Developing Energy and Economic Initiatives for Rural Namibia

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Date: May 3rd, 2011

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Conceptualizing Containerized Businesses in Tsumkwe & Evaluating Wood Gasification Technologies for Electrifying Rural Namibia

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Sponsoring Agency: Desert Research Foundation of Namibia

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Report Submitted to:

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Abstract

Namibia's off grid settlements suffer from poor economic development due to an inadequate energy infrastructure. Limited resources in arid regions of Namibia have caused a surge in alternative energy use and resourceful capacity building. This report consists of designs for containerized services and an evaluation of small-scale wood gasification technologies for rural settlements where resource scarcity is an enormous hindrance.

Executive Summary

Rural developing communities around the world need to obtain secure sources of energy and income to thrive. Without proper power and infrastructure, communities can dissimilate or become forced to rely on external resources in order to survive. Furthermore, any community that exists in a harsh environment, such as the arid region of northern Namibia, must deal with not only the lack of energy and economic resources but also the remoteness of its geographic location, making travel, trade, and communication extremely difficult. An example of such community is Namibia's largest off-grid settlement, Tsumkwe.

Tsumkwe is home to approximately 200 households and also supports a population of nearly 3000 migrating San people. Due in part because of complex political history and the misguided efforts of some organizations, this community has begun to rely entirely on external assistance for subsistence. The vast majority of people who live in Tsumkwe must travel 300km to Grootfontein, the closest city, for basic goods and services. The San people, whose culture often conflicts with the modernizing trends spreading across Namibia, are offered free housing, food, and education through several governmental and non-governmental programs as part of a cultural assimilation and development effort. With little community participation, however, these well-intended programs are often met with limited and frustrating results.

Non-governmental organizations working in this region for many years have learned from this trend and have adapted their policies to integrate local residents into the decision-making and implementation process of their projects. One such organization is the Desert Research Foundation of Namibia (DFRN). The DRFN has assigned our team two projects on rural development initiatives. The first of these two projects is Conceptualizing Containerized Businesses in Tsumkwe, an extension of the Tsumkwe Energy Project. Tsumkwe is not scheduled for grid-electrification within the next 20 years due to cost limitations. The settlement currently subsists on a diesel mini grid that is inefficient, expensive, unreliable, and only runs for part of the day. To supplement the diesel mini grid and to provide stable 24-hour access to electricity, the DRFN is installing a 250kW solar array in Tsumkwe. This installation will be the largest solar-diesel hybrid generator system in operation. The new availability of reliable electricity will provide Tsumkwe with proper energy infrastructure necessary to foster economic development.

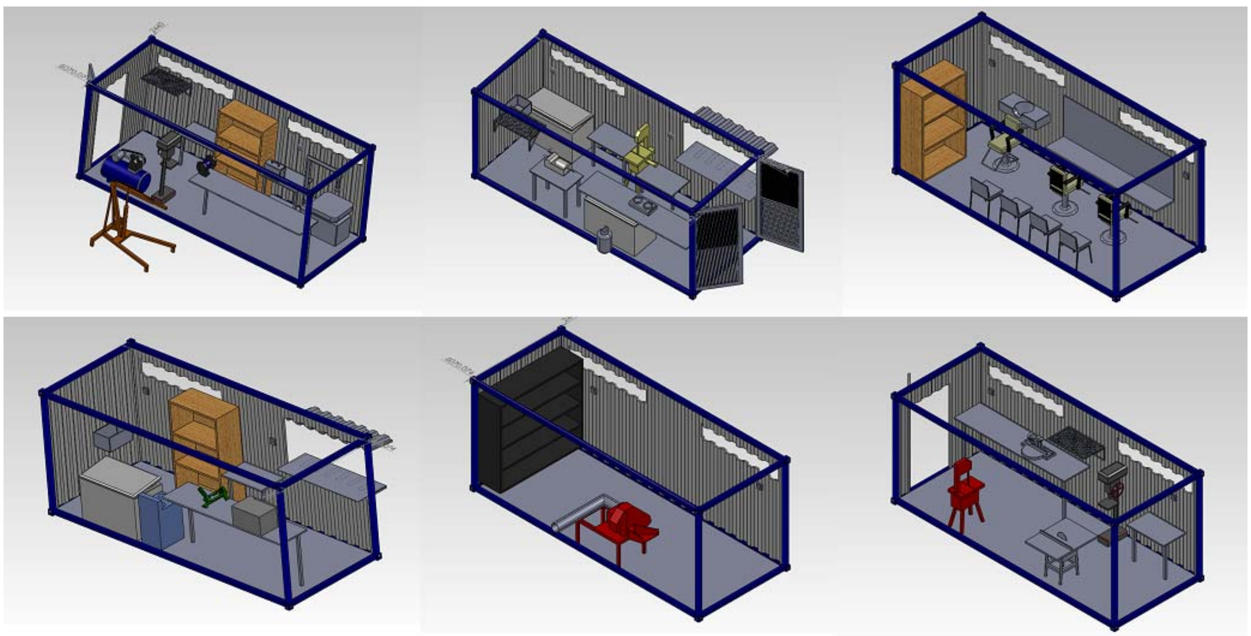
The DRFN requested an investigation from us into various methods for increasing the capacity of Tsumkwe's economy. The economic opportunities conceptualized by our project team in coordination with the DRFN staff would utilize the new energy available in Tsumkwe from the solar grid. Our research group was then presented with the task of designing various containerized small-and-medium enterprises (SME) for implementation in an SME park adjacent to the solar array. These businesses will be service stations designed to provide the necessary equipment for running a variety of enterprises in portable 6m shipping containers. For theses containers, we only considered large-scale pieces of equipment such as meat saws, metal grinders, welding machines, and table saws. All the equipment under consideration is currently unavailable in Tsumkwe. With the introduction of these service stations, we hope to provide the tools for the local community such that the people of Tsumkwe are able to expand their economic potential.

Our second project is Evaluating Wood Gasification Technologies for Electrifying Rural Namibia, which builds on the Combating Bush Encroachment for Namibia's Development (CBEND) initiative. The CBEND project aims to use the invasive thorny acacia bush species that are plaguing Namibia's once expansive Sub-Saharan plains for energy generation through wood gasification. As part of the CBEND project, the DRFN built a pilot plant in 2010. This plant was designed to produce 250kW of electricity by a controlled process of burning woody biomass in block or chip forms. This electricity is fed back into the grid and purchased by NamPower, the major electricity provider of Namibia. The CBEND pilot plant suffered from various difficulties such as technical robustness and financial feasibility. Sadly, even after overcoming most of the engineering complexities of the plant itself, the electrical infrastructure connecting the plant to the grid is still insufficient. The losses in the grid system reduce the power generated by the plant from 250kW to 50kW. The pilot plant was therefore shut down and is currently not operational.

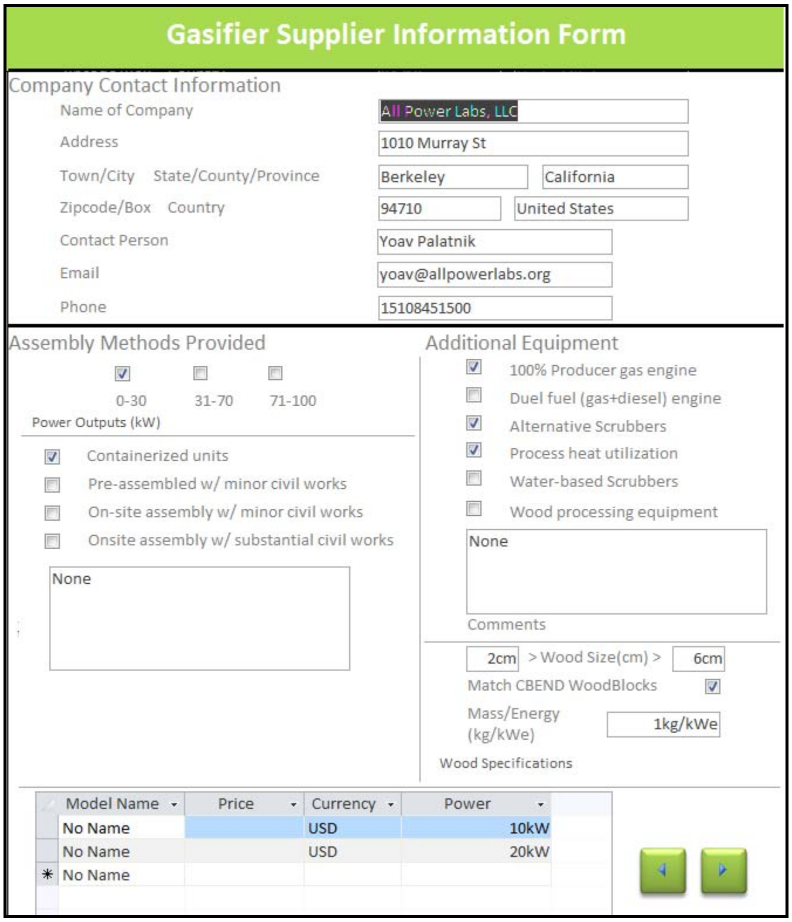
The DRFN's solution to the feasibility issues of the pilot plant is two-fold. First, the DRFN wants to downscale the size of the gasification system to between 30 and 100kW. This smaller-scale will allow for the decentralization of power consumption. Additionally, these gasifiers will be for off-grid settlements where electrical power is scarce. Our project was to aid in this shift in the CBEND project by researching various small-scale biomass gasification systems for off-grid implementation. To accomplish this goal, we contacted a multitude of gasification technology suppliers and then narrowed down the list of suppliers through the use of technical surveys and inquiries. The final list consisted of companies that supply technology in our desired power range and installation requirements. The final deliverable of this part of our project was to submit a feasibility assessment tool along with the specifications of the potential suppliers to the DRFN to aid in the decision-making process for future gasification plant projects.

Selected Results

Displayed below are the containerized SME prototype designs for metal work and auto repair shop, butchery, hair salon, service kitchen, grain mill, and wood work shop as part of the Conceptualizing Containerized Businesses in Tsumkwe project.



Displayed below is the feasibility assessment tool developed to evaluate the wood gasification technologies for Evaluating Wood Gasification Technologies for Electrifying Rural Namibia.


Gasifier Supplier Information Form

Company Contact Information

Name of Company: All Power Labs, LLC
Address: 1010 Murray St
Town/City: Berkeley
State/County/Province: California
Zipcode/Box: 94710
Country: United States
Contact Person: Yoav Palatnik
Email: yoav@allpowerlabs.org
Phone: 15108451500

Assembly Methods Provided

[x] 0-30 [ ] 31-70 [ ] 71-100
Power Outputs (kW)

[x] Containerized units
[ ] Pre-assembled w/ minor civil works
[ ] On-site assembly w/ minor civil works
[ ] Onsite assembly w/ substantial civil works

None

Additional Equipment

[x] 100% Producer gas engine
[ ] Duel fuel (gas+diesel) engine
[x] Alternative Scrubbers
[x] Process heat utilization
[ ] Water-based Scrubbers
[ ] Wood processing equipment

None

Comments

2cm > Wood Size(cm) > 6cm
Match CBEND WoodBlocks [x]
Mass/Energy (kg/kWe): 1kg/kWe
Wood Specifications

Model Name	Price	Currency	Power
No Name		USD	10kW
No Name		USD	20kW
No Name			

Conclusions

The local resident's response to outside economic development efforts is generally low in Tsumkwe. This is due to cultural differences between the San, the majority of the residents in Tsumkwe, and the rest of Namibia. Until an improved way of integrating these communities into the decision-making and implementation process is developed, efforts by outside organizations will continue to fail. Additionally, the geographic location of Tsumkwe means that proper supply chains are difficult and expensive to create and maintain. We determined that the best way for us to aid in the development of Tsumkwe was not to focus on product-driven businesses or stores. Instead, our designs focused on providing service hubs and production equipment. If we can provide the tools and equipment necessary to perform basic repairs, butcher work, and other vital services, then members of the community will be able to use this equipment and hopefully improve their ability to develop on their own. We are not creating businesses for the community, we are creating a convenient location for businesses to be developed and conducted. We are providing the tools for the community to make decisions for themselves. Our final goal was to present the DRFN with a series of designs for these SMEs as well as cost and power analyses for each container. Additionally, we supplemented our report with recommendations concerning the implementation of our SME designs, as well as further research that should be done to enhance the effectiveness of our project.

Due to the size, cost, complexity, and engineering intricacies of the CBEND pilot plant, it became clear that gasification systems on such a large scale are simply not feasible for rural Namibia. In addition to the physical difficulties of the plant itself, Namibia's electrical infrastructure in its rural areas is not sufficient enough to make a grid in-feeding system financially viable. The solution for these problems is to downscale and decentralize energy production facilities. These smaller gasification systems would provide sufficient energy to small off-grid settlements currently generating electricity through the burning of diesel fuels. Utilizing alternative fuel sources like woody biomass for energy production can also prevent small off-grid settlements from relying on diesel fuel which causes extensive harm to the environment. Our final goal was to present the DRFN with our analyses of market-ready wood gasification technologies worldwide as well as a feasibility assessment tool that would help the DRFN decide which gasifier-generator system should be purchased. We also included our recommendations on the purchasing and implementation of wood gasifiers in off-grid communities.

The Tsumkwe Energy project and the CBEND project are both working to address the substandard energy infrastructure and the underdeveloped economy of rural Namibia. While these two projects may seem different at first, their end goals are the same. Both are attempting to use readily available resources for sustainable development. Our work with both of these projects will hopefully serve to aid in the economic and energy infrastructure development of Tsumkwe, and serve as models for other rural settlements across Namibia.

For a visual representation of the key words in this IQP report, please refer to Appendix O for a word cloud.

Recommendations for the development of Tsumkwe

We recommend that a form of public transportation be developed between Grootfontein and Tsumkwe.

Formal, scheduled transportation should be established to transport people back and forth from Tsumkwe and the surrounding settlements to Grootfontein. This would help the community tremendously by creating a stable, safe, and efficient way of traveling to obtain basic supplies. We believe that a coordinated bus schedule could drastically improve conditions within Tsumkwe. This is a vital part of any long-term solution for a community like Tsumkwe that has extensive supply needs.

We recommend more emergency service vehicles be provided between Grootfontein and Tsumkwe.

At the time of this report, there exists one emergency vehicle that travels between Grootfontein and Tsumkwe. This vehicle also services the smaller settlements that branch off the more traveled road. We have learned through our visits to Tsumkwe that the emergency clinics in the settlement do not have the necessary supplies for serious injuries or incidents such as poisonous snakebites. We understand that the limited population in Tsumkwe diminishes the need for such an emergency clinic, but we believe the residents of Tsumkwe should be better protected by providing an opportunity to travel to locations where better services are available.

We recommend school-sponsored extra-curricular activities for all grades of students.

Currently there are few to no activities for children, teenagers, and young adults to do once the school day is over. If the school introduced afterschool programs such as sports teams, movie showings, or dance socials, students would have structured activities to do after school that would be a productive use of their time. It could also serve to improve school attendance and potential academic performance. Anything that the school or any other group could do to prevent kids from turning to alcohol for entertainment out of boredom will serve to strengthen the community.

We recommend the development of afternoon and night activities for residents of all ages.

There are very few entertainment options available in Tsumkwe to the members of the community. At the time of our visit, the majority of adult residents relied on television or shebeens (informal bars) for entertainment following work. We believe that the establishment of entertainment options for families and residents of all ages would greatly benefit the community in Tsumkwe. These forms of entertainment should cater directly to the desires of Tsumkwe's residents, and if possible should rely on little to no electricity to maintain the sustainability of Tsumkwe's future as an off-grid settlement. Some suggestions are board games, movie showings, fitness centers, and pool or billiards halls.

Recommendations for the Tsumkwe SME Park

We recommend additional research into green energy sources and sustainable practices for the SME park implementation.

Our container designs are such that the addition of solar panels is a minor physical addition but still requires more research before actual implementation. The DRFN should also evaluate the feasibility of additional green energy sources to power the SMEs such as wind power. Some of the SME designs we have created require large amounts of water and additional electricity, such as the auto repair shop or the wood working shop. To keep with the spirit of the Tsumkwe Energy Project, these designs should consume as little resources as possible.

We recommend community education and management search programs for the SME park.

Ideally, the residents of Tsumkwe would manage the maintenance and management of the SME park. In order to prepare the community such that the residents could manage the park and the solar array effectively and sustainably, we have to prove to the settlement the value of the solar array and potential benefits the SME park could have on the community. This will not be an easy process but if done successfully it could serve to re-vitalize this settlement. Additionally, research has to be conducted for locating individuals in Tsumkwe who are interested in maintaining and managing these SME Parks.

We recommend that further research should be done in both structural modifications and installation techniques for the containers themselves.

We recommend that the DRFN consider some of the structural and design modifications that we were unable to present to them due to time constraints, yet we believe are still worthwhile. One design concept we recommend for further research is considering opening up the sidewalls of both the auto repair and wood working container to increase the overall work space. Second, we recommend that the DRFN consider the use of multiple containers when attempting to design some of the more complicated services like auto repair and metalworking.

In addition to structural modifications, we recommend that each container be built with a twin-pitched roof rather than the single-pitched roof displayed on our designs. In the last week of our time with the DRFN, we held various meetings concerning the construction of these containers and determined that the double-pitched roof was the best solution for heat shielding. Additionally, we recommend that each container be built in a slight incline to facilitate adequate drainage during cleaning. Lastly, we recommend that the DRFN look into using refrigerated containers for designs like the butchery or the service kitchen because of their heavy-duty insulation and stainless steel interior.

We recommend that a detailed contract be created outlining the responsibilities of the renters and managers of the SME park.

There are many logistical questions remaining in the implementation of the SME park in Tsumkwe. A contract outlining the responsibilities of each party involved should be drafted, perhaps with the participation of the entrepreneurs in Tsumkwe. This contract should include liability concerns relating to the equipment and to the overall condition and cleanliness of the containers themselves. This contract should be reviewed with the potential renters for additional feedback.

We recommend that the DRFN consider the use of the superstructure concept to add to the overall construction of the SME park.

As outlined in our Results and Analysis section, we believe that a superstructure roof could add to the overall aesthetic nature of the SME park as well as provide additional heat shielding and energy generating potential for the park. While we fully understand that this roofing concept is not feasible at this time we believe that in the future, if the funding becomes available, such a concept would be a worthwhile venture.

Recommendations for CBEND Off-Grid Gasification Initiative

We recommend an evaluation on the level of interest in wood gasification and the creation of a promotional and educational program for energy farmers in rural communities.

More research should be done into the public interest in energy farming and the CBEND concept itself in rural communities. In order to successfully introduce wood gasification technologies across Namibia, rural communities have to be identified that are interested in alternative energy solutions. Additionally, a promotional campaign expressing the benefits of these systems and the potential economic opportunities that could be made in these rural communities should be developed and presented to key settlements and farmers.

We recommend further investigation and due diligence into suppliers before purchasing any gasification system.

As the DRFN saw directly with Ankur at their CBEND site, it is vital to do as much research as possible on various companies that could supply these systems. Our questionnaires and inquiries identified potential suppliers by their technical specifications and by some measure of their processes; however no survey will gather all necessary information. Information such as the structure of the companies, the longevity of their systems, and their corporate track record should be investigated further. All of these details need to be determined prior to any investment.

Authorship Page

Andrew Baker, Richard Brown, Robert Morlath, and Zhixin Wang all contributed to the various aspects of the project. The following is a breakdown of the individual contributions to the project.

Andrew Baker contributed to the writing of the Literature Review and Methodology for the “Evaluating Wood Gasification Technologies for Electrifying Rural Namibia” project and worked heavily on the SolidWorks designs of the containerized businesses for the “Conceptualizing Containerized Businesses in Tsumkwe” project.

Richard Brown contributed to the writing of the Abstract, Executive Summary, the Literature Review and Methodology for the “Conceptualizing Containerized Businesses in Tsumkwe” project, and worked on the design of the feasibility assessment tool for the “Evaluating Wood Gasification Technologies for Electrifying Rural Namibia” project.

Robert Morlath contributed to the writing of the Executive Summary, the Literature Review, Methodology, and Results and Analysis for the “Conceptualizing Containerized Businesses in Tsumkwe” project as well as the writing of the Conclusions and Recommendations for both projects. He also helped Andrew Baker on the SolidWorks designs of the containerized businesses.

Zhixin Wang contributed to the writing of the Literature Review, Methodology, Results and Analysis for the “Evaluating Wood Gasification Technologies for Electrifying Rural Namibia”, and worked on the design of the cost and power analysis tool for the “Conceptualizing Containerized Businesses in Tsumkwe” project. She also managed the formatting and finalization of this report.

In addition to the writing and design portions of the project, Andrew Baker, Richard Brown, Robert Morlath and Zhixin Wang as a group all contributed to the conceptualization of the containerized businesses as well as the survey process of the gasification technology evaluation. The group as a whole established the project objectives, determined conclusions and recommendations, and edited the report for content, grammar and flow.

Acknowledgements

We would like to express our deepest gratitude to the staff members of the Desert Research Foundation of Namibia (DRFN) who have been working closely with us throughout the duration of our project. We would like to thank Mr. Robert Schultz, our project sponsor and the Senior Project Manager of the Energy Desk, for offering his exceptional guidance and support. We would like to thank Ms. Caroline Coulson, the Project Manager of the Energy Desk, for offering her continuous assistance. We would like to thank Mr. Abraham Hangula, the Project Coordinator of the Tsumkwe Energy Project, for providing us with essential information on Tsumkwe and its current infrastructure conditions. We would like to thank Mr. Jimmy Itamba, the Field Facilitator of the Tsumkwe Energy Project, for guiding our fieldwork on site, as well as providing valuable design feedback. We would also like to thank Mr. Bernard Haas of the Senior Expert Service, for contributing his expertise to the architectural designs of the containerized businesses as well as the technical evaluation of wood gasification technologies.

Throughout our project experience, we have received support from numerous Namibia-based organizations as well as Namibian citizens. We would like to thank the Windhoek-based industrial suppliers, Windhoek-based businesses, shipping container prefabricators, Tsumkwe residents, Tsumkwe entrepreneurs, and CBEND pilot plant on-site staff members who have helped us in our various endeavors.

Additionally, we would like to show our appreciation to the overall support of the WPI faculty advisors, Ms. Ingrid Shockey and Ms. Ulrike Brisson.

Last but not least, we would like to thank the Polytechnic of Namibia and the Worcester Polytechnic Institute, as the collaboration of these two institutions has made our project experience in Namibia a reality.

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Chapter 1 Introduction

Due to the lack of economic opportunities in rural Namibia, people flood into the larger settlements and cities looking for work. This process serves to further hinder the economic development of rural communities by removing the available work force. One strategy to combat this trend is the development of rural economic initiatives. The inadequate energy infrastructure of rural Namibia, however, limits the kinds of businesses and services that can be created. In order to develop economic and energy initiatives for rural Namibia, The Desert Research Foundation of Namibia (DRFN), a non-governmental organization, has implemented two projects that serve to jointly accomplish the goal of rural development.

The DRFN is a non-profit organization whose philosophy is to "enhance decision-making for sustainable development of Namibia". Founded in 1990, the DRFN is a research institution focused on development in the arid regions surrounding the Kalahari and Namib Deserts (Desert Research Foundation, 2011). The DRFN works in collaboration with residents in these regions to develop sustainable solutions for its growing population. Additionally, the DRFN aspires to promote innovation in the projects it has sponsored.

The DRFN has projects categorized into three main areas of focus: water, land, and energy. For our project, we worked for the DRFN's Energy Desk, which addresses pertinent issues involving Namibia's energy infrastructure, especially the utilization of appropriate energy resources. What Namibia lacks in rivers, it makes up for with alternative and renewable energy sources. According to the Energy Desk, solar power is an obvious contributor to Namibia's energy resources (Desert Research Foundation of Namibia, 2009a). The Energy Desk has also identified invasive bush species as a source of biomass energy.

One of the Energy Desk's largest initiatives to date is the Tsumkwe Energy Project, in which the DRFN is installing the largest solar-diesel hybrid generating system in the world in the summer of 2011. While the solar generator system is being built to provide reliable energy to the off-grid settlement of Tsumkwe, the DRFN hopes to take this opportunity to further develop the local economy. The DRFN formulated an idea to create a small-to-medium enterprise (SME) park to foster economic development. A SME park is a collection of small businesses placed together similar to a mini mall or "strip mall". These parks can provide a central location for business in settlements like Tsumkwe. This SME park will be made up of readily-available 6m ISO standard shipping containers and powered by the electricity from the solar generator. Our containerized SME's will provide essential equipment for economic production otherwise unavailable to the Tsumkwe community. The DRFN's vision for the Tsumkwe SME park is to rent out these containers to local entrepreneurs. In this way, the DRFN is providing the tools necessary to expand businesses and services in Tsumkwe while leaving the decisions surrounding the implementation of these enterprises to the local community. Our goal was to create detailed prototype designs of these containerized SME units and present them to the DRFN.

Another goal of our project was to work in collaboration with a second DRFN initiative titled Combating Bush Encroachment for Namibia's Development (CBEND). The CBEND initiative endeavors to contribute to Namibia's energizing efforts by gasifying invasive bush species to produce electricity. Such technology can potentially be utilized to produce an alternative electricity source to power small off-grid settlements. Under the CBEND project, a pilot plant was constructed in 2010 to feed 250kW electricity into the national grid. However, the CBEND pilot plant has suffered from a multitude of obstructions with its construction, operation, technical performance and financial outcome. It became abundantly apparent that a plant of such size is not feasible for applications in Namibia. Our project was to perform a technical evaluation of market-ready small-scale wood gasification technologies to help the DRFN make a more informed decision on future CBEND installations.

Our work with the DRFN endeavored to offer rural off-grid settlements, currently running on limited electricity, an alternative source of energy or income. These resources, such as a SME machinery shop, or a local wood gasifier, can be utilized to fuel the economic development of rural Namibia. We hope that these alternative energy resources and additional economic infrastructure outlets can be implemented to aid the development of rural off-grid communities such as Tsumkwe and other settlements across Namibia.

Chapter 2 Literature Review

The DRFN has an interest in these two projects because both have the potential to enable local development in Tsumkwe and other rural settlements across Namibia. The prototype designs for small-to-medium businesses will inspire innovation with recycled shipping containers and provide the Tsumkwe entrepreneurs with the space and organization necessary to host businesses and services otherwise unavailable in the community. The CBEND technical evaluation will provide the DRFN a foundation for an accessible yet comprehensive guide on small-scale wood gasification systems for off-grid electrification. The availability of such alternative electricity sources has the potential to provide small settlements the power necessary for larger-scale economic and social development. Both projects provide communities with viable development strategies that utilize alternative and sustainable resources.

In order to achieve a deeper understanding of the feasibility of using shipping containers to house business facilities in Tsumkwe, we conducted background research on the social and economic conditions of Tsumkwe, especially pertaining to the indigenous San populations residing in Tsumkwe. We also researched the structural, architectural, and other technical specifications surrounding shipping container designs. Secondly, to achieve a working knowledge of the CBEND technical evaluation, we conducted research to understand the wood gasification technology and its applications globally; we also investigated the current energy infrastructure in Namibia to gauge how wood gasification technology can be integrated into the national system.

2.1 Part 1: Conceptualizing Containerized Businesses in Tsumkwe

Tsumkwe is Namibia's largest off grid settlement. Located in the Otjozondjupa region in northeastern Namibia, Tsumkwe is home to about 200 households (R. Schultz, personal communication, January 28, 2011). In reality, Tsumkwe's population is difficult to measure because of the number of nomadic families living around the settlement. Previous studies, as well as research conducted by the DRFN, have noted that the population living in the outskirts of Tsumkwe would increase the overall population by two or three thousand, with the majority of this nomadic population being San or of San descent (Ingalls, Hanlon, & Eisenbach, 2009, p. 32).

2.1.1 Developmental Initiatives in Tsumkwe

Because of its unique position as a rather large settlement that is not connected to the national grid, Tsumkwe suffers from an underdeveloped economy. Additionally, the community does not have adequate access to transportation services and the electrical infrastructure of the settlement is in widespread disrepair. The DRFN has been examining the best ways to develop the settlements' economy in conjunction with providing reliable electricity. In order to familiarize ourselves with Tsumkwe, we conducted research into the DRFN's previous and on-going efforts in the settlement.

Our project was conducted as part of the Tsumkwe Energy Project, an effort to install a solar-diesel hybrid generator mini grid in the settlement so as to create a stable and constant supply of energy sustainably and cheaply. The DRFN summarized this initiative in *Tsumkwe Energy* in 2008, which analyzed the options for expanding Tsumkwe's energy infrastructure. This paper collected background information about the settlement of Tsumkwe itself and updated the various documentary reports from previous years, as well as providing insight into the dynamics of the town relative to energy projects. The report highlighted various examples of businesses or organizations that have been impacted by the lack of reliable access to electricity (R. Schultz, 2008, p. 4). In addition to these findings, the report explores many of the inherent inefficiencies within the Tsumkwe diesel grid, as well as many alternatives to such inefficient practices. Currently this report is being used as a guide for the implementation of the Tsumkwe solar-diesel hybrid mini grid. This report helped us gain a deeper understanding of Tsumkwe as a settlement, and the local infrastructure conditions preventing the economy from developing further.

When considering placing various businesses and services into a community, it is essential to know the demands of the settlement and what skills can be identified in the community. We hoped to implement various solutions to Tsumkwe's service deficiencies, but first we needed to get more information about the conditions in the settlement. We read the findings from a second project sponsored by the DRFN, *The Tsumkwe Energy Skills Assessment*. This project, conducted by students from the Worcester Polytechnic Institute (WPI) in May of 2009, served to further justify the Tsumkwe Energy Project as well as provided further insight into the economic potential in the community.

The *Tsumkwe Energy Skills Assessment* found that most business owners in Tsumkwe cited a lack of stable electricity as significant hindrance to their ability to expand their businesses. In other cases, local entrepreneurs claimed that the instability of the electrical grid prevents them from running their businesses effectively. In addition to the lack of reliable energy, the research group found that local businesses struggle with supply lines, access to capital, and access to land (Ingalls et al., 2009, p. 32). This information was gathered through a survey of the local business owners.

The researchers also conducted a survey of the local residents called *The General Survey*. *The General Survey* gathered information about local interest in various businesses, as well as determined general awareness of the various energy initiatives in Tsumkwe. Based on the findings of *The General Survey*, the research team was able to draw conclusions about the current level of education in Tsumkwe and the most desired businesses, while taking differences of gender and economic status into account during data analysis. The group concluded that the business that most respondents wanted was a grocery store (Ingalls et al., 2009). The researchers also were able to get a sense for the types of training that people had, and would be required for various business interests.

These preliminary studies were useful for us in a number of ways. Firstly, the *Tsumkwe Energy Skills Assessment* highlighted the specific infrastructure needs of the community. Secondly, the research team highlighted previous research challenges including potential bias in the research based on the interview sample. The research team worried that the presence of their interpreter, and the fact that their interpreter chose most of the interview participants, could have influenced the project's findings. According to the report, the majority of people interviewed by research team spoke English (Ingalls et al., 2009, p. 25).

From *The Tsumkwe Energy Skills Assessment* we gained insight into the kinds of businesses that were desired in Tsumkwe and thus our first indication of which businesses to consider for our shipping container designs. Our project was the logical extension of *The Tsumkwe Energy Skills Assessment* as we took the demographic and economic data gathered by the research team and acted on it. Once we had established both the infrastructural and logistical limitations to Tsumkwe's economy we began to look into exactly how to create a business using a shipping container.

2.1.2 The History and Culture of San

The San population is a collection of indigenous groups in southern Africa. The population numbers collected on San varies greatly due to their migration as a result of war, displacement, and or ecological constraints. It is estimated that there are around 32,000 San people in Namibia, which accounts for approximately 36% of the total San population (Suzman, 2001, p. 5).

