Energy Efficient Barbecue
-A Minor Field Study in Namibia

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This study has been carried out within the framework of the Minor Field Studies Scholarship Programme, MFS, which is funded by the Swedish International Development Cooperation Agency, Sida.

The MFS Scholarship Programme offers Swedish university students an opportunity to carry out two months’ field work, usually the student’s final degree project, in a country in Africa, Asia or Latin America. The results of the work are presented in an MFS report which is also the student’s Master of Science Thesis. Minor Field Studies are primarily conducted within subject areas of importance from a development perspective and in a country where Swedish international cooperation is ongoing.

The main purpose of the MFS Programme is to enhance Swedish university students’ knowledge and understanding of these countries and their problems and opportunities. MFS should provide the student with initial experience of conditions in such a country. The overall goals are to widen the Swedish human resources cadre for engagement in international development cooperation as well as to promote scientific exchange between universities, research institutes and similar authorities as well as NGOs in developing countries and in Sweden.

The International Office at KTH the Royal Institute of Technology, Stockholm, Sweden, administers the MFS Programme within engineering and applied natural sciences.

Åsa Andersson  
Programme Officer  
MFS Programme, KTH International Office
SAMMANFATTNING

Detta examensarbete på 30 hp har utförts i samarbete med Creative Entrepreneurs Solutions (CES), en icke vinstdrivande organisation baserad i Ondangwa i norra Namibia. Marie Johansson, grundare av CES, hade identifierat ett behov av energieffektiva grillar för öppna marknaden då den huvudsakliga energikällan ved utgör en stor del av utgifterna för de som säljer tillagad mat på marknaden. Syftet med projektet har därför varit att ta fram ett koncept för att minska vedkonsumtionen.

För att förstå problemet och de förutsättningar som gäller i Namibia utfördes en två månader lång fältstudie. Användarinvolvering har varit en viktig del under arbetets gång och därför har intervjuer och observationer utförda på marknaden i Ondangwa och närliggande städer utgjort en stor del av informationsinhämtandet. För att vidga vyerna har även andra metoder för matlagning än just grillning undersöks både hemma hos privatpersoner och på marknader. Under fältstudien undersökes även olika material, möjliga tillverkningsmetoder och distributionssätt för det tilltänkta konceptet.

Under fältstudien uppdagades att det var vanligt att använda två eldar för att kunna både grilla och laga mat i kastrull. Ved utgör cirka 18% av kostnaden för matlagning under en dag och den genomsnittliga vinsten vid försäljning av grillat kött är N$ 13 per dag. Av resultaten från fältstudien togs sedan en kravspecifikation fram varpå ett koncept utvecklades där grillning och matlagning i kastrull kan ske med en och samma eld.

Av konceptet byggdes sedan en prototyp som demonstrerades på öppna marknaden i Ondangwa för att ge de tilltänkta användarna möjlighet att kommentera konceptet och komma med idéer på möjliga förbättringar. Efter en utvärdering byggdes och testades sedan en ny prototyp i Sverige. Då konceptet kombinerar grillning och matlagning med en och samma eld kan den mängd ved som behövs reduceras med circa 30% vilket innebär att försäljarna sparar cirka N$ 8 per dag.
This master thesis of 30 hp has been performed in collaboration with the non-profit organization Creative Entrepreneurs Solution (CES) based in Ondangwa in northern Namibia. Marie Johansson, the initiator of CES had identified a need for more energy efficient barbecues at the open markets in Namibia since firewood constitutes a large cost for the actors selling food at the market. The aim of this project has therefore been to develop a concept that decreases the firewood consumption.

To get further understanding of the conditions that apply in Namibia, a field study was performed during two months. User involvement has been an important part during the project, interviews and observations were therefore conducted at open markets in Ondangwa and neighboring cities. To widen the perspectives the whole process of cooking at markets and in homes was studied. Also aspects like material and manufacturing methods were examined along with possible ways of distribution.

The most important finding during the field study was that it is common to use two or more fires at the same time to be able to both barbecue and cook in pots. Firewood constitutes 18% of the total cost for barbecuing and cooking food at the open market and the vendors have an average profit of N$ 13 per day for selling barbecued meat. The findings from the field study resulted in a specification of requirements and thereafter a concept combining cooking and barbecuing was developed.

The concept was demonstrated at the open market in Ondangwa to let the users give their opinion on the concept and to get ideas of what refinements could be made. Some adjustments were made and a second prototype was built and tested in Sweden. Since the concept combines both cooking and barbecuing only one fire is needed which reduces the firewood consumption with approximately 30% meaning the vendors at the open market would save N$ 8 per day.
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<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>CES</td>
<td>Creative Entrepreneurs Solutions</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon Monoxide</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>ECTS</td>
<td>European Credit Transfer System</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
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<td>IDE</td>
<td>International Development Enterprises</td>
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<tr>
<td>KTH</td>
<td>Royal Institute of Technology, Kungliga Tekniska Högskolan</td>
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<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
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<tr>
<td>MFS</td>
<td>Minor Field Studies</td>
</tr>
<tr>
<td>N$</td>
<td>Namibian Dollar, NAD, (N$ 1 $\approx$ 1 SEK)</td>
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<tr>
<td>NGO</td>
<td>Non-Governmental Organization</td>
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<tr>
<td>PAH</td>
<td>Polycyclic Aromatic Hydrocarbons</td>
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<tr>
<td>PIEp</td>
<td>Product Innovation Engineering program</td>
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<tr>
<td>QFD</td>
<td>Quality Function Deployment</td>
</tr>
<tr>
<td>SEK</td>
<td>Swedish Krona</td>
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<tr>
<td>Sida</td>
<td>Swedish International Development Cooperation Agency</td>
</tr>
<tr>
<td>SLV</td>
<td>Swedish National Food Administration, Livsmedelsverket</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>US$</td>
<td>United States Dollar (US$ 1 $\approx$ 7 SEK)</td>
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<td>WHO</td>
<td>World Health Organization</td>
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This Master Thesis, corresponding to 30 hp/ECTS, has been carried out in collaboration with Creative Entrepreneurs Solution in Namibia. The purpose was to investigate how to diminish the consumption of firewood while cooking food. The project is based on a field study carried out in Namibia during two months in 2010. The result is presented in this report written by Emma Lindberg and Lisa Wärmegård, students at The Royal Institute of Technology, KTH, in Stockholm, Sweden.

This section will give an introduction to the project. First background including facts about Namibia and previous work is presented followed by a problem description, aims, objectives and limitations. Also the time frame of the project will be discussed.

1.1 Background

This project was initiated by Marie Johansson at Creative Entrepreneurs Solution (CES) in Ondangwa, situated in the northern part of Namibia, since a need for more efficient barbecues at the open markets had been identified. Marie has been working with regional development in northern Namibia for the last 8 years. She has good knowledge of the current situation in Namibia regarding the culture and people’s needs. CES, founded in 2007, specializes in helping Namibians to start up small businesses.

1.1.1 Namibia

The Republic of Namibia is situated in the southern part of Africa, by the Atlantic Ocean. It borders on South Africa in the south, Angola and Zambia on the north and Botswana on the east, see Figure 1.

Namibia used to be a part of South Africa but claimed independence in 1990 during the War of Independence. The Swedish government paid an important part during the liberation process between 1966 and 1990. They helped to organize secret meetings, form the Namibian state and helped founding the Bank of Namibia, Pettersson (2008). Over the years Swedish organizations like Sida have performed aid work and established trade exchange with Namibia.

Namibia has an area of 825.400 km², which is about two times larger than Sweden, and a population of 2.1 million people, Faktaresor (2010). The country is one of the most sparsely populated countries in the world. The majority of the population lives in Windhoek or villages and small towns in the northern part. According to CIA World Factbook the official language is English but still a numerous other languages like German, Africaans and Oshiwambo are spoken. The illiteracy of the population over 15 years old was 15% in 2001. Most of the young people speak English and all schools in Namibia use English as principal language from young age.
Namibia has one of the most stable economies in Africa. The Gross Domestic Product (GDP) was US$ 9.4 billion in 2009 (South Africa: US$ 286.0 billion and Sweden: US$ 406.1 billion), Worldbank (2010). According to CIA World Factbook (2010) the unemployment rate was 51.2% in 2008 and 55.8% of the population had an income below the poverty line meaning they survive on less than US$ 2 per day. In the north most people can supply themselves, the soil is fertile and a lot of people grow their own food, Verlinden (2005). Farming and agriculture is the main income sources for many families in the north. In the southern part many people are dependent on governmental subsidence for their livelihood.

Summer is warm, up to 40°C, and periods of heavy rain causing flooding is common in the northern part of Namibia. During winter (April – September) rainfall is very rare and the temperature can reach below freezing point at night, Weather Ondangwa (2010).

1.1.2 Previous work

In 2009 three master theses were carried out in Namibia; Project Sunbaker, by Kjellström and Voyce (2009), Energy supply in Namibia, by Bjurselius and Ernow (2009), and Development of Innovative Small Scale Electrification Concepts, by Berglund and Björklund (2009).

During these projects contacts were established between KTH and Creative Entrepreneurs Solutions. According to the Department of Machine Design at KTH, this project constitutes an important part of maintaining the collaboration, Lars Hagman (2010).

1.1.3 Problem description

Open markets are common meeting places and people from the villages in Namibia travel far to trade and sell their goods at the markets. The open markets have an area where food is prepared and sold.

According to Kojwang (2000) firewood is one of the most commonly used energy sources while cooking food in Namibia this also applies at the open markets. However the number of trees is reduced every year due to over consumption and firewood is becoming a scarce commodity. Kojwang also points out that it is common to use the whole tree including the root system; this causes deforestation and desertification. Large amounts of wood are cut down illegally in Angola and sold in Namibia to be used as firewood for cooking according to Kojwang (2000).

Since firewood has become a scarcity it constitutes a significant cost for households and small business using firewood. The vendors at the open markets are highly dependent on their income and every dollar counts. Except increasing the price of food sold, reducing firewood consumption is the only parameter that can be modified to increase the profit, Marie Johansson (2010).

Another aspect of using firewood is that the smoke affects the health negatively. Being exposed to smoke during a long period of time can cause asthma, cancer and cardiovascular diseases, Länsstyrelsen Södermanlands län (2010). However most of the people does not know about these side effects and does not reflect over the fact that diseases can be caused by factors in their surroundings, such as smoke. It is therefore also important to decrease the amount of smoke released while cooking and barbecuing. In developing countries, where burning firewood indoor is common, the World Health Organization has estimated that 1.6 million deaths per year are caused by the smoke emissions from burning wood, WHO (2004).

1.1.4 Aims, objectives and limitations

The aim of this project was to reduce the amount of firewood used while barbecuing at the open markets. However, to broaden the perspective and keep an open mind the whole procedure of cooking food has been examined.
The goal for this project was to develop a conceptual solution and verify it at the open market. To enable further work and development of the product, suggestions of improvements were made after the testing phase.

