to community members?		
48. What is your main source of income?		
49. (If not addressed above) Do you have a job?	Yes	No
50. Do other Tsumkwe residents travel outside the region for work?	Yes	No
51. Has this changed in the last six months?	Yes	No
52. If yes, how has it changed?		
53. Do you have any additional relevent information that I did not ask?		
54. Do you have any questions for me? (List questions, if any)		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Business Owners

Date:	Time:	
Name/Type of Business:		
Respondent/Interviewee name(s):		
Capacity/Position of Interviewee:		
Highest level of education obtained:		
Number of respondents interviewed:	Male:	Female:
Age(s) of respondent(s):		

1. What does your business entail?				
2. What are your roles and responsibilities in this business?				
3. When did you establish this business?				
Now we're going to talk about electricity in Tsumkwe…or some segue like that				
4. Is the electricity always 24 hours a day?			Yes	No
5. If no, how often is electricity unavailable?				
6. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
7. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
8. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
9. How has 24 hour electricity affected your job performance? Is your job easier or harder now?				

10. Do you directly employ any members of the community?	Yes	No
11. If yes, how many before and after electrification?	Before:	Current:
12. Has your business been affected by the 24-hour electricity?	Yes	No
13. If yes, in what ways?		
14. Does your business utilize electrical appliances?	Yes	No
15. If yes, what do you use?		
16. Do you plan to buy (more) electrical appliances for your business?		
17. Have you noticed an increase in profitability since the electrification? To what extent? (Probe for relative quantity)		
18. Are you able to offer any new services or products because of the 24 hour power?	Yes	No
19. If yes, what services?		
20. What are your hours of operation?		
21. Have you expanded your hours of operation since the institution of 24 hour power?	Yes	No
22. If yes, what were your hours of operation before 24 hour power?		
23. Do you have any additional relevent information that I did not ask?		
24. Do you have any questions for me? (List questions, if any)		
25. Do you have any reports which will help us evaluate the Tsumkwe Energy Project?		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Clinic

Date:	Time:	
Respondent/Interviewee name(s):		
Capacity/Position of Interviewee:		
Highest level of education obtained:		
Number of staff members interviewed:	Male:	Female:
Age(s) of respondent(s):		

1. What are your roles and responsibilities in your capacity as (insert position here)?				
2. How long have you been working in this area?				
3. Do you live in the area?			Yes	No
4. If yes, for how long?				
Now we're going to talk about electricity in Tsumkwe…or some segue like that				
5. Is the electricity always 24 hours a day?		Yes	No	
6. If no, how often is electricity not available?				
7. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
8. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
9. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
10. How has 24 hour electricity affected your job performance? Is your job easier or harder now?				
11. In what ways has the clinic's service improved with the newly available electrical services?				

12. How are medications refrigerated?		
13. Does the clinic operate at night?	Yes	No
14. Have the clinic's hours of operation changed?	Yes	No
15. If yes, can you describe them?		
16. Do you have any additional relevant information that I did not ask?		
17. Do you have any questions for me? (List questions, if any)		
18. Do you have any reports which will help us evaluate the Tsumkwe Energy Project?		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Police Station

Date:	Time:	
Respondent/Interviewee name(s):		
Capacity/Position of Interviewee:		
Highest level of education obtained:		
Number of staff members interviewed:	Male:	Female:
Age(s) of respondent(s):		

1. What are your roles and responsibilities in your capacity as (insert position here)?				
2. How long have you been working in this area?				
3. Do you live in the area?			Yes	No
4. If yes, for how long?				
Now we're going to talk about electricity in Tsumkwe…or some segue like that				
5. Is the electricity always 24 hours a day?			Yes	No
6. If no, how often is electricity unavailable?				
7. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
8. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
9. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
10. How has 24 hour electricity affected your job performance? Is your job easier or harder now?				
11. To your knowledge, do residents feel safer after			Yes	No

dark with the installation of street lights?		
12. Why or why not?		
13. What types of crimes were most common before 24 hour electrification?		
14. Have you noticed a decrease in crime since the installation of street lights?	Yes	No
15. If yes, what types of crime?		
16. Is the entire settlement provided with light during all hours of the night?	Yes	No
17. Is the lighting consistent?	Yes	No
18. If no to either of the above, why not?		
19. Does the police station use a radio calling system or equivalent?	Yes	No
20. If yes, has the use of this system changed since August?		
21. If no, have you considered using one (or a similar system)?		
22. Do you have any additional relevant information that I did not ask?		
23. Do you have any questions for me? (List questions, if any)		
24. Do you have any reports which will help us evaluate the Tsumkwe Energy Project?		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Radio Station