Many sources state that, during the colonial and Apartheid rule, the majority of San in southern Africa were perceived as landless underclassmen that labored or squatted on others' properties (Sylvain, 2002, p. 1074). After the Apartheid ended, the social status of the San has remained largely unchanged in southern Africa. The level of land ownership for San is still reported as extremely low. Even with the changing economic, political, and social dimensions in southern Africa after Apartheid, many still believe that dependency remains a defining feature of the San (Suzman, 2001, p. 8). Instead of being economically dependent on other land-owning individuals, many San have now turned to government run social welfare programs for aid. The San's perceived problem with dependency is multifaceted. When the San lost access to basic land rights, they lost the essential capacity for economic production on their own and were forced into collective poverty.

In Southern Africa, the San people are perceived as socially inferior and stereotyped as incompetent and uneducated. This leads to the exclusion of San people from community participatory processes in many development initiatives. Furthermore, the San population is extremely poorly represented in the political bodies in Southern Africa, making it even harder for the community to be involved in policy decisions. Therefore the San are almost completely uninvolved in the design and implementation of governmental policies, especially the policies regarding themselves (Suzman, 2001, p. 23-24).

The San people residing in Tsumkwe and its outskirts are known as the Ju/'hoansi. They are considered the "best picture of 'pristine' hunter-gathers living in splendid isolation from the forces of the global economy" (Sylvain, 2002, p. 1076) by both literature and mass media. Until 1920s, the Ju/'hoansi were strictly hunter-gatherers. Before the establishment of a Native Commissioner in 1959 they lived largely autonomously beyond the scope of any authoritarian body. Then, after 1959, the Ju/'hoansi started to be incorporated into the sedentary lifestyle. By mid-1970s, they lost 70% of their foraging territories.

In the following years leading up to Namibia's independence in 1990, the Ju/'hoansi suffered from poverty, starvation and aggressive army drafting efforts. After Namibia gained independence, the Ju/'hoansi secured access to land and natural resources against pastoralists and tourism companies, which resulted in the 9000 square kilometers of land within the Nyae Nyae Conservancy. However, even on the Nyae Nyae San homeland, the administrative rights are given to other non-White Namibians. (Suzman, 2001, p. 11)

Fortunately, the Ju/'hoansi San in the Tsumkwe region enjoy some form of access to land and natural resources. In Tsumkwe's policy framework, the San people still withhold their identity of "San" or "Bushmen". This allows the importance of the Ju/'hoansi culture to be to some extent preserved and provides the members of San in Tsumkwe with a form of proud identification. The San can utilize government aid systems because of their purposeful identification as Ju'/hoansi. This is beneficial to the San in this area when compared to other major San populations, who are reported to not uphold their unique identity, and are being forcibly incorporated as underclass members in our western-oriented society.

2.1.3 Structural Analysis of Shipping Containers

In order to foster economic development in Tsumkwe and vitalize the community, the DRFN proposed the idea of utilizing surplus shipping containers to house businesses and services. The goal of the Conceptualizing Containerized Businesses in Tsumkwe project was to design several prototypes to be used for different local business and service purposes, using readily available steel shipping containers. These designs are for both small and medium-sized enterprises. The DRFN presented us with a number of ideas of what types of businesses they wanted us to design. The business suggestions represent the interests of existing entrepreneurs in Tsumkwe, and what the DRFN believed would be the most beneficial to the prosperity of Tsumkwe (R. Schultz, personal communication, January 28, 2011).

International shipping containers come in a variety of sizes. Standardizing those shipping containers is necessary to ensure the fluid travel of goods from one place to another. The shipping containers used in our project match the international standard ISO 668 (Sawyers, 2011, p. 12). Shipping containers come in two standard lengths, 6 meters and 12 meters. Each type is 2.4 meters wide and 2.6 meters high (Container, 2009). These structures are usually made from high-quality Corten steel, which passes the Japanese Industrial Standard G3125 (Sawyers, 2011,

p. 13). This type of steel is used because they are intended to carry and support large loads of cargo and to prevent corrosion. The containers are engineered in a way that maximizes structural integrity while limiting the overall weight.

In order to successfully modify steel shipping containers for use as construction materials, one must understand the physical dimensions and capabilities of these containers. Two studies proved helpful in our analysis of container engineering. The first was titled *Shipping Container Emergency Shelters*, a Major Qualifying Project (Capstone Design Project) conducted by a group of WPI Civil Engineering students in 2010. The second study, *Intermodal Shipping Container Small Steel Building*, serves a guide on using shipping containers as construction materials. The findings of these studies provide a historical background of shipping containers themselves, as well as technical and metallurgical specifications. Both sources discuss the necessary modifications to make these containers structurally sound and livable.

The researchers from the *Shipping Container Emergency Shelters* project found that trade deficits and international tariffs have created a situation where, in many cases, it is cheaper for shipping companies to continue to buy new containers instead of shipping them back to be refilled. The report elaborates, “Since containers are available in large (even excess) quantities around the world, they are relatively cheap compared to current construction materials” (Zabinski, Brodaski, Campanelli, & Pietroforte, 2010, p. 1). The Emergency Shelters research group explains that the strength in shipping container comes from the four corner posts and the floor. Thus cutting holes out of the sides, or modifying the doors, should have very little effect on the overall structural integrity of the containers (Zabinski et al., 2010, p. 10). In terms of the technical details of such modifications, the research group admits that certain elements of these modifications are beyond the scope of their project, such as specifics for electrical and plumbing systems (Zabinski et al., 2010, p. 71). The authors’ recommendation were that shipping containers could be used effectively as emergency shelters due to their structural integrity, abundance, and the ease with which they can be modified and transported (Zabinski et al., 2010, p. 70-71). In fact, shipping containers are used widely around the world for business and residential purposes in both temporary and permanent installations. For our purposes, this research indicated to us that these containers could be easily modified to make various different workspaces. The same characteristics that allow these containers to be used as emergency shelters such as cost, structural reliability, and ease of modification, enabled us to use these containers as viable construction materials for the businesses in Tsumkwe.

Along with the understanding that major modifications to these containers are possible without sacrificing structural integrity it is vital to know exactly how to carry out these changes. Paul Sawyers wrote a guide for do-it-yourself construction with steel shipping containers titled *Intermodal Shipping Container Small Steel Buildings*. He describes how to take advantage of the structural elements of shipping containers to maximize the use of full space. His findings were that while the corner posts and the floor supports are the main stabilizing components of the structure, the walls themselves add a degree of stability such that removing them will reduce the overall strength of the container. He also describes, in significant detail, how removing large amounts of certain elements, like the walls, will cause flexing within the structure (Sawyers, 2011, p. 13). This knowledge proved especially important to our project as it became necessary to consider joining or stacking containers to meet the needs of the businesses planned for Tsumkwe.

Just as the structural stability of the walls is a primary concern when designing a business out of a shipping container, we had to consider the construction of the roof and the footings used to hold up the structure. Due to the near constant sunshine and intensive heat of Tsumkwe in the summer months insulating these containers was one of our primary concerns. Roofing represented one of the potential solutions for protecting our business designs from the intense desert heat. Sawyer recommends using roofing as a primary way of insulating one of these containers (Sawyers, 2011, p. 61). The researchers for the Emergency Shelters project did not discuss roofing designs for heat insulation as Sawyer did. Instead they focused their research on a specific type of insulation, Prodex Insulation, which could be installed on the interior walls of the container to act as a heat shield (Zabinski et al., 2010, p. 33). Through our discussions with our sponsor, and with shipping container suppliers, we decided focus on roofing the containers for heat shielding. Our Results and Analysis section includes a more detailed description of our roofing techniques. We also believe that more research be done to determine how best to install solar panels on these containers for both heat shielding and power generation. Based on the recommendations from our sponsor we chose to leave this part of the research for a future project. In terms of footings for these structures, Sawyers recommends that concrete footings are placed under each of the four corners. According to Sawyers, “Concrete footings 2-3ft above the ground create the preferred foundation for a container structure" (Sawyers, 2011, p. 37). While the area where these containers will be installed does not face any of the frost or rain drainage issues that others areas do, footings were still necessary in terms of supporting the structure itself as well as attempting to allow air to flow around all surfaces of the container. Sawyer also recommends installing mid-span footings in the events of removing interior walls to fully support the structure (Sawyers, 2011, p. 38). The information in this guide enabled us to evaluate the structural integrity of various possible designs for the businesses in Tsumkwe. This research provided us with a baseline understanding of the structural elements of ISO standard shipping containers from which we could create initial ideas of the major structural changes that were possible with these containers.

2.1.4 Applications of Shipping Container Architecture

We investigated three successful applications that converted shipping containers to habitable environments for working and living, and one project into using similarly dimensioned trailers for worker accommodations. Shipping containers are becoming a popular material for construction in urban development projects because of their availability and how easily one can convert a container to living quarters. We examined the following shipping container designs because of their resourcefulness and practical applications. Though the examples are very elaborate and utilize modern building materials that may not be accessible in Namibia, they still provide useful information and criteria our team will apply in our own designs.

Bsq, a landscape design and architecture firm located in Toronto, designed a 2-person office in a 6m shipping container. This reclaimed container will be used as a supporting office for Bsq, and was recently shown at the Interior Design Show in 2009 (Alter, 2009). They used an exterior roof-mounted solar array, which generates enough power for LED lighting, two computers, and a printer. The most unique aspect of this design was the use of the roof as a deck and terrace. Forty percent of the roof space is used as a deck while the remaining sixty percent is being used to grow sedum moss. The design replaces the back of the container with a large windowpane for extra natural light. They also cut a secondary door into the one of the sides of the container. The office is insulated with 10.16 cm of rock wool, a more eco-friendly version of fiberglass insulation (see figures below) (Alter, 2009).

Figure 2.1: The Bsq business container model (Alter, 2009).
The Computer Aided Design(CAD) of the model (Alter, 2009).

Figure 2.2: The Bsq container business CAD model, rotated (Alter, 2009).

This design is especially pertinent to our project because this is exactly what we were attempting to do. The project uses identically sized containers to those that were used in our project as well as a roof mounted solar array to power the lights inside of the container.

Another shipping container prototype we investigated was Keetwonen Student Housing plan implemented in the city of Amsterdam. The project uses 12m containers, providing each person with his or her own container. Each unit is equipped with a kitchen, bathroom, bedroom, and has its own ventilation system (TempoHousing, 2011). Heat and hot water is supplied to each container from a central source.

The building as a whole is designed to take advantage of the inherent stacking capabilities of these containers. This project is an example of the potential that shipping containers have as construction materials. While the scope of the Keetwonen Housing Project is far beyond what is feasible for our project, it was useful to see what these containers are capable of supporting, and that it is possible to make comfortable living and working spaces in these containers, as seen in the figures below.

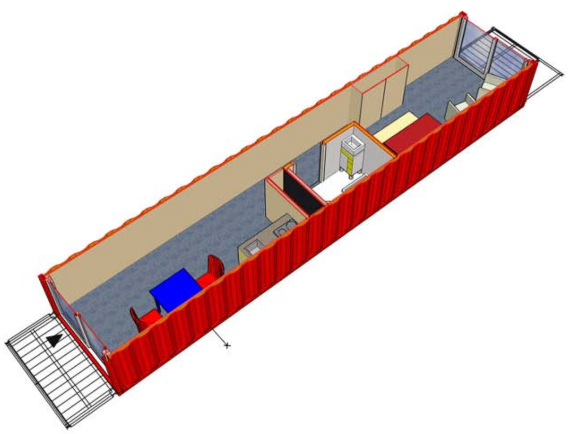


Figure 2.3: CAD model of the Keetwonen Housing Project (TempoHousing, 2011). The Student Housing complex during construction (TempoHousing, 2011).

Additionally, we investigated the All Terrain Cabin designed by BARK, a Canadian design collaboration team. The All Terrain Cabin project was designed to show the capabilities of shipping containers as off-grid housing solutions. The main design elements that make this cabin stand apart from the rest of these designs are the folding walls and an expandable back section. The cabin is designed so that it can be transported to the desired site, and then unfolded, to create enough living space for a family of four. In relation to our project, this displays the potential for not only having drop-down foldable walls, but also expandable sections utilizing tent material to create more space (see figures below) (Alter, 2006).

Figure 2.4: The All Terrain Cabin CAD and life-sized model on display (Alter, 2006).

This was applicable to our project because while we were attempting to use a shipping container as the main design element, our sponsor encouraged us to think of the container as a footprint rather than the entire structure. The fold-down, deck-like sidewalls of this shipping container were considered for our project to create more usable workspace but were deemed to be expensive for widespread use.

In 2008, another project in conjunction with the DRFN developed designs for accommodation trailers for workers. Namibia has fallen victim to an invasive species of bush that is threatening to destroy what is left of the countries open field and cattle grazing land. Some farmer’s employ teams of workers to go out into their land and cut down this invading bush species. More information on the problem of bush encroachment is included in the CBEND portion of our report as we are researching various methods of using this invader bush species for energy generation (see section 2.2). Often these trips are weeks long and require the workers to stay in tents, which do not provide adequate protection from the elements (Baldiga, Graham, Rosenfelder, & Van Ness, 2008, p. 2). This project solved this issue by designing housing trailers that could be used to support the workers out in the field.

The research groups used 3.3m and 5.3m trailer designs that closely matched our container specifications in terms of width and height. They also conducted research into the various electrical components and appliances necessary for equipping these trailers. To price these elements they created a dynamic costing tool. This tool aided us in understanding how to determine the overall cost of our containers. They also utilized the exterior of the trailers for showers, clotheslines, and a dining area, a technique that allowed them to be as space-efficient as possible.

In terms of structure these trailers were designed to provide adequate living, cooking, and entertainment and sanitation conditions for workers. The research team created an 8-person, 5.3-meter long trailer, as shown in Figure 2.5. A four-person, 3.3-meter long trailer, as shown in Figure 2.6, and an unoccupied storage trailer, as seen in Figure 2.7. These designs show an efficient use of space and various techniques that we had previously not considered for fitting components in to the limited space of a shipping container. Using these designs for guidance, we were able to better understand the geometric limitations of working in such confined spaces as well as how best to use the outside of the containers for further use.

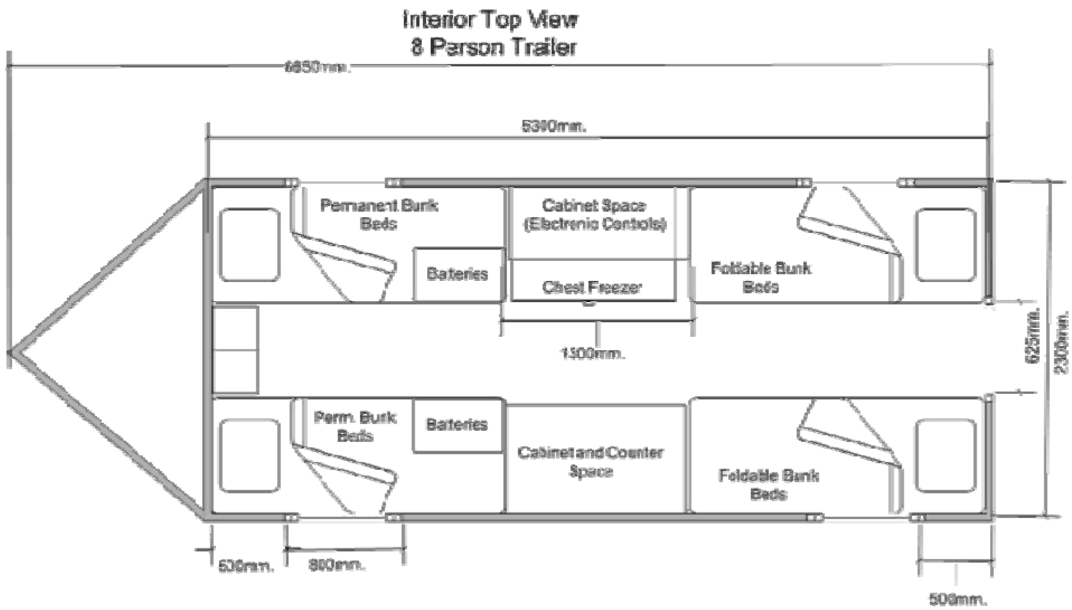


Figure 2.5: 8 Person Accommodation Trailer (Baldiga et al., 2008, p. 77).

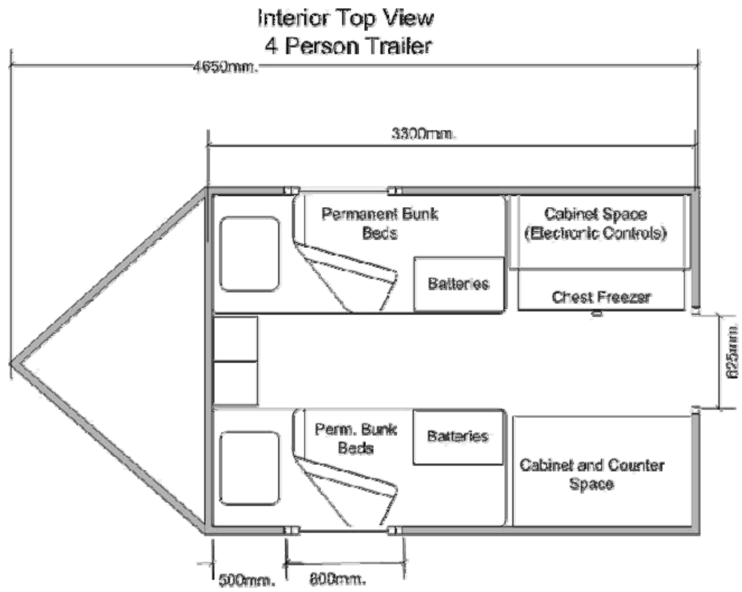


Figure 2.6: 4 Person Accommodation Trailer (Baldiga et al. 2008, p. 84).

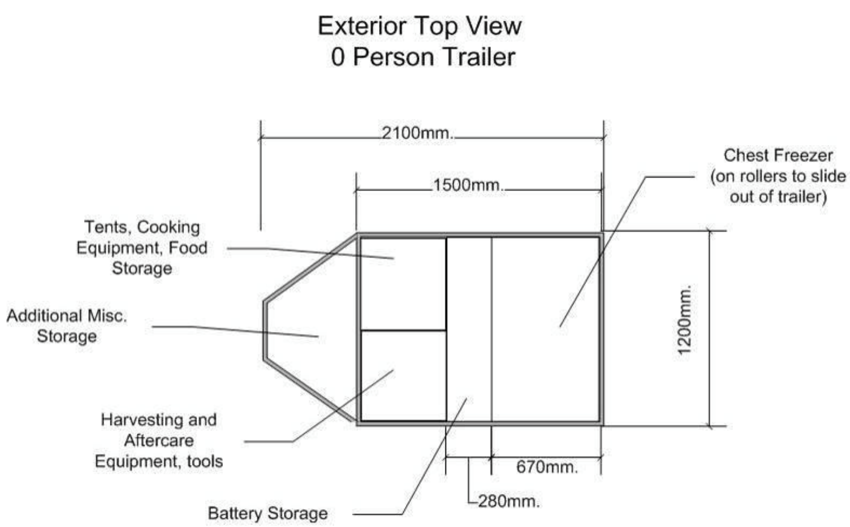


Figure 2.7: Unoccupied Storage Trailer (Baldiga et al. 2008, p. 91).

Utilizing containers as construction material is a unique solution to many architectural problems. In this case we used these containers to create sustainable services within an off-grid, underdeveloped settlement. By using containers for capacity building, as we did in this project, one can accomplish a number of things. First, one can expand the economy of a settlement in desperate need of basic services; second, one can create templates that can be used in a variety of situations. Our designs can be implemented in other rural communities, or in conjunction with containers designed for accommodation to help relocate people displaced by a natural disaster. Most importantly these containers represent a sustainable use of readily available materials to aid in Namibia's development.

2.2 Part 2: Evaluating Wood Gasification Technologies for Electrifying Rural Namibia

CBEND, or Combating Bush Encroachment for Namibia's Development, is a proof-of-concept project that utilizes Namibia's invasive thorny woody biomass species for power generation, to ultimately electrify the rural off-grid communities across Namibia. In order to better familiarize ourselves with the application of wood-to-electricity technology in energizing rural Namibia, we took two approaches. First, we analyzed the technological aspects of wood gasification and its applications worldwide, in order to explore the past efforts of utilizing such power-generating technology. Next, we investigated the energy structure of Namibia and focused on past off-grid energizing efforts, in order to examine how the CBEND concept can complement Namibia's energy scheme. Finally, we delivered a technical, environmental, and social assessment of the installed 250 kW CBEND pilot plant.

2.2.1 Biomass Gasification Technology and Its Applications

Biomass gasification is the process of extracting ignitable gaseous fuel from organic materials through incomplete combustion. Gasification technology received its first real push towards large-scale application with the onset of World War II. Biomass fuel was implemented to help meet the public's demand for energy when access to petroleum was limited due to the war (Rajvanshi, 1986, p. 5). With an increasing demand for clean renewable energy sources in recent years, biomass fuels are again sought out as a viable supplement to fossil fuels throughout the world. In addition, the potential portability of the generators and the abundance and renewability of the fuel source make the biomass gasification technology a well-suited option to provide power to off-grid communities.

There are four stages that biomass fuel progresses through before a burnable gas is produced. These stages are drying, pyrolysis, combustion, and reduction (Rajvanshi, 1986, p. 4). Drying occurs at the point where biomass fuel is added to the gasifier. Water is vaporized from the fuel by radiant and convective heat transfer. The pyrolysis stage takes place at an elevated temperature of roughly 250˚C (Chawdhury & Mahkamov, 2010). Initial formations of tar, carbon dioxide, hydrogen, and traces of methyl alcohol can be seen (Rajvanshi, 1986, p. 5). Typical exothermic reactions through oxidizing carbon and hydrogen occur in the combustion stage. The chemical formulas of carbon binding with oxygen to form carbon dioxide and of hydrogen binding with oxygen to form water are illustrated in Figure 2.8 below.

$C + O_2 = CO_2$ (carbon dioxide)

$2H_2 + O_2 = 2H_2O$ (water)

Figure 2.8: Combustion zone stoichiometric gasification formulas.

Temperatures can be averaged to roughly 1100˚C during combustion. In the reduction zone, the final volatile gases are formed by further processing the reactants of the combustion zone by passing them through an ember bed. Here various endothermic chemical reactions take place. Carbon is bonded to carbon dioxide to form carbon monoxide, carbon dioxide bonds with hydrogen to create carbon monoxide and water, carbon is added to water to form carbon monoxide and hydrogen, and finally carbon is bonded with hydrogen to from methane. All of these formulas are depicted in Figure 2.9 below.

$C + CO_2 = 2CO$ (carbon monoxide)

$CO_2 + H_2 = CO + H_2O$ (carbon monoxide and water)

$C + H_2O = CO + H_2$ (carbon monoxide and hydrogen)

$CO + H_2O = CO + H_2$ (carbon monoxide and hydrogen)

$C + 2H_2 = CH_4$ (methane)

Figure 2.9: Reduction zone stoichiometric gasification formulas

The temperature is lowered, due to its endothermic nature, to a typical value around 900˚C (Chawdhury & Mahkamov, 2010). The three target gases are carbon dioxide, hydrogen, and methane. The water vapor is removed during a post-gasification cleaning process.

Another inherent topic of interest for any biomass gasification system is the issue of tar and other contaminating particulates in the produced gas as by-products of gasification. Various methods have been developed to clean and cool the gas as thoroughly as possible. There are three general varieties of filters used to clean the producer gas: dry, moist and wet (Rajvanshi, 1986). Unless the producer gas is burned directly at the exit of the reactor, a cooling and scrubbing process is employed. The quality of the gas needed is dependent on the desired application that the gas is intended for (Rajvanshi, 1986).

Almost all biomass gasification systems can be placed into two broad categories: fixed bed and fluidized bed. Fixed bed gasifiers were the standard for gasification plants until recently. Fixed bed gasifiers are divided into three categories: updraft, downdraft, and crossdraft. These terms refer to the manner in which air is added, and where the producer gas is retrieved. All three are fed biomass from the top of the plant. Updraft gasifiers have a combustion zone at the bottom where air is added. The reduction zone lies atop the combustion zone and below the pyrolysis and drying zones. Gas exits form the top of the gasifier. Some characteristics of this design are its great thermal efficiency, and its simple and strong structure. The producer gas tends to be filled with tar and other debris, which usually requires substantial cleaning (Bridgwater et al., 1999; Chawdhury & Mahkamov, 2010).

Crossdraft gasifiers have a combustion nucleus in the bottom-middle section of the plant where it is oxidized. The pyrolysis and drying stages ripple out and up from the combustion zone. The reduction zone is across from the combusting biomass. The producer gas exits after passing through the reduction zone, across from the air intake. Some benefits of the crossdraft approach are its smaller size and the quickness that it responds to any change in load. Usual drawbacks are its tendency to be hampered with a buildup of ash and tar (Rajvanshi, 1986).

Downdraft gasifiers stack the combustion, pyrolysis and drying zoned atop the reduction zone. Air is again added to the combustion zone, and the gas produced drops through the reduction zone to exit at the bottom (Rajvanshi, 1986). This design is reliable and known for its relatively clean exiting producer gas. Some drawbacks are that it requires a more uniform size biomass, and each design tends to be specifically made for the biomass used (Bridgwater et al., 1999). A design of a downdraft gasifier is shown in Figure 2.10 below.

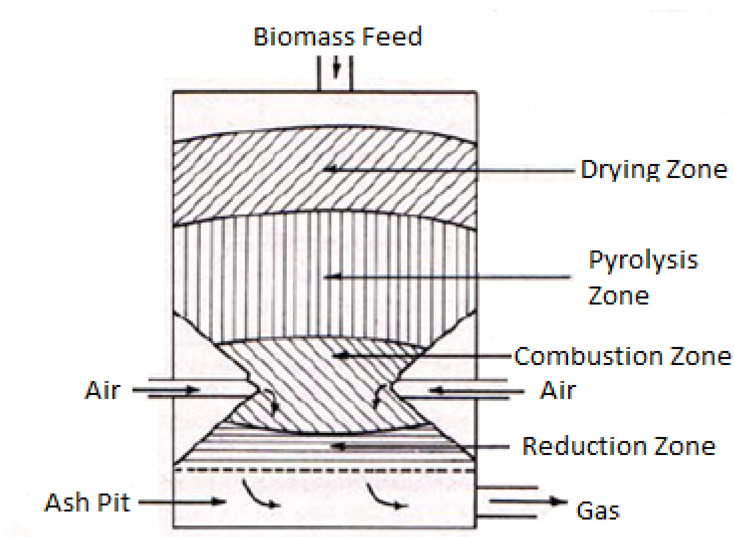


Figure 2.10: Design of a downdraft gasifier

Fluidized bed gasifiers are similar in layout to updraft gasifiers. The difference is that the biomass is added directly to the combustion zone, and the combustion zone has a dynamic bed of inert sand or other like materials. The flowing air pushes the sand, and makes it act as an abrasive, removing insulating ash from the burning biomass. This process speeds the burning rate, and makes it possible to add higher volumes, and more diverse selections of biomass to the gasifier (Energy Products of Idaho, 2011). Other varieties of fluidized bed gasifiers exist, including, but not limited to, circulating fluidized bed, twin fluidized bed, and bubbling fluidized bed gasifiers, but a review of these processes is beyond the scope of research (Bridgwater et al., 1999).

There are various approaches to using the producer gas from a biomass gasifier, ranging from supplementing existing sources of energy like coal to synthesizing a more refined product. A common hindrance when applying producer gas to do work on a system is the buildup of tar and other byproducts that any current method of modern cleansing cannot remove. One simple approach is to maintain the naturally high exit temperature of the gas through the cleansing process and ignite it at this initial temperature. Burning the producer gas without cooling it shows evidence of reducing the frequency of developing a tar and debris buildup problem (Maniatis, 2001).

The first application, co-firing, is the process of taking an existing system, for example, a coal-firing power plant, and supplementing the required fuel with producer gas. In doing this the volume of fossil fuel needed to maintain a desired level of performance is decreased. Biomass gasifiers currently co-firing with coal are the Lahti Plant built by Foster Bheeler CBF in Finland, the BioCoComb Plant in Zeltweg Austria operated by DRAUKRAFT, and the AMER Project at Geertenberg in the Netherlands supplied by LURGI (Maniatis, 2001).

Power is also generated through the burning of producer gas in an indirect firing of gas turbines approach. Here, the heat generated by burning the producer gas is transferred in a heat exchanger to raise the temperature of air to around 900˚C. The heated air then feeds into a turbine to generate power. Examples of this approach are the Free University of Brussels project, BINAGAS in Belgium (here a Fluidized Bed gasifier is implemented), and the Freiberg Project in Saxony, Germany (Maniatis, 2001).

Directly firing the producer gas to kilns, forges, power plants (similar to co-burning), and boilers is a fundamental way to attain a productive output. This is one of the simplest applications, and one of the easiest to maintain, because the gas is easily ignited without prior cooling, reducing problematic tar buildup. Examples of current facilities are the Varnamo Plant, in Varnamo, Sweden, and the ARBRE Plant in North Yorkshire, United Kingdom. Examples of this approach are the Free University of Brussels project, BINAGAS in Belgium (here a fluidized bed gasifier is implemented), and the Freiberg Project in Saxony, Germany (Maniatis, 2001).

Using the producer gas to run an internal combustion engine is also common. Standards for removing tar and other debris from the gas are much stricter because buildup of such contaminants can foul the working components of the engine (Alec Hollingdale, n.d.). Stirling engines are also very promising devices to convert the potential of producer gas to usable energy. The gas is burned in a direct manner, more similarly to the heat exchange segment of the gas turbine, than internally combusting in an IC engine. Other applications of producer gas applications exist, however further investigation is beyond the scope of our project.

2.2.2 Energy Profiling and Off-Grid Energizing in Namibia

Namibia has an institutionalized energy infrastructure under the leadership of The Ministry of Mines and Energy (MME), whose mission is “to regulate the responsible development and sustainable utilization of Namibia's mineral and energy resources for the benefit of all Namibians” (De Vita, Endresen, & Hunt, 2006, p. 3450). Liquid fuels, mainly in the form of petroleum and diesel, dominate Namibia’s national energy structure. Together they account for 63% of the total energy demand. The remainder is supplied by electricity and coal. All of Namibia’s liquid fuel, most of its coal, and approximately half of its electrical energy are imported internationally (The Ministry of Mines and Energy, 1998). On the national level, the Namibian electricity sector is monopolized by NamPower, a state-owned electricity generator, importer, and transmitter (De Vita et al., 2006). The majority of Namibia’s own electricity is generated from the major hydroelectric power plants and the large numbers of small diesel units throughout the country (The Ministry of Mines and Energy, 1998). The Namibian government allows independent electricity production, however, such efforts have been extremely limited (De Vita et al., 2006).

Comprehensive efforts have been taken, both domestically through the MME and internationally through foreign aids, to expand electrical grid coverage since Namibia’s independence in 1990. Namibia’s rural grid extension commenced in early 1990s in the more populated northern regions of the country, and moved clockwise around the country. The focus was to connect the public facilities and nearby residential homes to the national grid (Wamukonya & Davis, 2001). The grid extension program, however, has been moving slowing through the agenda (Shigwedha, 2010). The Namibian government, international governmental organizations, and non-governmental organizations have all been providing alternative solutions to quicken the pace of Namibia’s rural electrification. Emphasis is placed on technologies that utilize domestic and renewable resources, that decentralize energy production, and that enhance energy efficiency.