To be able to develop a prototype fulfilling the users demands a field study has been carried out. The possibility to start a local production with local artisans using materials that are available in the area was also examined during the field study.

A basic economic calculation has been made to establish an approximate price for the concept. This to make sure that the target group will be able to afford the final product.

The studied area has been limited to Ondangwa and neighboring cities.

1.1.5 Planning

The project has been divided into three phases; preliminary study, field study and final stage, see Figure 2. A more detailed schedule is presented in Appendix 1.

![Figure 2. Workflow of the project.](image)

The preliminary study was carried out in Sweden and consisted of literature studies to get basic knowledge of Namibia. Also different methods for cooking and barbecuing were studied and a few barbecues that appeared to be of special interest were examined further.

After the preliminary study a field study was carried out over a period of two month. To be able to manage unforeseen incidents during the field study a rolling wave plan was applied, Tonnquist (2008). The plan made in advance was covering the first five weeks in Namibia. The remaining time was planned according to what the project required at the time. During the first weeks of the field study different open markets were visited and interviews were made. Thereafter an idea- and concept-generating phase was performed followed by a concept evaluation phase. A concept was developed, a prototype was built and tested at the open market.

The final stage took place in Sweden. During this phase the prototype was evaluated and enhanced. Thereafter a new improved concept was developed. The report was finished during the final stage and the project was also presented at KTH.
1.2 Actors involved in the project

This section gives a brief presentation of the organizations involved in the project.

1.2.1 Sida

“Sida works according to directives of the Swedish Parliament and Government to reduce poverty in the world. The overall goal of Swedish development cooperation is to contribute to making it possible for poor people to improve their living conditions.” Sida (2010).

Sweden does no longer provide any financial development assistance to Namibia. Today’s cooperation between Sweden and Namibia is based on other collaborations such as partnerships in trade and investment, institutional cooperation and the civil society, called participant cooperation. Sida’s target is to maintain the existing relations without financial aid contributions. In the future Sida will focus on developing cooperation regarding environment, economic development, democracy and human rights in Namibia, Sida (2010).

1.2.2 Minor Field Study (MFS)

Sida provides the Minor Field Study (MFS) scholarship, intended for students at universities in order to gather information for their Bachelor or Master Thesis. The scholarship aims to provide Swedish students with the opportunity to increase their knowledge about developing countries and development issues, MFS Sida (2010).

1.2.3 Creative Entrepreneurs Solutions (CES)

Creative Entrepreneurs Solutions is a non-profit organization based in Ondangwa in northern Namibia. The organization was founded in 2007 and is operated with founding from Sida among others. The organization collaborates with rural communities to improve entrepreneurship and environmental sustainability. They have specialized in helping women and young people to develop and promote their ideas.

CES believe that “you should dig where you stand and utilize the resources within and around you”. Their aim is to create wealth by supporting small enterprises through education, entrepreneurship training and Self Help Group formations. Since 2009 CES is a part of the Community Based Adaptation to Climate Change program formed by the United Nations (UN). In this program CES are working with communities in the north central regions of Namibia.

CES’ initiator, also the local supervisor of this project, Marie Johansson has been living in Ondangwa for eight years. She has been working together with the local community in different projects aiming to increase people’s incomes through education and thereby improve people’s living conditions, Marie Johansson (2010).

1.2.4 The Product Innovation Engineering program (PIEp)

The Product Innovation Engineering program (PIEp) is an academia-based Swedish program aimed to increase the innovation capability in Swedish universities and industrial organizations. The program started in 2007 and is now an established national network organization with nodes in some of the largest universities in Sweden. Today PIEp is working towards a new innovation climate involving knowledge, professionals, products, processes and businesses, PIEp (2010).
2 THEORETICAL FRAMEWORK

In this section an overview of innovation including the general way of describing the product development and how it can be applied in developing countries is given. Also the importance of user involvement and environmental aspects are given. Finally some theory regarding the impact fire has on human health is discussed.

2.1 Innovation

Innovation is to “achieve something new” meaning to invent a new product or a service and successfully introduce it to the market or to society, Nationalencyklopedin (1992).

2.1.1 Product development

When a product is developed a certain procedure is normally followed to make sure the end result is optimized. According to Ulrich and Eppinger (2008) the product development process can be divided into six different phases, see Figure 3. The process begins with a planning phase where thorough research, market objectives and different technologies are examined. Corporate strategy is set and when all the facts have been gathered, the mission statement of the project is formed.

![Figure 3](image)

**Figure 3.** The product development process constitutes six phases: planning, concept development, system-level design, detail design, testing and refining and finally production ramp-up.

During the second step the actual concept development starts. The needs and requirements of the target users are identified and concepts that fulfill each need are generated. To develop different concepts, normally one or a few methods for idea generation are used. The concepts are then evaluated and the most suitable concept is chosen for further refinement and testing.

The third step, system-level design, is to define every component that is needed for the concept and how the components are going to be assembled. This phase usually results in a geometric layout of the product, a functional specification of the product’s sub-system and a preliminary flow chart of the final assembly process.

During the fourth step the detail design of each component is made. This includes making a complete specification considering geometry, materials and tolerances of every unique part. Also standard components that are going to be purchased from other suppliers are listed. Special tools needed for manufacturing the components are designed. This phase often results in drawings of every component and a process plan for fabrication and assembly of the product.

The fifth step constitutes testing and refinement of the product. Early stage prototypes are built and tested. The first stage prototype, Alpha, is usually built using the same geometry and material properties as the final product but not necessarily fabricated according to the intended manufacturing methods. Alpha prototypes are used to determine whether the product will function according to plan and to make sure customer needs are fulfilled. After evaluating the Alpha prototype a second stage, Beta, prototype is built. This prototype contains all the
components that are going to be used in the final product but the assembly methods might not be the intentional. The Beta prototype is usually tested internally by a number of selected customers in the intended use environment. The goal with the Beta prototype is to determine whether the performance and reliability is good enough or if changes needs to be made.

The final stage is production ramp-up where the product is produced using actual production methods. In this phase the work force is trained and any possible obstacles in the production process is sorted out. These products are sometimes supplied to preferred customers and carefully evaluated before the final product is launched. The six stages of product development are shown in Figure 3.

Other types of product development processes are parallel development and the Stage-gate Innovation process. In parallel development two or more product features are developed simultaneously using the same starting point, see Figure 4.

![Parallel Development Diagram](image)

**Figure 4. Principal scheme of parallel development.**

This is common in software development when detected defects need to be corrected and new product features are developed using the same base code. The results are then merged into the following release. By using this method, many features can be upgraded fast and the product can be custom made. However, if the merging is poorly planned, problems like tracking earlier versions and non-working features might occur, Cooper (2004).

One of the most commonly used product development processes is the Stage-Gate Innovation process developed by Dr. Robert G. Cooper. This process resembles the process described by Ulrich and Eppinger but contains five steps (stage 1-5) that each needs to be passed and approved by the management (gate 1-5) before continuing to the next step, Stage-Gate® (2010). This process is illustrated in Figure 5.

![Stage-Gate Diagram](image)

**Figure 5. Stage-Gate innovation process, Cooper (1994).**

In the article *Make your New Product Process Agile & Adaptable with ‘Spiral Development’* from 2008 Cooper recommends an improved version of his process called Spiral Development, where iterations with customers are made after each stage. Cooper describes the process as a set of “build- and- test, then seek feedback- and revise” that is particularly useful in the early stages of product development where fast feedback from customers is desirable. Cooper further states that this process allows “smart- and- fast failures” since the process is relatively inexpensive. The first few spirals often results in negative response, the design team then rebuilds and tests again until the target group is satisfied, Cooper (2008).

By implementing a structured process, like the Stage-Gate process, Cooper claims that the product development process becomes faster, reduces the amount of re-work and has a higher success rate than an unstructured process. However one of the main issues with a structured process is that too much organization might affect the creativity negatively, Cooper (2008).
2.1.2 Aspects to consider regarding product development

When developing a product an important step is to identify who the customers are. According to Ullman (2003) the most important users are normally the consumers who are going to buy the product. Wickens (2003) refers to this group as the primary user. However there are other important groups of users that need to be considered, like the production customer handling the manufacturing and assembly process, Ullman (2003). This group is often referred to as secondary customers, Wickens (2003). Ullman (2003) also gives an example of other groups that should be taken into consideration during the design process such as people handling the transport, sales personnel and service personnel. When the customers have been identified the next step is to determine what needs and requirement’s the different groups of customers have.

According to Ullman (2003), consumers require a product that functions properly, is long lasting, easy to maintain and have an attractive design. The secondary user, customers handling the production, wants the product to be easy to produce meaning standard components and standardized manufacturing methods should be used. To achieve this, the raw material and tools needed should be easily accessed. It is also important to apply lean production meaning minimizing the waste of material and lowering the cost of material. For the sales- and marketing group it is important that the product meets consumers requirements, is easy to package, transport and store, Ullman (2003).

Ullman states that the design process is an iterative process, meaning the design can change many times during the development process. Ulrich & Eppinger (2008) claims that the prototyping phase is normally the most time consuming and expensive phase. The authors however point out that it is important to make prototypes to ensure the product and manufacturing methods will function. According to Ullman (2003) it is more expensive to make changes late in the design process than in early stages, it is therefore important to involve customers in an early stage and get feedback to achieve an optimized and desirable product.

2.1.3 Design quality

Ullman (2003) states that effectiveness of the design process can be measured by three parameters: product cost, quality and time to market. Ullman claims that the actual cost of design normally constitutes a small part of the manufacturing cost for a product. However the effect of a qualitative design usually affects the manufacturing cost a lot. By considering materials and efficient manufacturing methods in the early design process the total cost for manufacturing can be reduced considerably. Ullman states: “The decisions made during the design process have great effect on the cost of a product but cost very little”. The perceived quality of a product is highly dependent on the design process. Ullman quotes: ”Quality cannot be manufactured into a product unless it is designed into it”. The design process also affects the time needed for producing a new product. By spending more time on the first stages described above; planning and concept development, fewer changes needs to be made during the prototyping and testing phases. This saves both time and money.

According to Ullman, American consumers find that the two most important aspects to define quality of a product are function and lifetime. The life of a product is determined in the design phase. The design affects the whole process from cradle to the grave, including stages as; production, choose of material, distributions, usage phase and end of life; that is waste and reuse. For a product to be long lasting chose of material, construction and manufacturing methods becomes important. Since the 1980’s the knowledge of how products impact the environment has increased both among companies and the general public. This has forced designers to consider their products entire life cycle, hence designing for disassembling and reuse has become important, Ullman (2003).
2.1.4 Product development for developing countries

“The majority of the world’s designers focus all their efforts on developing products and services exclusively for the richest 10 percent of the world’s customers. Nothing less than a revolution in design is needed to reach the other 90 percent”, Paul Polak (2007).