Date:	Time:	
Respondent/Interviewee name(s):		
Capacity/Position of Interviewee:		
Highest level of education obtained:		
Number of staff members interviewed:	Male:	Female:
Age(s) of respondent(s):		

1. What are your roles and responsibilities in your capacity as (insert position here)?				
2. How long have you been working in this area?				
3. Do you live in the area?			Yes	No
4. If yes, for how long?				
Now we're going to talk about electricity in Tsumkwe…or some segue like that				
5. Is the electricity always 24 hours a day?			Yes	No
6. If no, how often is electricity unavailable?				
7. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
8. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
9. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
10. How has 24 hour electricity affected your job performance? Is your job easier or harder now?				

How many hours a day do you broadcast?		
11. Has the number of hours you broadcast changed since August?	Yes	No
12. If yes, can you describe the changes?		
13. What forms of media are broadcast?		
14. Has this changed since August?	Yes	No
15. If yes, what changed?		
16. Do you have any additional information that I did not ask?		
17. Do you have any questions for me? (List questions, if any)		
18. Do you have any reports which will help us evaluate the Tsumkwe Energy Project?		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

School

Date:	Time:	
Respondent/Interviewee name(s):		
Capacity/Position of Interviewee:		
Highest level of education obtained:		
Number of staff members interviewed:	Male:	Female:
Age(s) of respondent(s):		

1. What are your roles and responsibilities in your capacity as (insert position here)?				
2. How long have you been working in this area?				
3. Do you live in the area?			Yes	No
4. If yes, for how long?				
5. Now we're going to talk about electricity in Tsumkwe…or some segue like that				
6. Is the electricity always 24 hours a day?			Yes	No
7. If no, how often is electricity not available?				
8. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
9. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
10. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
11. How has 24 hour electricity affected your job performance? Is your job easier or harder now?				
12. Do all students have the ability to study at home?			Yes	No
13. If yes, what times of the day can th-ey study at home?				

14. If no, why not?		
15. Are there any educational tools powered by electricity (overhead projectors, televisions, DVD players, computers, etc.)?	Yes	No
16. If yes, what are they?		
17. If no, why not?		
18. Are there any plans in place to buy (more) electrically powered educational tools?		
19. Are there night classes available?	Yes	No
20. If no, why not?		
21. Do you have any additional relevant information that I did not ask?		
22. Do you have any questions for me? (List questions, if any)		
23. Do you have any reports which will help us evaluate the Tsumkwe Energy Project?		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Settlement Officials

Date:	Time:	
Respondent/Interviewee name(s):		
Capacity/Position of Interviewee:		
Highest level of education obtained:		
Number of staff members interviewed:	Male:	Female:
Age(s) of respondent(s):		

1. What are your roles and responsibilities in your capacity as (insert position here)?				
2. How long have you been working in this area?				
3. Do you live in the area?			Yes	No
4. If yes, for how long?				
Now we're going to talk about electricity in Tsumkwe…or similar segue				
5. Is the electricity always 24 hours a day?			Yes	No
6. If no, how often is electricity not available?				
7. How satisfied are you with the expansion of electricity to 24-hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
8. How satisfied are you with your access to electricity now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
9. How satisfied are you with public services now that there is 24 hour power compared to before? Answer on a scale of 1-5 with 1 being "Much Less Satisfied" and 5 being "Much More Satisfied."				
1	2	3	4	5
10. How has 24 hour electricity affected your job performance?				
11. How has the settlement as a whole reacted to the electrification?				
12. What have residents liked about the 24 hour electricity?				