In 1993, MME launched an initial evaluation of the potentials of Namibia’s wind resources for electricity generation, which has since been garnering private investment promises from abroad (Abramowski, Posorski, Simonis, & Mueller, 1999). In 1996, MME, with the support of international donors, initiated the *Home Power!* program that assisted households with acquiring solar home systems (SHS) through loans, thus lowering the barrier of the upfront installation costs (Wamukonya & Davis, 2001). In 2001, the United Nations Environment Programme (UNEP) African High-Level Regional Meeting on Energy and Sustainable Development published a conference preceding that pointed to the underutilized natural gas and uranium resource base for domestic power generation (Wamukonya, n.d.). In 2006, MME, along with the United Nations Development Programme (UNDP) and Global Environment Facility (GEF), initiated the *Off-Grid Energisation Master Plan For Namibia* (OGEMP), which proposed the installation of small-to-medium entrepreneurial energy shops that provided renewable energy technology and services (RETS). These services were provided mostly through solar products to communities far from the central grid (Schultz et al., 2007). In 2005, MME issued an energy production license to Tullow Oil, a British oil company, to commence the Kudu natural gas combined cycle power plant (Tullow Oil, 2006).

Even if some of the above-mentioned projects have been executed and have contributed to the electrification agenda (Rothermel, Lowell, & Kendrick, 2007; Wamukonya & Davis, 2001), most of Namibia's alternative energy developments so far have been faced with inconsistency in institutional funding and execution (Abramowski et al., 1999; Tullow Oil, 2006), and lack of community awareness and participation (Kleine, 2004; N. Wamukonya, Unknown; Wamukonya & Davis, 2001). Independent energy generation and community participatory approaches are extremely rare. Currently, the national electricity grid in Namibia only supplies 40% of the 2 million total population (The Ministry of Mines and Energy, 2006), and 8-9% of its rural households (The Ministry of Mines and Energy, 1998). It is an imperative challenge for Namibia to achieve greater rural coverage of electricity with greater independence of energy production and greater community involvements. The DRFN has interest in independent energy production through their CBEND project.

2.2.3 Bush-to-Electricity Initiative and the CBEND Pilot Plant

The CBEND pilot plant, one 250-kilowatt wood gasification power generator, was completed by DRFN in September 2010 on Farm Pierre, 90 kilometers northwest of Otjiwarongo in the Outjo District. The electricity generated from the pilot plant was used to supply the national grid (Rhodes, 2010). The CBEND project utilizes domestically-obtained, readily-available bush species as the feed for the waste-to-energy production, and engages the local participation of Independent Power Producers (IPPs) for producing and selling the electricity products which could potentially enhance the livelihoods of the off-grid Namibian residents (Hager, 2007). The CBEND pilot plant is the first independent commercial electricity feeder in Namibia (Brüntrup, Herrmann, & Gaebler, Unknown).

As previously described, Namibia is faced with the severe encroachment of bush, or woody shrubs, which degrades around 26 million hectares of woodland savannas in the country. Bush encroachment is posing substantial barriers to the grazing potentials of livestock, the wellbeing of game, and the livelihood of 65,000 households, 6,283 commercial farmers, and 35,000 wage farming laborers. Conversion of bush into biomass electricity not only provides an off-grid energizing solution, but also reduces the invader bush problems currently facing the Namibian agricultural and rural economic development (Herrmann & Brüntrup, 2010).

Figure 2.11: CBEND pilot plant gasifier

The CBEND pilot plant, as pictured in Figure 2.11, uses the ANKUR WBG-400 model developed by Ankur Scientific Energy Technologies Pvt. Ltd. in India. The pilot plant is a downdraft wood gasifier. When the pilot plant is operating at 100% full load, it consumes 731MW/hr of the wood gas and 850kW thermal energy, and achieves an electricity capacity of 250 kW. The majority of exhaust gases are in the form of nitrogen (48-54%), carbon monoxide (15-21%), hydrogen (15-18%) and methane (1.5-3%) (Ankur, 2007), 30 wood-chipping workers and limited higher-skilled transport and maintenance labors are requirement for running the CBEND pilot plant project (Brüntrup et al, 2010).

The major technical problems with the CBEND pilot plant project involve the quality of the wood chips and the quality of the wood gas, in particular the content and type of volatile tars and techniques of tar removal. The major social problem identified is the uncertainty of profitability under the current condition in Namibia. For electricity farmers, the CBEND concept poses both an income opportunity and a risk. According to the calculations presented, the CBEND project won’t reach the break-even point until 13 years down the line (Brüntrup et al, Unknown).

Along with the technical and economic evaluations of the CBEND project proceedings, a detailed environmental impact report was also published in September 2009. In the report, it was discovered that the impact of the operation and maintenance of the gasification plant on air, land and water systems was expected to be much less than open wood burning or diesel burning. Concerns were raised over the polyaromatic hydrocarbon contamination from tar and charcoal residues. Little impact on flora and fauna were detected. Supervision oversight, inspections, and first aid training were recommended to enhance occupational health and safety practices (Desert Research Foundation of Namibia, 2009f).

The CBEND project hoped to explore the possibility of utilizing small-scale wood and biomass gasifiers in order to provide additional electricity. Although the pilot plant in place now is connected to the national electrical grid, the information we have provided to the DRFN can possibly be used for smaller off-grid settlements with modest electricity needs.

2.3 Conclusion

To prepare us for the Conceptualizing Containerized Businesses in Tsumkwe project, we reviewed the past development initiatives in Tsumkwe and the previous efforts using shipping containers as housing facilities. We also familiarized ourselves with the culture of the San people and the Ju’/hoansi specifically. To prepare us for the Evaluating Wood Gasification Technologies for Electrifying Rural Namibia project, we obtained a working knowledge of the applications of biomass gasification technologies and Namibia’s previous off-grid energizing efforts, such as the CBEND pilot plant installation. A review of the relevant literature prepared us with a baseline understanding of the multiple facets of our project from which we could formulate how to accomplish our goals in the most effective and meaningful way.

Chapter 3 Methodology

In this chapter, we have divided the discussion of our methodological approaches into two sections. Below we will address the objectives of each project, how we attempted to meet these objectives beforehand and on-site, and how we conducted evaluations for both the Tsumkwe containerized businesses and the CBEND off-grid gasifiers from the holistic perspectives of environment, society, and technology.

3.1 Part 1: Conceptualizing Containerized Businesses in Tsumkwe

The goal of the Tsumkwe containerized business conceptualization was to develop off-grid containerized SME facilities along with detailed technical specifications and cost analysis. The project aimed to enhance local economic development in rural areas by assessing suitability of these containerized SME facilities in the settlement of Tsumkwe. These containerized businesses would be placed in Tsumkwe's containerized SME park, which was designed as a central facility fostering economic development in Tsumkwe.

In order to accomplish this goal, we completed the following objectives:

1) Develop a list of businesses with a focus on the needs of an off-grid community.
2) Determine a list of features, equipment and utilities necessary to facilitate optimal business operations within the confined shipping container space;
3) Determine structural modifications to the containers themselves that would enhance business operations;
4) Conduct a site assessment in Tsumkwe for familiarization with the community;
5) Liaise with Windhoek industrial suppliers and businesses regarding equipment for each design, with the intention of receiving information pertinent to business operations and cost analysis;
6) Liaise with Namibia's shipping container suppliers for ideas on structural modifications of the containers, to obtain cost estimates for cost analysis;
7) Draft initial SolidWorks designs of the containerized businesses;
8) Gather feedback on the designs from Tsumkwe entrepreneurs during the presentation site assessment;

9) Make necessary modifications to the SolidWorks designs utilizing feedback gathered from the Tsumkwe presentation assessment;
10) Design a costing analysis tool for determining the costs and power consumptions of the each containerized business design;
11) Present our work to the DRFN.

3.1.1 Containerized Business Conceptualization

In this initial conceptualization phase, we attempted to brainstorm as many potential businesses as possible that could be feasible in an off-grid settlement like Tsumkwe. Many of these businesses would prove vital to the project, while others were not as feasible as the project unfolded. Each business was conceptualized within the limiting dimensions of the 6m ISO shipping container model. Along with each business concept, we established a baseline set of equipment for each business. Additionally, structural modifications were adapted in order to allow for more functionality and to fit needs specific to Tsumkwe and its residents. By request of our sponsor, any large-scale modification was only considered when absolutely necessary in order to not increase the cost of the containers by a large amount. Any design modifications to the containers themselves were made so as to preserve as much structural integrity as possible. Therefore, none of the structural modifications we made interfere with the corner posts or the floor supports. During this phase, each business concept along with equipment needs and structural modifications was reviewed with our sponsor staff: Abraham Hangula, the DRFN Tsumkwe Energy Project Coordinator, and Robert Schultz, the Senior Project Manager of the DRFN's Energy Desk. We utilized the DRFN staff's extensive knowledge of the Tsumkwe community, and off-grid economic development, prior to continuing into the prototype design portion of our project.

3.1.2 Tsumkwe Site Assessment

Our site assessment in Tsumkwe gave us an opportunity to observe the dynamics of the settlement and its current infrastructure first-hand. In this visit, we prioritized which businesses would be beneficial to the settlement and its residents, and identified which were already provided. We were introduced to various residents of Tsumkwe by the DRFN staff and discussed with them the economic opportunities in Tsumkwe and the potential of using shipping containers to house business facilities. These individuals chosen for our interviews are considered relative "outsiders" to the community. In general these people have lived in and worked with the Tsumkwe settlement for the past few years. These individuals often stand somewhat apart from the rest of the community by their actions and associations.

The reason that we chose to interview "outsiders" was multifold. First, the targets of our work in conceptualizing and designing containerized SMEs were the entrepreneurs of the community. Therefore we would like to gain perspective from those residents having certain levels of experience and expertise as well as certain knowledge of the limitations and realities of operating a business in Tsumkwe relative to other communities. Second, the DRFN has already conducted *The General Survey* as part of *The Energy Skills Assessment* gauging local residents' interests in economic opportunities. According to the DRFN, the results of *The Energy Skills Assessment*, while useful in determining public opinion, do not help us in determining what businesses to actually design for Tsumkwe. Often the local people request businesses that are simply not feasible within Tsumkwe, or would not be appropriate for the purposes of our project. The target group of our project is entrepreneurs as they have both the technical understanding of these businesses and the interest level required to rent our containers and use them effectively. The DRFN strongly suggested that we follow their advice when choosing interview candidates in an effort to ensure that we gather the information they were looking for. Third, since the containerized business initiative was still in its conceptualization stage, we were encouraged not to raise unrealistic expectations in the general community for the final project outcome. According to Mr. Hangula, people of Tsumkwe have been "over surveyed"; meaning that various NGOs have initiated projects in the community and conducted numerous surveys, but few has carried their project through.

The main focus of this visit was to observe and assess the site for gaps in the local economy. The site assessment methods we used were observational studies and informal interviews. To prepare ourselves for our informal discussions with the residents, we compiled a protocol for a short, informal interview and a checklist for assessing both existing and anticipated businesses and services in Tsumkwe (See Appendix A). These questions were developed under the consultation of Mr. Schultz and Jimmy Itamba, the DRFN's Field Facilitator in Tsumkwe. The questions acted only to ensure that sufficient information had been collected during our interviews. The site assessment provided us with the pertinent current condition of Tsumkwe, such as new business ventures, that we could not discover through background research alone

(Doyle, n.d.). In this way, we were able to gain a deeper understanding of the economy of Tsumkwe and thus were more confident in prioritizing which businesses to further evaluate and how best to move forward with the project.

3.1.3 Interior Designs and Structural Modifications

After the site assessment, we prioritized the list of businesses that we would like to develop for the SME park so that we could start the process of determining interior design specifications and structural modifications of the shipping containers.

In terms of the interior designs of the containers, we used equipment available through Namibia-based industrial suppliers. Following the consultation of the DRFN staff, we began contacting retail stores in the industrial parks in Windhoek to verify the availability of equipment in Namibia. We recorded pertinent technical details specific to the equipment provided in each store. The details recorded included cost, dimensions, power ratings and workflow conditions. The dimensions and workflow conditions were pertinent to the prototype designs of the containerized businesses, while the power rating and cost specifications were pertinent to the cost analysis of each business. In order to record these details, photographs were taken of the equipment, store catalogues and equipment manuals were requested if available, and notes were taken if we were able to interview briefly with store managers or assistants. In addition to the visit to industrial suppliers, we also visited businesses in Windhoek to observe the workflow conditions and held informal discussions with the business managers about the potential to downscale these businesses into the limited space of a shipping container.

In terms of the structural modifications of the containers, we took into account the ventilation, roofing, wall and floor lining needs for the different businesses. Not only were these structural modifications designed for optimum business operations, they were also designed to adapt to the heat and the prevalence of mosquitoes in Tsumkwe. In addition, structural modifications were designed to allow for the future installations of alternative energy retrofits, which would be used to power the different equipment in the containers.

3.1.4 SolidWorks Prototype Designs

After the interior equipment orientations and structural modifications were determined, our project team used SolidWorks as the design program to prototype the prioritized containerized businesses. We chose to use SolidWorks to create our models because the program enabled us to input specific dimensions into the designs. Each component in our designs was made using real dimensions to scale with the rest of the components. Utilizing the real dimensions in our designs allowed for an accurate visual representation of workflow conditions. The program also enabled us to freely alter the orientations of the various components in the design, which allowed for efficient on-the-spot layout changes.

The prototype design stage was crucial to our project. It demonstrated the results of our work in the form of professional architectural drawings, which could potentially be a guide and resource for the civil contractors once the project reaches implementation stage.

3.1.5 Tsumkwe Presentation Visit

Our presentation visit to Tsumkwe enabled us to propose our designs to the local entrepreneurs and therefore receive feedback on not only the containerized designs themselves but also the concept of the containerized SME park as a whole. To prepare for this visit, another short and informal interview protocol was created under the consultation of Mr. Schultz and Caroline Coulson. Ms. Coulson is the Project Manager for the Energy Desk. The interview protocol is displayed in Appendix B. Upon arriving in Tsumkwe, we further reviewed the interview questions with Mr. Itamba. The targets of the presentation visit interviews were the Tsumkwe entrepreneurs who were interested in operating their businesses in the containerized SME facilities. We used snowball sampling based initially on Mr. Itamba's knowledge of the settlement and its residents.

During our interview process, we presented our initial SolidWorks designs on papers to the entrepreneurs due to the constraints of Internet availability in Tsumkwe. Shipping container blank templates, equipment and tool templates were also supplied (refer to Appendix C for the templates used in the presentation visit interviews.). In the event when a new business idea or new workflow orientations was proposed by the entrepreneurs, we developed the designs along with the entrepreneurs on the blank templates. Such brainstorming discussions helped us visualize the thinking of the entrepreneurs and engaged the local entrepreneurs in the design process of the containerized SMEs.

3.1.6 Finalized Prototype Designs, and Cost and Power Analysis

Based on the input from entrepreneurs in Tsumkwe, we were able to finalize our SolidWorks designs. These final designs were again reviewed with the DRFN staff. We also developed a cost analysis tool using Microsoft Excel to record and calculate the total cost and power consumption of each containerized SME design. This dynamic cost analysis tool was designed to output estimated cost information based on the equipment and structural modifications chosen for each design. Power consumption rates were included in the calculations for yearly and monthly utilities cost estimates. The cost analysis tool was loaded with cost and power rating information gathered from our visits to Windhoek industrial suppliers. The tool could potentially serve as another resource to assist the DRFN to make educated purchasing decisions during the implementation stage of the Tsumkwe containerized SME park.

3.2 Part 2: Evaluating Wood Gasification Technologies for Electrifying Rural Namibia

The goal of the CBEND Technical Evaluation project was to identify and assess small-scale (30-100 kW) wood gasification technologies for applications in Namibia’s rural off-grid settlements. Our goal was to deliver an overview of small-scale woody biomass gasification technologies available on the international market, a tabulated comparison among the different market-ready technologies, and a feasibility assessment tool to be used in the selection of the most ideal system for off-grid applications in Namibia. In order to achieve our goal, we accomplished the following objectives:

1) Conduct a site assessment of the 250 kW pilot plant and recognize lessons learned;
2) Identify the key suitability parameters for future CBEND installations in Namibia;
3) Create a screening questionnaire and a follow-up inquiry for small-scale wood gasification suppliers based on the key suitability parameters.
4) Identify small-scale wood gasification suppliers globally and submit the screening questionnaire to the suppliers;
5) Shortlist potential suppliers based on their responses to the screening questionnaire, and submit the follow-up inquiry for more comprehensive information;
6) Compile a tabulated comparison among the different market-ready technologies provided by the potential suppliers;
7) Design a feasibility assessment tool to determine the most ideal technology based on key suitability parameter performance;
8) Present our work to the DRFN.

3.2.1 CBEND Pilot Plant Assessment

We visited the 250 kW CBEND pilot plant and were guided by the CBEND pilot plant manager, the DRFN consulting engineer Bernard Haas who was on-site for the entire duration of the installation of the pilot plant, Mr. Schultz, and the pilot plant on-site employees. We were provided with an overview of the wood harvesting and processing procedures, the wood gasification techniques, the gas cooling and cleansing process, the tar and ash removal process, the wastewater treatment process, and the electricity generation techniques. Our main concern during the assessment was to recognize lessons learned from the dysfunction of the pilot plant, and to identify the key parameters defining suitability of future CBEND installations.

3.2.2 Screening Questionnaire

The screening questionnaire was designed to produce a shortlist of potential suppliers from the large number of suppliers currently active on the global wood gasification market. From previous survey databases (Reed & Gaur, 2001), we identified a full list of firms identified as suppliers of small-scale wood gasification systems. We submitted the request for the completion of our screening questionnaire to these suppliers through emails or, if available, website inquiry forms.

The main focuses of our screening questionnaire were:

1) Whether or not the supplier was interested in providing their systems to Namibia;
2) Whether or not the supplier provided technology in the 30-100 kW power output range;
3) Whether or not the supplier provided technology meeting the key suitability parameters.

The majority of the questions were designed to be multiple-choice for the convenience of the respondents. Due to the length limitations of the screening questionnaire, we were not able to obtain in-depth knowledge of the parameter performances to address our 3rd focus; yet we were able to collect basic information of the technical parameters, which would guide us to construct a targeted follow-up inquiry for a more comprehensive response.

In order to demonstrate professionalism, the request for the completion of our screening questionnaire was submitted along with an introductory letter explaining the purpose of the questionnaire. The introductory letter mentioned the DRFN's missions, the CBEND concept, and the installation of the CBEND pilot plant. Because the anticipated respondents of the questionnaires are based all over the world, online survey tool Survey Monkey was used to collect the questionnaire. For those suppliers who did not respond to the questionnaire within 2 weeks of the initial submission of the introductory letter, an additional email or website inquiry form was sent. The introductory letters and the screening questionnaire are displayed in full in Appendix D and Appendix E.

3.2.3 Follow-up Inquiry

Based on the results of the screening questionnaire, we produced a shortlist of potential suppliers who expressed interest in providing their systems to Namibia and who provided technologies within the 30-100 kW power output range. The follow-up inquiry was designed to:

1) Obtain more comprehensive information on the key suitability parameters;
2) Request price quotes.

These inquiries were tailored to each supplier based on his response to the screening questionnaire. The questions were all designed to be open-ended. In addition to requesting information from the suppliers, we provided the suppliers with the photographs and field notes from the CBEND pilot plant assessment such that they would have a better understanding of the challenges facing the implementation of the bush-to-electricity concept in Namibia.

A complete follow-up inquiry letter is available in Appendix F.

3.2.4 Feasibility Assessment Tool

The DRFN requested that our team provide a feasibility assessment tool for the technical evaluation of the gasification technologies for the selection of the most ideal technology. We decided to use Microsoft Access as the program for the feasibility assessment tool. The software is commonly used for database management. Using Microsoft Access, we created an application that could select qualified suppliers that would match a certain combination of criteria desired by the user. The application would allow the DRFN to continually add, remove and edit gasifier information as more gasification suppliers are identified after our 8-week on-site work. In order to facilitate continued use of the feasibility assessment tool after our departure, we also wrote a short user manual of the application.

3.3 Project Timeline and Conclusion

Provided below is a Gantt chart showing the work schedule during our 8-week stay in Namibia. The red items are specific to the Conceptualizing Containerized Businesses in Tsumkwe project, while blue items are specific to the Evaluating Wood Gasification Technologies for Rural Electrification project. The purple items are common to both projects.

Objective	*3/15 to 3/18*	*3/18 to 3/25*	*3/25 to 4/1*	*4/1 to 4/8*	*4/8 to 4/15*	*4/15 to 4/22*	*4/22 to 4/29*	*4/29 to 5/5*
Develop a list of businesses								
Determine features, equipment and utilities								
Determine structural modifications								
Tsumkwe site assessment								
Liaise with Windhoek industrial suppliers and businesses								
Liaise with shipping container suppliers								
Draft initial SolidWorks designs								
Tsumkwe presentation visit								
Modify SolidWorks designs								
Design cost analysis tool								
CBEND Pilot Plant assessment								
Identify key suitability parameters								
Collect screening questionnaire								

Collect follow-up inquiry								
Compile tabulate comparison								
Design feasibility assessment tool								
Present our work to the DRFN								

Table 3.1: Gantt Chart of the project timeline

For privacy concerns, all compromising information gathered through the interviews were saved in an encrypted file on a laptop provided by the Academic Technology Center (ATC) while developing our report. Upon submission of our project, all information not utilized in this report will be destroyed.

Chapter 4 Results and Analysis

In this chapter, we have also divided the discussion of our results and analysis into two sections. The SME Park architectural drawings and cost analysis are detailed for the Tsumkwe containerized business project. Tabulated comparisons of market-ready wood gasification technologies and feasibility assessment tool are delivered for the CBEND Technical Evaluation project. Throughout the course of our 8-week stay in Namibia, certain aspects of our projects changed. This chapter also highlights how we adjusted to the shift in our project focus.

4.1 Part 1: Conceptualizing Containerized Businesses in Tsumkwe

The Conceptualizing Containerized Businesses project comprised six stages: Initial Business and Equipment Conceptualization, Tsumkwe Familiarization Site Assessment, Interior Designs and Structural Modifications, Tsumkwe Presentation Site Assessment, SolidWorks Prototype Designs, and Cost Analysis. The two site visits to Tsumkwe served to bring socio-cultural considerations and community engagement to the design process. Additionally the Interior Designs and Structural Modifications, SolidWorks Prototype Designs, and Cost Analysis sections served to highlight the engineering aspects of the project outcome.

4.1.1 Tsumkwe Site Assessment

The familiarization visit to Tsumkwe was scheduled to help us gain a more personal perspective of the challenges facing the socio-economic conditions in the off-grid community, Tsumkwe. The familiarization visit served to not only highlight the widening gap between the needs and provisions in the community, but also served to outline the socio-cultural complexities that exist between San culture and western style economic thinking that have brought previous development projects to failure.

Tsumkwe, a settlement in the Otjozondjupa Region, is located in northeastern Namibia. An approximately 300 km gravel road connects the settlement to Grootfontein, the nearest city. Upon arriving in Tsumkwe from Windhoek, the tranquility of the settlement immediately hit us. The settlement is an oasis of calm; often the only sounds we could hear were faint cowbells and mothers' gently singing to their children. The settlement is spread along two partially paved main roads. The bush, stretching off as far as the eye can see, dominates the landscape beyond the barren roads. No buildings in town are higher than a single story. Most civil facilities are brick or concrete. While a few homes have plastic sheeting and thatched or corrugated steel roofing, most homes are merely stick-and-mud huts. A neighborhood in Tsumkwe consists of a small circle of huts around a central fire pit. Women can be seen hand-making crafts, or fanning the flames of a small wood fire stove. Children are often running up and down the dirt paths between huts laughing and playing. As we drove through town a group of teenagers were gathering around the only volleyball net in town for an afterschool game. Down the road students were gathered in the fields outside of the school playing soccer.

The centralized businesses of Tsumkwe include the Tsumkwe Country Lodge, the Tsumkwe General Dealer (see Figure 4.1), a craft center, an Internet café, a clothing stand, a fat cake stand where they sell small balls of fried dough, a bakery, and a number of shebeens (informal bars). As far as civil infrastructure was concerned, Tsumkwe has the Magistrate's Court, the local NamPost office, an elementary school, the Tsumkwe Secondary School, a church, a clinic staffed with two nurses, and a woman who provides nursery day-care. The best-stocked store in the settlement, the Tsumkwe General Store, supplies the settlement with flour, bread, pasta, refrigerated drinks, canned foods, spices, and some stationary.

Figure 4.1: Tsumkwe General Dealer

In order to further understand the community needs and identify the economic opportunities in Tsumkwe, we conducted interviews with 8 Tsumkwe residents who offered us unique perspectives as relative newcomers to the community who move to the settlement within the last few years. We chose these residents over local people for a number of reasons. First and foremost our sponsor and support staff at the DRFN strongly suggested that we follow this route. Secondly we focused our attention on outsiders to gain a better understanding of the economic realities in this settlement relative to other Namibian communities. The justification for using outsiders instead of long-term local residents is further explained in the methodology chapter.

These residents included the Tsumkwe Energy Project Field Facilitator of the DRFN, the engineering contractor of the Chinese-government-sponsored Tsumkwe Secondary School, a Namibian teacher at the Tsumkwe Secondary School, a Kenyan social worker at the soup kitchen for tuberculosis patients, a secretary at the Tsumkwe Magistrate's Courts, an employee at the local NamPost office, the craft shop manager of the Nyae Nyae Conservancy, and a teacher at the Den/ui Village School on the outskirts of Tsumkwe. Summaries of the informal interview scripts are provided in Appendix H.

From our interviews, we learned that Tsumkwe is heavily dependent on the city of Grootfontein for goods and services, ranging from groceries and clothes to hair salons and auto repair. Unfortunately, there is no public transportation available between Tsumkwe and Grootfontein. Hitchhiking through the 300 km gravel road is the only form of transportation for most of the residents of Tsumkwe who do not own private vehicles, including almost 300 boarding students at the Tsumkwe Secondary School. Furthermore, due to the transportation distance, most goods are overpriced and such basic services as hospitals, banks, mechanics and electronics shops, are inaccessible to most of the Tsumkwe community.

Another major theme that came across in our interviews was the perceived lack of community response to economic development initiatives. Our interviewees spoke about the traditionally hunter-gatherer San community in and around Tsumkwe, many of whom made a living from making and selling handcrafts. As most of the Sans' basic subsistence, such as food and education, is provided for them by various governmental and non-governmental organizations, the non-San population of Tsumkwe believes that the San community has a sense of entitlement towards free goods and services. Previous governmental and non-governmental efforts had attempted to integrate the San community into "mainstream", or the western view of mainstream society. Many of these efforts have been unsuccessful because many NGO's have overlooked the importance of community involvement. This has only served to further widen the socio-cultural gap between the San people and the rest of Namibia. Based on our interviews and experiences in Tsumkwe, the San in this community are often treated as outcasts of society. The residents we spoke with often referred to the citizens of Tsumkwe as either black or San. There was a clear differentiation between the different ethnic groups.

There are some entrepreneurial interests in the community. There is some form of butchery, mechanical repair, and haircutting in the settlement, but these businesses lack essential equipment and supplies. Therefore they cannot truly compete with the services provided in Grootfontein. Previously there was a co-operative program in the settlement where women shared facilities and tools required for sewing, nursery, cooking, and so on, but the program did not sustain itself and eventually failed. These findings demonstrated that the absence of housed business facilities was not a hindrance on entrepreneurial activities. Instead, other factors such as poor planning and low community interest in these projects seem to be more of a factor in hindering business development in Tsumkwe. Our DRFN support staff, and some of the individuals that we interviewed, noted another reason as to why some of these efforts have failed. In the case of the sewing shop specifically, the project was designed and implemented solely for the San population. Other local ethnic groups such as the Oshiwambo or Herero were not allowed to use the sewing machine facility. Therefore when the initial users of the facility stopped using the machines other potential users were turned away and the project ground to a halt. The individuals we interviewed told us that there have been a number of projects implemented in a similar fashion, only allowing the San population to benefit, and each project with this strategy has fallen into disrepair and is no longer functioning.

Following our observations and interviews in the familiarization visit, we had developed a more complete understanding of the socio-economic complexities of the Tsumkwe settlement. We realized that from the perspective of many local residents Tsumkwe suffers from a substantial deficiency of goods and services. In addition, the lack of successful economic development initiatives and the unique economic demands and needs of this settlement make it particularly difficult to establish and sustain a “western style” business that would require extensive resources, high community demand, and fast turnover and goods.

We therefore shifted the focus of our prototype designs from product-driven, high demand based businesses to services that could provide Tsumkwe with the basic infrastructure and equipment for community driven economic production. Our prototype designs would house industrial equipment currently unavailable to the Tsumkwe community such that local entrepreneurs would have all of the tools necessary to work their craft, but would have control over the business plan and operation of the service hub. In this way local people could drive these businesses to fit the needs of this particular community rather than fit an outside view of what the community “needs”. The list of businesses and services that our project team designed is displayed in Appendix G.

During our visit in Tsumkwe, it also came to our attention that vandalism and thefts were common in the community. We therefore amended our designs to only provide large, essential equipment that would be difficult to steal. Smaller equipment such as gloves and hand tools would be outside the scope of our designs. Finally, during our site assessment, we had a preview of the DRFN Tsumkwe Energy Project hybrid solar-diesel power plant, which will be installed in the summer of 2011. The containerized businesses will be placed in this SME Park adjacent to the power plant. See Figure 4.2 for a map of Tsumkwe and the location of the SME park relative to the solar array.

Figure 4.2: Map of Tsumkwe showing the relative locations of the SME park

During our informal interviews with outsiders to Tsumkwe, we asked our interviewees about their knowledge of the Tsumkwe Energy Project. Following the guidance of our sponsor, we left out the specifics of this SME Park, for which we are developing the designs. This park, which utilizes energy obtained from the new solar array, was still rather unknown at the time of our familiarization site assessment. The DRFN is attempting to keep the concept of the SME Park quiet for now so as to not raise community expectations before the project is finalized and budgeted.

4.1.2 Interior Designs and Structural Modifications

After initial conceptualization of the list of businesses and services we would like to provide to the Tsumkwe community (See Appendix G), we visited shops and industrial suppliers in Windhoek to assist our determinations of the equipment needs and workflow concerns of the containerized businesses. We recorded the dimensions, cost, power ratings, and workflow concerns of large, heavy-duty equipment such as band saws, hammer mills, grinders, compressors, and table saws. Specifically, we visited Agra for the technical specifications of food and agricultural equipment and Adendorff Machine Mart for the technical specifications of woodwork and metalwork equipment. These two visits offered a generalized view of the functions of large-scale industrial equipment. However, the high power consumption of the equipment became a concern, as Tsumkwe's energy structure is currently too limited and unstable for these kinds of operations. Additionally our sponsor gave us a 100kW maximum power consumption rating for each container.

In order to attain advice regarding the down-scaling of industrial shops, we also visited Pupkewitz Megabuild for the technical specifications of smaller-scale woodwork equipment; Terrasol for the technical specifications of smaller-scale metalwork equipment and the workflow layout of small-scale industrial design shops; and a Windhoek wood joinery shop for the workflow layout of wood joineries. A table detailing the dimensions, cost, power ratings, and workflows of the industrial equipment are provided in Appendix I.

This table was utilized during our design implementation phase, where we began constructing the interior container designs in SolidWorks. During the week of our presentation visit to Tsumkwe, half our team conducted interviews with local entrepreneurs while the remaining group members along with Robert Schultz constructed several container templates.

These templates were designed solely considering outside structural modifications. The designs were created in order to obtain cost estimates from container prefabricators around Namibia.

Our project team conducted brainstorming sessions with our sponsor in order to categorize each template design, only three template designs were identified which were needed depending every business. These containers fit into the following categories: a customer-service oriented container, an all-purpose container, and a "hands-on" container. The customer service container, pictured above, utilizes a convenient counter space for easier interaction between customers and the entrepreneurs. This template is considered for use for our butchery unit and food service units. The all-purpose container utilizes windows on each side of the container to allow for easier ventilation in the hot climate of Tsumkwe. Finally, the "hands-on" container utilizes a large hole on one side of the container.   This was essential following contact with suppliers where our group learned the standard arrival length of wood and metal medium.