This statement gives an image of how most enterprises look at product development and their clients today but according to Görnerup (2009) the perspectives can be changed. In the report *Innovations for the base of the pyramid*⁠¹ he states that many products originally developed for developing countries also becomes successful in the industrialized countries. Görnerup further claims that low price products do not necessarily bring the company a low income margin.

According to Görnerup (2010) some parts of Africa are starting to influence the world economy since the social development and economic growth has stabilized and made investments in infrastructure and education possible. Namibia is no exception, according to the CIA World Factbook (2010) Namibia’s GDP was -0.8% in 2009 compared to Sweden’s GDP of -5.1% the same year. Görnerup (2009) states that the needs for new products and services are constantly increasing along with the growing market when people are getting wealthier. This however leads to environmental challenges. The development of new products must be closely linked to the economic growth which in turn finances the efforts of developing environmental friendly products and will lead to new innovations, Görnerup (2009).

In the book *Design Revolution* the author Emily Pilloton (2009) writes “Where there is a need, there is a market, and where there is a market, there are consumers”. But on the other hand she states that just because something is selling it does not mean that it is addressing a human need. Görnerup (2009) declares that in some cases the target group is not aware that they have a need for a certain product. As an example he points out that people without access to purified water might not be aware of the health risks contaminated water brings. Education is therefore important when new products are distributed, Görnerup (2010).

Pilloton (2009) claims that people’s needs should be the primary reason for product development to achieve maximum social impact and long-term usability. In the process of product development there are some questions that have to be answered, such as; “What is the problem and how can it be approached?” and “What is the most basic need the design can serve?”

Dr. Paul Polak (2010) and his non-profit organization, International Development Enterprises, claim that the right approach is to treat every single user as a customer regardless social status. The customers, not the companies, should be the ones to decide whether the product offered have a value for them. “Only when we listen to the men and women we work with do we discover what they need in order to increase their incomes.” IDE (2010).

According to Görnerup (2009) one of the biggest obstacles in developing countries is that the market is dominated by only one or a few companies. This leads to increasing prices but also decreases the company’s willingness to develop products or services according to customer’s needs and requirements. Görnerup (2009) points out that an open and free market with many actors stimulates entrepreneurship and innovation and thereby will use the country’s resources more efficiently.

According to Görnerup (2009) companies claim that one of the most common obstacles while launching a new product on the market in a developing country is that the product is considered to be too expensive. However all of the companies in Görnerup’s study are using existing products or services that they try to adapt to the new market. Not any of the companies had developed a product or service especially designed for developing countries. Görnerup recommends foreign companies to collaborate with local actors and entrepreneurs to obtain a sustainable economic development.

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¹ Which he refers to as the poorest people in the rural societies.


2.1.5 User involvement

The traditional way to look at the process of product development is that the user has a need which product developers and manufacturers identify and fill by designing new products.

Eric von Hippel (2005) states that by involving the user into the developing process a more efficient process and better end result is usually obtained. “Users may innovate if and as they want something that is not available on the market and are able and willing to pay for its development” von Hippel (2005).

According to Wickens (2003) there are four different approaches to involve the user into the design and product development process:

- “Early focus on the user and tasks.”
- “Empirical measurement using questionnaires, usability studies and usage studies focusing on quantitative performance data.”
- “Iterative design using prototypes, where rapid changes are made to the interface design.”
- “Participatory design where users are directly involved as part of the design team.”

When defining the target group it is important to create a complete description of the potential user population. Wickens identifies some important characteristics that are usually included like; age, gender, education level or reading ability, physical size, physical abilities and task relevant skills. If an already existing product or system is being studied, the characteristics can be determined by reviewing the existing population of users, Wickens (2003).

A product developer has to understand the needs of the user, von Hippel (2005). Cooper (2008) states that it is important to visit the customer in their work environment to better understand their unspoken needs, problems and the attributes needed in the new product. Von Hippel (2005) continues, if the developed product does not fulfill the needs, it will not be used the intended way, or may not be used at all. To understand the user properly, interviews can be made. The interviews should however be combined with other types of methods, like observations, to give a reliable result, von Hippel (2005).

When involving users into an experiment or survey there is always a risk that the participants feel insecure since their performance is being evaluated. The participants might fear that they are not performing good enough, Wickens (2003).

By using prototypes the concept can be tested on the target group and evaluated at an early stage. This way the product developers can confirm that they have identified the actual problem and that the concept is solving the problem. They can also get feedback on usability and the participants can help the design team with new ideas, Wickens (2003).

Robert G. Cooper claims that the customers and users do not know what they want until they see it. He therefore states that prototypes that users can respond to are an important part of the product development process. Cooper (2008) further states that this will result in a better and more innovative product that is more likely to please the customer.

However Hernon and McClure (1994) argues that the process of making prototypes usually is associated with high cost.
2.1.6 Sustainable innovation

All products do to some extent cause an impact on the environment. Some products affect the environment most during the manufacturing phase, some during the usage phase and some products after the service life have expired and the product is considered to be waste, Dalhammar (2007).

In an article written by Luttropp and Lagerstedt in 2005, the authors state that one of the big obstacles in creating environmentally friendly products is that companies in a long term perspective puts the demands of the markets ahead of focusing on environmental issues. Further on, the authors claim that most people do want products to be sustainable, however very few are prepared to pay extra for products with an outspoken environmental profile, Luttropp and Lagerstedt (2005). Dalhammar (2007) emphasizes the importance of good design and points out that the environmental impacts in the different life cycle stages are determined by the product design.

To assist product developers in the development process towards sustainable products Luttropp has developed a tool, called the Ten Golden Rules, containing ten general guidelines that should be followed:

- Do not use toxic substances and arrange closed loops for necessary but toxic ones.
- Minimize energy and resource consumption in production and transport.
- Minimize energy and resource consumption in the usage phase, especially for products with most significant environmental aspects in the usage phase.
- Promote repair and upgrade, especially for system dependent products.
- Promote long life, especially for products with most significant environmental impact after the usage phase.
- Use structural features and high quality materials to minimize weight without interfering with necessary flexibility, impact strength or functional priorities.
- Use materials, surface treatments or structural arrangements that protect the products from dirt, corrosion and wear.
- Prearrange upgrading, repair and recycling through access ability, labeling, modules, breaking points and manuals.
- Promote upgrading, repair and recycling by using few, simple, recycled, not blended materials and no alloys.
- Use as few joining elements as possible and use screws, adhesives, welding, snap fits for geometric.

Luttropp and Lagerstedt (2005) also states that: “In less developed parts of the world, prosperity is very much linked to enhanced functionality of transport, sufficient food and clean water.” He means that these factors must be considered in the creation of sustainable products and that sustainable performance of products is crucial regardless of what market the product is intended for.

\[\text{During an interview the author further explains that the described phenomenon is global and particularly applies for people in developing countries. Luttropp claims that people in industrial countries are not willing to pay more for a product just because it is more environmentally friendly, however they do expect their neighbors to do so. People in developing countries tend to buy products that indicates status regardless the products environmental impact. He exemplifies that people in China saves up money to buy a car, since it signals status, instead of improving their living conditions.}\]
2.2 Fire theory

The open fire has had great importance in human society for a long time. Until a hundred years ago people in the west used climate neutral fuel, like firewood, for cooking and as a source of heat. In developing countries the open fire still has a very important role in the society both socially and as an energy source, Johansson, B. (2007). During the rain period it is common to make fires indoors to be able to cook. However the hydrocarbons that are released along with the smoke when firewood is burning affect people’s health negatively. When people are making fires indoors, often without chimney, the smoke gets encapsulated and the health is effected even more, Johansson (2007).

To achieve a sufficient combustion with low emissions and little smoke, the following three components are needed; time, temperature and turbulence. It is more difficult to obtain sufficient combustion in a small fireplace with large pieces of firewood than in a large combustion chamber with small pieces of firewood, Johannson (2007).

Smith (2008) describes combustion as:

\[
\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{heat.} \quad (1)
\]

When the combustion is insufficient, the carbon is not completely combusted into CO\(_2\). Small toxic particles, CO and other carcinogenic gases are released, Smith (2008). Also Polycyclic Aromatic Hydrocarbons (PAH) are released along with the smoke. Some of these dense hydrocarbons are condensed to soot particles, which mean that these particles enlarge the risk of cancer in large dozes or frequent exposure, Länsstyrelsen Södermanlands län (2010).

The Swedish National Food Administration (2010) also advises not to barbecue meat over open fire because of the release of toxic gases. They recommend that the meat should be barbecued over embers.

It is almost impossible to obtain an adequate combustion from one single piece of wood. All of the emitted heat radiates out to the surroundings and the temperature thereby becomes too low to keep the fire burning. If two or more pieces of wood are used, heat is exchanged in between the pieces, which stabilizes the fire, Johansson (2007).
In this chapter the procedure of how this master thesis has been performed is presented along with the methods used. The section describes how the information has been gathered, analyzed and summarized. Thereafter the methods used to develop and evaluate the concept is presented.

### 3.1 Method introduction

The workflow of the project has been an iterative process that started off by defining the problem. Figure 6 shows the structure of how the information needed to define the problem has been gathered.

![Diagram](image.png)

**Figure 6.** The method used to gather information and form a concept.

### 3.2 Defining the problem

When a project is initiated the first step is to define the problem. This is an important stage since the problem description directs the entire development process. What the client or customer defines as the problem might not always be the actual problem. To make sure the problem is correctly defined, different methods can be used; for example creating storyboards, Stappers et al. (2005) or using personas, Wickens (2003). These methods aim to make sure the whole process is examined and no factors that might affect the problem description are overlooked. To identify the problem information has been gathered using a funnelling method, see Figure 6. The task given by Marie Johansson was to design an energy efficient barbecue, the process however started off by looking at the whole procedure of cooking and the effects of burning firewood. The process was then narrowed down by observing and interviewing users of existing systems at the open markets.
3.2.1 Literature study

According to Wickens (2003) a literature study can often substitute an experiment. By reviewing findings made by other researcher’s questions, that otherwise would need an experiment, can be answered. Wickens also recommends one particular form of literature study, the meta-analysis. This method uses statistical data collected through a large amount of experiments examining a common independent variable. The data is compared and evaluated and conclusions with high reliability can be drawn.

The theory of this project is based on literature, scientific articles, governmental websites and other references achieved at the Internet. Denscombe (2007) believe that documentary research is an easy and inexpensive way to access permanent sources of data; vast amounts of information can be found in articles, books or on web pages.

One of the disadvantages to take into consideration is that the credibility of a source always has to be evaluated. Also the information gathered from written sources often has been produced for other purposes than the current subject.

Denscombe (2007) emphasizes the importance of evaluating the validity of documentary sources, since this is something that cannot be taken for granted. He gives some guidelines of how to ensure the validity of written sources:

- Journals that has existed for a long time is in general more trustworthy than new ones.
- The articles from a journal published by a professional association can be considered more credible than other articles.
- Books published by university press offers some confidence about the academic quality.
- University or government web sites might add some credibility to the source.
- Private web pages should be viewed with caution.