13. What have residents disliked about the 24 hour electricity?		
14. Have any groups or neighborhoods expressed a strong opinion about the 24 hour electricity?	Yes	No
15. If yes, which group(s) and what is their opinion(s)?		
For the OTRC:		
16. How do you communicate with customers/clients?		
17. How do they communicate with you?		
18. Do you have a protocol in place for addressing customer concerns?		
19. Do you feel the system has sufficient capacity to continue operating? Why?		
20. Are there any areas in which the system needs to be strengthened? Why?		
21. What overall challenges do you forsee in maintaining the system?		
22. Are there any areas in which you will need outside support in maintaining and running the system?		
23. Do you have any additional relevant information that I did not ask?		
24. Do you have any questions for me? (List questions, if any)		
25. Do you have any reports which will help us evaluate the Tsumkwe Energy Project?		
Thank you for your time. If you wish, we will be happy to share our final report with you.		

Appendix E: Additional Findings, Recommendations, & Future Opportunities

We developed a separate set of findings, recommendations, and future opportunities we felt were necessary to address in the report, although the content is not tied directly to our proposed objectives.

Findings

The current 766 kWh battery bank of the solar-diesel hybrid system can only retain 35% of the potential energy produced by the solar panels.

The current battery bank operates at 45% efficiency and can only retain 123,188 kWh of the 353,904 kWh annual capacity of the solar panel field. The estimated annual demand of the settlement is 580,350 kWh, based on a three-month estimate from January to March of 2012. Because the batteries can only store 35% of the excess energy produced by the solar panel field, the diesel generators must produce the deficit of energy. Accordingly, the diesel generators produce 313,444 kWh annually, resulting in a diesel cost of N $ 1,001,136 per annum. The estimated annual revenue collection is N$ 360,000 per annum, based on same three-month period. This results in an annual operational deficit of N$ 641,136 absorbed by the OTRC.

Residents do not use the solar charging kiosk in Tsumkwe Central due to its location in the settlement.

As an additional output of the TEP, the PMU installed a solar kiosk in Tsumkwe Central at the Councilor's office as shown in Figure 27. The PMU distributed 52 rechargeable LED lamps to residents to be charged at the solar kiosk. Residents have not used the kiosk because they do not feel comfortable leaving their property to charge at the station unattended. The

project manager of the TEP stated that he is aware of only five or six residents that are still in possession of their rechargeable lamps.

Figure 27: Solar kiosk installed in Tsumkwe Central at the Councilor's office (Hangula, [Photograph], 2011)

The Local Government does not properly manage solid waste, which poses a risk to the health and safety of Tsumkwe residents.

Waste management is a serious problem in Tsumkwe. WPI students conducted a study in collaboration with the DRFN in 2010 on Tsumkwe's solid waste. The study identified that waste management is a serious problem in Tsumkwe and is a risk to the health and safety of residents (Diemand, Geddes, Kalauskas, & Ridley, 2010). However, the Local Government has not addressed the problems presented in the study in any observable way.

During our site visit, we observed complete disregard for the management of waste in nearly every part of the settlement. Waste bins at households, institutions, and government offices were overflowing throughout Tsumkwe. Many residents did not have waste bins and threw their solid waste into piles on their property. Even the Local Government Guest House we

stayed at had an overflowing waste bin on the property that stray dogs frequently knocked over picking food out of the solid waste.

The Local Government hired a resident with a truck to pick up solid waste throughout the settlement every Wednesday. The solid waste collector brings the waste to a dumpsite three kilometers outside of the settlement as seen in Figure 28. However, windblown solid waste scatters across the settlement because most residents do not use the dumpsite. Residents do not bring their solid waste to the dumpsite because it is too far to carry and most residents do not own cars. Waste at the dumpsite is not contained and continues to litter neighboring agricultural land. The volume of solid waste in and around the settlement is a health risk to the entire community and needs to be addressed promptly.

Figure 28: The Tsumkwe dumpsite, 3 km outside of the settlement (Diemand, Geddes, Kalauskas, & Ridley, 2010)

Recommendations

We recommend the Local Government and Housing:

1. *Reestablish ownership of the solar kiosk by relocating it to outside the Settlement Office and assigning the Settlement Office receptionist to manage its use.*

We recommend that the Local Government office consider relocating the solar kiosk to outside the main entrance of the Settlement Office. Unlike the Councilor's office, the Settlement Office main desk is always open during working hours. The kiosk would then be available for residents to use by checking their rechargeable items with the Settlement Office receptionist. By operating the solar kiosk in this manner, residents can feel safe knowing that their electronic items are under the supervision of the Settlement Office.