When considering various heat management systems our research team investigated both shade and wind ventilation and cooling systems. For heat shielding, our project team researched heat reflective paint and angular roofing as seen below in Figure 4.3. These roofs were designed to be oriented in the most efficient direction to maximize the shade provided to the container. Additionally we researched wind based cooling methods like whirlybirds, or other passive devices. These systems were later rejected based on the shipping costs associated with a roofed container. The current roof construction process utilizes a hinge system to maximize shade through several different seasons. This design is also helpful for solar panels because they are adjustable for different angles. This adjustable feature makes the addition of whirlybirds or other similar ventilation devices simply not feasible. These structural modifications were added to our SolidWorks designs following the presentation visit to Tsumkwe.

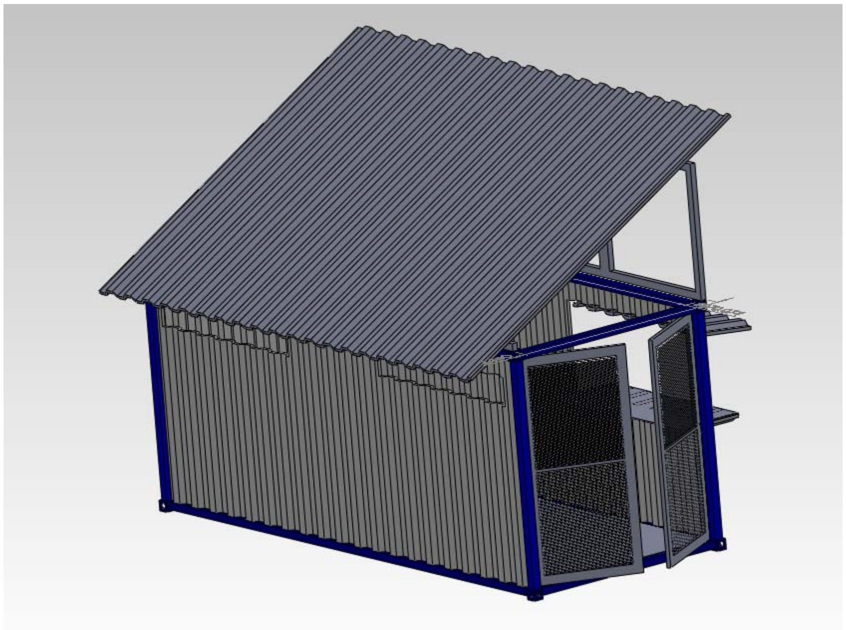


Figure 4.3: Single Pitched Roofing

4.1.3 Tsumkwe Presentation Visit

Once we had established our initial SolidWorks designs were then able go back to Tsumkwe to meet with local entrepreneurs concerning the designs themselves, as well as the concept of a containerized business. This visit served to further develop our designs, highlight new services that we had missed in our initial assessment, and to assess the local interest in the containerized SME park concept.

In order to gain feedback on our designs we interviewed 7 local entrepreneurs. Our DRFN field facilitator, Mr. Itamba, chose these residents based on their expressed interest in the container business idea. These residents were: Simeon Mingara, a local welder, Thomas Modginda and E-Hemba, two individuals interested in co-renting the woodworking container, Veronica, a woman interested in developing and renting a hair salon container, Wendy, the local Nyae Nyae conservancy coordinator, Jimmy Itamba himself with regard to the butchery, and Rosa, a local shebeen and catering business owner interested in a take-away kitchen. Summaries of these interviews can be found in Appendix J.

From our interviews, we learned that there is a strong interest in these containers from local entrepreneurs. Most of them were very excited at the idea of having this kind of equipment made available to them. When asked about renting the container each interviewee told us that they would want to rent out the container for at least a year if not two. Renting the containers for such a long period of time allows us to consider a number of new ideas about the security and the layout of the containers themselves.

Originally the concept was that each piece of equipment provided would have to be bolted to the floor to prevent them from being stolen and that the maintenance of each container would fall to whichever group is managing the park. But by placing the containers in the renters control for a year or longer it may be possible avoid these security and logistical concerns. Not bolting the heavy equipment to the floor means that each entrepreneur could customize the container to meet his or her needs, which is something that Mr. Itamba strongly suggested we allow. Also by suggestion of Mr. Itamba, the safety and good operating condition of the various pieces of equipment should be the renter's responsibility, not the DRFN or the party managing the SME park. This relieves some of the financial pressure and liability on the DRFN and provides increased community ownership of these containers.

This visit also changed our business and services list by adding the take-away service kitchen back to the list. We had previously discarded it based on feasibility concerns like the distance of the SME park from the center of the town, but upon learning that a resident that is already running a catering business in town was interested in renting a business at the SME park, the design was brought back to the list for consideration. In addition to creating a completely new design for the food service container, we also made a series of changes to the butchery container and the auto repair container. Based on feedback from Mr. Itamba, we re-designed the auto repair shop for increased functionality as well as to better meet the needs of the community. The new design moves the majority of the heavy equipment to the exterior of the container and changes the use of the container from a work area to a storage area. In addition to the auto repair shop we also modified the butchery concept to better match Mr. Itamba's preferences. These changes include an area to display certain cuts of meat, increased workspace, and a more efficient use of cold storage. The hand drawings by the Tsumkwe entrepreneurs are displayed in Appendix K.

Another result of our presentation visit was to fundamentally change the layout concept of the SME park. The original concept was to make a series of standalone containers, each with their own roofing, hot water supply, and independent footings and or ground support. Based on our interviews, some of the entrepreneurs we talked to were more interested in creating a superstructure for all of the containers to fit under. The idea, which came about as a result of our interview with Mr. Itamba and was then further supported by consulting with Bernard Haas, was to create a single concrete slab, with its own roofing, hot water, and ventilation system and to place the containers inside of this superstructure. The containers would benefit from increased heat shielding as well as a shared hot water supply. We could then create various sitting and eating areas around the containerized businesses that require eating areas. Having a single facility in which all of the containers fit under would make security much easier to manage and increase the overall aesthetics of the SME park.

Upon returning to the DRFN we discussed the superstructure concept with our DRFN staff, Robert Schultz, Abraham Hangula, and Caroline Coulson. While they were interested in the potential of the superstructure they recommended that for the purposes of this project we focus on standalone units. As standalone units each container could be built and then shipped and installed in Tsumkwe with little to no construction going on in Tsumkwe itself. Any superstructure design involves construction on a scale that the DRFN simply does not envision for this project. Their hope was that we would provide them with designs that they could make and deliver anywhere based on the needs of a given situation. In the end the DRFN may use our designs for future projects in other settlements across Namibia therefore the more modular we can make them the better. We will leave the superstructure idea in our recommendations section for future projects that may require a more structured SME park.

Based on our presentation visit to Tsumkwe entrepreneurs, we began to finalize our designs and conduct the final cost and power analysis for each business idea. We are now able to provide additional recommendations to the DRFN about the container renting process, the overall management of the SME park, and the installation of the containers themselves.

4.1.4 Finalized Prototype Designs

Displayed below are our finalized designs for the containerized SMEs. Each design was thoroughly reviewed with our DRFN staff for feasibility and cost considerations. These containers were developed with the intention of creating modular, standalone units housing vital equipment for businesses in Tsumkwe. It is our hope that these containers will aid in the economic development of Tsumkwe by providing the infrastructure required for various businesses and services within the settlement. Displayed below in Figure 4.4 is an example of a template unit showing various sidewall modifications. We created two different template designs; both include windows for ventilation and exterior modifications for walls and doors.

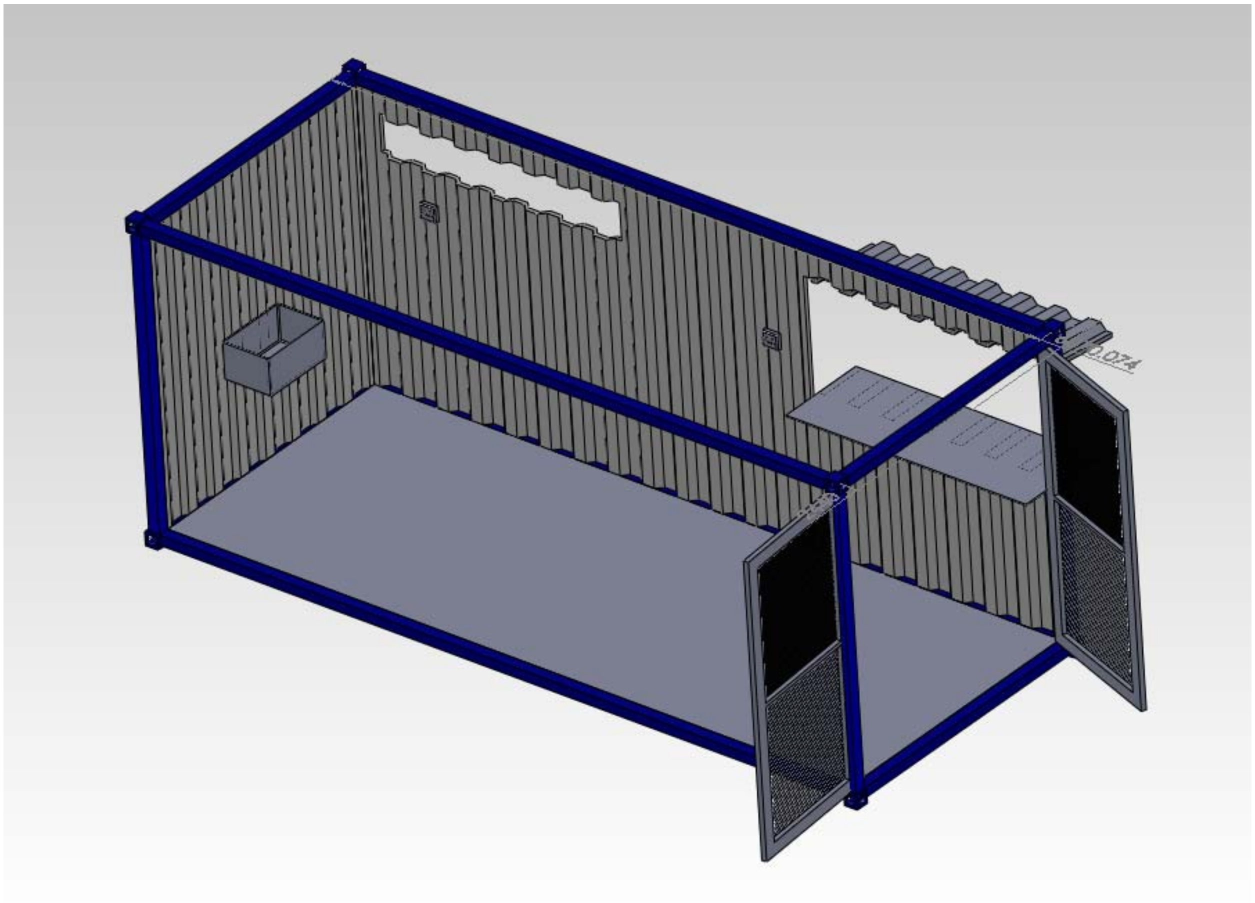


Figure 4.4: Container template Type A

This template design was used for the butchery and the service kitchen. We also utilized a sidewall cut out to create a service counter with its own additional shading. Inside the container, we have included a sink and four power units each with two outlets. In addition to the large metal doors of the container we also included another set of screen doors to prevent flies or other insects from entering the food prep areas. These designs were developed with a great deal of input from not only our DRFN staff but also local entrepreneurs in Tsumkwe who are interested in renting these containers. Initially our research team considered placing the sinks for both the butchery and the kitchen on the outside of the container, with an access window, to save space. But as we met with our DRFN staff and the entrepreneurs from Tsumkwe this design strategy proved to be unnecessary. Therefore we moved the sinks inside the container for easier access and cleaning purposes.

Our second template design is located below in Figure 4.5.

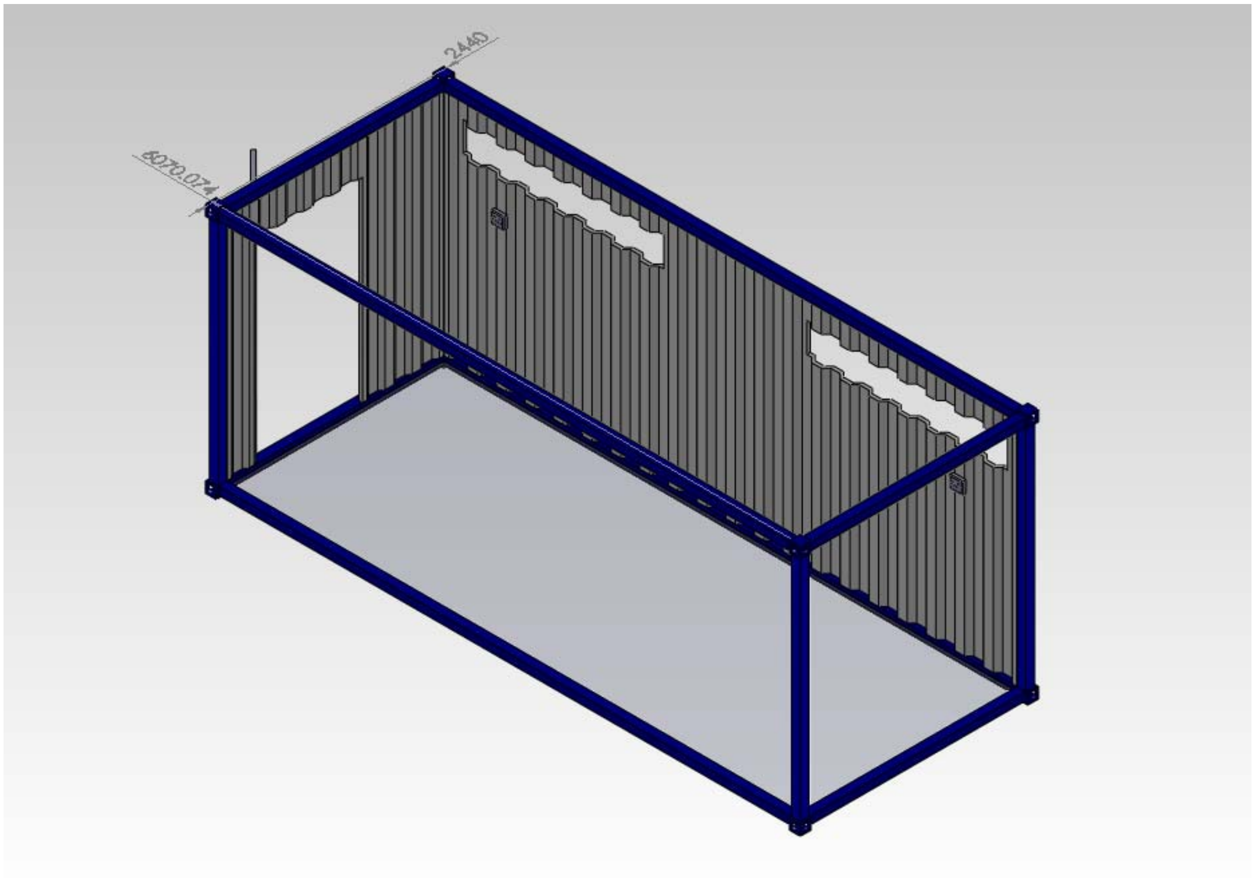


Figure 4.5: Container template Type B

The second template design that we developed would be used for the woodworking and auto repair shops. This design includes the same angled roofing as the first template as well as an additional back door. The back door will be used to get large pieces of material such as plywood or metal sheeting into the container. This template also includes the same electrical outlet scheme as the first template.

The third container modification, Container template Type C, is in Figure 4.6.

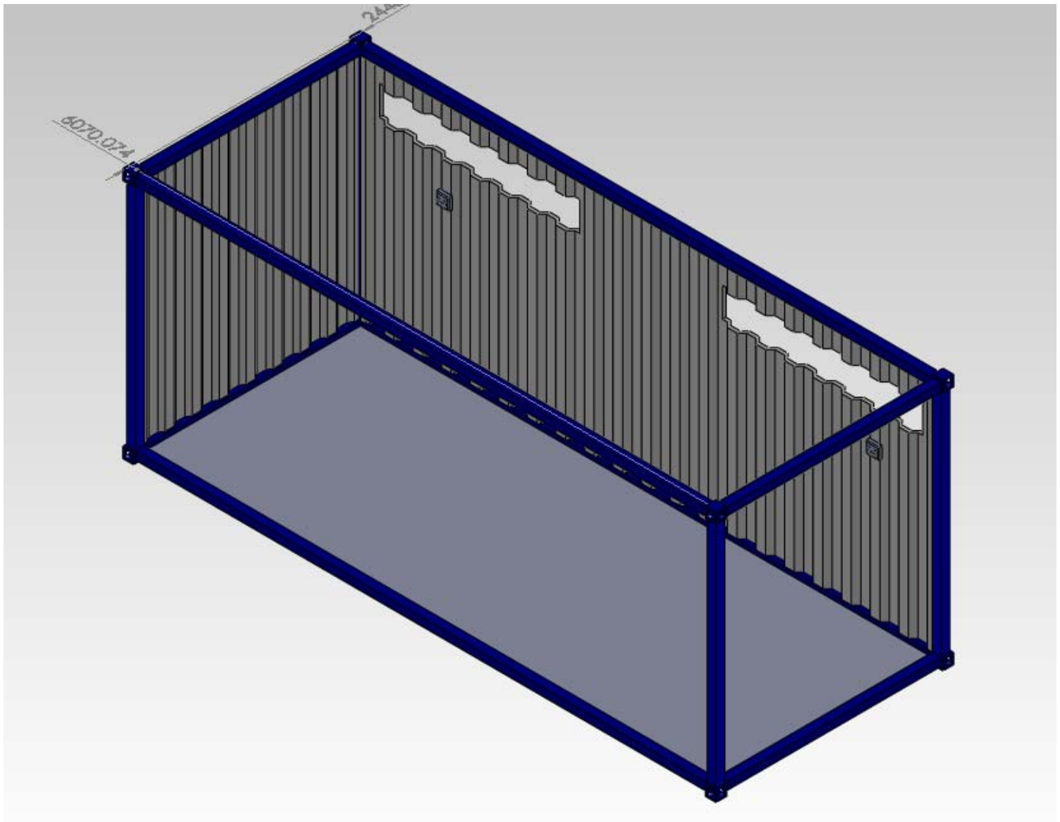


Figure 4.6: Container template Type C

This template is used to house the mill service. Again an angled roof is needed to provide shade to the renter. This template is simple by nature and is primarily needed to securely store the milling machine and a stockpile of grain and seeds.

Displayed below in Figure 4.7 is our design for the butchery.

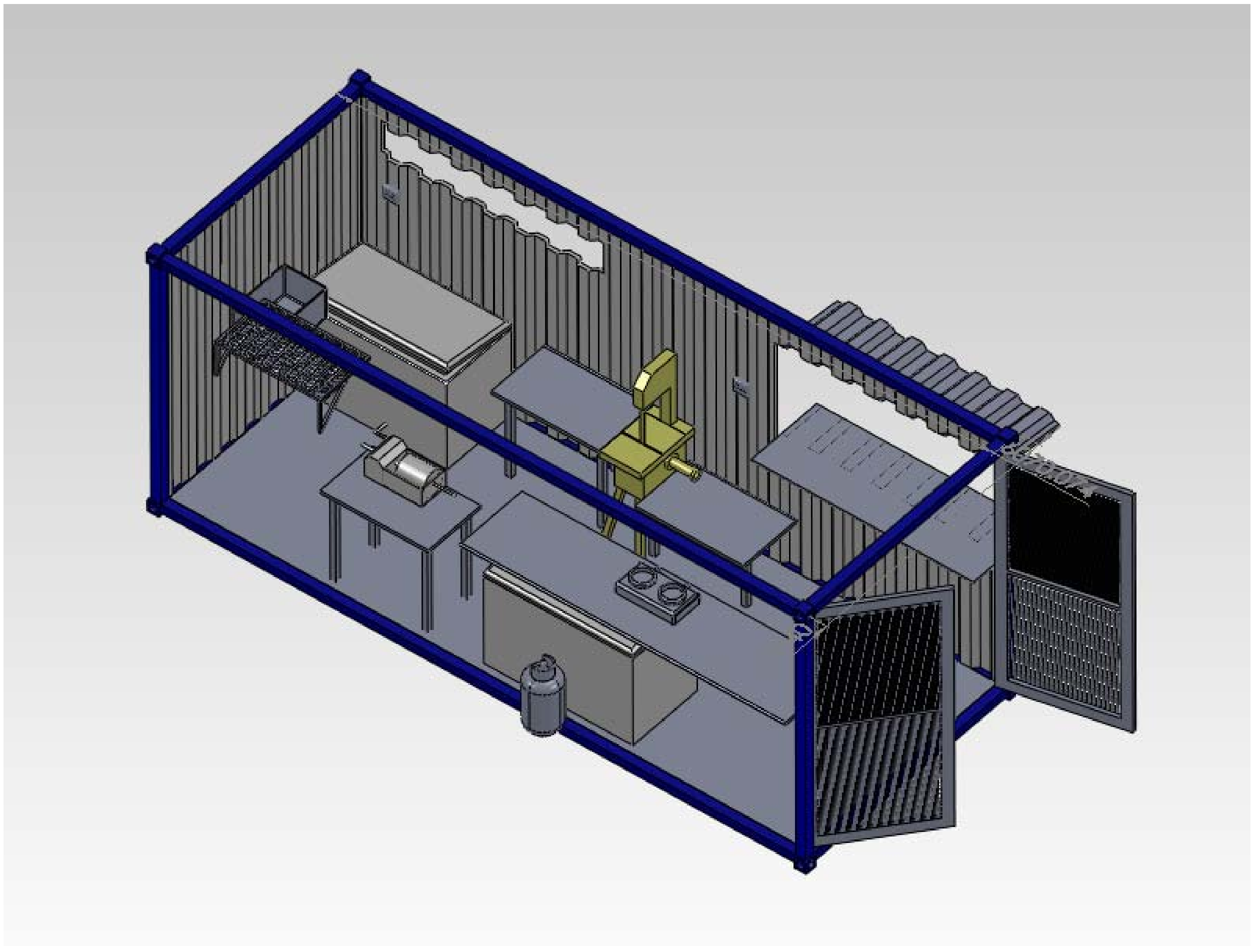


Figure 4.7: Butchery design

As previously stated this butcher shop utilizes our first template design. In addition to the template modifications, we have included a fold down table as a work area, two deep freezers, a band saw with grinder attachment, and a sausage extruder. We also included space for additional appliances in the future as by the request of Jimmy Itamba.

In Figure 4.8 we have our design for the service kitchen.

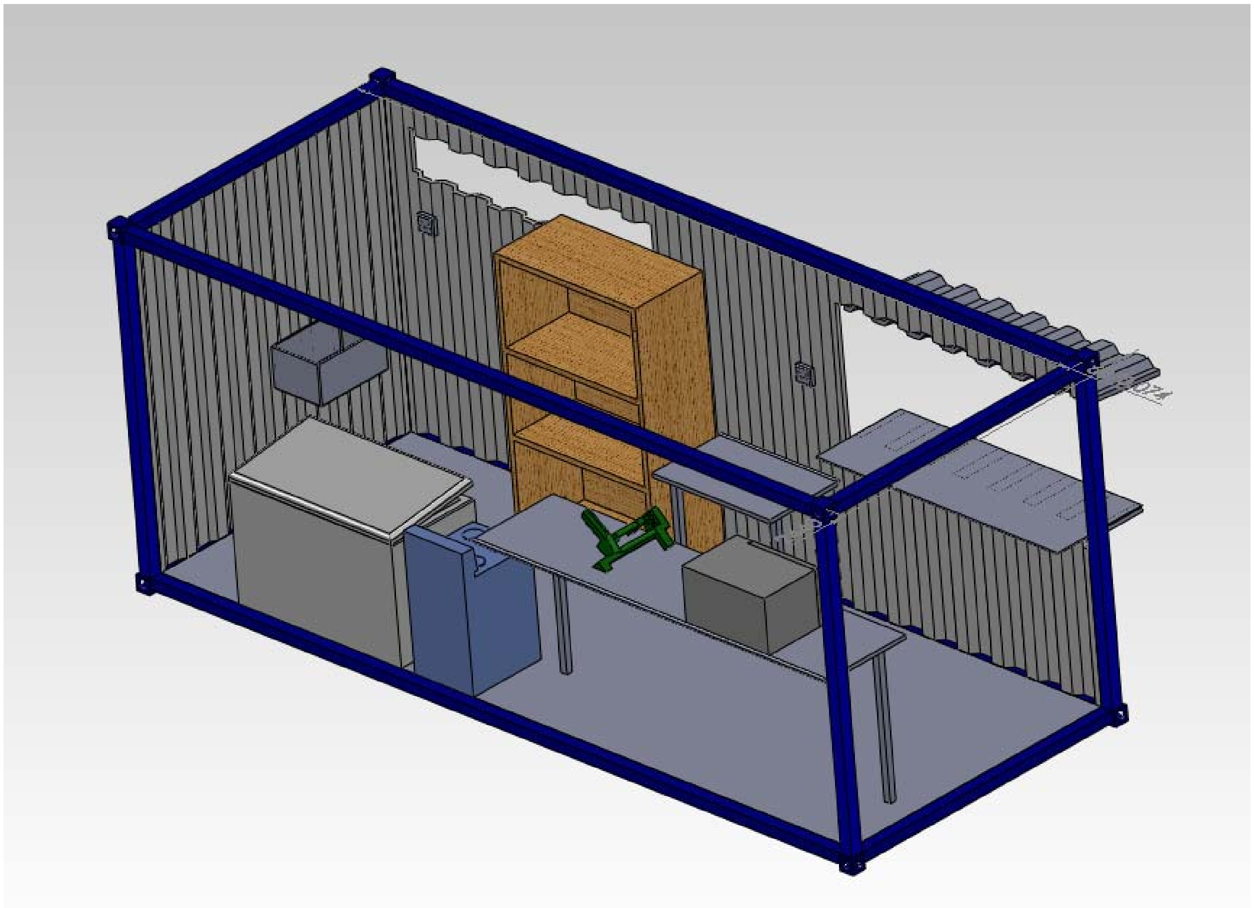


Figure 4.8: Service kitchen design

This kitchen is complete with an oven, storage cabinets and a deep freezer. We also included a microwave and a French fry potato cutter. This container specifically was designed with express input from Rosa, an entrepreneur in Tsumkwe who currently runs a catering business. We placed all of the cooking appliances on one side of the container for ease of use and placed most of the storage along the opposite wall.

Figure 4.9 displays our design for the hair salon.

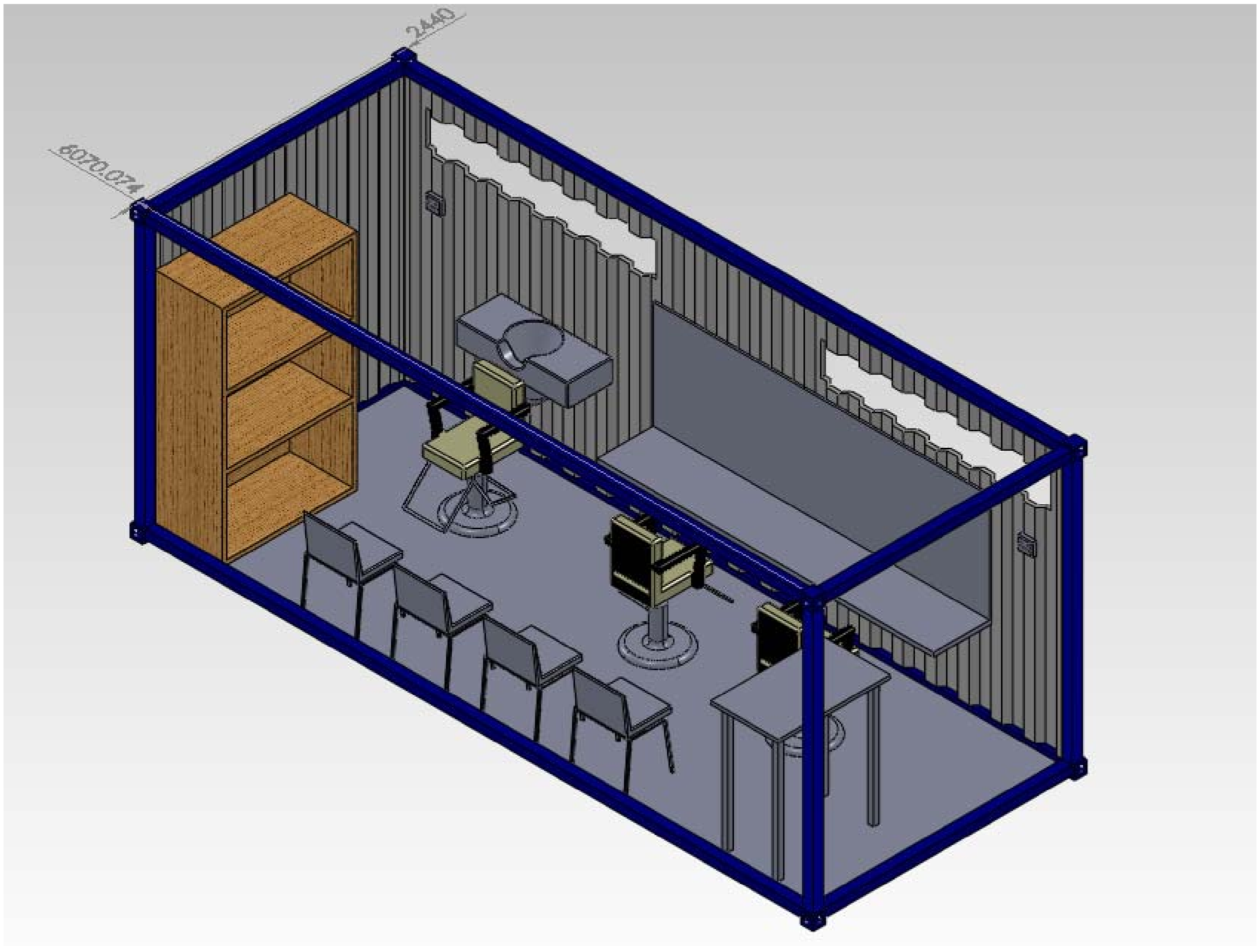


Figure 4.9: Hair salon design

Our design for the Hair salon comes from a modified version of the butcher / kitchen template. In this design we have modified the interior sink for washing hair. Also we have included a waiting area for customers. As you can see we have included a total of three salon chairs, two for cutting or styling hair, and the other for the hair wash station. We also included a service counter for selling cosmetics. This design leaves space for additional appliances should the renter want to include things like a small fridge for drinks.