In the beginning of this project web pages and books was read to obtain information about Namibia where the project would be implemented. Since three related projects were carried out previous year, the reports of those projects were read to get further knowledge of what to expect in Namibia, what to do and what not to redo. In addition different methods of barbecuing and theory about what impact fire and smoke has on human beings were studied.

Once the field study had been accomplished a more thorough literature study was made to confirm the thesis that formed the basis of the developed concept. A number of scientific articles and governmental web sites were studied.

3.2.2 Market research

To get further knowledge of existing products and solutions a market research was performed. Efficient barbecue solutions discovered during the literature study were investigated further at a visit in a retail store. Also observations of different cooking areas in northern Namibia was made.

In order to increase the understanding of how products can be locally produced in Namibia the authors got involved in a project run by Marie Johansson at CES. The project, EzyStove, aimed to manufacture and distribute an energy efficient stove developed by the Swedish company Ergonomidesign (2010). The authors helped to interpret and explain the blueprints to a local artisan and supervised the manufacturing process.
3.3 Field study

A field study is conducted to obtain a better understanding of; the problem itself, the target users, the environmental aspects and the interaction between user-system or user-product. A field study is usually carried out in the field where the product or system is used. Denscombe (2007) states: “The sites to be included in the research are deliberately selected by the researcher for what they can contribute to in the research”. The sites should be chosen to allow comparison and contrast with previous sites. That way emerging concepts can be tested to verify the developing theory as the research continues, Denscombe (2007).

A difficulty while performing a field study is that it is hard to estimate the outset in advance. It can also be difficult to plan exactly what sites are going to be included and the amount of data needed to verify the result of the field study.” It is only when the new data seems to confirm the analysis rather than add anything new that the sampling ceases and the sample size is “enough”, Denscombe (2007).

A reference group of women working at the open market in Ondangwa had been put together by Marie Johansson in collaboration with Meme Kaino Shikokola. Meme Kaino is one of the more successful and social women at the open market in Ondangwa, she was therefore trusted to choose the people to be included in the reference group. The reference group consisted of seven women all selling food at the open market. Six of the women were barbecuing meat at a barbecuing area and one person works in a kiosk selling food that is boiled, fried or deep-fried. The people in the reference group has an age of 30 to 50 years and they all live in Ondangwa or neighboring villages. Due to the cultural differences and the language barrier, Meme Kaino also helped interpreting both verbal- and body language. The group participated in interviews and was observed several times while performing their daily work tasks.

To widen the perspectives, open markets in neighboring cities were visited. The aim was to determine whether the open markets in the area resembled each other or not. This to make sure the product is suitable for more than one open market.

Ulrich and Eppinger (2008) states that in a product development project where an existing product is developed further it is important to know how the customer uses the product and what they think about it. According to Denscombe (2007) this can be achieved by for example written surveys, interviews, focus groups and observations.

Ulrich and Eppinger (2008) do not recommend written surveys for gathering raw data. They mean that this method generally is ineffective in revealing unanticipated needs. Ulrich and Eppinger further recommends that interviews should be the primary data collection method since they are less costly (per hour) than focus groups and because an interview often allows the product development team to experience the use environment of the product. Wickens (2003) on the other hand states that observations often are more valuable than interviews and focus groups since what people say does not always match how people behave and act in a certain situation.

To validate the findings in this project the researchers used triangulation and mixed methods, Denscombe (2007). If the mixed methods produce data that are more or less the same, the findings can be assumed as reliable.

3.3.1 Observations

Wickens (2003) describes observations as a method used to reveal important details about customer’s needs. This method have the advantage not only relying on what is said but what is done. Observations can either be completely passive, without any interaction from the observer, or participating, which means that the observer participate side by side with the customer. In participating observations the researcher gets to experience how the product is used in its use environment, Wickens (2003). Ulrich and Eppinger (2008) claims that this method is ideal to observe the product when it is used in its actual use environment.
When planning an observational study the researcher identifies the variables to be measured, the methods to be used and the equipment needed to document the study. The time frame for each observation and the surrounding conditions are also determined, Wickens (2003).

During observations of systems the user is asked to perform a task in the environment where the task is normally accomplished. Otherwise simulated situations can be used, Wickens (2003). He also states that the goal with an observational study is “to get representative samples of behavior, this is more easily accomplished by sampling over different days and during different conditions.”, Wickens (2003).

The observations in this project were mostly passive, the researchers observed the cooking procedures at the open markets and in a few homes during two weeks time.

### 3.3.2 Interviews

Denscombe (2007) claims that interviews can be structured, semi-structured or unstructured. Structured interviews is a quantitative method where a predetermined questionnaire containing predefined questions set at certain order are used during the interview. The results of a series of structured interviews are easily comparable. Denscombe also describes that a disadvantage of using a predetermined questionnaire is that it does not allow follow-up questions from the researcher. It is also important that the person formulating the questionnaire is familiar with the subject to ensure that the “right questions” are asked.

According to Kvale (1996) semi-structured interviews is a qualitative method where a sequence of pre-determined questions is used. The semi-structured interview has an openness to change the sequence and questions in order to follow up the answers given. An advantage of this method is that the interviewer can direct the interview towards new findings. A disadvantage of the semi-structured interview is that the answers are not as easy to compare as the answers given by a structured interview, Kvale (1996).

In unstructured interviews, the interviewee sets the agenda and has considerable control of the progression of the interview, Corbin (2003). The researcher focuses on listening and can enhance the data collection process by asking questions. The benefit of using this method is that when the interviewee speaks freely a wider range of information can be obtained. A disadvantage is that the focus of the interview can take an unwanted direction, Corbin (2003).

People in Namibia are still to some extent influenced by the apartheid regime, Johansson (2010). They are used to answer what they believe is the “right answer” instead of their true opinion. Johansson further states that this facts makes unstructured interviews formulated as small talk the best method to gather information.

The interviewees were women working at the open market. Also people working at Town Council in Ondangwa were interviewed. During the interviews at the open market a local interpreter was used, this made it possible to understand the Oshiwambo speaking women at the open market. The presence of the interpreter increased the womens trust towards the researchers. The interpreter also helped to explain cultural differences and nuances to the researchers.

### 3.3.3 Documenting

According to Denscombe (2007) there are four main methods used to document information gathered while involving users; audio recording, hand-written notes, video recording and still photography. Each method has its benefits; it is easier to get the information verbatim if the interview or observation has been recorded. On the other hand, hand-written notes followed by photographing is more discrete.

The interviewees in this project are not used to video- and audio-recorders, this kind of equipment might steal the attention and move focus from what is important. To keep focus on the interview only hand-written notes were used, complemented by some photographing made
later on. Throughout the interviews and observations careful notes was made. The results were thereafter compared and discussed to validate the inputs. In order to compare the future concept to the methods used during the observations the time it took to perform the different tasks was noted.

3.3.4 Analyzing data

According to Denscombe (2007) there are several different ways to handle raw data collected during the information gathering process. The aim of the analyze is to evaluate if the data have something in common, if any conclusions can be drawn and then used during the product development process. To make it easier to evaluate the data, categorizing or tables can be a helpful tool. There are also a number of computer software programs like Microsoft Excel that can be used to help organize the data.

Wickens (2003) mentions that all methods of collecting data has certain limitations. When existing products are used, the analysis should not be made too much in detail. Instead the analysis should focus on the user’s basic goals and needs and not exactly on how the tasks are carried out. It can also be useful to focus on evaluating the environment where the task is performed instead of the focusing on how the task itself is performed. This kind of analysis often reveals new ways of performing tasks that might not be discovered by only talking to users. Wickens also points out that it is important to complete the task analysis before starting off the product design phase.

To validate the findings from the field study, the results were compared and discussed with project members from projects carried out in the regions during the same time frame but with different objectives, Dahlin, Pålsson, Edlund and Lindén.

3.4 Concept

Once the user’s needs and requirements had been identified the concept development phase started. The findings were combined into a specification of requirements for the needs that should be fulfilled by the product. Early stage prototypes were made to visualize the ideas. Wickens recommends using paper models since it is an easy, fast and cheap way to sketch up ideas effectively and verify that the user needs are correctly defined.

3.4.1 Idea generation

There are many methods for idea-generation; brainstorming, brainwriting, turn around, six thinking hats and brainfire to mention a few. When the new concept was developed the methods brainfire and brainstorming were used. Brainfire is a method where the product development team is given a problem to solve during a certain period of time, for example two weeks. Other tasks are performed simultaneously and when the predetermined period of time has passed the team is gathered to present their ideas. Härén (2004) describes the five steps of brainfire as: 1) gather information, 2) organize the material, 3) keep information in the subconscious, 4) get ideas and 5) evaluate the ideas. Härén (2004) claims that people tend come up with new ideas while performing tasks not related to the actual idea generation process.

The method brainstorming was used later on in the project to develop new sub-solutions for a second concept. Härén (2004) describes brainstorming as a quantitative idea generation method. The goal is to create as many new ideas as possible. To achieve this it is desirable to find other than the most obvious ways to solve a given problem, Härén (2004).

3.4.2 Prototype

Once the first concept was set a 3D-model was made using the computer software Solid Edge V20. Some adjustments hade to be made along the way to make all the parts fit together. To
make sure the blueprints made in Solid Edge V20 were correct, a paper model of every part was made and thereafter fitted together.

A first stage prototype was made using the intended materials and possible manufacturing methods. Since the field study was coming to an end it was important to assure that the material and manufacturing methods were compatible. Another important aspect was to show the prototype to the end users to evaluate the concept and get feedback for further refinement.

The making of the prototype, Concept 1, started on the 27th of August in Ondangwa where the materials, metal sheets and round bars, were purchased. The paper models were used to facilitate the placement of the parts on the metal sheet to make sure no material was wasted. Markings were made on the round bars to make the cutting and welding process faster and to make sure no mistakes would be made. The prototype was put together by an artisan in Windhoek.

Back in Sweden a second prototype, Concept 2, was built by the authors.

3.4.3 Test methods

An important part of the product development process is to evaluate the concept in order to ensure that the process is heading in the right direction. Therefore the developed concept was compared to the cooking methods studied during the field study. The EzyStove developed by CES and Ergonomidesign, a three-stone stove and two versions of the developed concept were evaluated. The concepts were compared with regard to efficiency. A common way to measure efficiency for heating sources is to boil one litre of water and compare the time or energy used.

The aspects considered most important to examine in this project were; the amount of firewood used during a certain time of cooking and time until the fire is burning well enough to start barbecuing and cooking food. Also boiling time for water and cooking oil was examined.

Three different tests were carried out, all of them with firewood from mopane trees as fuel since this is the same kind of firewood that is used at the open markets in northern Namibia. The first test was carried out at Chameleon Backpackers in Windhoek on the 6th of September. During the test two sets of 250 g macaroni was cooked in 1 litre of water over the open fire, hamburgers was fried over the open fire and sausages were barbecued over the embers.