Future Opportunities

We recommend the OTRC:

1. *Investigate tripling the size of the solar-diesel hybrid system battery bank to meet the annual production capacity of the solar panel field and reduce the cost of diesel fuel by N$ 793,919 per annum*

We advise the OTRC add two battery banks with a total capacity of 750 kWh each to reduce the operational costs of the solar-diesel system by N$ 793,919 per annum.[27] The total investment capital cost of the two battery banks is N$ 5,365,754, which includes installation costs and inverters. The OTRC will make an annual profit of N$ 152,783 with the installation of the two additional battery banks based on an estimated annual revenue of N$ 360,000 and annual diesel cost of N$ 207,217. Appendix F: *Expanded Solar Energy Storage Capacity Opportunity* outlines the basic project proposal.

[27] Adding two additional battery banks of 750 kWh will make the total system capacity equal to approximately 2,250 kWh.

We recommend the DRFN:

1. *Work closely with the Ministry of Local Government and Housing and Department of Works in Tsumkwe to develop a solid waste management plan and construct a solid waste recycling facility*

   The management of solid waste in Tsumkwe is a very serious problem. We recommend that the DRFN first begin by conducting a waste audit to characterize the waste stream of the community. Based on the results of the waste audit, the DRFN can work with the Local Government and Department of Works to formulate a waste management plan with the intention of constructing a recycling center to manage waste safely. We further recommend that the Local Government begin by constructing a containment fence to prevent the spread of waste to the surroundings at the dumpsite. The Local Government will need to investigate strategies to transport recyclable materials to large recycling facilities.

Appendix F: Expanded Solar Energy Storage Capacity Opportunity

The current solar-diesel hybrid system is referred to as Scenario 1 (766kWh) and the proposed upgraded battery bank system is referred to as Scenario 2 (2,250kWh). Figure 29 illustrates the annual cost of diesel for Scenario 1 and 2. The difference in operating costs is N$ 793,919 per annum. Figure 30 presents the difference in annual profits between Scenario 1 and Scenario 2.