Displayed in Figure 4.10 is the auto repair shop

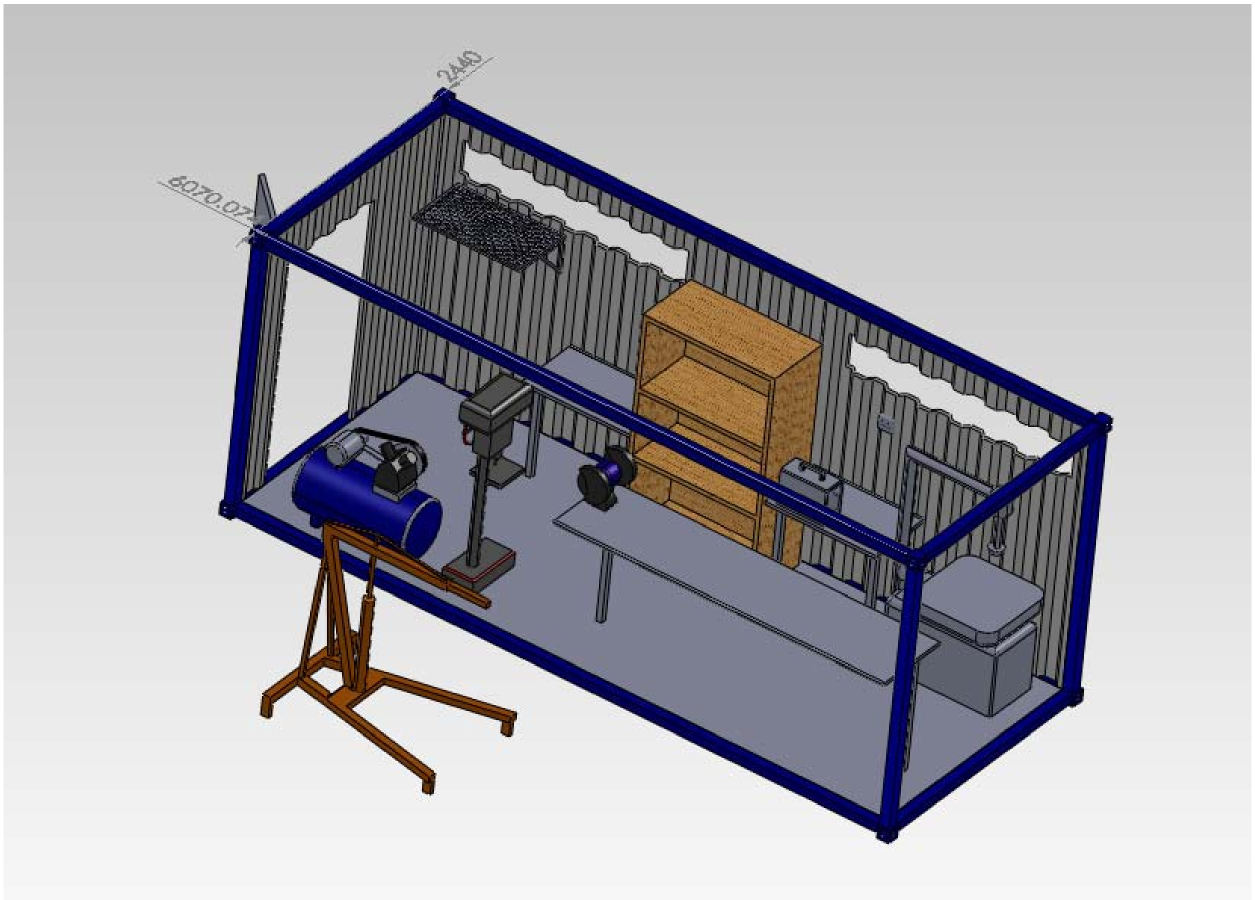


Figure 4.10: Metal works and auto repair shop design

This design features a number of pieces of equipment on the interior of the container. Based on our interviews with entrepreneurs in Tsumkwe, and our DRFN staff we made a serious of recommendations to the DRFN on how best to change our design to better meet the needs of the community. Our DRFN staff was uneasy about the idea of locating any pieces of equipment outside of the container, however the entrepreneurs and contractors we talked to said that it was the only way to make the design work. Our current design features all of the vital equipment on the inside of the container in a layout that works for space but wouldn't work for realistic repair concerns. Our recommendation section includes a series of changes to the design both in layout and in overall structure that will make the auto repair shop feasible in the future.

Figure 4.11 displays the woodworking container.

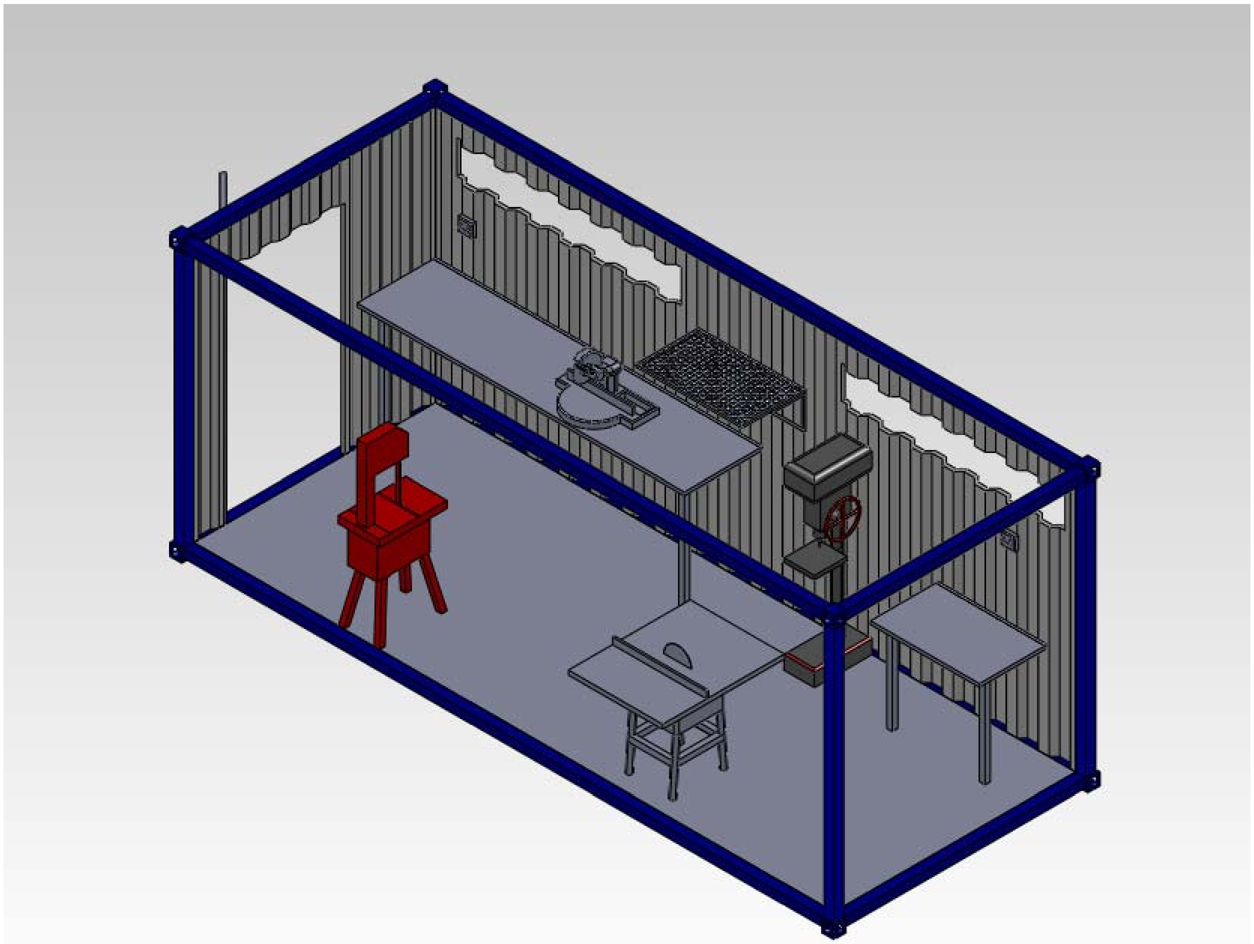


Figure 4.11: Wood work shop design

The woodworking container includes both structural modifications and the vital equipment for making basic repairs, coffins, and furniture. These pieces of equipment include a miter saw, a table saw, and a drill press. Similarly to the auto repair container this container needs some additional modifications in order to become fully effective. Our research team had a series of meetings in our last workweek concerning these modifications and they will be features in our recommendations section.

Our next design was for a grain mill displayed in Figure 4.12.

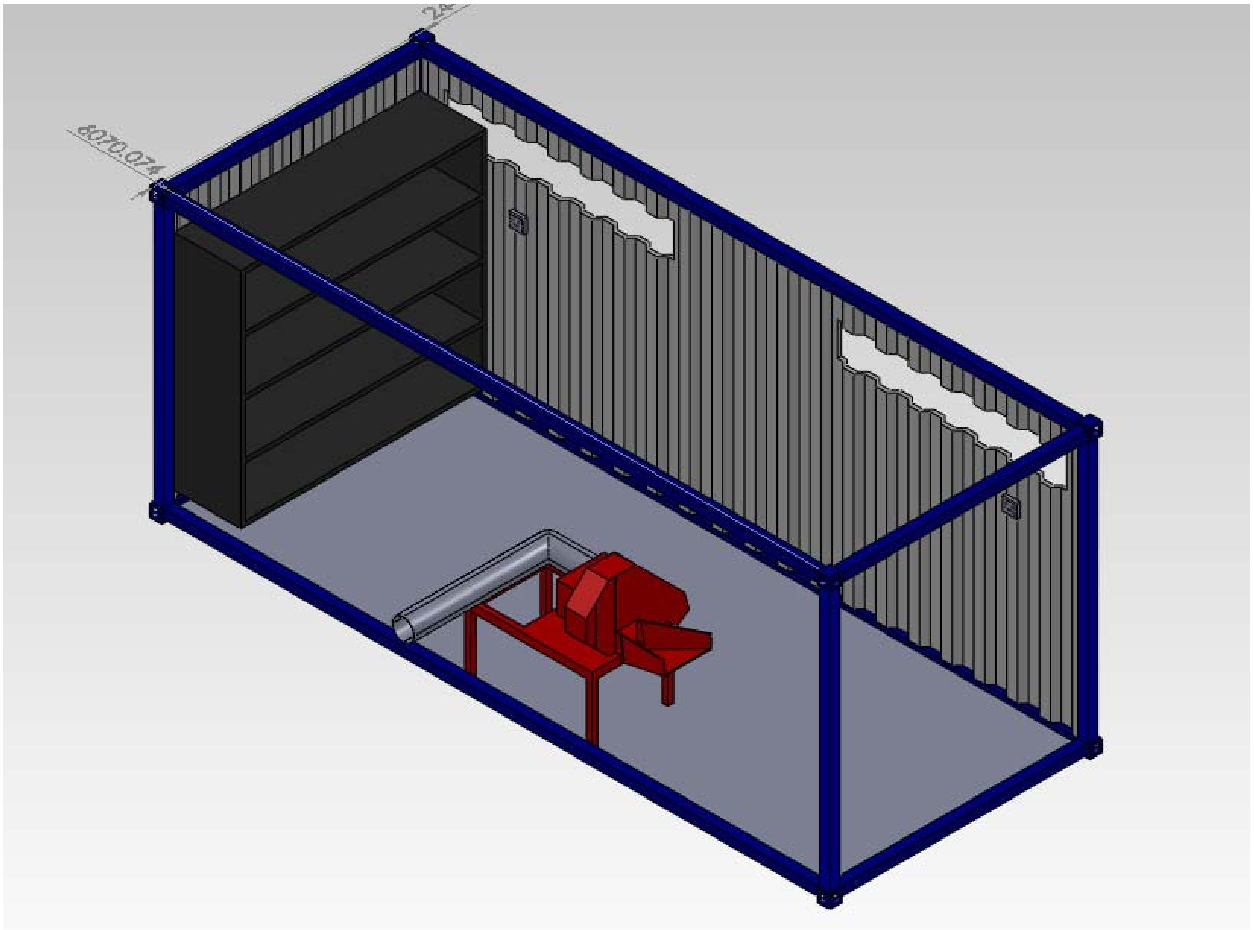


Figure 4.12: Grain mill design

Due to the nature of grain milling this container design is very simple. In addition to the mill itself we have installed a lofted working platform to make operating the mill easier. There is also a set of shelves for storage. Overall the most important part of this design is the inclusion of an extractor vent for the gas exhaust of the mill. If we didn't include this then the container would quickly fill with exhaust fumes making it unusable.

Overall these containers represent the finalized designs that we presented to the DRFN. There is room for improvements in every design; some of these changes have been included in our recommendations section. Further work will need to be done to prepare these designs for construction but we believe that we have provided the DRFN with a substantial foundation from which they can develop the Tsumkwe SME park.

4.1.5 Cost and Power Analysis

A cost and power analysis tool was constructed to calculate the price and power consumption of each containerized SME design, based on the type of equipment and structural modifications the DRFN would like to pursue in the SME park implementation.

	A	B	C	D	E	F	G
1	Containerized Business - Butchery						
2							
3	Shipping Container						
4	*Shipping Container*	*Name of Supplier*	*Unit Cost*	*Unit Power Rating*	*Number*	***Cost***	***Power Consumption***
5	ISO 6m Shipping Container					0	0
6						0	0
7						0	0
8					***Container Total***	0	0
9							
10	Equipment Needs						
11	*Name of Equipment*	*Name of Supplier*	*Unit Cost*	*Unit Power Rating*	*Number*	***Cost***	***Power Consumption***
12						0	0
13						0	0
14						0	0
15						0	0
16						0	0
17						0	0
18					***Equipment Total***	0	0
19							
20	Structural Modifications						
21	*Structural Modifications*	*Name of Contractor*	*Unit Cost*	*Unit Power Rating*	*Number*	***Cost***	***Power Consumption***
22						0	0
23						0	0
24						0	0
25						0	0
26						0	0
27						0	0
28					***Modifications Total***	0	0
29							
30					***Total***	0	0

Figure 4.13: An example of the Microsoft Excel cost and power analysis tool

Due to time constraints we were not able to obtain all the pricing information for the structural modifications of the shipping containers. We drafted a letter to request pricing information for the future use of the DRFN. The letter is displayed in Appendix L. Once the cost and power consumptions estimates were all gathered, the DRFN staff could simply load the information into the cost and power analysis tool. In making the decisions on which equipment to purchase and which structural modifications to perform, the DRFN could resort to the tool and select the desired combination by inputting 1 into the highlighted "Number" column of the desired equipment and modifications.

4.2 Part 2: Evaluating Wood Gasification Technologies for Electrifying Rural Namibia

The Evaluating Wood Gasification Technologies for Rural Electrification project included 4 stages: the CBEND Pilot Plant Assessment, Screening Questionnaire, Follow-up Inquiry, and Feasibility Assessment Tool. We began with a site assessment of the CBEND Pilot Plant. In this visit, we learned the complications of the 250 kW CBEND pilot installation and the urgency of downscaling and decentralizing the CBEND concept for off-grid applications. The Screening Questionnaire and the Follow-up Inquiry sections summarized our search process for applicable 30-100 kW market-ready wood gasification technologies. The final section described the development of a feasibility assessment tool that assists the selection of the ideal gasification system based on technological parameter performance.

4.2.1 CBEND Pilot Plant Assessment

The CBEND pilot plant assessment was scheduled to offer us a more concrete understanding of the technology involved in the process that converts invasive bush biomass to producer gas, and ultimately to electricity. However, while on-site, the poor performance of the pilot plant came to our attention. The CBEND pilot plant is located on Farm Pierre, north of Otjiwarongo, approximately 4 hours of drive north of Windhoek. The location was chosen primarily for three reasons: abundance of bush biomass sources, proximity to electricity grid in-feed, and proximity to running water sources.

The CBEND pilot installation consists of the wood chipper, the gasification reactor, the gas cooler and scrubber, the electronic synchronizer, and the producer gas generator. The system was supplied by Ankur Scientific (Pty) Ltd. A P&I Diagram of the entire process is displayed in Appendix M. Due to the substantial amount of assembly work required, engineering contractors were employed sporadically for a period of six months before the system could begin its operation. They leveled the ground, poured concrete slabs, installed a weather shield, and constructed civil and electrical assembly system connecting each of the gasification, cooling, scrubbing, generation, and waste treatment units. The extensive engineering work was not expected by the DRFN, who was anticipating a mostly pre-assembled and pre-containerized system. The extent of additional assembly work is pictured in Figure 4.14.

Figure 4.14: The CBEND pilot plant facilities with metal roofs and concrete slabs

Not only did its assembly work cause unexpected complications, the pilot installation has also raised many operational issues along the process, from biomass preparation all the way through electricity generation. The operation was so plagued with technical dysfunction that it operation had to be ceased after the test run.

Ankur Scientific (Pty) Ltd supplied the CBEND pilot plant project with wood preparation equipment, which chips and dries bush biomass using a rotatory conveyor. Such method is time and labor consuming, taking up to 4 workers to manually feed the bush biomass continuously into the conveyor. Furthermore, the chipping process does not cut the wood into uniform pieces, leaving splinters and stringy fibers that serve to clog the system. The DRFN had to resort to other wood preparation methods. Currently, the wood is prepared through a manually-fed multiple-blade cutting table, which requires only two workers, one cutting the wood, and the other transporting the wood into the gasifier feeder. One of the workers at the pilot plant demonstrated to us the process of cutting wood using the blade. He held the bush branches against the blade using bare hands because the loading bar on which the bush should have been handled was removed due to the non-uniform size of bush branches. We were told that a worker almost cut his fingers through. Even if the current wood chipping method is less technologically advanced and more dangerous than the one provided by Ankur Scientific, it is nonetheless more suitable for the preparation of these invasive bush species.

Figure 4.15: The supplied rotatory conveyor (left) and manually-fed cutting table (right)

Another major problem with the operation of the gasification system is the process with which high-temperature high-waste-content gas is cooled and cleansed. After the gasification process where wood blocks are burned to produce gas, it is fed into a cyclone where the gas goes through a tornado action to weed out particulates. In this process, the gas is cooled from 600 °C to 40 °C. However, the heat is dissipated and lost into the ambient air as opposed being captured as a source of thermal energy. In addition the system provided by Ankur Scientific utilizes a closed-circuit water system to cool and cleanse the gas, meaning that the gasification system is limited geographically to be close to a water source. To cool down the 40 °C gas further to the ambient temperature of 20 °C, an active cooling method using refrigeration is used, using 15 kW of energy that could otherwise be used to produce electricity.

After the gas is cooled to ambient temperature, it is fed to a mist eliminator to soak up moisture, and then to a series of filtration tanks covered with sawdust to remove tar and ash content. However, the passive and pleated filters provided by Ankur Scientific do not have an internal waste collection system. The engineering contractors were asked to therefore lift the filtration tanks and place trashcans underneath the outlet streams to manually collect the tar and ash content from the filtration process.

The very last stage of the process is electricity generation. The biomass gasification system was designed to produce 250 kW of electricity. However, the national grid only registered 50 kW out of the 250 kW output, due to the incompatibility of grid in-feeding software. The low electricity distribution efficiency made it financially infeasible to continue the pilot operation.

From our CBEND Pilot Plant assessment, it became apparent to us that the current pilot installation was far from satisfactory, suffering difficulties such as technical robustness, financial feasibility, and operational complexities. The pilot plant assessment pointed to us the main hurdles that needed to be overcome for biomass gasification systems to be successful in Namibia.

1) To ensure the successful implementation of the CBEND concept in Namibia, especially in the rural biomass-rich regions where skilled labor is in short supply, the pre-assembly of the gasification units is an important factor.
2) To ensure continuous bush biomass feed into the gasifier, a more reliable and efficient wood preparation method should be employed.
3) To ensure the sustainability of the future CBEND plant, alternative cooling and cleansing methods should be favored, as high water consumption is not ideal in an arid country like Namibia. It is also recommended if the process heat can be captured for energy applications.
4) To ensure the financial feasibility of future CBEND operations, high electricity distribution efficiency is desired. One of the methods is to decentralize the CBEND operations, such that the electricity generated through the CBEND gasification process is not fed to the national grid, but directly to Namibia's off-grid communities.

4.2.2 Screening Questionnaire

In the process of identifying suitable small-scale woody biomass gasification technologies, screening questionnaires was submitted to 57 biomass gasification suppliers on the international market. For future references of the DRFN, these 57 suppliers' contact information is listed in Appendix N. 17 questionnaire responses were received. Additionally, 4 companies replied stating that their technologies were not suitable for our application. Therefore, a total response rate of 36.8% was achieved. We speculated that the main reasons for the relatively low response rate were:

1) Some suppliers only provided technologies outside of the 30-100 kW power output range;
2) Some suppliers were reluctant to work with Africa-based NGOs for fear of insufficient project funding;
3) Some suppliers might no longer be in operation.

Out of the 17 questionnaire responses received, 11 suppliers met both qualifications of providing small-scale woody biomass gasification technologies within the desired 30-100 kW power output range and expressing interest of being contacted further to discuss details of the DRFN's CBEND project. The 11 suppliers are All Power Labs, LLC (APL), Alternative Energy Solutions International, Inc (AESI), Ankur Scientific (Pty) Ltd (Ankur), Aruna Electrical Works (Pty) Ltd (Aruna), Carbo Consult & Engineering (Pty) Ltd (Carbo), Community Power Corporation (CPC), Gasification Australia (Pty) Ltd (Australia), New Range Power Corp (NRPC), Paradocs Enterprises, Inc (Paradocs), Planet Green Solutions, Inc (PGS), and Thermogenics, Inc (Thermogenics).

Below is a table showing the geographic locations, years of operations, and gasifier power output range of these 11 suppliers. Most of the suppliers are US-based, which might be attributed to the fact that the screening questionnaire was submitted in American English. However, we did offer to provide translation assistance to suppliers who may experience difficulties understanding the questionnaire. Half of the suppliers have been in operation for more than 10 years. On average, they offer technologies of a wider power output range than those who have been in operation for less than 10 years. It came to our attention that APL and Australia only provide below 30 kW micro-to-small scale gasification systems. We nonetheless decided to submit follow-up inquiries with these 2 suppliers as their portable-scale technologies may present unique advantages in off-grid applications.

Name of supplier	*Location*	*Years of operation*	*0-30 kW*	*31-70 kW*	*71-100 kW*	*>100 kW*
APL	Berkeley, CA, USA	<5	√			
AESI	Wichita, KS, USA	>10	√	√	√	√
Ankur	Baroda, Gujarat, India	>10	√	√	√	√
Aruna	Rampakkam, Tamil Nadu, India	5-10	√	√	√	√
Carbo	Johannesburg, South Africa	>10	√	√	√	√
CPC	Littleton, CO, USA	>10	√		√	
Australia	Melbourne, Australia	<5	√			
NRPC	Utica, KY, USA	<5		√	√	√
Paradocs	Lafayette, IN, USA	>10	√	√	√	√
PGS	Fairfield, FL, USA	<5	√	√	√	
Thermogenics	Albuquerque, NM, USA	5-10	√	√	√	√

Table 4.1: CBEND Screening questionnaire responses: locations, years of operation, and gasifier power output

Below is a table indicating the types of gas scrubbing technologies and electricity generation technologies provided. To our advantage, most of the suppliers provide alternative scrubbing methods and methods to capture process heat for thermal and electrical applications. With the exception of AESI, all suppliers provide some forms of gas engine. In order to gauge whether their scrubbers and generators are suitable for the off-grid applications in Namibia, we would need to request more details through our follow-up inquiries.

Name of supplier	*Water-based scrubbers*	*Alternative scrubbers*	*Capture of process heat*	*100% gas engine*	*Dual fuel gas-diesel engine*
APL		√	√	√	
AESI	√	√	√		
Ankur	√		√	√	√
Aruna	√		√	√	
Carbo	√		√	√	√
CPC		√	√	√	√
Australia		√		√	
NRPC	√	√	√	√	√
Paradocs	√	√	√	√	√
PGS		√	√	√	
Thermogenics		√	√	√	√

Table 4.2: Screening questionnaire responses: range of technology supplied

Below is a table showing the suppliers' responses to the question on the level of assembly work required. All suppliers indicated that they provide pre-assembled and pre-containerized technologies. However, the level of pre-assembly is dependent on other factors, such as the range of electrical power output, the complexities of the cooling and cleansing processes, etc. In addition, the level of on-site assembly civil works is subject to interpretation. Therefore, we would like to be provided with more details about the specific pre-assembly methods in our follow-up inquiries.

Name of supplier	*Pre-assembled in containerized units*	*Mostly pre-assembled with minor civil works*	*On-site assembly with minor civil works*	*On-site assembly with substantial civil works*
APL	√			
AESI	√	√		
Ankur	√		√	
Aruna			√	
Carbo	√			
CPC	√			
Australia	√			
NRPC	√	√	√	√
Paradocs	√	√	√	√
PGS	√			
Thermogenics	√			

Table 4.3: Screening questionnaire responses: assembly methods

Below is a table summarizing the suppliers' responses to the questions pertaining to the woody biomass parameters. Since AESI does not supply electrical gasifiers, the question on wood consumption per kW electrical power output does not apply. Suppliers answered the open-ended wood fuel format question with varied specifications, e.g., size, moisture content, bulk density, energy density, it is necessary to acquire more comprehensive information through follow-up inquiries for ease of
comparisons.

Name of supplier	*Wood processer*	*Wood consumption*	*Wood fuel format*
APL		1.2 kg/kWe	2-6 cm, wood chunks
AESI	√	N/A	<5 cm, <50% moisture
Ankur	√	1.3 kg/kWe	1-5 cm, >150 kg/m^3, <20% moisture
Aruna	√	1-1.2 kg/kWe	2.5-5 cm diameter, 5 cm length
Carbo		1 kg/kWe	Wood chips or chunks
CPC		1.8 kg/kWe	<5 cm, <50% moisture, wood chips
Australia		1.33 kg/kWe	1.5-5 cm, wood chunks
NRPC	√	1 kg/kWe	1-5 cm, <15% moisture
Paradocs	√	2 kg/kWe	1-5 cm, wood chunks
PGS		1 kg/kWe	Wood chips or chunks
Thermogenics	√	1.5-2.2 kg/kWe	>11630 kJ/kg

Table 4.4: Screening questionnaire responses: feedstock specifications

4.2.3 Follow-up Inquiry

The follow-up inquiries aimed to obtain more detailed information pertaining to our major system suitability concerns: 1) extent of assembly civil and earth works; 2) format of woody biomass feedstock; 3) water usage in the scrubbing process. The following information was tabulated according to the suppliers' responses to the follow-up inquiries and their promotional brochures.

Name of supplier	*Extent of civil and earth works*	*Compatibility with 10-15 cm long, 5-10 cm wide bush wood blocks*	*Type of wood processing equipment*
APL	None	Yes, but more compatible with 5-8 cm long wood blocks	None
AESL	Not provided	Not provided	Not provided
Ankur	Leveled concrete ground and exterior shield	Yes	Chippers, choppers, and cutters available
Aruna	Not provided	Not provided	Not provided
Carbo	Leveled concrete ground and exterior shield	Yes	None
CPC	None	No, only works with <5 cm wood chips	Wood sorter and dryer available
Australia	None	Yes	None
NRPC	Not provided	Not provided	Not provided
Paradocs	Leveled concrete ground and exterior shield	Yes, multiple grate sizes available	Off-the-shelf equipment available
PGS	None	Yes	None
Thermogenics	None	No, needs to be ground to <1 cm to allow for plug forming in the feeder	Since gasifier does not require wood blocks, a regular grinder would be enough

Table 4.5: Follow-up inquiry responses: assembly work and wood compatibility

Name of supplier	*Alternative scrubbing system*	*Capture of process heat*	*Water treatment process if water-based scrubbing*	*Water softening equipment if water-based scrubbing*
APL	A packed-bed barrel filter and a washable air filter	Heat used for tar-cracking	N/A	N/A
AESI	Not provided	Not provided	Not provided	Not provided
Ankur	None	Heat Exchanger to generate hot air and water, chilling, etc.	Settling, filtration, adsorption and sludge separation	Off-the-shelf equipment available
Carbo	None	Heat Exchanger to generate hot water for larger-scale units	Closed circuit water system	Water hardness has no effect on gas production
CPC	Dry filtration	Heat Exchanger to generate and transfer hot water to dry feedstock	N/A	N/A
Australia	Air to gas tube bundle heat exchanger, forced convection via axial fans on air side	None	N/A	N/A
NRPC	Not provided	Not provided	Not provided	Not provided
Paradocs	Oil bath and paper cartridge filtration	Not provided	N/A	N/A
PGS	Air cooling and filtration	Heat Exchanger to efficiently reuse engine waste heat	N/A	N/A
Thermogenics	Combination of refrigerant chilling and recyclable water cooling	Not provided	N/A	N/A

Table 4.6: Follow-up inquiry responses: water usage and process heat applications

In addition to technological parameters, the follow-up inquiries also requested an estimated price quote for a complete gasification-generation system of the standard size of 30kW, 50kW, and 90kW power output. Below is a compilation of these price quotes in US dollars.

Name of supplier	*0-30kW system*	*31-70kW system*	*>70kW system*
APL	10kW: Not provided 20kW: Not provided	N/A	N/A
AESI	Not provided	Not provided	Not provided
Ankur	11kW: $25,842 22kW: $38,762	32kW: $57,324 40kW: $73,593	70kW: $178,757 120kW: $214,958
Aruna	Not provided	Not provided	Not provided
Carbo	N/A	40kW: $126,300 64kW: $143,140	112kW: $211,712
CPC	Have no interest in selling single units, nor the ability to compete cost-wise with systems fabricated in developing counties		
Australia	15kW: $41,100	N/A	N/A
NRPC	Not provided	Not provided	Not provided
Paradocs	~30kW: $75,000	~50kW: $113,000	~90kW: $180,000
PGS	~30kW: $76,800	~50kW: $114,800	~90kW: $148,800
Thermogenics	$110,000-175,000 for a single unit order, volume discounts apply		

Table 4.7: Follow-up inquiry responses: estimated price quote

4.2.4 Feasibility Assessment Tool

In order to ensure the sustainability of our gasifier evaluation, we presented the DRFN with a feasibility assessment tool. This tool was created in Microsoft Access, which is a database management program. We created several different input and data-management forms and generated a variety of useful reports which query the information already entered into the database. The assessment tool will allow our sponsor to easily add or remove information about suppliers when new corporations are identified. The database houses all quantitative information pertinent to each supplier.

One issue that arose when compiling the information gathered through our initial and follow up inquiries was the categorization of pertinent information. In order to easily filter through gasification suppliers, this software requires that each article of information collected must fit into a valid and specific data type. Data types commonly used in our assessment tool were checkboxes and text boxes for contact information and comments; however the information collected in our follow up inquiry was in paragraph form. There is no clean way to automatically filter or categorize such subjective, personal or human-readable responses.

In order to solve this problem, our group discussed the idea of creating a ranking system for supplier information with our sponsor. We decided that this approach would be too subjective to our own opinions, and instead we categorized which qualitative information was common in each gasifier response. We generated database fields for such responses, and directly copied the supplier's responses into comment fields. We also attached the follow-up responses received from each gasifier. An example of this was a question addressing the extent of civil works required for installation. This question asked the respondents to compare their installation requirements to that required at the CBEND plant.

The majority of respondents used terms such as "no more complex than" or "most likely suitable" which is entirely reliant on subjective ranking. Our group simplified this to utilize fields which mimic a ranking system but were much more specific. Following this question and others similar to it, a comment field was added which contained the suppliers' response verbatim. In the future, our sponsor can select the fields we categorized then view the entire comment from suppliers once a report is generated.

Below is the input form created for entering contact information for a gasification supplier. There are convenient navigation buttons for switching between data records, and a button which will bring the user to a list of gasification units provided by the selected company. Another form was created which shows the gasification units provided by the selected gasifier. This pricing information was gathered through our follow up inquiry.