The second and third tests were carried out at the open market in Ondangwa on Thursday 9th and Friday 10th of September. The aim with these tests was to show the product and get opinions and reactions from the people at the market rather than to make them try the prototype.

When the first prototype was tested and evaluated it got clear that a number of improvements needed to be made. New features were developed and a second prototype was built and tested in Sweden.

The fourth test was performed at KTH in Stockholm, Sweden on the 16th of November. This time birch wood was used as fuel in lack of firewood from mopane trees. During the test 250 g macaroni was cooked in 1 litre of water and sausages was barbecued over the embers.

3 The women at the market are poor and highly dependent of their daily income to survive. To make them spend more money than normal on a daily basis is therefore not an option. It is thereby difficult to find a proper way to make them test a new prototype. If the prototype consumes more firewood than the current way of barbecuing, one way could be to buy all the firewood needed for the testing but that would make the women “earn” money and therefore be more positive than if they paid for the firewood themselves. If they had to pay for the extra firewood needed they could on the other hand get a more negative attitude. To get the women’s true opinion it is therefore important to find the right day of testing and the right persons to test the prototype. The persons testing the prototype must also be well informed about the aim with the testing and that it is their true opinion that is desired not what the person thinks that researcher wants to hear. The tests should also be carried out with different people not just one person. Unfortunately this was not possible with in the time frame of this project.
3.4.4 Evaluation of sub-solutions

One of the most extensive methods to evaluate concept solutions for products is Quality Function Deployment, QFD. This is a systematic method to identify customer needs, requirements, preferences and target values of the product in the product development process. The aim of the method is to obtain an optimized concept. According to Ullman (2003) this technique organizes major pieces of information needed to understand the problem. An example of a QFD-matrix is shown in Figure 7.

![QFD-matrix diagram](image)

**Figure 7. Example of QFD-matrix.**

Performing a full QFD-analysis is time-consuming but Ullman (2003) means ”Time spent here saves time later”. A completed QFD-matrix show how the product features suggested affects one another and how the product relates to existing products on the market.

A simplified version of the QFD-analysis was used to evaluate the solutions generated to solve the different sub-problems. The observed problems and corresponding sub-solutions obtained through the brainstorming were organized according to Figure 8.

![Brainstorming diagram](image)

**Figure 8. The organization of the observed sub-problems and corresponding sub-solutions in Concept 1.**
The QFD-matrix was then used to set up the observed sub-problems as requirements on the left hand side of the relationship matrix, see Figure 9. Next, the solutions were set up as product features corresponding to each requirement, see Figure 9.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Product features</th>
<th>Feature 1</th>
<th>Feature 2</th>
<th>Feature 3</th>
<th>Feature 4</th>
<th>Feature 5</th>
<th>Feature 6</th>
<th>Weighting</th>
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<tr>
<td>2</td>
<td>Requirement 2</td>
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<tr>
<td>3</td>
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</tr>
</tbody>
</table>

Figure 9. The matrix used in the simplified QFD-analysis.

The evaluation of the product features correspondence to the suggested modifications begun. Each product feature was discussed to find out if a relation regarding the ability to meet each customer requirement existed. If there was a relationship, the next step was to determine how strong that relation was. Figures or symbols can be used to plot the relevance of the relations. In this project figures were used, where 0 signified “no” relationship, 1 meant “weak” relationship, 3 represented “medium” relationship and 9 implied “strong” relationship.

Finally the importance of each refinement was set in relation to the other identified modifications. The main demand got the maximum figure and the least significant demand got the lowest figure. The figures were entered in the weighting column at the right hand side of the matrix, see Figure 9.

Then the relationship figure and the weighting number were multiplied and summarized for each product feature. The summarized number was then inserted in the “Total”-field below the relationship matrix and the QFD-matrix was analyzed. The feature with the highest sum in the “Total”-field was considered to constitute the “best” solution and was therefore chosen.
4 RESULTS

In this section results from the literature study and the information gathered through observations and interviews conducted during the field study is presented. Thereafter a sub-project, the EzyStove, is presented followed by the developed concept including test results and refinements made.

4.1 Results from the field study

During the field study a number of barbecues were studied, a sub-project named EzyStove was accomplished and visits along with observations and interviews was carried out at open markets in Ondangwa and neighboring cities.

4.1.1 Ondangwa

Ondangwa is situated in the Oshana region in northern Namibia, about 700 km north of Windhoek, see Figure 10.

![Figure 10. Ondangwa's location on the map.](image)

The city has 30,000 inhabitants and the region holds 100,000 households. The city of Ondangwa is spread out along a main road with houses and homesteads just behind the stores and local bars, shebeens, see Figure 11.

![Figure 11. Ondangwa is spread out along the main road.](image)

4.1.2 Open market in Ondangwa

In the middle of the city a market place has been constructed and was ready to be used in February 2010. The open market used to be placed along the main road near the bus station but when the Town Council decided to construct a new market place it was moved away from the road. According to Kaino Shikokola (2010), moving the market place has caused the people working there great losses of income since people passing by cannot see the market from the main road and no signs shows where the market is situated. According to Town Council the bus station will be moved next to the open market in 2011.
The open market has a few different sales areas, see Figure 12, where spices, meat, vegetables, clothes and prepared food like barbecued meat and chicken stews is sold.

**Figure 12. Schematic illustration of the open market in Ondangwa.**

The barbecue area at the open market in Ondangwa is situated at the left hand side of the entrance; see marking in Figure 12 above. This area consists of 23 barbecues of which six were used daily during the field study. The barbecue area is placed behind other buildings and is therefore hidden and difficult to find for people visiting the market. The stationary barbecues are made of bricks or concrete and has a simple design consisting of an area for barbecuing and a storage space below, see Figure 13. One of the vendors is using an oil barrel for barbecuing.

**Figure 13. The stationary barbecues at the open markets.**

Most of the food vendors supplement the barbecues with a so called three-stone stove which is a stove placed on the ground consisting of three stones forming the corners of a triangle. A pot is placed in the middle, onto the stones, and is heated by a fire underneath the pot. The three-stone stove is used to cook other types of food than barbecued meat for example traditional porridge or deep fried bread and fish, see Figure 14.
4.1.3 Open markets in the region

During the field study, five other open markets were visited and studied. These markets were located in the Oshana and Omusati regions, at a range of 130 km, north west of Ondangwa. Three of these markets were organized by the municipality and resembled the open market in Ondangwa. The other market places were, unorganized marketplaces consisting of self-built market stalls, see Figure 15.

Two of the organized market places had stationary, bricked barbecue places. At the other visited open markets no stationary barbecues were found, instead oil barrels cut in half were used for barbecuing. In a few cases, these oil barrels were modified. The modification usually consisted of removing one side of the barrel to thereby make it possible to use long pieces of firewood without having to lift the grill rack. The size of the oil barrels had sometimes been reduced, see Figure 16. It was also common that the grill racks were bent downwards to get the meat closer to the embers.
At the open markets constructed by the municipality there were small kiosks for rent. The kiosks had electricity, which made it possible to run small businesses like restaurants, hair salons or photo studios, see Figure 17.

The firewood used at the open markets is compact dark hardwood from mopane trees, most of it imported from Angola. This firewood has a high density and is difficult to ignite but will burn for a long time once lit. The firewood is sold at the market; a pack of long pieces costs N$ 20 while smaller packs of wood costs N$ 10, see figure 18. The long pieces are on average about 120 cm while the short pieces are about 70 cm and each pack of contains 5-6 pieces of firewood. Meme Kaino Shikokola at the open market in Ondangwa usually uses two large wood packages per day.
4.1.4 The EzyStove project

As a part of the field study the authors got involved in building a prototype for a CES project called the EzyStove. The EzyStove project resulted in understanding of how a manufacturing process could be implemented. The materials used were 0.8 mm steel sheets and 8 mm round bars of steel. During the manufacturing process the artisans used an angle grinder to cut out parts of steel sheet and to cut the round bars. The parts were then welded together. During the manufacturing process no protective clothes or gloves were used, however a pair of sunglasses was used while welding, see Figure 19.

![Figure 19. The cutting, assembling and the first test of the EzyStove.](image)

While building the prototype it got clear that it is very important to make products easy to manufacture and assemble. The artisans in Namibia do not have the same education as artisans in Sweden and it is common that they manufacture and assemble parts in the way they think is right even if instructions or blueprints are given.

4.1.5 Barbecues

To get knowledge of what kind of barbecues that are available in Europe and Namibia a market research was performed. Pictures of the barbecues are shown in Figure 20. Most of the barbecues sold in Sweden are run on charcoal or Liquefied Petroleum Gas (LPG). Two models were examined further during a visit at a retail store. The first one, Cobb, was according to the manufacturer very energy efficient and only required 6-9 barbecue briquettes. The second one, a vertical barbecue, Bosse Basic, was studied since it releases a small amount of toxic gases compared to for example LPG-barbecues, Testfakta (2007).
Figure 20. A few of the different barbecues found in Sweden. The vertical barbecue, Bosse Basic is shown in the upper left corner and the Cobb barbecue is shown in the upper right corner.

In Windhoek a few different barbecues, all run on wood, were found see Figure 21. All of these barbecues uses the same principle; firewood is placed in a metal container and once the embers are ready for barbecuing the meat is placed on a grill rack above the embers.

One of the barbecues was considered more advanced than the others. In this barbecue the wood is placed in a small container at the right hand side. Once the firewood burns into embers, small pieces of embers fall downwards onto a tray and can thereafter be spread out on the tray. The food is placed on a grill rack, which is placed above the embers. This makes it easy to adjust the amount of embers needed, it also makes it possible to use the barbecue for a long time since more wood can be added while barbecuing without having to lift the grill rack. This method makes it possible to keep the fire burning and barbecuing over embers at the same time.

Figure 21. Different barbecues found in Windhoek. The barbecue shown in the middle was considered more advanced than the others.
4.1.6 Observations

During the field study a number of observations were made. Some of the most important results from the observations made at the open market are listed below:

- The barbecues are used at least 13 hours per day.
- Two or more fires are often used at the same time, one for barbecuing and one for cooking in pots. The latter fire is placed on the ground; this placement is not ergonomic for the users. This also forces the users to keep focus on two fires at the same time.
- The three-stone stove can only heat one pot at a time.
- It is common that the users light the fire with cooking oil or plastic since these materials are flammable, burn for a longer time than paper and are available on site.
- The users keep the fire burning in the three-stone stoves for several minutes before the pots are placed above the fire.
- Sometimes the fire is burning besides the pot instead of underneath the pot. If the user is on the opposite side of the pot it is difficult to see where the fire is heading.
- There is no functional garbage disposal at the open markets, unwanted things are thrown on the ground and might get burned, eaten by the dogs, or used by somebody else.
- Meat is grilled over open fire instead of over embers, see figure 22. This is unhealthy since more dangerous substances are released and absorbed by the meat, see Chapter 2.2 Fire theory.