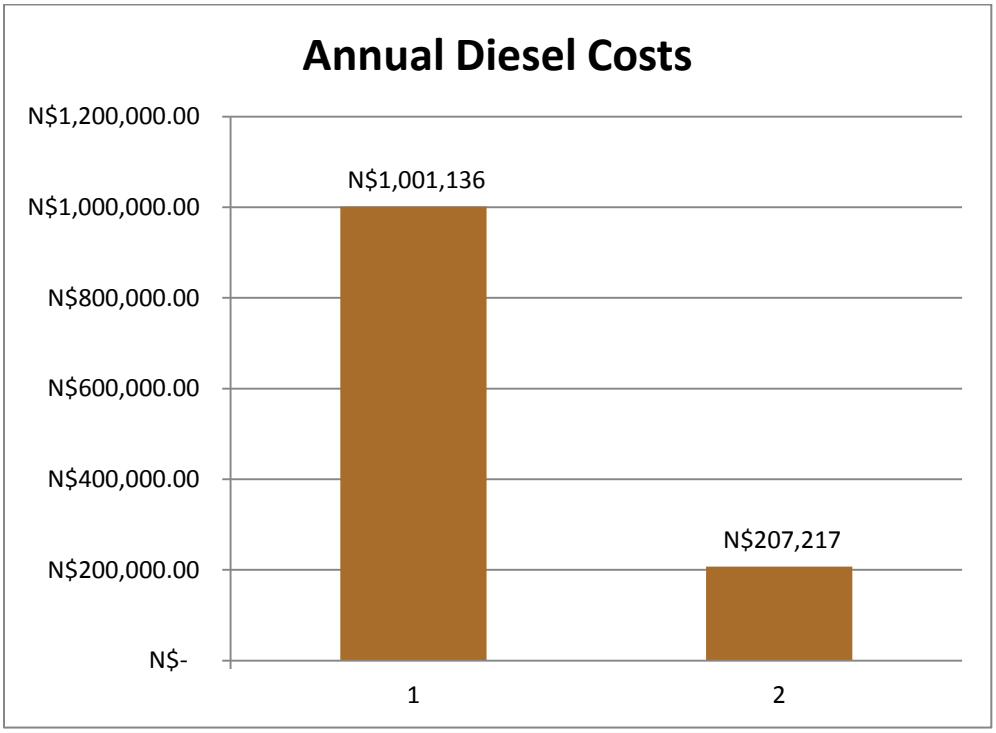

Figure 29: Comparison of Scenario 1 and Scenario 2 annual diesel costs

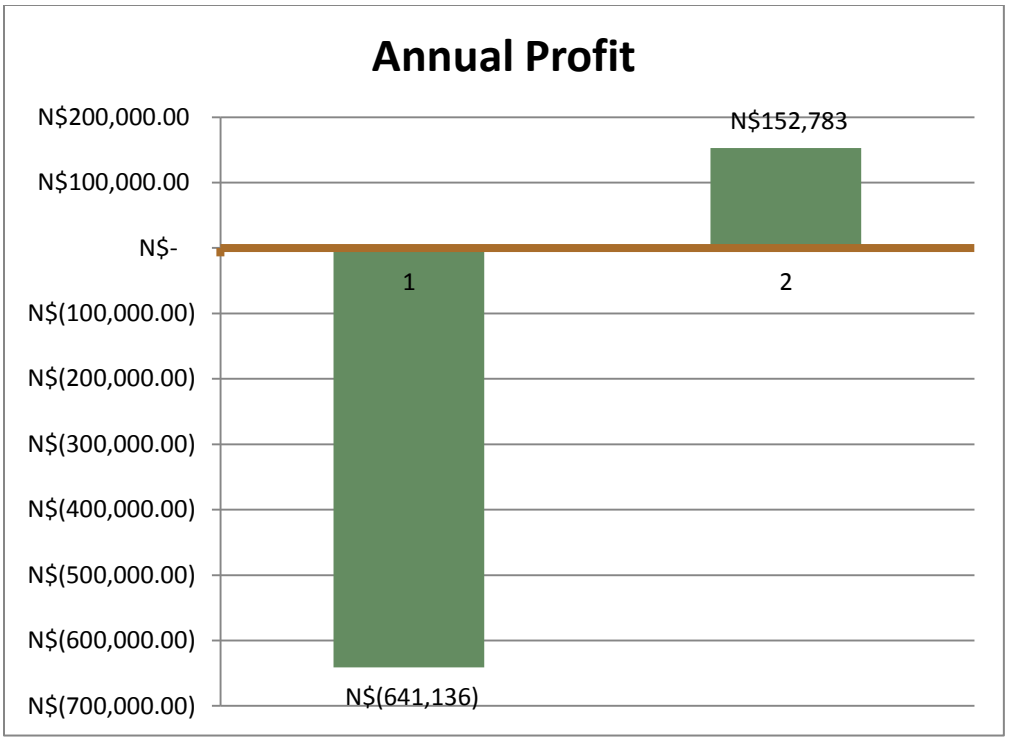

Figure 30: Comparison of Scenario 1 and Scenario 2 annual profits based on an estimated revenue of N$ 360,000 per annum

The annual profit from an estimated revenue of N$ 360,000 for Scenario 2 is N$ 152,783 while Scenario 1 is a deficit of N$ 641,136. By adding two additional battery banks with a total capacity of 1500 kWh, the system can fully utilize the potential energy produced by the solar panel field.

The battery banks of Scenario 2 will have the capacity to store 98% of the energy produced by the solar panel field. The diesel generators will have to compensate for a difference in energy of 67,069 kWh annually, reduced from the 310,816 kWh of Scenario 1. Scenario 2 will significantly reduce the cost of operation and the annual deficit absorbed by the OTRC, making it a viable option. Table 2 displays a comparison of Scenarios 1 and 2. In conclusion, we advise the OTRC investigate the feasibility of a battery bank expansion by obtaining battery and installation quotes to formulate a more accurate cost-benefit analysis. We further recommend the OTRC consider the future costs of replacing battery banks every 5-7 years to produce an accurate scenario analysis.