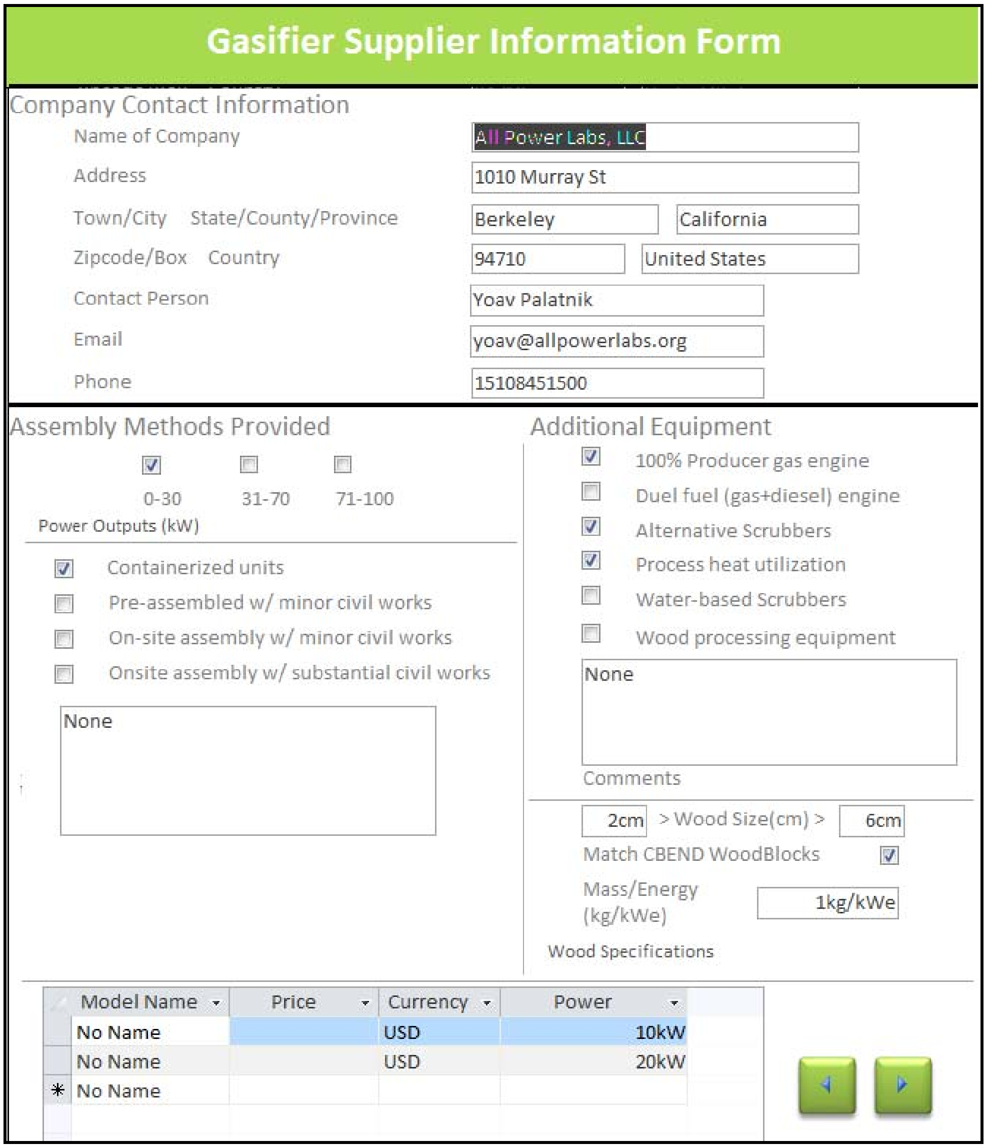
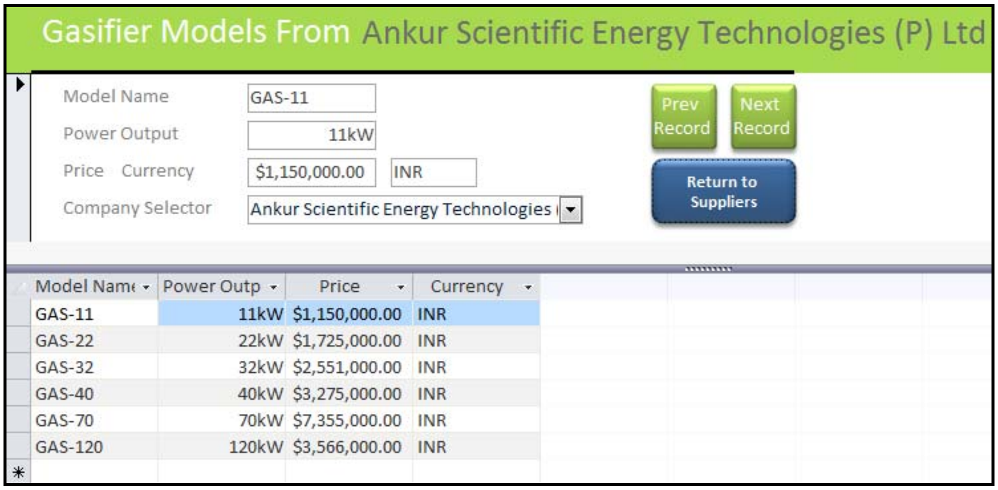


Figure 4.16: Microsoft Access gasifier supplier information input form



Gasifier Models From Ankur Scientific Energy Technologies (P) Ltd

Model Name: GAS-11
Power Output: 11kW
Price / Currency: $1,150,000.00 INR
Company Selector: Ankur Scientific Energy Technologies (

Prev Record | Next Record | Return to Suppliers

Model Name	Power Outp	Price	Currency
GAS-11	11kW	$1,150,000.00	INR
GAS-22	22kW	$1,725,000.00	INR
GAS-32	32kW	$2,551,000.00	INR
GAS-40	40kW	$3,275,000.00	INR
GAS-70	70kW	$7,355,000.00	INR
GAS-120	120kW	$3,566,000.00	INR

Figure 4.17: Microsoft Access form for viewing gasifier models from a specific supplier

Based on the information collected through our data entry forms, the DRFN staff can generate custom queries. For example, our sponsor can select to view only gasification companies which offer units between 0 and 30kW, and do not require water-based scrubbing methods. Once a query is generated, only the suppliers which match the chosen criteria will remain. One can then view those companies through the forms above, or print out a report with contact information and models. As a final deliverable, we hope that our assessment tool will provide a convenient method of storing gasifier information. Additionally, this assessment tool will provide the most elegant form of ranking available without utilizing subjective opinions of separate gasification suppliers.

Chapter 5 Conclusions and Recommendations

In our research we uncovered a number of problems facing both the settlement of Tsumkwe and the CBEND project. Many of these problems could be solved with a small amount of attention and possibly a small investment, while others may require much more substantial funds or additional research. Below we have listed our recommendations based on the issues that arose during our research.

5.1 Conclusions

The local resident's response to outside economic development efforts is generally low in Tsumkwe. This is due to cultural differences between the San, the majority of the residents in Tsumkwe, and the rest of Namibia. Until an improved way of integrating these communities into the decision-making and implementation process is developed, efforts by outside organizations will continue to fail. Additionally, the geographic location of Tsumkwe means that proper supply chains are difficult and expensive to create and maintain. We determined that the best way for us to aid in the development of Tsumkwe was not to focus on product-driven businesses or stores. Instead, our designs focused on providing service hubs and production equipment. If we can provide the tools and equipment necessary to perform basic repairs, butcher work, and other vital services, then members of the community will be able to use this equipment and hopefully improve their ability to develop on their own. We are not creating businesses for the community, we are creating a convenient location for businesses to be developed and conducted. We are providing the tools for the community to make decisions for themselves. Our final goal was to present the DRFN with a series of designs for these SMEs as well as cost and power analyses for each container. Additionally, we supplemented our report with recommendations concerning the implementation of our SME designs, as well as further research that should be done to enhance the effectiveness of our project.

Due to the size, cost, complexity, and engineering intricacies of the CBEND pilot plant, it became clear that gasification systems on such a large scale are simply not feasible for rural Namibia. In addition to the physical difficulties of the plant itself, Namibia's electrical infrastructure in its rural areas is not sufficient enough to make a grid in-feeding system financially viable. The solution for these problems is to downscale and decentralize energy production facilities. These smaller gasification systems would provide sufficient energy to small off-grid settlements currently generating electricity through the burning of diesel fuels. Utilizing alternative fuel sources like woody biomass for energy production can also prevent small off-grid settlements from relying on diesel fuel which causes extensive harm to the environment. Our final goal was to present the DRFN with our analyses of market-ready wood gasification technologies worldwide as well as a feasibility assessment tool that would help the DRFN decide which gasifier-generator system should be purchased. We also included our recommendations on the purchasing and implementation of wood gasifiers in off-grid communities.

The Tsumkwe Energy project and the CBEND project are both working to address the substandard energy infrastructure and the underdeveloped economy of rural Namibia. While these two projects may seem different at first, their end goals are the same. Both are attempting to use readily available resources for sustainable development. Our work with both of these projects will hopefully serve to aid in the economic and energy infrastructure development of Tsumkwe, and serve as models for other rural settlements across Namibia.

Recommendations for the development of Tsumkwe

We recommend that a form of public transportation be developed between Grootfontein and Tsumkwe.

Formal, scheduled transportation should be established to transport people back and forth from Tsumkwe and the surrounding settlements to Grootfontein. This would help the community tremendously by creating a stable, safe, and efficient way of traveling to obtain basic supplies. We believe that a coordinated bus schedule could drastically improve conditions within Tsumkwe. This is a vital part of any long-term solution for a community like Tsumkwe that has extensive supply needs.

We recommend more emergency service vehicles be provided between Grootfontein and Tsumkwe.

At the time of this report, there exists one emergency vehicle that travels between Grootfontein and Tsumkwe. This vehicle also services the smaller settlements that branch off the more traveled road. We have learned through our visits to Tsumkwe that the emergency clinics in the settlement do not have the necessary supplies for serious injuries or incidents such as poisonous snakebites. We understand that the limited population in Tsumkwe diminishes the need for such an emergency clinic, but we believe the residents of Tsumkwe should be better protected by providing an opportunity to travel to locations where better services are available.

We recommend school-sponsored extra-curricular activities for all grades of students.

Currently there are few to no activities for children, teenagers, and young adults to do once the school day is over. If the school introduced afterschool programs such as sports teams, movie showings, or dance socials, students would have structured activities to do after school that would be a productive use of their time. It could also serve to improve school attendance and potential academic performance. Anything that the school or any other group could do to prevent kids from turning to alcohol for entertainment out of boredom will serve to strengthen the community.

We recommend the development of afternoon and night activities for residents of all ages.

There are very few entertainment options available in Tsumkwe to the members of the community. At the time of our visit, the majority of adult residents relied on television or shebeens (informal bars) for entertainment following work. We believe that the establishment of entertainment options for families and residents of all ages would greatly benefit the community in Tsumkwe. These forms of entertainment should cater directly to the desires of Tsumkwe's residents, and if possible should rely on little to no electricity to maintain the sustainability of Tsumkwe's future as an off-grid settlement. Some suggestions are board games, movie showings, fitness centers, and pool or billiards halls.

Recommendations for the Tsumkwe SME Park

We recommend additional research into green energy sources and sustainable practices for the SME park implementation.

Our container designs are such that the addition of solar panels is a minor physical addition but still requires more research before actual implementation. The DRFN should also evaluate the feasibility of additional green energy sources to power the SMEs such as wind power. Some of the SME designs we have created require large amounts of water and additional electricity, such as the auto repair shop or the wood working shop. To keep with the spirit of the Tsumkwe Energy Project, these designs should consume as little resources as possible.

We recommend community education and management search programs for the SME park.

Ideally, the residents of Tsumkwe would manage the maintenance and management of the SME park. In order to prepare the community such that the residents could manage the park and the solar array effectively and sustainably, we have to prove to the settlement the value of the solar array and potential benefits the SME park could have on the community. This will not be an easy process but if done successfully it could serve to re-vitalize this settlement. Additionally, research has to be conducted for locating individuals in Tsumkwe who are interested in maintaining and managing these SME Parks.

We recommend that further research should be done in both structural modifications and installation techniques for the containers themselves.

We recommend that the DRFN consider some of the structural and design modifications that we were unable to present to them due to time constraints, yet we believe are still worthwhile. One design concept we recommend for further research is considering opening up the sidewalls of both the auto repair and wood working container to increase the overall work space. Second, we recommend that the DRFN consider the use of multiple containers when attempting to design some of the more complicated services like auto repair and metalworking.

In addition to structural modifications, we recommend that each container be built with a twin-pitched roof rather than the single-pitched roof displayed on our designs. In the last week of our time with the DRFN, we held various meetings concerning the construction of these containers and determined that the double-pitched roof was the best solution for heat shielding. Additionally, we recommend that each container be built in a slight incline to facilitate adequate drainage during cleaning. Lastly, we recommend that the DRFN look into using refrigerated containers for designs like the butchery or the service kitchen because of their heavy-duty insulation and stainless steel interior.

We recommend that a detailed contract be created outlining the responsibilities of the renters and managers of the SME park.

There are many logistical questions remaining in the implementation of the SME park in Tsumkwe. A contract outlining the responsibilities of each party involved should be drafted, perhaps with the participation of the entrepreneurs in Tsumkwe. This contract should include liability concerns relating to the equipment and to the overall condition and cleanliness of the containers themselves. This contract should be reviewed with the potential renters for additional feedback.

We recommend that the DRFN consider the use of the superstructure concept to add to the overall construction of the SME park.

As outlined in our Results and Analysis section, we believe that a superstructure roof could add to the overall aesthetic nature of the SME park as well as provide additional heat shielding and energy generating potential for the park. While we fully understand that this roofing concept is not feasible at this time we believe that in the future, if the funding becomes available, such a concept would be a worthwhile venture.

Recommendations for CBEND Off-Grid Gasification Initiative

We recommend an evaluation on the level of interest in wood gasification and the creation of a promotional and educational program for energy farmers in rural communities.

More research should be done into the public interest in energy farming and the CBEND concept itself in rural communities. In order to successfully introduce wood gasification technologies across Namibia, rural communities have to be identified that are interested in alternative energy solutions. Additionally, a promotional campaign expressing the benefits of these systems and the potential economic opportunities that could be made in these rural communities should be developed and presented to key settlements and farmers.

We recommend further investigation and due diligence into suppliers before purchasing any gasification system.

As the DRFN saw directly with Ankur at their CBEND site, it is vital to do as much research as possible on various companies that could supply these systems. Our questionnaires and inquiries identified potential suppliers by their technical specifications and by some measure of their processes; however no survey will gather all necessary information. Information such as the structure of the companies, the longevity of their systems, and their corporate track record should be investigated further. All of these details need to be determined prior to any investment.

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Appendix A Tsumkwe Site Assessment Interview Protocol

Introductions:

Hello our names are ____________. We are students working with the DRFN as part of the Tsumkwe Energy Project. Our specific job is to identify local businesses and productive opportunities for Tsumkwe. As the Tsumkwe Solar System will provide more reliable electricity to the settlement, we are attempting to see what kinds of businesses and productive opportunities can be developed in settlements like Tsumkwe.

Questions:

1. How long have you lived in Tsumkwe?
2. How is it living here, do you like it?
3. How does living here compare to other places you have lived?

Topics to address:

- Groceries
- Transportation to Grootfontein
- Clothing / Shoes / Repair
- Auto repair / Welding
- Electronics repair / Appliances
- Home improvement / Lumber / Steel
- Medical services
- Laundry
- Copies / Fax / Office suppliers
- Fun / Entertainment
- Childcare
- Take-away food
- Feminine hygiene products / Hair salon
- Banking

Appendix B Tsumkwe Presentation Visit Interview Protocol

Introductions:

Hello. We are students working with the DRFN as part of the Tsumkwe Energy Project. Our specific job is to identify local businesses and services that Tsumkwe could benefit from. As part of our project we are making a proposal to the DRFN of various businesses designed for installation inside of shipping containers. These designs are not ready for construction yet and will need to be further approved by the DRFN. Would you be interested in answering a few questions and taking a look at our designs?

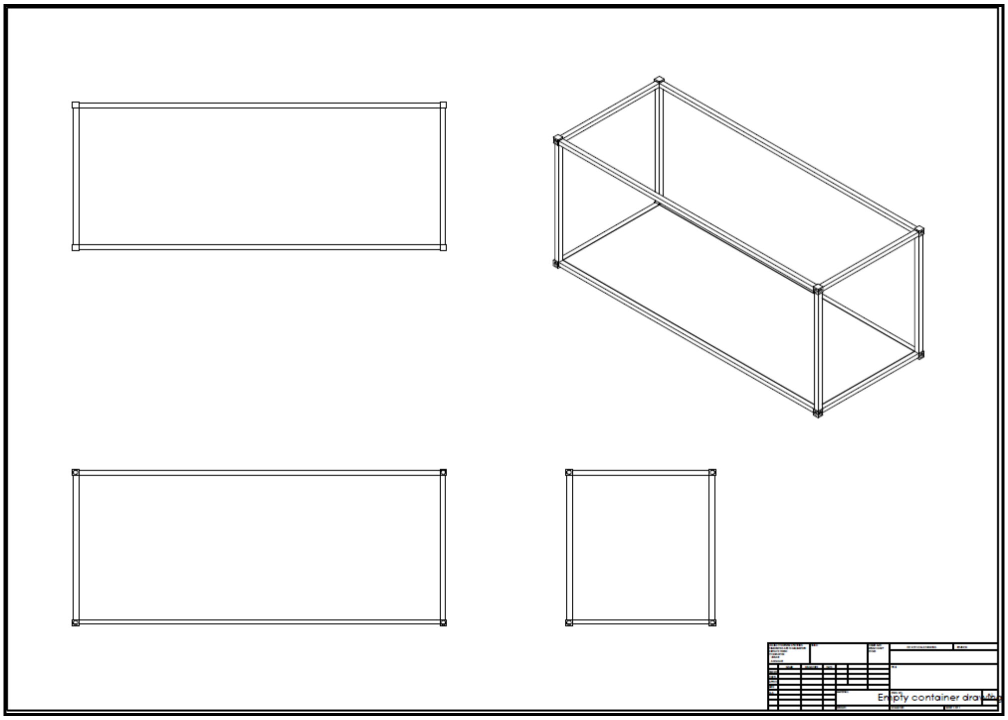
Questions:

1. Do you live here in Tsumkwe?
2. If so, how long have you lived here for?
3. (If applicable) What do you do here in Tsumkwe?
4. We have designed some businesses using shipping containers for building materials. Those businesses and services are a butcher shop, and auto repair shop, and wood joinery, a Laundromat, a cinema, a grain milling facility
5. Do you think that there are any additional businesses or services that Tsumkwe needs that we haven't thought of?
6. Would you like to take a look at our design(s) for ______?
7. Here is the design for X (describe the design). Would you move any of the pieces of equipment? Are we missing something? (Explain the layout that we have based on workflow. If they move something, ask why and how does that make it better?)
8. Now imagine that you are visiting or working in one of these containers. Does that change your outlook on the design?
9. The plan right now is for these containers to be available for people to rent out on say a daily, weekly, monthly basis, do you think that is a good idea?
10. If you were to use this container how much would you be willing to pay for rent for a day, a week, or a month?
11. Do you see any problems with the idea of these containers? Do you think that the people of Tsumkwe will use them?

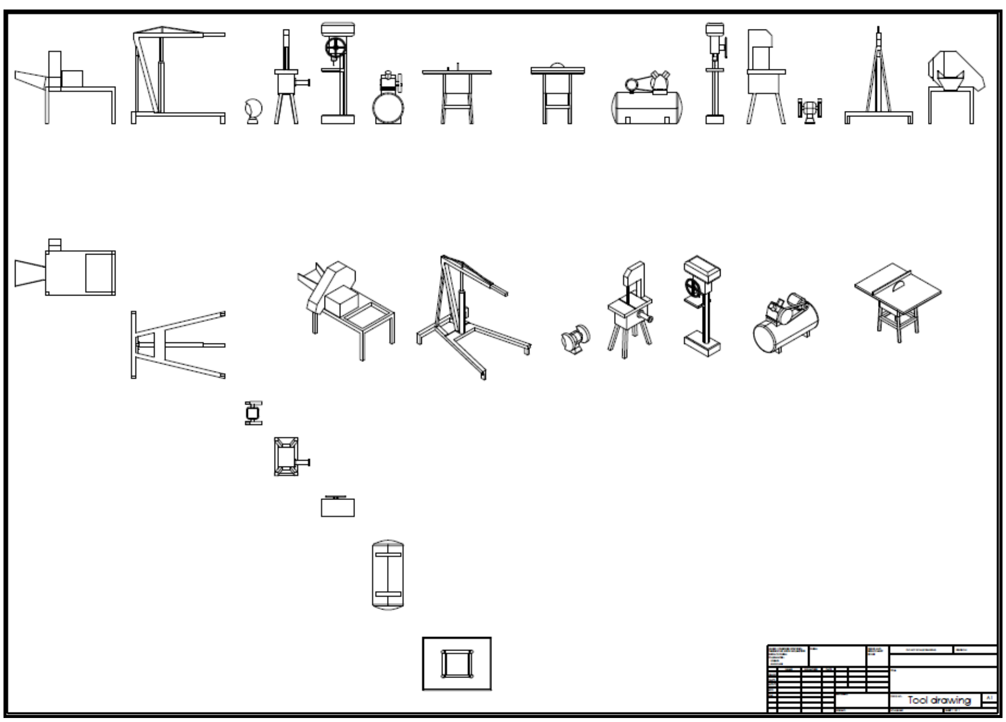
12. If entrepreneur: do you know anyone else who has ideas for businesses and could look over our designs? Thank you.

13. Do you have any closing remarks or recommendations for us? Thank you for your time.

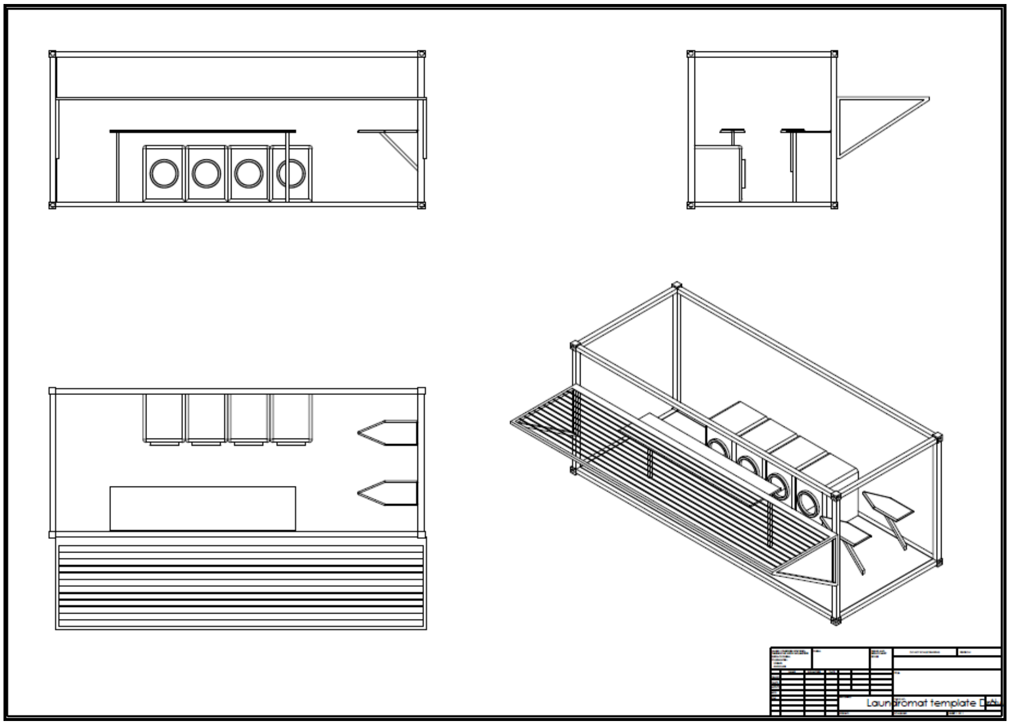
Appendix C Design Templates Used in the Presentation Visit Interviews



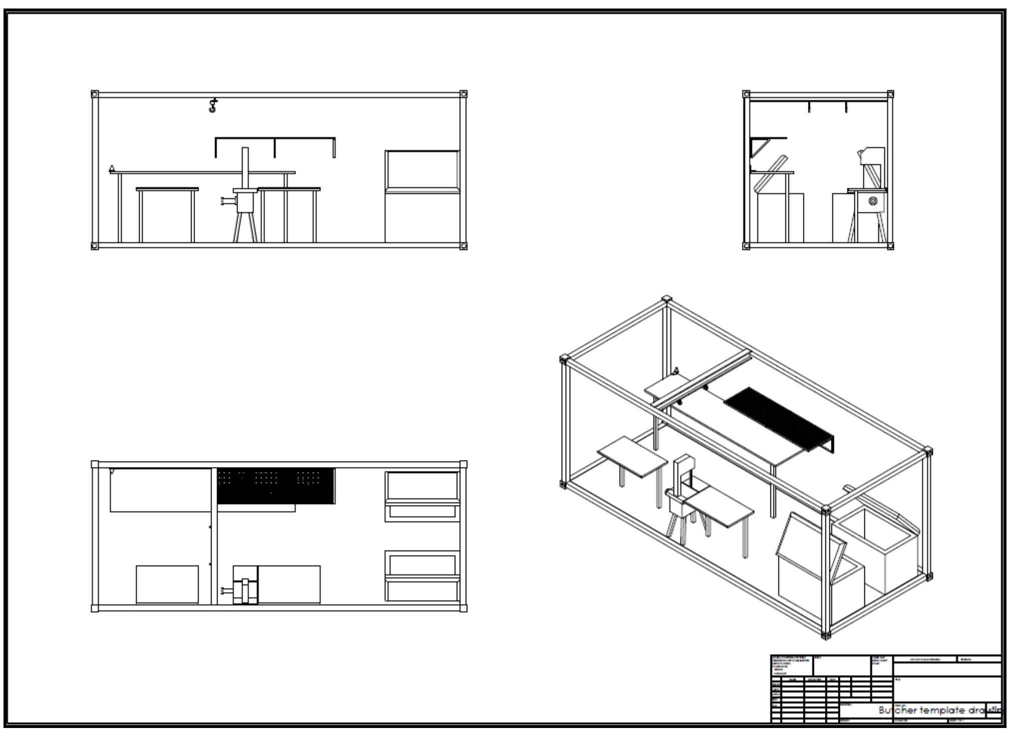
Shipping Container Blank Template



Equipment and Tools Template



Laundromat Template



Butchery Template

Appendix D CBEND Screening Questionnaire Introductory Letters

Below is the 1st introductory letter sent to suppliers.

Dear ________

We are students from the Worcester Polytechnic Institute (WPI) of Massachusetts working on a rural energy development project for the Desert Research Foundation of Namibia (DRFN), a non-profit NGO focused on sustainable development in Namibia, a country in Southern Africa. We are hoping to attain information about gasifiers that could convert woody biomass to electricity.

The DRFN established a 250 kW biomass gasification power plant in 2010 with grid in-feeding under the CBEND (Combating Bush Encroachment for Namibia's Development) project. Information about the CBEND project can be found at http://cbend.forst.nu/. This pilot installation has raised many issues, such as financial feasibility, technical robustness, operational complexities, etc. Our project aims to complement the CBEND project through investigating gasification technologies under 100 kilowatts to replace farm-based diesel generators.

Our goal is to assess 30~100 kW woody biomass gasification technologies available on the international market. We would appreciate if you could spare some time to fill out a 2-minute questionnaire at http://www.surveymonkey.com/s/32RJQ3L.

We would sincerely appreciate a response by April 4th.

Thank you very much for helping the DRFN make an informed decision on what gasifier to purchase for Namibia's off-grid rural settlements.

To learn more about the DRFN and WPI you can visit www.drfn.org.na, and www.wpi.edu respectively.

Sincerely,

Andrew Baker

Richard Brown

Robert Morlath

Zhixin Wang

Below is the 2nd introductory letter sent to suppliers who did not respond within the first 2 weeks.

Thank you for those who have taken the time to complete our survey. Unfortunately, it appears that some spam filters and faulty email addresses affected some addressees. We are therefore informing you that we have extended the deadline of our survey from April 4th to April 8th. For ease of your reference, we have attached our survey with this email, or you could complete online at http://www.surveymonkey.com/s/32RJQ3L.

Should there be any translation issues for German and Dutch companies, please feel free to contact Mr. Robert Schultz at robert.schultz@drfn.org.na.

Thank you again for helping the DRFN make an informed decision on what gasifiers will be appropriate for Namibia's off-grid rural settlements.

To learn more about the DRFN and WPI you can visit www.drfn.org.na, and www.wpi.edu respectively.

Sincerely,

Andrew Baker

Richard Brown

Robert Morlath

Zhixin Wang

Appendix E CBEND Screening Questionnaire

1. Name of Company:

____

2. Do you provide biomass gasification technologies in the following kW power output range? (Choose all that apply)

0-30 kW

31-70 kW

71-100 kW

<100 kW

Additional Comments:

____

3. How long have your biomass gasification systems been available on the market?

Less than 5 years

5-10 years

More than 10 years

Additional Comments:

____

4. Do you provide the following equipment as part of your gasification systems? (Choose all that apply)

100% producer gas engine

Dual fuel (producer gas + diesel) engine

Wood processing equipment (ex. chippers)

Water-based scrubbers

Alternative scrubbers (ex. air cooling and cleansing)

Capture of process heat for other applications (ex. electricity)

Additional Comments:

____

5. Among the systems below 100 kW power output, what is the assembly method required? (Check all that apply)

Pre-assembled in containerized units

Mostly pre-assembled with minor civil and earth works

On-site assembly with minor civil and earth works

On-site assembly with substantial civil and earth works

Additional Comments:

____

6. Among the systems below 100 kW power output, please specify the size and physical characteristics of the biofuel source needed.

____

7. Among the systems below 100 kW power output, what is the average kg wood required for 1 kW power output?

____

8. Has your company earned any professional accreditations and/or certifications (ex. ISO, TUV, OHSAS)?

____

9. May we contact you again for further information? (If yes, please provide us your contact information in the box below.)

____

Thank you very much for completing the questionnaire.

Appendix F CBEND Follow-up Inquiry

Thank you very much for completing our survey. We are very interested in learning more about the technology that your company offers. We are specifically interested in technologies below 100 kW power output that require minimal assembly and civil works. Attached is a survey customized according to the information you have provided so far and where it is relevant for the current CBEND power plant. In addition, we would appreciate it if you could provide **brochures**, **user manuals** and **P&I diagrams** that would help us learn more about the technology your company offers. We understand that some of this information may be proprietary, and we deeply appreciate any information that you can provide to us.

1. The gasifier in mind should work with woody biomass consisting of thorny bush species with a chunky wood fuel format (as opposed to wood chips). Example pictures are provided of the bush species and of the wood block fuel currently fed into the CBEND pilot plant. Each block is between 10-15cm in length and 5-10 cm wide. Does your company supply any gasifier model that will be appropriate for burning such wood fuel?

Pictures of the wood blocks and the thorny bush species.

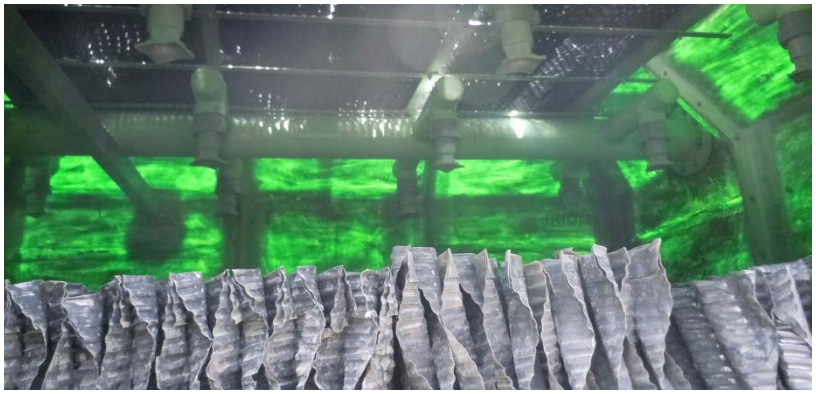
☐ Yes

☐ No

2. (If the supplier indicated that they provide wood processing equipment in screening questionnaire) The wood processing equipment currently in place at the CBEND pilot plant is a manually-fed multiple-blade cutting table (see example picture). You have indicated in your responses that your company provides wood processing equipment. Can you provide more details of the technical parameters and labor requirements of the wood processing equipment?

Picture of the machinery used for creating wood blocks.

3. (If the supplier indicated that they provide alternative scrubbers in screening questionnaire) You have indicated in your responses that your company has alternative scrubbing and cooling technology. Currently, the CBEND pilot plant uses water-based evaporative cooling (See example picture). In Namibia, this can result in excessive water consumption, which is unsustainable. Can you provide more details on the type of alternative scrubbing /cooling processes that your company has developed?



Picture of the water cooling method at the CBEND plant.