Figure 22. Meat is usually barbecued over open fire at the open markets.

- There is no counter besides the barbecues in Ondangwa. The two markets resembling the open market in Ondangwa had space behind the barbecues where tables could be placed.
- The stationary bricked barbecues in Ondangwa measures: H x W x D = 19 cm x 69 cm x 67 cm, see Figure 23, and the height from the ground, h, is 91 cm.
- The concrete barbecues in Ondangwa measures: H x W x D = 17 cm x 70 cm x 81 cm, see Figure 23, and the height from the ground, h, is 98 cm.

Figure 23. The stationary barbecue area can be described with the measurements; height, width, depth and height from ground.
While barbecuing a lot of smoke is developed. According to chapter 2.5, Fire theory, smoke can cause cardiovascular diseases.

Over the barbecue area in Ondangwa a roof is placed which encapsulates the smoke from the barbecues. At the market in Ongwediva the roofs contain a chimney which is covered by a smaller roof that directs the smoke onto the outside of the roof, see Figure 24.

Figure 24. The open market in Ongwediva has roof with a chimney placed over the barbecue area.

4.1.7 Interviews

During the field study a number of interviews were made. Early in the project the focus was primarily to figure out what the vendors are selling and how much money they earn per day. This to be able to make an approximation of a possible price range when implementing new products. The field study showed that the education level is generally very low and that the women do not understand the difference between profit and income. Some of the most important results from the interviews made at the open market in Ondangwa are listed below:

- None of the vendors knows how much the daily profit is.
- None of the women knows how many customers they have per day.
- To rent a barbecue place costs N$ 15 per month while a kiosk costs N$ 250 per month.
- The vendors usually buy the ingredients from other vendors at the market on credit in the morning and pay later in the evenings.
- All of the vendors at the open market sell more or less the same kinds of food and they all use the same price range. A piece of meat costs N$ 6 and a fat cake costs N$ 1.
- The approximated profit per day is N$ 13.
- The cost for firewood constitutes 18% of the daily expenses.

For further information, see Appendix 2.

During the field study interviews with Ondangwa Town Council were conducted. The interviews gave information about the market place and problems related to the new location of the market. The information considered to be most important is listed below:

- Ondangwa is a natural center of commerce since the city is located in a junction of two arterial roads. The Town Council serves about 200,000 people including areas nearby.
- Ondangwa got classified as a town later than the neighboring cities Ongwediva and Oshakati, although Ondangwa is much older. This has resulted in big companies moving from Ondangwa to nearby cities.
- Some of the areas at the market are currently used as storage by salesmen who used to sell their products at the market and now have moved their business elsewhere, see Figure 12. These areas are therefore not used at all; still Town Council is constructing new sales areas at the market. According to Town Council only 10% of the vendors at the market pay rent, however Town Council does not seem to force the vendors to pay either.
4.2 Defining the problem

Of all the findings from the field study four problems were chosen for further analysis. These particular problems were chosen since they were considered to be among the most important issues to solve and because the possibilities to correct these problems using small means was considered high:

- The meat is barbecued over open fire.
- The vendors use two different fires at the same time.
- The three-stone stove placed on the ground can only heat one pot at a time.
- The fire often spreads out in unwanted directions from underneath the pot.

These four problems are illustrated in Figure 25.

![Figure 25. An illustration of the four problems identified at the open market in Ondangwa.](image)

After a brainfire session aiming to find solutions for each sub-problem a specification of requirements was developed, the result is presented below:

### 4.2.1 Specification of requirements

The new solution **shall**

- Make it possible to barbecue different kinds of food.
- Make it possible to barbecue different amounts of food.
- Not consist of flammable or combustible materials.

**Desired** features:

- The solution should be able to keep the food warm without burning it.
- The solution should be able to be implemented onto the stationary barbecues.
- The solution should prevent embers from falling out risking to hurt the user.
- The solution should prevent objects close to the barbecue to ignite.
- The solution should be able to use the same firewood as today;
  - Large pieces 120 cm x 6 cm x 10 cm.
  - Small pieces 60 cm x 5 cm x 3 cm.
- The solution should not tip over if pushed.
4.3 Concept

As an attempt to reduce the wood consumption, a concept combining cooking and barbecuing was developed, see Figure 26. As described in section 2.1.2 Aspects to consider regarding product development, it is important to design the product for all possible users. The vendors at the market were identified as primary users while manufacturers were identified as secondary users. Also the people that are going to distribute the barbecues, along with the people selling and recycling the product are taken into consideration.

![Figure 26. The concept combines two activities: barbecuing and cooking.](image)

The concept consists of two main parts; a cooking area for pots and pans and a barbecuing area, see Figure 27. Firewood is placed in a combustion chamber, see figure 27.

![Figure 27. The concept consists of two main parts; a cooking area and a barbecuing area. The firewood is placed in the combustion chamber underneath the cooking area.](image)

When the wood burns into embers, it falls down through a sparse grid, onto an embers tray and can be spread out underneath the grill rack onto which food is placed, see Figure 28.

![Figure 28. Firewood is placed in the combustion chamber, embers slides downwards to the embers tray. Food can be cooked in pots on top of the combustion chamber and barbecued over the embers.](image)

By regulating the amount of embers or where the embers are placed on the embers tray, the heat intensity can be adjusted. Underneath the embers tray an ashtray is placed.
The concept is to be placed onto the stationary solutions of bricked/concrete barbecues seen at the open markets, see Figure 13. To make the concept fit at more than one market place, the width have been made adjustable. By pushing the *embers tray* into a slot, underneath the combustion chamber, the width is adjusted. The *grill rack* is resting on a *side piece* and/or onto the edge of the fixed bricked barbecue and is therefore flexible to adjustments sideways, see Figure 29.

![Exploded view of the concept](image)

**Figure 29. Exploded view of the concept.**

### 4.3.1 Prototypes and tests

To test and evaluate the concept a prototype was made using 0.8 mm metal sheets and 8 mm round bars. This prototype will further on be referred to as Concept 1. Tests were then performed and showed that once the fire is burning, it took 9 minutes (mean value) to boil 1 liter of water and 65 minutes (mean value) before the barbecuing could start. The tests showed that some improvements could be made, these are described below:

- The space between the *embers tray* and the *grill rack* was considered too big, food like sausages and meat took more than 20 minutes to cook.
- When long pieces of wood were put in the combustion chamber the wood tended to fall out toward the user.
- Since the distance between the *embers tray* and the *grill rack* is quite big the users might fall back into old habits and put firewood on the *embers tray* instead of using the combustion chamber.
- The cooking area was considered to be too high and hard to reach also the placement of the pots and pans were considered unstable.
- Pieces of burning wood tended to fall through the gaps between the round bars at the bottom of the combustion chamber. As described in Fire theory (section 2.2) barbecuing should be done over embers not open fire.
The sub-problems were categorized and analyzed to find the underlying cause for each problem. Thereafter a number of solutions to the problems were developed through brainstorming sessions carried out both in Namibia and in Sweden. To get more ideas and inputs during the brainstorming sessions conducted in Namibia student from the closely related project participated. Figure 30 shows one of the identified sub-problems, the assumed cause and corresponding solutions. The other sub-problems are described in Appendix 3.

Figure 30. One of the observed problem along with assumed cause and suggested solutions.

The evaluation of the QFD-matrix ended up in five sub-solutions described below, the QFD-matrix is found in Appendix 4:

- One of the most common commentaries during the demonstration at the open market was that the distance between the *embers tray* and *grill rack* was too big. The vendors at the open market desired that the distance should be adjustable. Discussions whether it would be more beneficial to make the *grill rack* or *embers tray* adjustable took place. The final decision was to make the *grill rack* adjustable.
- To prevent long pieces of burning firewood from falling out of the combustion chamber, risking hurting the user, an apron plate could be attached at the front of the combustion chamber.
- To prevent firewood from falling through the gaps at the base of the combustion chamber the base should be construct as a damper. This way the bottom of the combustion chamber can be closed, which would also make it easier to light the fire. When embers are starting to form the damper is opened. Embers can fall through and be distributed over the *embers tray*.
- To prevent the user from putting firewood on the *embers tray* an *apron plate* of steel should be attached at the front.
- To make the placement of pots more stable, more round bars should be attach at the top of the combustion chamber. The total height of the combustion chamber should be decreased to make the cooking more safe and accessible even for short people.
- Another important issue to handle is to make sure the users understand the purpose of the product. Education along with demonstration was therefore considered very important. A plan for how to educate the users was however not included since this project is still in the early stages of the product development process.

These sub-solutions were implemented into a second edition of the prototype, further on referred to as Concept 2, see Figure 31.
This prototype, Concept 2, has the same main functions as Concept 1. However the bottom is designed as a damper containing an upper slot and a lower slot. When firewood is to be lit the lower slot is pulled out making the damper close. Once the fire is burning the lower slot is pushed inwards making the damper open, see Figur 32. Embers can then fall through the gaps onto an embers tray.

Concept 2 also has an apron plate, see Figure 33, that will make long pieces of wood lean inwards the combustion chamber and prevent long pieces of firewood from falling out and hurting the user. The height of the combustion chamber has been reduced. Concept 2 has a total height of 250 mm compared to 340 mm the previous prototype, Concept 1. One feature that was considered important was to keep the width adjustable. The maximum width has been set to 670 mm and the depth is 628 mm. The weight has been approximated to 10.3 kg according to the computer software program Solid Edge V20. To make the placement of the pots more stable the number of round bars on top of the combustion chamber has been increased to thirteen instead of eight.
Concept 1 had an *ash tray* placed underneath the *embers tray*. The *ash tray* has been removed for Concept 2 since the field study showed that parts that are not essential for the product to function often are used for other purposes. The *ash tray* would probably be used for other purposes such as a cutting board or cover, and was therefore removed to decrease the amount of material needed, more pictures of Concept 2 are shown in Appendix 5.

The two concepts, Concept 1 and Concept 2 were tested, see Figure 34, and compared to the three-stone stove.

![Figure 34. Tests of Concept 1 and Concept 2.](image1)

Concept 1 and the three-stone stove were tested in Namibia during similar environmental conditions such as humidity. However the temperature fluctuated and different materials to ignite the fire were used. Concept 2 was tested in Sweden during winter meaning high humidity and cold temperature. The results from the tests are shown in Table 1.
Table 1. Results of observations and tests using three different cooking methods.