Table 2: Comparison of Scenario 1 and 2

	Scenario 1	Scenario 2
Size of Battery Bank	766 kWh	2250 kWh
Annual Storage Capacity of Battery Bank	123,188 kWh	346,825 kWh
Annual Capacity of Solar Field	353,904 kWh	353,904 kWh
Annual Solar Energy Storage Capacity	35%	98%
Annual Diesel Cost (N$)	1,001,136	207,217
Annual Profit (N$)	- 641,136	152,783

Appendix G: Stabilized Soil Brick Business—Income Generating Activities

Stabilized Soil Brick Business: Income Generating Activities

Project Proposal submitted to:

Abraham Hangula & Clarence Mazambani
The Desert Research Foundation of Namibia

Date: May 3, 2012

Submitted by:

Brennan Ashton
Lauren Bisacky
Donal Boyd
Jessica López

Introduction

Interlocking Stabilized Soil Bricks (ISSB) can be used as a practical construction material for low-income rural communities. A brick-making business can provide employment to community members and minimize local construction costs.

In Tsumkwe, Namibia, there are very few jobs available for the large quantity of unskilled workers. Furthermore, there is a demand throughout the settlement, especially Tsumkwe North, for low-cost construction materials to construct new homes. Many community members in Tsumkwe North are not connected to the electrical infrastructure because their homes do not meet the qualifications to be classified as a permanent structure.

The settlement clerk, Benedict Tjombuua, describes a permanent structure as "[a] home or building that is not just made of mud, but of brick; a home that will be able to support the electrical infrastructure that would be installed. We need something to attach the meter box to, not just mud." However, the residents living in structures made of mud and stone cannot afford to buy the materials to construct new homes that meet the qualifications for a connection to the electrical grid.

Furthermore, the demand for low-cost construction materials will increase as the settlement of Tsumkwe develops. We propose that the DRFN act as the implementing agency to initiate an ISSB business in Tsumkwe in which the Ministry of Local Government and Housing will eventually assume ownership. The project will require initial funding from a donor organization or government office interested in economic development of Tsumkwe. An ISSB business will provide employment to 11 community workers, revenue for the Local Government, and subsidized construction materials for residents to build *permanent* structures. The following

sections describe ISSB technology, outline a business plan, and present the various impacts and limitations of implementing an ISSB business venture in Tsumkwe (Lewis, 2009).

Background

The process of making bricks by mixing soil with a stabilizer such as cement or lime stone has been practiced for thousands of years. Additionally, ISSB technology has evolved over the past 20 years as a supplemental construction material in rural communities.

Soil stabilization involves mixing cement or similar stabilizing agents with soil to make it stronger and waterproof. The physical properties of the brick or block produced by a particular mixture is dependent on soil type, force applied during compacting, and the properties of the stabilizing agent. The "interlock" refers to the specific shape of the brick as seen in Figure 31. Also seen in Figure 31 is an example of a manually operated interlocking block press machine, manufactured in Kenya.

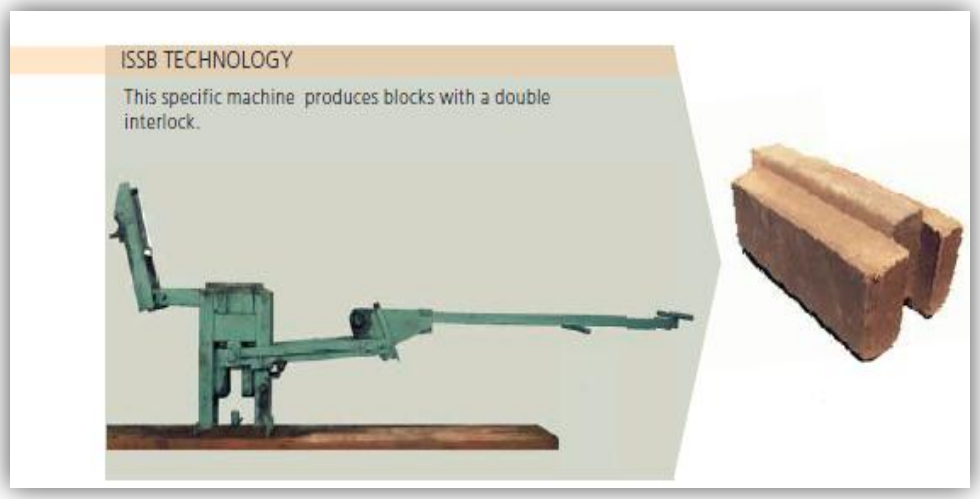

Figure 31: Straight Double Interlocking Bock and manually operated block press (Lewis, 2009)

ISSB Business Plan

We propose that the DRFN initiate an ISSB business in Tsumkwe in which the Ministry of Local Government and Housing will eventually assume ownership.