4. (If the supplier indicated that they capture process heat for other applications in screening questionnaire) Can you provide more information on your capture of process heat and your utilization thereof? Currently the CBEND plant only uses the heat from generator exhaust for active drying of wood blocks. A picture of the drying bed is below.

Picture of the drying beds using heat from exhaust.

☐ Yes

☐ No

5. (If the supplier indicated that they provide water-based scrubbers in screening questionnaire) If your system utilizes a water-based scrubbing method, can you briefly describe your water treatment process? Do you have information on the concentration of impurities before and after water treatment?

6. (If the supplier indicated that they provide water-based scrubbers in screening questionnaire) The water used at the CBEND plant has a high level of hardness. Do you provide water softening equipment?

☐ Yes

☐ No

7. (If the supplier indicated that they require some extent of civil and earth works in screening questionnaire) You have also indicated in your responses that your gasifier units require some extent of civil and earth work. Attached are two views of the CBEND plant's extent of civil works. Can you provide indicative information on what the civil and earth work entails? Please provide information for each of the gasifier models you provide below or attached to an email to cbend2011@wpi.edu.


Concrete slabs and exterior housing at the side of the gasifier.

8. ((If the supplier indicated that they provide dual-fuel engine in screening questionnaire) You indicated a dual-fuel engine is used in you generator. Does this imply that your engine will run on a mixture of diesel and gas continuously (and at what ratio), or whether the diesel is used as a pilot fuel for startup only, then phased out at peak production?

9. It would be most valuable to receive cost estimates for the complete systems you provide [according to standard sizes of ~30kW, ~50kW and ~90kW]. This will be used for a cost comparison with current prevalent diesel-only generators in Namibia.

Thank you again for your assistance in the development of alternative energy in Namibia. Please email us the completed document and any additional attachments you feel obliged to send to us.

Sincerely,

Andrew Baker

Richard Brown

Robert Morlath

Zhixin Wang

Appendix G Tsumkwe Containerized Business and Equipment Conceptualization

Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
High	**Butchery**	Provide access to sanitary meat processing facilities Prepare cuts of meat for selling Cold storage for perishable goods	Chalk board Meat Saw Deep Freezer Display refrigerator Grinder Extruder Scales Register Work table Hosing to wash down entire inside Clothing hooks Vacuum sealer	Ceramic tile walls and flooring Exterior sinks Drying grid sturdy enough for meat Cut out wall counter top Drainage pipes for floor Ceiling ventilation whirlybirds Hot and cold running water Possible exterior shading	No slaughtering on site Talk to Coca-Cola about the fridge for drinks Went to Agra and Adendorf Machine Shop for dimensions
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
High	**Auto Repair / Metal Working**	Make minor to moderate repairs of cars in town Also serve as a metal working shop, cuts and modifies piping, roofing, etc. for house or personal property repairs	Compressor Welding equipment Pneumatic wrench Jacks Engine lift Tire mount machine Fire protection Lockers	Rails for engine lift Exterior sinks Hosing Ventilation Lots of shelving Back door loading bay	Provide plenty of exterior room, place as close to road as possible Contact supplier about dimensions Combine with steel working Went to Adendorff Machine Shop

			Work table Cleaning equipment Metal cutting tools Grinder Plumbing equipment Racks for metal parts		for dimensions Went to Terrasol for workflow concerns and vital equipment
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
High	**Wood Joinery**	Provide the settlement with access to wood working tools Provide basic home repairs Bed and other furniture making Coffin making	Scales Miter saw Table saw Drill press Vice Compressor for pneumatic nail gun or staple gun Racks for wood Work table or bench Fire protection Lockers Cleaning equipment Heavy Duty ventilation system for dust	Ventilation Shelving for small parts Back door loading bay	Potentially make a separate coffin making specific operation Visited a wood joinery for workflow concerns and equipment list
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
High	**Hair Salon**	Expand available hair services in community	Chairs Mirrors Interior hair washing	Windows Ventilation	Going to need running water Waiting area May want to

			sinks Safe / Register Hot running water Shelves		include a fridge for cold drinks Interviewed local resident of Tsumkwe for design
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
High	**Mill**	Provide the people of Tsumkwe with milling equipment for staple grain Mahungo	Milling grinder Bagging equipment Scales	Ventilation Windows Exterior sinks	Possible off-season use? Maybe combine with wood working station Went to Agra for workflow concerns and dimensions
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
High	**Food Service Kitchen**	Provide take away and catering services to Tsumkwe Also act as a coffee or tea shop for workers Provide food and refreshments access to the entire SME park	Gas stove top Gas oven Deep Freezer Cabinet space Hosing for brining water inside container Chalk Board Electric kettle	Ventilation Windows Exterior sinks Service counter	Heat management system is a major priority with the oven Provide a diner area outside of container
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Medium	**Cinema**	Provide access to	Safe / Register	Booth for	Place next too

		alcohol free entertainment sources Act as a day care center during the day while parents use the Laundromat, salon, or repair stations	Screen Projector DVD or VCR Speakers Chairs / Benches	equipment Windows Ventilation Sound proofing?	Laundromat No alcohol zone
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Medium	**Bank**	Provide banking services to Tsumkwe, ATM and deposit services	Extra Security Safe / Register Safety deposit boxes ATM Wireless internet connection for transactions	Bared Windows Ventilation	Community may not use safety deposit boxes Need to find a bank branch that is willing to place an ATM
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Low	**Laundromat**	Provide basic laundry services to the people of Tsumkwe Provide access to washing machines, maybe dryers, irons, and a drying rack	3-4 washing machines Exterior racks for drying Fold down ironing boards Irons Sewing machine	Increased ventilation Water recycling system	Work on logistic of this in conjunction with Cinema for managing kids

Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Low	**Electronic Repair**	Provide access to individual work station for small appliances repair Possible integration with hair salon	Soldiering irons Electronic testing equipment Fire protection Large lights Lockers	Individual work stations Shelving	Focus on small individual work stations
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Low	**Fitness Center**	Provide access to fitness and weight equipment	Bench press Squat rack Punching bag Speed bag Treadmill / bikes Lockers Exterior hosing for cleanup	Large windows Heavy duty ventilation system Floor padding Showers Drainage piping	Possible combination with arcade Feasibility concerns: demand, safety, spacing issues, maintenance
Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Low	**Arcade**	Alcohol free entertainment alternative for people of all ages	Pinball Pool Table Soccer Shuffleboard Safe / Register Music system	Large windows Ventilation system	Going to need people to manage this site Stress no alcohol zone

Priority	***Business***	*Uses*	*Equipment*	*Structural Changes*	*Design Notes*
Low	**Museum**	Station with maps and information about the solar array and the settlement itself Provide information on the energy project to the people of Tsumkwe Provide information about the settlement to tourists	Display cases Counter tops	Windows Potentially mural	Need people to supply the information for museums

Appendix H Tsumkwe Site Assessment Interview Summaries

1. Jimmy Itamba, the DRFN Tsumkwe Energy Project Field Facilitator

Jimmy Itamba is the Field Facilitator for the DRFN's Tsumkwe Energy initiative. Born and raised in Grootfontein, he has resided in Tsumkwe for 6 years. Jimmy has extensive knowledge of the Tsumkwe community. Prior to joining the DRFN, Jimmy worked with the Red Cross in developing communities across Africa and Asia.

The supplies Jimmy needed included groceries, toiletries and clothes, all of which needed to be bought in Grootfontein and then transported to Tsumkwe on a monthly basis. Jimmy cited a trip where it took him more than three full days to finally arrive back in Tsumkwe from Grootfontein. He also remarked that it was only plausible to have fresh vegetables for the first week after a trip from Grootfontein due to limited storage facilities in Tsumkwe for perishables. Jimmy remarked that one man in Tsumkwe normally sold fresh meat from cattle. When he was not around, meat prices surged. Fortunately, Tsumkwe residents, used to expecting products to be unavailable at times, quickly adapted their food consumption patterns. In general, canned and dried foods were popular among Tsumkwe residents.

In the discussion of the services available in Tsumkwe, Jimmy cited that two women in town who owned razors worked as haircutters. There was no centralized facility for haircutting, so instead, they provided the services at your homes upon appointments. They charged fairly cheap price for their services. There was no formal laundry facility in Tsumkwe, so residents either washed clothes by themselves or paid other women to wash clothes for them. Jimmy had to purchase supplies such as soap in Grootfontein, as they were overpriced in the Tsumkwe stores due to transportation costs. There was a clothing store in town, but nowhere to go for sewing and repairs. As to banking services in Tsumkwe, there were two ATM facilities. There was one ATM service at the NamPost office, but Jimmy claimed that it frequently broke down. The more popular ATM service was available at the Tsumkwe Lodge; however the owner charged a 5% fee in addition to the bank's charge for withdrawal and depositing transactions.

In terms of health care facilities, according to Jimmy, there were two clinics stocked with no more than bandages and anti-inflammatory medicines. Anything more severe than a small cut would require an ambulance to Grootfontein. However, there was only one ambulance in the area spanning from Grootfontein to Tsumkwe. Therefore someone suffering from an extreme injury such as a venomous snakebite would not survive the encounter. There was no optometrist or dentist in the settlement, but a dentist came up to Tsumkwe to do check-ups twice a year. A bulletin would be posted in the settlement for residents to schedule appointments. In Tsumkwe, besides cellular phones, the most convenient way to spread information was through the bulletin. It was used to announce settlement-wide messages, such as to publicize an NGO informational session in the hopes of garnering a large audience.

When asked about his evening entertainment activities, Jimmy cited "Namibia's Finest" (beer) and his laptop as his two major options. Recently his computer had broken down, so he began using the Internet café and its all-in-one printing, faxing, and copying machine. However, due to limitations on transportation, Jimmy was in no rush to fix his laptop. Jimmy mentioned that an NGO sent US student volunteers to teach the community how to use a computer.

2. Leia Upingasana, Secretary at the Tsumkwe Magistrate's Court

The secretary at the local magistrate's court has been living in Tsumkwe for 2 months with her niece. She is originally from Gam, a settlement further east of Tsumkwe. Her opinion of the conditions in Tsumkwe was generally positive. She remarked that despite the inconsistent electricity Tsumkwe was actually improving rather quickly relative to the other settlements in the area. She highlighted that the establishment of the schools and the surrounding development projects was rather impressive and beneficial for the growth of the settlement.

In terms of her interaction with the settlement, she told us that most of the time she goes directly from work to home and vice versa and seldom goes into the community for socialization. When asked about the entertainment options for either adults or youths, she laughed because in her opinion there is no entertainment option available. When asked about day-care or afterschool activities for her niece, she reacted similarly. Once school is over around midday for her niece, she comes to the magistrate's court office for the rest of the workday.

For basic groceries, supplies, repairs, she either drives the company car or hitchhikes to Grootfontein about once a month. For hair salon services, she told us that while there are some haircutters in Tsumkwe, they don't offer a lot of popular styles and thus people end up going to Grootfontein for the more recent fashions. For medical services she relies on the clinic in the settlement, though she was concerned that the clinic is not open 24 hours. For any serious medical care, she told us that residents have to be transported to Mangetti and then on to Grootfontein. Apparently, despite being further away, Gam has far more services such as clothing and mechanic repair available to the community.

We asked her about the potential businesses and services we could introduce into Tsumkwe. Her general attitude was that the Tsumkwe residents are very tight with their money; if any of these services cost money to use, the community will ignore them. She liked the idea of a Laundromat, but was skeptical of the idea of security deposit boxes. She expressed her frustration at having to rely on Grootfontein for basic goods and services. She hoped to see a full grocery store or a proper clothing shop in Tsumkwe.

Close to the end of the interview, she provided us with some insight into the attitude of the community response to the development programs and services provided for the Tsumkwe community. She told us that, while the school is a great accomplishment, the San people in and around the settlement don't appreciate the importance of an education and consider it as a daycare service.

3. Margret Haokhoas

Margret Haokhoas runs the postal services for Tsumkwe, in a small office in the center of the settlement. Born and raised in Tsumkwe, she is native to the community.

Margret expressed Tsumkwe's heavy reliance on Grootfontein on basic goods and services. Fortunately, she had access to a car, so that it would only take her roughly 4 hours one-way. However, for most Tsumkwe residents, hitchhiking to Grootfontein could take up to 3 to 5 days.

She remarked about one trip that she had to stay overnight at the Grootfontein bus station because there was no transportation available back to Tsumkwe.

As a NamPost employee, she remarked that the NamPost office in Tsumkwe not only processed all of the incoming and outgoing mails, but also run the local banking services. The lack of constant electricity made it extremely difficult for her to run the postal service. When the electricity shut down in Tsumkwe from 14:00 to 17:00, the entire settlement ceased functioning. She believed that she could be a lot more productive in these 3 hours if not for the electricity shutdown.

When asked about her entertainment activities, she remarked that most residents went out to shebeens between the hours of 19:00 to 22:00. She believed that alcohol was basically the only form of entertainment available in the settlement.

4. Martha, the craft shop manager of the Nyae Nyae Conservancy

Martha runs the craft center sponsored by the Nyae Nyae Conservancy as well as overseeing a number of other projects and initiatives within Tsumkwe. In this interview, we had a rather extensive conversation about Tsumkwe, the San people, NGOs, and the realities of economic development in an area as isolated as Tsumkwe. The interview also helped us gain understanding of the cultural background about the San community.

Martha first explained her work in Tsumkwe. Nyae Nyae Conservancy is attempting to help the San people sell their crafts at a higher price and in a more regulated environment. When the San people sell their crafts on the roadside, they often sell them for no more than a few Namibian dollars, which is hardly what they deserve for their handcrafting work. Nyae Nyae Conservancy is attempting to counter this situation by establishing a craft center where the San people can make handcrafts and sell them at a more reasonable price, thus supporting the local economy.

Martha's job is to oversee the operations of this craft center despite the setbacks. The San people in Tsumkwe have little formal education, and even less knowledge of how to run a business. According to Martha, the concepts of personal finances and entrepreneurship simply don't exist in San culture. Her solution is to hold business training programs and awareness campaigns to communicate with the community the importance of selling their crafts and managing their earnings responsibly.

In addition to the craft center, Martha has also worked on Nyae Nyae's other development initiatives. Martha believed that, even if NGOs intends to aid the development of Tsumkwe, their efforts are often met with frustrating results. In her experience, most NGOs don't even attempt to involve the community in the decision-making and implementation process. Therefore, the community doesn't feel a sense of ownership in the development project and rejects it later on. She cited the survey method of another Nyae Nyae representative as the best she had ever heard: instead of asking the underdeveloped communities what kinds of businesses or technologies they would like to see, he raised the question, "If I gave you a N$20,000 loan, what would you do with it?" According to Martha, few San people are ever asked such questions as "what do you want to do when you grow up", or "what kind of business would you like to run". Martha believed that, if the community begins to ask itself these kinds of questions, it is ready to develop on its own.

Martha was in full support of the Tsumkwe containerized SME concept. She believed that, if some members of the community take the initiative to run businesses, others will see it as an example and try to replicate their neighbor's success. One recommendation that Martha made was to base the earnings of the SME Park managers and maintenance personnel on the success of the rental SMEs. Hopefully, it would increase the community ownership of the containerized SME Park and thus the Park will be more likely to succeed. It would also provide an incentive for the managers and maintenance personnel to keep the SMEs in a clean and organized manner. Martha also suggested a new business idea: a grain milling facility for the local staple grain Mahangu.

5. Mr. Xiong, the engineering contractor of the Tsumkwe Secondary School funded by the Chinese government

Mr. Xiong arrived in Tsumkwe in October 2009 from Jiang Xi Province, China. He has stayed in Tsumkwe for 18 months, and goes back to China once or twice each year since then to visit his families. As soon as he found out Zhixin Wang, one of the project team members, is a Chinese native, he started to use Mandarin Chinese in this interview.

He is the contractor of the Tsumkwe Secondary School funded by the Chinese government. Different from all the other interviewees, he receives his daily goods and supplies from a logistical support station in Windhoek along with other construction materials for the school. The truck arrives once every two weeks. Some of the supplies and materials are shipped all the way from China, with the rest purchased in Windhoek.

He remarked that he can only have fresh vegetable the first few days after the truck's arrival, and then he has to mostly rely on dried and canned food. The Internet he uses is connected to a U.S. satellite, so he can sometimes watch Chinese programs when the connection is good. However, when the electricity goes out, he has to go to bed. In terms of repairs of this electronics, he said that he relies on the Chinese government to ship new ones to replace the old ones.

At the beginning, he brought with him 10 Chinese workers and hired 100 Blacks and Sans for the construction of the school. But he said that soon he notices that the San workers were not eating or working. Most of the San workers then left for home. Now all the workers on the construction sites are Black.

Mr. Xiong cited that the Namibian government supports the San people with food. The Tsumkwe Secondary School is free tuition, room and board for the San students. In the next month, the Chinese government will transport schoolbags, stationaries, sports equipment to the school. Even the schoolteachers, the majority of them are sent to Tsumkwe from other parts of the region, are provided free housing. However, with all the monetary incentives, the retention rate of San students is still extremely low. In the first year of operation, the school went from around 500 students to around 200 students.

He also remarked that there are a lot of international volunteers coming to Tsumkwe each year, but most of them are short-term volunteers. He believed that it is simply too difficult to live long-term in Tsumkwe for outsiders.

When asked about the idea of the containerized SME Park, he commented that external assistance cannot change the internal attitudes of the community. He did not envision any substantial socio-economic changes in Tsumkwe in the next 50 years.

6. Mr. Kalonda, Tsumkwe Secondary School teacher

Jimmy Itamba showed us around the Tsumkwe Secondary School, where Mr. Kolanda was working. Kolanda is a schoolteacher who has been in Tsumkwe for 7 years. He is originally from Katima Mulilo. Mr. Kolanda seemed like a well-educated man, and was able to provide us with extensive information pertaining to the student body at the school and their extra-curricular activities. Similar to previous interviews, Mr. Kolanda relies heavily on Grootfontein for his supplies on a monthly basis. Thankfully for him, Kolanda owns car. This led us to ask questions about auto care in Tsumkwe.

Despite having someone in the settlement that could fix minor car problems, there is no dedicated mechanics or mechanic services available all the time in Tsumkwe. Mr. Kolanda was forced to have his car transported all the way to Tsumeb in order to get it fixed. Besides a grocery store, Kolanda's other greatest hope was some form of auto mechanic services.

Following our conversation about transportation in and out of Tsumkwe, Mr. Kolanda discussed how transportation affects the school community and its curricula. The Tsumkwe Secondary School is a boarding school for students around Tsumkwe and its outskirts. The hostel used for students has to close once every four weekends for school breaks or maintenance purposes. This means that all students have to go back to their homes during this time. However, due to the unavailability of a secure means of transportation, the students must begin hitch-hiking home up to a whole week in advance. They don't even have an idea when they will arrive home. Two-week-worth of classes is lost per month on the students' trip to and from home.

There are 89 boy- and 68 girl- boarding students. We asked Mr. Kolanda about afterschool activities available to students. He said that there are no formal sports teams, but every Wednesday afternoon is considered a sports day by the school. The students have the equipment to play volleyball and soccer, and there are more supplies arriving from the Chinese government soon for activities such as badminton, tennis and basketball, hula hooping. The students also arrange their own sports games on Fridays and the weekends. There is no other afterschool activity for the students, except turn to alcohol.

At the school, there is no nurse or medical technician. The only medical supplies provided to the school are first aid kits containing bandages and gauze, and those are running dry. The school receives all its necessary books and school supplies from the Chinese government, except for stationary. Students have to buy stationary at the store nearby on their own, but Mr. Kolanda said that they are readily available. The school also receives food for the students on a weekly basis. All meals for the week are sent at once. Mr. Kolanda hoped to get fresh bread for the students, because currently the bread can get stale by the end of the week.

In the end we asked what Mr. Kolanda does for entertainment after work. He enjoys reading before going to bed. He does not feel affected by the power outages at night. He discussed the chaos Tsumkwe encounters during the beginning and the end of each month; this is the time of the month when most people are paid for work. According to Kolanda, the streets get loud; and you can hear bottles smashing and fights breaking out. He proposed the idea of a location for non-alcohol entertainment and relaxation for our containerized SME Park.

7. Noreen, a social worker at the soup kitchen project for Tsumkwe tuberculosis patients

Noreen is a social worker spreading awareness about tuberculosis in Tsumkwe. She works with the soup kitchen project that provides nutritional food options to the tuberculosis patients. Originally from Kenya, she had only been in Tsumkwe for about 2 months.

Noreen purchased her foods and supplies in Grootfontein on a monthly basis. She mentioned the difficulties of having to plan for an entire month's worth of foods at a time. She remarked that she was unsure if she would have enough onions for the remainder of the month.

An important service deficiency Noreen pointed out was the absence of a hair salon. According to Noreen, the haircutters in Tsumkwe only had equipment for a select few hairstyles. She had to go to Grootfontein to get her braids done. When asked about where to purchase female hygiene products, Noreen again resorted to the answer: Grootfontein. She mentioned that such basic products as pads were available at the Tsumkwe General Store, but due to the high cost and the low variety, she preferred to purchase her female hygiene products in Grootfontein. According to Noreen, women of the San community had to improvise when the need arrived.

As we began describing the containerized business concept, Noreen offered some crucial advices from the perspective of an international development worker. Noreen remarked that the culture of the San community was a barrier against development. She explained that community development should not be reliant on external sources as had been seen in Tsumkwe. It should instead come from within. She recommended to us that before developing economic initiatives, the Tsumkwe community needed to raise its morale through some form of a community festival, where the diverse ethnic groups within the community and the non-governmental and governmental development workers from outside the community could share values and cultures with each other. She hoped that such festival could change the negative attitudes towards and within the Tsumkwe community

Noreen offered us insights of the cultural divide between the San people and the black people (a term used to refer to the black Namibians not of the San ethnicity) in Tsumkwe. In a survey conducted with the San and the black children in Tsumkwe about their career goals, only 1 of the San children had the slightest idea in mind while the remainder could not think of any potential goal. She explained that most of the black children had some, even if unrealistic, ideas in mind. Noreen suggested that, to revive the community, the youths would be our starting point. Currently, because of the deeply rooted cultural indifference towards education, San youths were unwilling to go to school despite being offered free education. Even worse, the schoolteachers set bad examples for the youths such as alcoholism in front of the students, which was also detrimental to their education.

Noreen also remarked that, according to her experience working with tuberculosis patients, the amount of free goods and services had to large extents unknowingly raised the expectations of the San community. The soup kitchen project was initially designed to feed those suffering from tuberculosis. However, when they fed one member of a San family, they were expected to feed all members of the family. It had gotten to the point where the San community expected that nearly everything be provided for them.

Appendix I Equipment Cost, Dimensions, Power Ratings, and Workflows

Equipment	*Brand Name*	*Store*	*Cost*	*Length*	*Width*	*Height*	*Power Rating*	*Work Flow concerns*
Arc Welder	TIG - 250	Adendorff	4225	48cm	21cm	33cm	220 Volts	Small, easy to move
Band Saw	Meat-o-matic	Agra	8158.5	38cm	62cm	154cm	.75kW	Comes with a grinder,
Band Saw	Spring Bok Saw Super 5234	Agra	8158.5	46cm	70cm	169cm	.75kW	Has two ports on the side for attachments
Drill Press	Model # ZJ4116HA	Adendorff		53cm	28cm	165cm	550W	
Drum Sander	Renov Namibia, MS3140	Adendorff	7735	11cm	50cm	132cm	1100W	
Electric Winch	Model # EWX1200	Adendorff	2085	59cm	29cm	21cm	12V DC	Small, easy to move
Hammer Mill	M and F	Agra	8625	163cm	92cm	119cm	Diesel Engine	Engine Exhaust
Hanging Scale	Camry	Agra	280.15					Max weight = 100kg
Metal Band Saw	Renov Namibia, 120g swive	Adendorff	3717	94cm	56cm	150cm	550W	articulating cutting arm, cutting capacity of 90 degrees
Planer	Model # F7802	Adendorff					1.7hp, 7 amps	
Sausage Filler		Safari Den	3147.62	100cm	43cm	104cm		
Table Saw	MJ10315	Adendorff					2kW, 50Hz	
Freezer	Sears	Sears.com		74.93cm	121.92 cm	88.9cm		

Appendix J Tsumkwe Presentation Visit Interview Summaries

Provided below are the summary notes taken from our informal interviews during our presentation visit in Tsumkwe. The information is provided in paragraph form, following the pattern of the interviews. We have made sure to note any and all unique remarks and personal information regarding each interviewee. Each person that we interviewed, excluding the Nyae Nyae Conservancy officer, had previously expressed interest in renting a container in the SME Park and had discussed some logistics with Jimmy Itamba. These interviews include details on possible design changes, equipment additions, and overall concept reactions of the various entrepreneurs in Tsumkwe.

1. Simeon Mingara, a welding and metal repairer

Simeon Mingara has been living in Tsumkwe for 13 years and specializes in welding and metal repairs. He provides his services to residents in Tsumkwe and in the nearby settlement of Gam. While we were in Tsumkwe, Simeon was working on repairs to a metal donkey cart. Simeon can be seen working on the cart in the picture below.

In addition, his wife runs a fat cake stand a short distance away from where Simeon has set up his welding operation. Simeon told us that he is very interested in the concept of the SME Park because he wants an official workshop. He would like to rent the container shops for at least a year at a time. His plan was to co-rent the container with another individual in town who specializes in auto repair. Jimmy Itamba also spoke with the auto repair specialist but was unable to coordinate a meeting between our group and this individual because of scheduling conflicts.

When our project team began showing Simeon the container designs, he suggested an outside storage space for metal lengths and pieces. Simeon also requested that we place the large metal cutting tools along the long side of the container for ease of use. We showed him the concept for the expandable engine lift assembly and he preferred the idea of the assembly frame being attached and built into the roof of the container instead of a freestanding engine lift. Part of the auto repair specialist's requests, according to Jimmy, were to utilize the container itself for storage but to place the majority of the heavy equipment outside of the container for ease of use. Simeon agreed with this sentiment and suggested that we acquire a large electronic powered tire-changing machine and fix it to a concrete slab footing outside of the container.

As will all of our interviews we asked Simeon his opinion of not just the concept of a business in a container but also the physical placement of the SME Park in the corner of town. Simeon believes that, while the SME Park is relatively far from Tsumkwe central, the overall quality of the products and services will determine how successful the SME Park is. In his opinion, if the products and services are of good quality, the distance will not matter to the residents of Tsumkwe.

2. and 3. Thomas Modginda and E-Hemba, furniture makers

This interview was broken up into two parts for each individual but then complied together because these two entrepreneurs intend on co-renting the woodworking container. Thomas has been living in Tsumkwe since 1992 and currently works on making furniture for Tsumkwe and Gam. We did not receive any previous or current occupation information about E-Hemba, however it was reasonable to assume that he works in the furniture making business alongside Thomas. Thomas was interested in renting the container for a 2-year period.

Thomas said that if he had the container he would use it to build beds, chairs, and tables. He had his own access to a supply of lumber in Tsumkwe. E-Hemba suggested that we include clamps measuring equipment and some other small hand tools along with the container. Thomas thought that our concept, equipment lists and workflow ideas seemed viable. Both individuals were interested in the idea and were not at all concerned with the distance from town.

4. Veronica, hair braider

Veronica has been living in Tsumkwe for the past two years and her specialization is braiding hair. Currently women in town buy the braids in Grootfontein and then bring them to her so that she can braid their hair. She expressed interest in renting the container, possibly in conjunction with another hair stylist in the community for a 1 to 2 year period.

For this interview we sat down with Veronica outside her home and created a technical sketch of one of the template container drawings that we had in mind. This drawing was then imported into SolidWorks and can be seen in Appendix K. The major design elements of this container were the large mirror with 2 large salon chairs along the long wall of the container. These chairs will serve as the main work area of the container. In addition to the mirrors and fixed salon chairs, Veronica requested at least 2 interior hair-washing sinks along the back wall of the container. Veronica also requested that we include at least 4 chairs for a waiting area for customers as she estimates she has about 75 clients a week and needs to have adequate space for her appointments. In terms of other pieces of furniture, Veronica noted the need for a small cosmetics counter and possible a small fridge to sell cold non-alcoholic drinks to her customers. She also asked about the possibility of adding a small clothing repair station into the container possibly with a sewing machine.

We finished the interview by asking if she had any concerns about the container itself or the location of the SME Park. Veronica liked the idea of putting the business in a container but was unsure of the real size and dimensions of the container. She also noted that the distance from the center of town would not be a problem for her customers.

5. Wendy, Nyae Nyae Conservancy Tsumkwe branch manager

Wendy runs the local Nyae Nyae conservancy branch in Tsumkwe. She is not a local entrepreneur, but the interview was nevertheless insightful and a good opportunity to brainstorm our ideas with another NGO representative. This interview did not follow the interview protocol developed for the other entrepreneurs. Instead we focused more on the concept of the containerized SME Park and the Tsumkwe Energy Project as a whole and its potential effect on the local San population.

The first question that Wendy asked us was about the viability and purpose of the Tsumkwe Energy Project. As a representative of the Nyae Nyae conversancy, Wendy is far more concerned about development projects that deal exclusively with the local San population. Projects regarding the other ethnic groups in Tsumkwe are of far less concern to Wendy. In her opinion, the end result of the Tsumkwe Energy Projects is simply adding another financial cost in the form of electricity to the already impoverished San population within and around Tsumkwe. Jimmy Itamba explained to Wendy that the overall purpose of the Tsumkwe Energy Project is to expand the capacity and improve the condition of the Tsumkwe electrical supply. He also explained that this project is designed to help all of the residents of Tsumkwe by providing access to stable, sustainable electricity as an alternative to the grossly inefficient and unsustainable diesel generator system already in place.

We also went through the potential list of businesses and services with Wendy and she remarked that the bank idea was viable and interesting. She insisted that we should talk to First National Bank. She also questioned the potential supply of meat for the butcher shop, as it is her belief that the majority of the cattle in the settlement would be relocated or consumed within the next few weeks. She also noted that some of our other businesses might not be feasible due to a lack of demand based on the relatively limited consumer base of 1,100 San adults migrating around the settlement and 400 residents within Tsumkwe. In her opinion, this relatively small consumer base may not sustain these kinds of operations.

6. Jimmy Itamba, the DRFN Tsumkwe Energy Project Field Facilitator who is interested in running the butchery business

While there are butchers that offer meat in Tsumkwe, the current process is unsanitary and informal. Jimmy Itamba has experience with butchering as his mother has run her own butcher shop out of her home in Grootfontein for a number of years. Therefore Mr. Itamba is interested in renting out the butcher shop container to start his own butchering operation. As a result of our interview, we learned that the butchers in town often hand weigh the various pieces of meat and sell at high prices relative to what the people of Tsumkwe can afford and to the prices in Grootfontein. Mr. Itamba wants to establish his butchery as a clean, safe place to find good meat at good prices.

To change our initial design into a full functioning shop, Mr. Itamba rearranged the equipment on the inside as displayed in Appendix K. We also integrated foldable-segmented tables into the walls of the container so that the user can create a customized workspace. The tables also fold away into the wall for more storage space. Mr. Itamba requested that we install a sausage extruder as he sees real opportunity in the availability of sausages. This extruder would be an attachment of the meat band saw.

Mr. Itamba also recommended various structural modifications to the container itself. The most important recommendation was to line the floors and halfway up the walls with ceramic tiles for easy cleanup and a more professional look. In an effort to make the container business more attractive, Mr. Itamba recommended the use of screen doors on the exterior to keep the flies away, a refrigerated display case right in the front of the container, and the possible addition of a small refrigerator for cold drinks. Mr. Itamba's complete concept of this butchery is to act not only as a place to get different cuts of meat, but also to get different spices for cooking, and as time goes on, to stage weekly braais (barbeques). In the end his idea is to create a sustainable business that will offer real quality services to the community at affordable prices.