<table>
<thead>
<tr>
<th></th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Three-stone stove</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Chameleon backpackers, Windhoek</td>
<td>Open market, Ondangwa</td>
<td>KTH, Stockholm</td>
</tr>
<tr>
<td><strong>Ambient temperature</strong></td>
<td>25°C</td>
<td>35°C</td>
<td>0°C</td>
</tr>
<tr>
<td><strong>Total test time</strong></td>
<td>95 min</td>
<td>137 min</td>
<td>74 min</td>
</tr>
<tr>
<td><strong>Time to reach boiling point</strong></td>
<td>11 min, 7 min, 10 min</td>
<td>8 min</td>
<td>16 min, 8 min</td>
</tr>
<tr>
<td><strong>Type of liquid</strong></td>
<td>Water, 1 L</td>
<td>Cooking oil 2.25 L</td>
<td>Water, 1 L</td>
</tr>
<tr>
<td><strong>Time to achieve embers</strong></td>
<td>70 min</td>
<td>60 min</td>
<td>46 min</td>
</tr>
<tr>
<td><strong>Able to start cooking with pot</strong></td>
<td>5 min</td>
<td>--------</td>
<td>7 min</td>
</tr>
<tr>
<td><strong>Amount of wood used</strong></td>
<td>6 pieces of mopane</td>
<td>12 pieces of mopane</td>
<td>7 pieces of birch</td>
</tr>
<tr>
<td><strong>Time for each piece of wood</strong></td>
<td>16 min</td>
<td>11 min</td>
<td>11 min</td>
</tr>
</tbody>
</table>

The test results shown in Table 1 are analysed below:

- The time to reach boiling point with 2.25 liters of cooking oil is 3 minutes shorter when Concept 1 is used instead of the three-stone stove. In comparison between Concept 1 and Concept 2, the test shows that water boils in 9 minutes (mean value) using Concept 1 while Concept 2 boils the same amount of water in 16 minutes. However during the second test of Concept 2 the water was pre-heated to 60°C to simulate the conditions during the test of Concept 1 in Namibia. The water then boiled in 8 minutes.
- The time to achieve embers is about 20 minutes shorter for Concept 2 compared to Concept 1.
- The three-stone stove is the most inefficient product, among the compared, regarding wood consumption.
4.3.2 Financial aspects

During the field study observations showed that the three-stone stoves are used approximately five hours per day while the barbecues are used thirteen hours per day. The total number of cooking with fire is therefore eighteen hours. According to the interviews the vendors spend N\$ 30 per day on firewood. If Concept 2 would be used instead the vendors would save firewood enough for five hours of cooking, this way the vendors would save N\$ 8.3, see equation (2)

\[
\frac{5}{18} \cdot 30 = N\$ 8.3
\]

(2).

There are three or four stoves used daily. Concept 2 has space for using at least two pots at the same time. If the vendors collaborates and uses the same fire they would save even more money.

4.3.3 Manufacturing

The prototype for Concept 2 was manufactured using 1 mm steel sheets and 8 mm round bars. However the embers tray and grill rack are supposed to be made of expanded metal. These materials are all available at local hardware stores in Ondangwa and are commonly used in Namibia. The round bars will be cut, bent and welded together. The steel sheets will be cut, bent and then welded onto the round bar. The expanded metal will be cut. Blueprints are found in Appendix 6.

The Town Council in Ondangwa found it important to create job opportunities and to decrease transport emissions. The barbecue should therefore be produced locally. The tools needed for manufacturing Concept 2 are; a grinder, a welding machine and a sabre saw. All these tools along with protective clothing like gloves and welding helmets are available at hardware stores in Namibia. After a visit at the local hardware store, Pupkewitz Megabuild in Windhoek, Namibia the total cost for tools and equipment was approximated to N\$ 2500.

4.3.4 Material

The barbecue consists of three different types of steel; steel sheet, round bars and expanded metal. These materials were chosen since steel is easily accessible, commonly used and thereby a “known” material for artisans in Namibia. Steel is a sustainable material that resists high temperatures. The thickness of the parts made out of steel sheet was increased from 0.8 mm to 1 mm after the testing Concept 1. During tests with Concept 1 the embers tray made of 0.8 mm steel sheet started to buckle due to the heat from the embers. The new solution, Concept 2, contains two slots, onto which the firewood is placed. To prevent the slots from buckling a thicker steel sheet was chosen. Tests with Concept 2 showed no signs of buckling.

The total cost of material for one barbecue has been calculated to N\$ 215, see Table 2. This calculation is based on prices found at the hardware store Pupkewitz Megabuild in Windhoek, Namibia.
The benefits of using only one type of material, steel, are many: the recycling process is facilitated, the materials require the same condition during storage and the tools needed are few.

The negative aspects of using steel is that the material will corrode eventually. The time it takes for a material to corrode depends on the environmental aspects, the percentage of carbon mixed into the steel and the surface treatment of the material, Ashby (2005). Corrosion is accelerated during warm and humid conditions which describes the climate in northern Namibia during the summer. The service life of the concept has therefore not been determined.

4.3.5 Distribution

The goal is to manufacture the barbecues in northern Namibia. As an attempt to create job opportunities the barbecues can be manufactured by local people starting up small businesses. The start up phase when tools are bought can be financed by micro loans. The start up cost for the business includes, rent, tools, electricity, material and labor. The barbecues can then be sold to neighbouring Town Councils and distributed to the open markets. The Town Councils can make a package deal out of the fixed bricked/cemented barbecues and this new concept. To prevent theft the new barbecue can be cemented onto the existing fixed barbecues. The vendors at the open market rent a stall where the new concept is included but pay a few dollar more per month since they are expected to save money using less firewood.

The total cost for material to make one barbecue is N$ 215. The cost for tools needed have been approximated to N$ 2500. If 25 barbecues are made the cost of tools for each barbecue is N$ 100.

Then salaries and rent need to be included. The total price to makes one barbecue can be approximated to N$ 500. With a pay off time of 4 years, 48 months, this would mean the vendors need to pay N$ 10.5 per month.

If the barbecues are sold to vendors at the market and they save N$ 8 per day by using the new barbecue concept the pay off time would be 63 days.

Table 2. Calculation for the cost of material for Concept 2.

<table>
<thead>
<tr>
<th>Material</th>
<th>Steel sheet 0.8 mm</th>
<th>Round bar Ø8 mm</th>
<th>Expanded metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements (mm)</td>
<td>1225 x 2450</td>
<td>6000</td>
<td>1225 x 2450</td>
</tr>
<tr>
<td>Price (NS)</td>
<td>327</td>
<td>23</td>
<td>300</td>
</tr>
<tr>
<td>Quantity needed per barbecue</td>
<td>1/3</td>
<td>2</td>
<td>1/5</td>
</tr>
<tr>
<td>Price per barbecue (NS)</td>
<td>109</td>
<td>46</td>
<td>60</td>
</tr>
<tr>
<td>Total price per barbecue (NS)</td>
<td></td>
<td></td>
<td><strong>215</strong></td>
</tr>
</tbody>
</table>
In this section the results are discussed further, also suggestions for further work are presented.

5.1 Results

The solution is based on four problems that were considered to be among the most important. There are still a numerous of problems that needs to be taken into consideration. One of the important issues is the smoke developed while barbecuing. However this problem was considered too big and one of the solutions that seemed obvious, to rebuild the roof and install a ventilating system, was therefore not handled. Since the open market is new and the financial resources are very limited, a big reconstruction was not an option. Instead a solution that could be implemented in a reasonable time frame for a reasonable price was developed.

The concept can also be applied for domestic use and according to the local supervisor of the project, Marie Johansson, people in the catering business had shown interest for the barbecue.

The tests could have been planned more thoroughly and been more organized during the performance. In an ideal test environment, for example a laboratory, the efficiency could have been measured with more reliable results. However, at this early stage of the product development process, it was considered more important to get feedback and to see if the target users would accept the product. Also the initial goal was not even to build a prototype in Namibia, to be able to perform tests is therefore adding an additional value to the project. Another aim of showing the women the concept was to make the target group open their eyes to new ways of cooking and new types of food to sell. The women selling food at the barbecuing area in Ondangwa all sold the same kind of food. By introducing new kinds of food competition could increase along with their profit.

The test results from the EzyStove might be affected by the users ability to light the fire since only hardwood and no flammable materials for lightening the fire was available. The test of Concept 2 performed in Sweden differed a lot from the tests performed in Namibia. The ambient temperature was about 30°C lower and the humidity was remarkably higher. Birch wood was used instead of mopane wood, the birch was easier to ignite and burned faster than the mopane. To be able to compare the amount of firewood used during the tests a standardized measurement has been developed where a mopane log was used as reference.

In addition to decrease the firewood consumption the focus during the field study was put on teaching the women to calculate profit related to their business. This gave us knowledge about the average level of education which was further confirmed when we were asked where we learned how to use a measuring tape. This awareness was very helpful during the product development process since it forced us to make a product that would be easy to understand, use and manufacture. During the EzyStove project this was confirmed once more.

One of the disadvantages of this concept compared to the barbecues used today is that it probably takes longer before enough embers are formed for barbecuing compared to using an open fire. The tests showed that it takes about an hour using Concept 1 and Concept 2. On the other hand pots can be put onto the cooking area once the fire is lit. The vendors at the open market can then start by cooking in pots and use the barbecue once the embers are ready.

Early in the project it got clear that the people still are affected by the apartheim regime. Many people still find it hard to trust white people and expects them to either provide them with aid or to rule and dominate the society. To earn the peoples trust and get information that is trustworthy it was important to get to know the target group. Focus was therefore put on manking few and thorough interviews rather than many and unsubstantiated.
5.2 Recommendations for further work

Even though the concept has been developed further than planned, there are still many aspects that needs to be processed. In a near horizon further technical development and testing of the prototype needs to be made. The efficiency needs to be confirmed also users needs to be involved in the testing. Materials with regard to sustainability and the manufacturing needs more attention. In the long term a business plan and an education plan, both for manufacturers and users, needs to be developed.

During the field study we discovered that the organized open markets had been planned and built without consulting an architect. This got clear when one of the concrete fences at the open market in Ondangwa suddenly fell down since the concrete was not reinforced. The fence had to be constructed all over again. Also the planning of the market had shortcomings. Some areas were hidden behind houses and some areas and houses was not used at all. The Town Council had not made a sufficient market research before planning the market. These kind of issues turned out to be common even at the other organized market places visited. A suggestion for further work in Namibia is therefore to help the Town Councils to make a plan for how to construct the future open markets.

5.2.1 Creativity

Observations made in the northern part of Namibia during this project shows that one major thing missing is creativity among the people, both children and adults. The school system is poor and the children do not get sufficient education since no creative subjects such as art or music are implemented in the public schools. Neither is information of critical thinking or analyzing different alternatives given. Children are not encouraged to ask questions at home or in school and if they do they are believed to be “naughty”. There seems to be a lack of innovation ability. Observations and interviews at the market showed that all the ladies at the market are selling the same products, for example, no one has even tried to sell sausage instead of meat. Another problem is that small businesses usually are run as family businesses. When hiring new staff the family always has to be considered, if any of the relatives need a job the family member is hired although the person might not be suitable for the job. No one seems to understand that if you hire a person that is suitable for the job, the business is going to generate more money and that money can be brought home to the family.