An ISSB business operated by the Local Government of Tsumkwe will provide employment to the community, produce revenue for the Local Government office, and significantly reduce local construction costs. Table 3 outlines the required capital costs associated with beginning the ISSB business operation.

Table 3: Capital costs to purchase 5 brick presses

Start-up Costs			
Item	**Unit Cost (N$)**	**Unit (s)**	**Total Cost (N$)**
Brick Press	6,750	5	33,750
Transportation	7,500	5	37,500
Wheelbarrows	112.5	15	1,687.5
Spades/Hoes	37.5	25	937.5
Other Tools	225	5	1,125
Contingency Fund	1,500	-	1,500
Total Start-up Cost:	-	-	**76,500**

The proposed business scenario includes the purchase of five brick presses, the cost of shipping them from the supplier to Tsumkwe, and the purchase of various other tools required for brick production.

On average, each group of two men can produce between 300 and 480 bricks per day and a minimal of 14,400 bricks per month. Table 4 depicts the cost of producing 72,000 bricks in one month.

Table 4: Operational cost to produce 72,000 bricks

Monthly Production			
Item	**Unit Cost (N$)**	**Units**	**Total Cost (N$)**
Cement	90	600	54,000
Labor	532	10	5,320
Maintenance	375	5	1,875
Plastic Sheeting	7.5	325	2,437.5
Total Operation Cost			**63,632.5**

The total cost of producing 72,000 bricks in the first month of operation including the initial capital investment, production materials, workers' wages, and other maintenance is N$ 140,133.

Each brick press employs two men. Accordingly, five brick presses will employ ten men. The ten laborers will be paid the minimum wage of N$ 3.80 per hour to sift soil and operate the brick press. The subsequent monthly salary per worker will be N$ 452 per month accounting for VAT and assuming a 35-hour workweek (7 hours a day).

The first month's salary assumes that there is no profit made from selling bricks and that all of the bricks produced will be used directly to construct homes in Tsumkwe. Following the first month, the cost of producing each brick will amount to N$ 1.20 per brick. Assuming that each brick can be sold for N$ 1.90, the revenue per month (72,000 bricks) will be N$ 71,367.50.[28] Assuming that N$ 10,000 of the monthly profit is set aside for allowances for wages, the new monthly salary for each of the ten workers will increase from N$ 452 to N$ 1,302.

Furthermore, supposing that the cost of shipping the bricks to buyers in either Windhoek or Grootfontein will cost N$ 7,500 and occur once each month, the profit after allowances for wages is estimated to be N$ 53,867.50 as outlined in Table 5.

[28] Estimates of brick prices are based on an average of prices of the lowest quality interlocking bricks in Windhoek at several construction supply companies.

Table 5: Profits realized after first month of brick production

Profits: *Month 2*	***(N$)***
Cost per brick	0.88
Price of Brick Sold to Buyer	1.88
Profit per Brick	1.00
Revenue per Month	**71,367.50**
Allowances for Wages	10,000
Monthly Salary of Worker (- VAT)	1,302.2
Cost of Shipping Bricks to Buyer	7,500
Final per Month	**53,867.50**

The profits from brick production could be used to:

- Pay for homes constructed in the future to be connected to the electrical grid
- Pay for meters and service lines to extend the electrical infrastructure in North Tsumkwe and other locations
- Hire additional employees in the Department of Works
- Purchase tools for the employees of the Department of Works
- Fund additional development projects in Tsumkwe

Home Construction

A typical household in Tsumkwe has an approximate floor plan of 12’ by 16’ with 10’ ceilings. Roofs are often made of corrugated metal sheets or reeds and mud. Assuming that eight standard sized interlocking bricks are required to construct one square foot of wall section, each standard sized home would require an estimated 5,120 bricks. Accordingly, 51,200 bricks produced in the first month of production will be used to construct 10 homes, leaving 19,900 bricks unused. The left over bricks will be sold for a profit of N$ 37,000 which will be used to buy corrugated steel roofing, wooden framing for windows, mortar, and other tools for future construction of the 10 worker homes.