As we discussed the concept of the SME Park as a whole, Mr. Itamba also offered a number of recommendations for how best to implement management services for the Park as a whole. Mr. Itamba recommended making the maintenance and fair operating condition of the equipment in the container the responsibility of the renters themselves. This change in liability would allow us to consider different equipment installation methods. If implemented according to Mr. Itamba's recommendations we wouldn't have to worry about bolting everything down for security purposes. Whatever organization is created to manage the overall operation of the Park could then count on the renters themselves to act in the best possible interest in the Park as a whole. In addition to the renter contract recommendations, Mr. Itamba also wanted us to consider creating a superstructure roof and flooring that would house all of the containers, providing heat shielding, access to hot water, and possible extra energy from added solar panels to all of the containers in the Park. The addition of such a structure, in Mr. Itamba's mind, would serve to create a better overall environment for the Park as well as make it more attractive to customers.

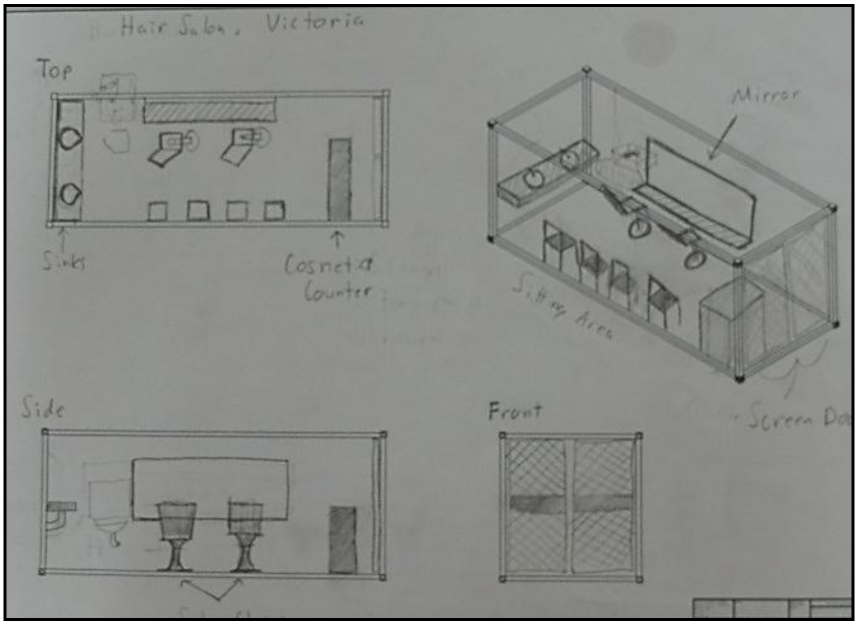
7. Rosa, shebeen owner and caterer

Prior to our presentation visit, we had removed the service kitchen concept from our business list. Rosa, the woman that owns and manages the shebeen behind the DRFN Tsumkwe project house, however, expressed interest in managing a food service container. Rosa has been living in Tsumkwe since 1997 and has been operating a shebeen and a catering business since the Savanna II, a local shop, closed down.

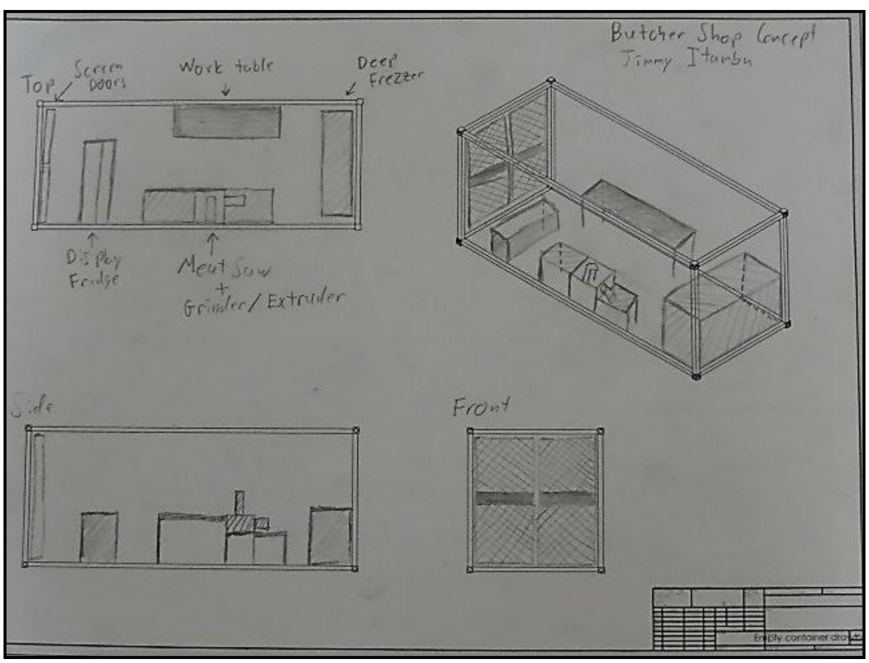
Rosa wants her business to exist as a combination café, take away restaurant, and catering business. She requested that we work to make her container face outwards towards the road so as to invite customers in to get a cup of coffee or a quick lunch, as well as include seating and dining area in front of the container. Rosa sees her business as supporting the SME Park staff as well as Tsumkwe residents. In terms of the overall management structure of SME Park, Rosa believes that a fair and consistent monthly payment plan should be established to ensure the best possible operation of the containerized businesses. Rosa also liked the idea of having a superstructure-roofing scheme to create better environment for her customers.

To design this business, we followed the same pattern as we did with Veronica with the hair salon. We first asked Rosa about the vital pieces of equipment for her to run her business and then worked out an orientation and an overall business concept. The design that we developed with Rosa is displayed in Appendix K. The design includes a deep freezer, a gas oven and stovetop, a large worktable, and cabinet space for her utensils and dishes. We also included a service counter and discussed the options for making a sales counter cutout of the side of the container. In terms of equipment, Rosa wanted us to include a deep fryer, a French fry cutting machine, an electric kettle for making coffee and tea, and a microwave. Lastly, Rosa saw no issue with running the business relatively farther away from the center of town.

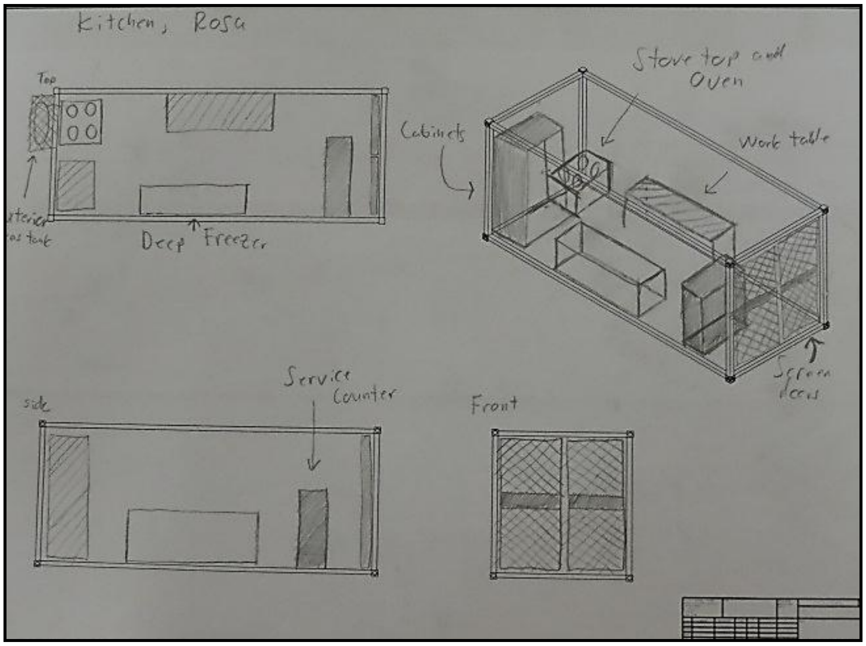
Appendix K Hand Drawings by Tsumkwe Entrepreneurs during Presentation Visit



Above: Hair salon drawing done by Victoria



Above: Butchery drawing done by Jimmy Itamba

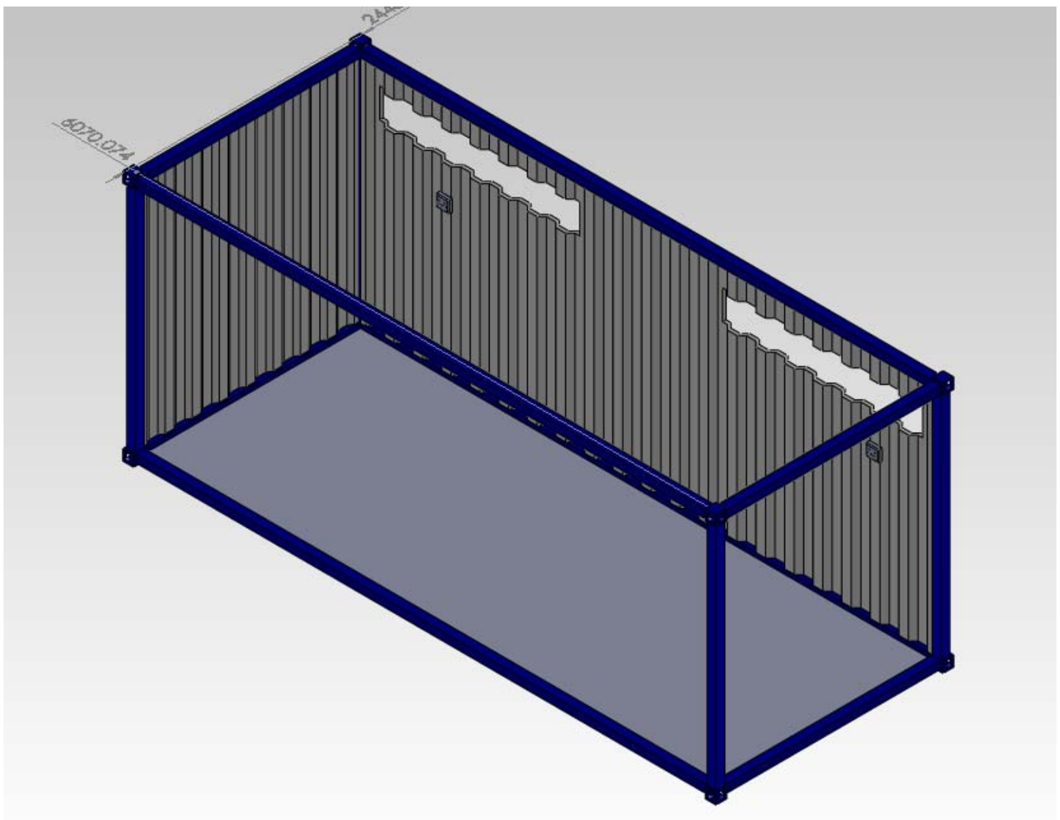


Above: Kitchen drawing done by Rosa

Appendix L Cost Estimate Inquiry Letter to Shipping Container Suppliers

Dear _________________________-

We are students from Worcester Polytechnic Institute (WPI) of Massachusetts working on a capacity building project in rural settlements for the Desert Research Foundation of Namibia (DRFN), a non-profit NGO focused on sustainable development in Namibia, a country in Southern Africa. We wish to obtain total cost estimates for the following pre-fabricated container designs, including purchasing the used or new container. Below are the three designs we have in mind. Could you please provide cost estimates for each structural modification we have listed? We are only interested in 6m ISO containers.



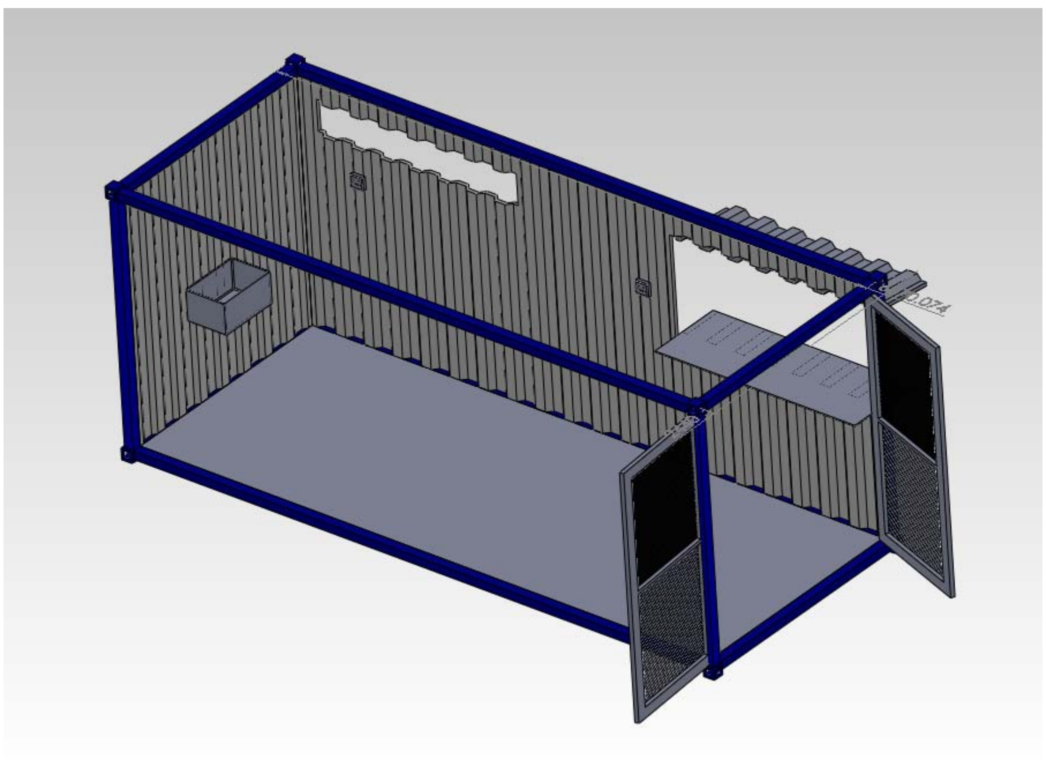
This container has minimal structural modifications and was coined as a "general purpose" container. Like every other container, there is a pitched roof with some sort of hinging system for easier adjustments. The only other modifications are small raised windows. The measurements we have calculated are provided in the attached Picture 1 as a rough estimate.

Structural modifications we would like to get pricing for:

1) Heat reflective paint on every exterior surface

2) 30º adjustable pitch roof (corrugated iron)
    a. Adjustable legs on outside of container which lock into exterior wall at different heights
    b. Hinging system at leg and roof joints
3) 3x aluminum frame and glass windows
    a. Per window price if available
4) Distribution board with power outlets at corners.
5) Area lights (CFL) – two on container ceiling.
6) Screen doors (installed behind container doors)

As stated above, we would like to receive pricing on these modifications because similar ideas are used for the following container designs. Below we will list only new structural modifications per container; however the drawings indicate additional structural modifications from above. Please include the above modifications as well if calculating a total, overall price for each container picture provided. Thank you.

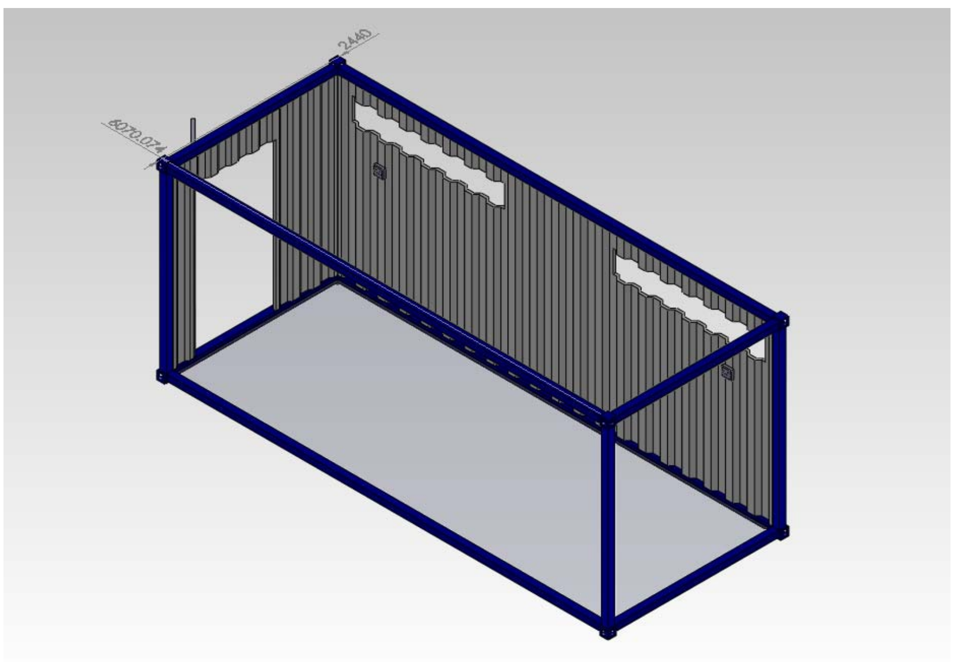


This container mimics the container in picture 1, however there is a large counter/shade area cut into one 6m side. This container is coined the “butchery” container because the counter area allows for interaction with customers. The picture attached should provide sufficient detail into the orientation of the counter/shade area.

Structural modifications we would like to get pricing for:

1) Small section of 6m side cut into two lengths
    a. Hinged and adjustable counter and shade space cut into side (90 º brackets)
        i. Including a support system
        ii. Method to lock pieces of wall back together when not in use.
2) Linoleum floors (not in drawing)
    a. Continues up the wall about .75m
3) Ceramic tile floors (instead of linoleum)
    a. Also continues up the wall about .75m

Please include the above modifications for both pictures 1 and 2 if calculating a total, overall price. Thank you.



This container also mimics the container from picture 1, however there is a large square hole cut into the end opposite the container doors. This is the only difference between picture 3 and 1, and we would like to request pricing on the following:

1) Large hinged opening on side opposite door

    versus

2) A container with doors on both sides

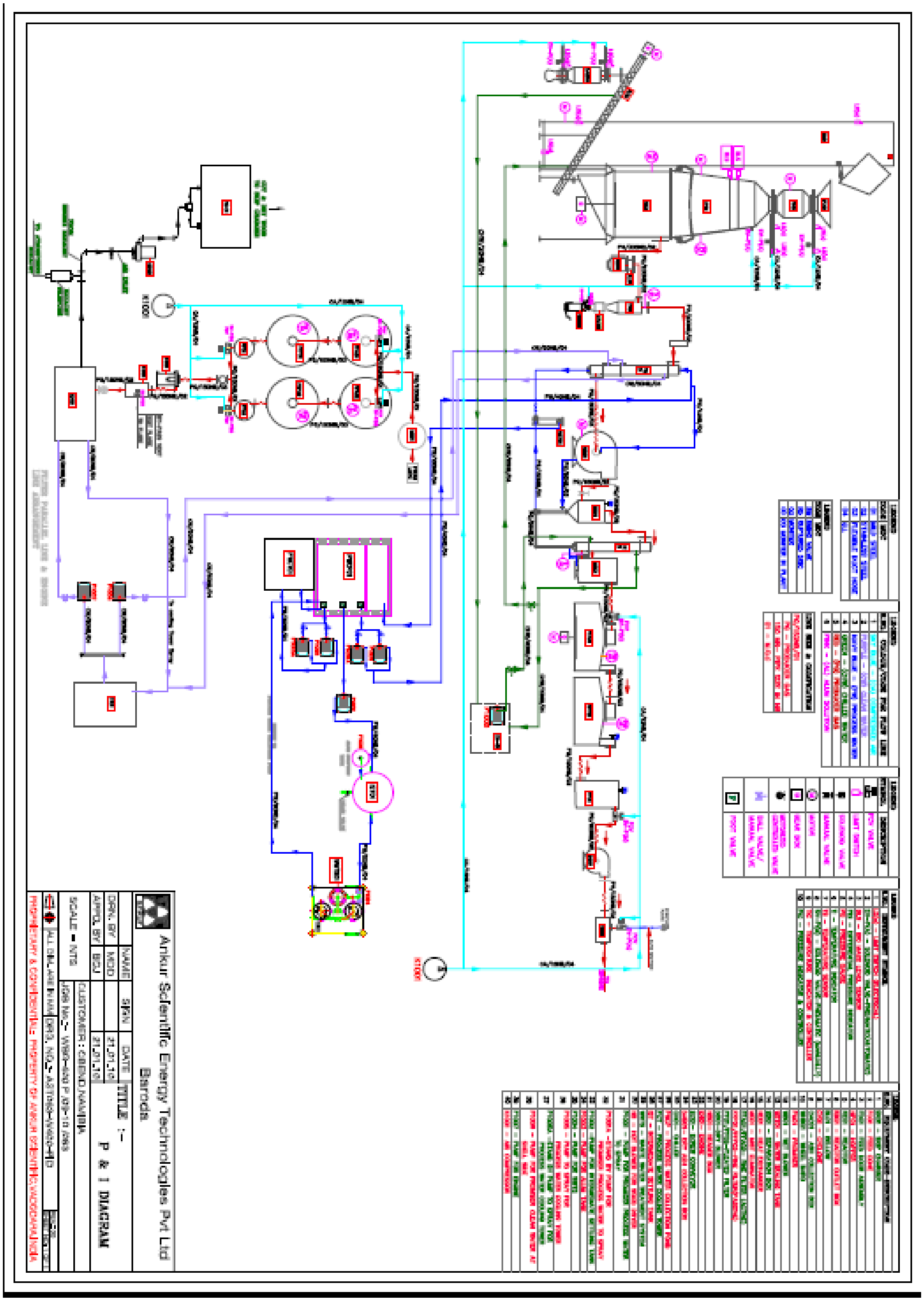
Please include the above modifications for both pictures 1 and 3 if calculating a total, overall price.

We appreciate your assistance in providing cost estimates for each container design above. Please use the 6m ISO container length for any cost estimates you provide to us.

Thank you,

Andrew Baker
Richard Brown
Robert Morlath
Zhixin Wang

Appendix M CBEND Pilot Plant P&I Diagram



Appendix N Gasification Supplier Contact Information Master List

Supplier	*Place of Origin*	*Website*	*Contact Person*	*Email*	*Phone*	*Fax*	*Address*
3i		http://www.3ialternativepower.com/tak.htm		Info@3iAlternativePower.com			
Advanced Alternative Energy Corporation				lbj@cjnetworks.com			
AESI (Alternative Energy Solutions International) Inc	Wichita, KS, USA	http://www.aesintl.net/contact		info@aesintl.net	316-201-4143	316-201-6223	316 S Laura Street, Wichita, KS 67211
AEW, Associated Engineering Works	India			aewgamini@rediffmail.com			
ALL Power Labs / GEK Gasifier	Berkeley, CA, USA	http://www.gekgasifier.com/contact		gek@allpowerlabs.org	510-845-1500	510-550-2837	1010 Murray Street, Berkeley, CA 94710
Ankur Scientific Energy Technologies (P) Ltd	Gujarat, India	http://www.ankurscientific.com/contact.htm		ascent@ankurscientific.com / info@ankurscientific.com /	91-265-2793098 / 2794021	91-265-2794042	Near Old Sama Jakat Naka, Sama Road, Baroda-390008, Gujarat, India
Aruna Electrical Works (P) Ltd	Tamil Nadu, India	http://www.arunaelectricalworks.com/biomass/ContactUs.aspx		arunabiomass@rediffmail.com / sadhavan@arunaelectricalworks.com / ankur.energy@smn.sprintrpg.e	0413-2699484-85 / 2699546 // 91-9940255967	0413 - 2699547	Rampakkam post, Villupuram District - 605 105, Tamil Nadu, India

				ms.vsnl.net.in			
Associated Physics of America	Monroe, LA	http://www.associatedphysics.com/Company.html		information@AssociatedPhysics.com	662-453-3379		1651 Louisville Ave, Suite 121, Monroe, LA, 71201
Babcock Volund	Denmark	http://www.volund.dk/contact		hnc@volund.dk	+45 76 14 34 00	+45 76 14 36 00	Falkevej 2,DK-6705 Esbjerg Ø, Denmark
Biomass CHP Ltd	Northern Ireland	http://www.biomasschp.co.uk/internal.php?page=contact					19 Point Street, LARNE, Co. Antrim, Northern Ireland, BT40 1HY
Biosolutions USA, INC				bstwalley@yahoo.com			
BTG biomass technology group BV	Enschede, The Netherlands	http://www.btgworld.com	Harrie Knoef	knoef@btgworld.com	+31 53 4861180		P.O. Box 217, 7500 AE Enschede, The Netherlands
Camp Lejeune Energy from Wood (CLEW)				purvis.carol@epa.gov (jgc@rtiorg)			
Canadian Gasifier Ltd.	Manitoba, Canada	http://www.cangas.ca/		info@cangas.ca	204 726-1851		Site 150, Box 20, RR 1, Station Main, Brandon, Manitoba, Canada, R74 5Y1
Carbo Consult	Johannesburg, South Africa	http://www.carboconsult.com/contact.asp		info@carboconsult.com	+27 11 314 1354		P.O. Box 1397, Cramerview 2060 Johannesburg, South Africa
Chanderpur Works Pvt. Ltd.	India	http://www.chanderpur.com/enquiry.ht		info@chanderpur.com	(91)-(1732)-203460	(91)-(1732)-203463	Jorian, Delhi Road, Yamuna Nagar - 135 001,

		ml					Haryana (India)
Community Power Corporation	Littleton, CO	http://www.gocpc.com/contact/index.html		inquiry@gocpc.com	1 303-933-3135	(303) 933-1497	8110 Shaffer Parkway, Littleton, CO 80127
Consolidated Power Projects	Windhoek, Namibia		Bernard Werilowitz	concopowerproj@yahoo.com	+264 061 254239		
Crorey Alternative Fuels	Beverly Hills, MI	http://www.croreyrenewable.com/contact.html	Mark Crorey	mark.crorey@att.net	(248)203-1096		Crorey Biomass Gasifier Systems, 31120 Sheridan Drive, Beverly Hills, MI 48025
Dall Energy	Hørsholm, Denmark	http://www.dallenergy.com/Biomass+Gasification+Plants.12.aspx		info@dallenergy.com	45 2987 2222		Venlighedsvej 2, DK-2790 Hørsholm, Denmark
Davy-Kress	Harare, Zimbabwe		David Mjumira	davy-kress@zol.co.zw	+263 912 54 4404		
Diesel-Electric (Pty) Ltd	Windhoek, Namibia	http://www.denam.co.za	Dassie Swarts / Klaus Felsner	cswarts@denam.com.na / kfelsner@denam.com.na	+264 061 23 4001		P.O. Box 2197 Windhoek Namibia
Diversified Energy		http://www.diversified-energy.com/index.cfm?s_webAction=contactUs	info@diversified-energy.com				
Earth Systems Pty Ltd (Gasification Australia)	Victoria, Australia	http://www.earthsystems.com.au	Dr John Sanderson	john.sanderson@earthsystems.com.au	+61 3 9205 9519		Suite 507, 1 Princess St, Kew, Victoria, Australia, 3101

Energreen Power Ltd	Chennai, TN, India	http://gasifiers.bioenergylists.org/gasdoc/Energreen/energreen.html	T R Krisnaswamy	energreenpower@lycos.com / venusengineers@eth.net	91(44)24321339		#2, 3rd Street, Nandanam Extension, Chennai, TN, India - 600 035.
Enertech				slurrycarb@enertech.com			
Guascor Power	South Africa	http://www.guascorpower.com/donde_estamos.php		mdelatorre@guascor.com			
Husk Power Systems	India	http://www.huskpowersystems.com/contact_us.php		info@huskpowersystems.com			
Innovative Energy Incorporated	Missouri, USA		Jim Neumeier	jneumeier@innovativeenergyinc.com	+001 636 600 1230x3365		
JRJ Creations CC	Rehoboth, Namibia		Jonathon R. Classen	j.claasen@hotmail.com	+264 062 52 3095		3712 Rehoboth Namibia
Klean Industries	Canada	http://www.kleanindustries.com/s/ContactUs.asp?ReportID=127930			1.604.637.9609		Suite #903, 1495 Richards St., Vancouver, BC, Canada, V6Z 3E3
LL Biofuel Namibia (Pty) Ltd	Windhoek, Namibia		Kombadayedu Kapwanga	kk@sakawe.com	+264 061 386100		P O Box 3498 Windhoek, Namibia
Martezo Energie	Poitiers, France	http://www.martezo.fr/GB/plangb.html		martezo@martezo.fr	(33) 05 49 37 02 03		237, route de Paris B.P. 419 86010 POITIERS cedex FRANCE
Mothermik GmbH	Pfalzfeld	http://www.mothermik.de/p		info@mothermik.de	49 (0) 6746/80		Mothermik GmbH, Industriestr. 3, 56

		rod-1holzver.html			03-0		291 Pfalzfeld
NETPRO Renewable Energy (I) Pvt. Ltd.	Bangalore, India	http://www.netprorenewable.com/NETPRO/contact_us.html		netpro@netprorenewable.com	91-80-41328160		No.4, 2nd Floor, Above Amanath Cooperative Bank , 4th Main, KHM Block, R.T.Nagar Main Road, Bangalore 560032, India
New Range Power		http://www.biotenpower.com/contact-us.html	Neal	Neal@NewRangePower.com	1270275-9164		
Phoenix Energy	San Francisco, CA	http://www.phoenixenergy.net/contact.html		info@phoenixenergy.net	415.671.9300		1800 Scott Street, San Francisco, CA 94115
Planet Green Solutions	Fairfield, Florida	http://www.planetgreensolutions.com/index-5.html#			(352) 351-5783		PO BOX 507, FAIRFIELD, FLORIDA 32634 USA
Primenergy LLC	Tulsa, Oklahoma	http://www.primenergy.com/contact/			(918) 835-1011		PO Box 581742, Tulsa, Oklahoma 74158
PRM Energy Systems	Hot Springs, Arkansas	http://www.prmenergy.com/our-technology/applications/		inquiries@prmenergy.com	(501) 767-2100		504 Windamere Terrace, Hot Springs, Arkansas, USA, 71913
Radhe Energy	Rajkot	http://www.radheenergy.com/contact.htm		info@radheenergy.com	91-2827-287888		Plot No: 2621 / 2622, Road No. -D/2, Gate No. 1, Lodhika G.I.D.C., Metoda, Kalavad Road, Rajkot.
Renewable	Moody,	http://www.re		dgamblesr@aol.	205-		PO Box 159,

Energy Systems	AL	s-gasification.net/		com	910-5141		Moody, AL 35004
Schaffer & Associates International, L.L.C.	Louisiana, USA	http://www.schafferglobalgroup.com	Robert D. Miller	gcontini@fcscaffer.com	+001 225 343 9262		1020 Florida Boulevard Baton Rouge, Louisiana 70802
SolTec cc	Windhoek, Namibia	http://www.soltect.com.na	Heinrich Steuber	h.steuber@soltec.com.na	+264 061 235646		51 Marconi St - Southern Industria - Windhoek, P.O.Box 315 - Windhoek - Namibia
Stwalley Engineering (Division of Paradocs Enterprises, Inc.)							
Tau Advisory Associates	Bowie, MD		Darin Hickman	dhickman@tauadvisory.com	+001 301 576 4437		
Thermogenics, Inc	Albuquerque, New Mexico	http://www.thermogenics.com/more_info.html		thermogenics@thermogenics.com	505-463-8422		7100-F Second Street NW, Albuquerque, New Mexico 87107 USA
Thompson Spaven	London	http://www.thompsonspaven.com/acatalog/contactus.html		info@thompsonspaven.com	44(0)20 7223 9917		THOMPSON SPAVEN (Engineers), 44 BATTERSEA BUSINESS CENTRE, LAVENDER HILL, LONDON, SW11 5QL
XYLOWA	Belgium	http://www.x		info@xylowatt.			rue Thomas

TT sa		ylowatt.com/MainContactsEN.htm		com			Bonehill, 30, B-6030 Charleroi, Belgium
Zero Point Clean Tech	London, UK	http://www.zeropointcleantech.com/contact	David Pitt	pitt@zeropointcleantech.com			PO Box 706, Potsdam, NY 13676

Appendix O Word Cloud Representation of Report