To get Namibia’s economy to function, the government needs to understand that the solution needs to come from inside the country, from the people, and start supporting entrepreneurs and businesses. A climate for creative businesses and businesses generating money needs to be supported. To be able to start developing products and solutions people need to be creative and to have the knowledge how to even think “outside the box” in “new solutions”.

The creative thinking needs to start at young age and it is therefore our recommendation that a project focusing on creativity in schools is started. Classes that encourage the students to start solving problems themselves should be held. It is important to teach the children to think outside the box, something most of them does not know how to do today. There are a number of different exercises that could be tried out. A classic way to start the creative thinking is to give the students a certain amount of materials like paper, tape and scissors to build a certain thing (a bridge, a house and etcetera). Afterwards the students discuss why they used a certain way and analyze the other students result. Once the discussion is finished, new materials can be used to complete the same task or tools can be added or removed. Thereafter a new discussion will be held.

Another task could be to have the students make a certain box of paper. The students would be given paper, tape, scissors, a ruler and a paper box. It would be interesting to see if any of the students would dissemble the box to see how it is made.
In this section the authors summarizes their own reflections of the results achieved in this project.

- The identified problems in Chapter 4.2, Defining the problem, have been included in the concept and made the solution more beneficial than the cooking methods used today.
- With this solution the vendors can save N$ 8 per day. The pay off time is 63 days given that the price is N$ 500. During the field study one of the conclusions was that Namibians do not plan ahead or save money. Two months is therefore a long time to save up money but since this solution is to be distributed by the Town Council the vendors will not have to save up money. The amount they save on firewood will be used to pay off the barbecue. After 63 days the vendors will increase their profit with N$ 8 per day.
- The barbecue could probably generate more money both for the vendors at the market and the people manufacturing the product. The material would probably be cheaper if larger quantities were bought, thereby the income could be increased or the sales price could be reduced. If the vendors at the market would cooperate and share the barbecues instead of using one each they could save even more money since less firewood would be needed.
- The aim was to develop a concept to reduce firewood consumption however we developed two prototypes and got time to evaluate these with regard to other methods for cooking food. Hence the project was taken further than planned and is therefore considered successful.
- The theory regarding the impact fire and smoke has on humans formed the base to fully understand the problem and gave good arguments to why the current method for barbecuing needs to be improved.
- One of the obstacles was to determine the service life of the materials. However it got clear early in the project that steel was one of the materials likely to be used.
- When performing a project in a developing country it is extremely important to involve the user early in the project. The cultural differences and values require a flexible working process and an open mind.
- It is also important to explain the aim of the product and the project and to make sure the user understand what the benefits are for them in person, by for example financial gain.
- The way the people live is strongly related to the culture, the community cannot be developed too fast. This is important to consider when new products are implemented; the product needs to be related to existing products or systems. The homestead we were staying in had a gas stove but still the family was cooking food over open fire.
- During the field study it got clear that the education level in Namibia is inadequate. One of the things that was revealed during the manufacturing of the EzyStove was that the local artisans in Ondangwa found it difficult to understand blueprints and visualized ideas. Education is therefore important during manufacturing process. To build a prototype of Concept 1 was very valuable since the concept could be tested and verified by feedback given by the target group at the open market.
- The education level also limits the number of materials and the manufacturing processes that can be used in rural areas in northern Namibia.
- One of the lessons learned during this project is that the whole project cannot be planned in advance. It is important to have a flexible schedule and sufficient period of time, also a plan B and C is always recommended along with great patience.
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APPENDIX 1. GANTT CHART

The project has been divided into three phases; a preliminary study performed in Sweden, a field study carried out in Namibia and a final stage performed in Sweden.
APPENDIX 2. INTERVIEWS

Three women, all working at the open market in Ondangwa, were interviewed on the 27th of July 2010 to get further knowledge of what they buy, sell and earn. An estimation of the percentage firewood constitutes of the total expenses was then made.

1. Fixed bricked barbecue

The rent for a stationare barbecue stall, see Figure A, is N$ 15 per month. Electricity plugs are integrated at the back of the barbecues, but are rarely used. The interviewee estimated that she has up to 50 customers per day, but says this varies a lot. Fridays and Mondays are big market days so she has more customers these days.

![Figure A. Interviewee number one uses a bricked barbecue.](image)

Sells:
- Barbecued meat + tomatoes and onions for N$ 6 apiece.
- Fat cakes N$ 1
- Traditional bread N$ 1
- Cooked meat

Buys:
- Cooking oil
- Spices + vegetables for N$ 30 per a few days (probably 2 days).
- N$ 20 or N$ 30 wood per day. Wind makes the fire burn faster hence more wood is needed.

Some people buys meat with tomatoes and onions but some just buys a fat cakes so the income each customer brings varies a lot. According to the vendor onions are expensive but people like onions so onions needs to be included along with the barbecued meat.

Estimation on profit for barbecue meat

The interviewee buys meat for N$ 20 per steak which turns in to 5 or 6 pieces of meat that she can sell for N$ 6 per piece. If 30 customers out of 50 buy one piece of steak each the daily income for selling barbecued meat is N$ 180.

If the interviewee can get 6 pieces out of every steak she buys, this means that she has to buy 5 steaks at N$ 20. The cost for the meat is thereby N$ 100. To this, cost for cooking oil, tomatoes, onions and spices have to be added. According to interviewee number three, the total cost for these four commodities are about N$ 37, this amount is therefore used in these calculations.
The income is N$ 180.
The total cost is N$ 167.
The profit is therefore N$ 13.
The expenses for buying wood constitutes 17.9% of the total cost for making the barbecued meat.

2. Mini store

The mini stores are about 10 m² and have tables and benches placed in front of each store. The rent is N$ 250 per month, electricity included. Since electricity is included many of the mini stores have fridges and stoves for cooking, however it does occur that a traditional three-stone stove is used to cook some types of food like frying chips. These stores normally have a more varied food supply than the women barbecuing meat.

Figure B. Interviewee number two is selling food in a kiosk.

Sales:
Salad
Porridge
Spinach, traditional dish
Meat stew
Chips (home made on three-stone stove)
Fish
Caterpillar
Cold drinks (beer, fanta)

The interviewee could estimate neither the cost nor the income but did estimate the profit to be about N$ 50 per month. This would mean a daily income of N$ 1.6 to N$ 2.5 and is probably way below the actual profit.
3. Oil drum
The rent for this market place is N$ 15. This interviewee does not have access to electricity since the barbecue is placed besides the bricked barbecues, see Figure C.

![Image of a barbecue made out of an oil drum.](image)

**Figure C.** *Interviewee number three uses a barbecue made out of an oil drum.*

**Sales:**
- Caterpillar N$ 20 big can N$ 10 small can
- Porridge
- Barbecued meat
- Cooked meat
- Fat cakes
- Flour for porridge
- Chili
- Spinach
- Fish, Catfish

**Buys:**
- Wood N$ 40 per day
- Steak meat N$ 180 per day
- Tomatoes and onions N$ 29 per day
- Spices N$ 2.5 per day
- Cooking oil N$ 5.5 per day

The interviewee estimates she has 40 to 50 customers per day. The most popular items are meat, porridge and fat cakes.

**Estimation on profit for barbecued meat**
The interviewee normally buys all the wood, meat, tomatoes, onions and spices in the morning. The income was estimated to be N$ 270 presumed all meat is finished. The total cost per day is N$ 257. This results in a profit of N$ 13 for the barbecued meat, exactly the same amount as interviewee number one. The expense for buying wood is thereby 18.4%.
APPENDIX 3. THE OBSERVED PROBLEMS

When Concept 1 was tested a few points that needed further refinement was discovered. These sub-problems were categorized and analyzed to find the underlying cause for each problem, thereafter a number of solutions were suggested.
A QFD-matrix was made to evaluate the ideas generated during the brainstorming of how to improve Concept 1.

The different improvements were set up as requirements at the left hand side of the relationship matrix. Next, different product features corresponding to each requirement was set up above the relationship matrix.

The evaluation of how the product features correspond to the suggested modifications begun. Each product feature was discussed to find out if a relation regarding the ability to meet each customer requirement existed. If there was a relationship, the next step was to determine how strong that relation was. In this project figures were used to plot the relevance of the relations, 0 signified “no” relationship, 1 meant “weak” relationship, 3 represented “medium” relationship and 9 implied “strong” relationship.

Finally the importance of each refinement was set in relation to the other identified modifications. The most important demand got the maximum figure and the least significant demand got the lowest figure. This figure was then entered in the weighting column at the right hand side of the matrix.

The relationship figure and the weighting number were multiplied and summarized for each product feature. This number was then inserted in the “Total”-field below the relationship matrix. The sub-solution that was chosen has been marked with an asterisk in the QFD-matrix.
APPENDIX 5. PICTURES OF CONCEPT 2

Pictures of Concept 2 in different perspectives.
Appendix 6. Blueprints of Concept 2

Concept 2 contains twelve parts, these are shown below along with an assembly description for two of the parts.

Appendix 6.1 Side piece

The construction contains a Side piece that is cut out and then bent according to the instructions below.
Appendix 6.2 Bent side piece

The construction contains a Bent side piece. The metal sheet is cut out whereupon a slot for the embers tray is made. Then the sheet is bent according to the specific angles shown below.
Appendix 6.3 Back piece

The construction contains a Back piece.
Appendix 6.4 Upper slot

The construction contains a Upper slot that constitutes one piece of a damper. The holes are cut out with a grinder or sabre saw.
Appendix 6.5 Lower slot

The construction contains a *Lower slot* that together with the *Upper Slot* constitutes the damper on which firewood is placed. The holes are made using a grinder or sabre saw.
Appendix 6.6 Apron plate

The construction has an *Apron plate* that is made of steel and welded on to the combustion chamber.
Appendix 6.7 Top rod bar

The construction contains 13 Top rod bars that are made out of round bar.
Appendix 6.8 U-bar

The construction contains two *U-bars* which constitute the framework of the combustion chamber. A round bar is cut and bent twice to shape an “U”.
Appendix 6.9 Side bar

The construction contains a Side bar made of round bar. The bar is cut and then bent. Two Bar rods are then welded onto the Side bar.
Appendix 6.10 Bar rod

The construction contains six Bar rods, four of the Bar rods are welded onto the U-bars. The Upper slot and Lower slot are then placed onto the U-bar rods and thereby constitutes the damper on which firewood is placed. The remaining two Bar rods are welded onto the Side bar.
Appendix 6.11 Embers tray

The construction contains an *Embers tray* made of expanded metal.
Appendix 6.12 Grill rack
The construction contains a Grill rack consisting of expanded metal.
Appendix 6.13 Assembly description U-bar

Concept 2 contains two U-bars. Two Bar rods each are welded onto the U-bars this appendix shows where the Bar rods are to be placed on each U-bar.
Appendix 6.14 Assembly description Side bar

Concept 2 contains a Side bar. Two Bar rods are welded onto the Side bar, this appendix shows where the Bar rods are to be placed on the Side bar.