A program should be established to directly employ members of the community interested in constructing new homes. The desire to construct a new home should stem from the desire to be connected to the electrical grid by meeting the permanent structure qualifications.

The employed community members would receive a monthly salary of N$ 452 for the first month of brick production and receive approximately 5,120 bricks to construct a home of the previously described dimensions. After the first month of brick production, the workers monthly salary will increase to N$ 1,302 (Lewis, 2009).

Timeline

We recommend that a more complete and comprehensive project proposal be drafted using the basic information presented in this report. Additional research should involve reviewing case studies and formulating a list of potential project funding organizations.

Immediately after funding for the project is made available, an order of five ISSB presses will be placed from a supplier and shipped to Tsumkwe. Assuming the brick presses arrive in Tsumkwe one month after the order is placed; a team of two individuals working in collaboration with the DRFN as field facilitators will travel to the settlement. The team will survey empty plots in the Tsumkwe for potential production sites and take small samples of the soil for composition testing. The samples will be saved and later sent to the Polytechnic of Namibia's Materials Testing Institute (MTI) for analysis.

The team will then produce several sample bricks from each of the surveyed plots using different mixtures of cement and soil. The bricks will be allowed to fully cure and be sent to the MTI for structural testing, which will take one week; the students assigned to conduct the analysis will determine which mixture of cement and soil will produce the strongest bricks. The testing and analysis is predicted to take approximately three weeks to produce conclusive results on the most effective mixture and best plot for the future production site.

While the team waits for the results from the MPI, they will begin to speak with the community members and search for qualified workers. To qualify, the resident must live in a

home that is not connected to the electrical grid because it is not classified as a permanent structure. The individual must also be visibly capable of prolonged manual labor and be at least 18 years of age. The team will take applications and choose 10 qualified residents to work with the presses and one worker to be an operational manager and production supervisor. The Local Government office will be responsible for providing a production supervisor.

Once the future production site is chosen and the optimal mixture of soil and cement is determined, the team and the 11 workers will begin clearing the chosen plot. The team will take approximately two weeks to clear the site, arrange the equipment, and train the workers.

The DRFN facilitators will continue to supervise the operation for an additional two weeks. At the end of two weeks, the facilitators will then begin to train the workers on household construction methods. The group will use the newly produced bricks to build a home of one of the workers as a model for the other workers to learn how to construct non-traditional households.

Three months after the DRFN facilitators arrive in Tsumkwe, it is predicted that the ISSB production will be well established and the workers will have been trained to construct their own homes. The facilitators will spend one more month in Tsumkwe with minimal interaction with the production team to ensure that the operation continues to be successful. At the end of three months, the DRFN will hand over full business ownership of the operation (Lewis, 2009).

Assumptions

1. Residents of the community will actively participate in the ISSB program.
2. The Local Government will support the initiative and dedicate management capacity towards operating the business once the initiating organization (DRFN) has left.
3. The residents of Tsumkwe North and other residents living in un-electrified homes will be interested in being employed by the program and interested in constructing new homes with the intention of being connected to the electrical grid.

Limitations

1. The demand for the bricks produced in Tsumkwe may not be high enough to meet the production capacity.
2. The quality of the soil in Tsumkwe may not be sufficient to produce structurally usable bricks.
3. Production estimates are based on a case study performed on a similar successful business operation in Uganda. The estimated values should be further refined a revised project proposal to consider a production factor tailored to potential limitations that may be apparent in Tsumkwe (Lewis, 2009).
4. The prices of materials, tools and brick press units were estimated based on the Uganda case-study and quotes by various suppliers in Namibia. The estimated values are subject to change at any time and may influence the validity and feasibility of the proposed business plan (Lewis, 2009).

Conclusions

The proposed business plan will require an estimated N$ 140,000 in funding to be a successful operation. It is recommended that the DRFN produce a more complete and comprehensive business feasibility analysis for the proposed ISSB production operation. It is also recommended that the DRFN work collaboratively with the Ministry of Local Government and Housing in Tsumkwe to formulate a formal project proposal to a reputable funding organization.