

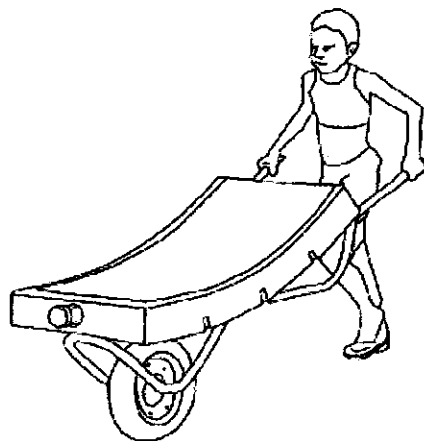
# **INVESTIGATION, DEVELOPMENT AND TESTING OF A LOW COST SOLAR HEAT BARROW (SHB) AND PURIFIER**

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**Thesis submitted in partial fulfilment of the requirements for the degree Master of  
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## **ABSTRACT**

**TITLE:** INVESTIGATION, DEVELOPMENT AND TESTING OF A LOW COST SOLAR HEAT BARROW (SHB) AND PURIFIER.

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**SEARCH TERMS:** SOLAR HEAT BARROW (SHB), WATER PURIFICATION DISPENSER, WATER TRANSPORTER, RURAL COMMUNITIES, ENERGY EFFICIENCY, SOCIO-ECONOMIC STUDIES, BUSINESS POTENTIAL

Many rural communities in South Africa do not have running water or electricity. The fetching and heating of water is therefore a time consuming and expensive daily ritual. The use of energy sources such as wood or coal are not readily available and cause environmental pollution.

Although solar water heaters are commonly available in South Africa, they are very seldom used in rural areas. Whilst this can mostly be attributed to a high system cost, current designs also do not cater for specific rural problems such as the transporting or purification of water.

A prototype model, designed with such an approach in mind, has already been constructed by TEMM International (Pty.) Ltd. The Solar Heat Barrow (SHB) was developed in the 1992 to 2003 period with the intention of combining a number of functions at low cost. Specific requirements were:

- low cost,
- a suitable design and materials for manufacture in large volume,
- sufficiently durable taking into account the harsh conditions of use,
- suitability for cases where no in-house piped water supply was available,
- the use of appropriate technology and
- the improvement of quality of life.

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The unit combines the absorption of solar radiation, the heating of a relatively small volume of water, the transport of the water from the point of supply and the storage of the hot water until it is used.

Untreated water sources such as surface waters (streams, rivers, lakes, etc.) or unprotected open wells are the vehicles for waterborne bacterial diseases such as cholera and typhoid fevers. In the case where water is collected from these sources, the SHB has a build-in Purification Dispenser that purifies the water in the collector against waterborne bacterial diseases.

Certain research questions need to be answered. They will be answered by demonstrating the SHB in two communities where no in-house piped water supply is available and by establishing the socio-economic response of the users. The research questions are as follow:

- What are the responses of the users concerning the SHB, in comparison to those of a control group, regarding its operation, durability, utility and satisfaction of needs?
- What is the daily use of hot water and the reduction in energy use and cost?
- To what extent will the target community purchase the SHB at the full or subsidised commercial price?
- Is there a business case that can be developed for the large scale production, marketing, financing and Small, Medium and Micro Enterprises (SMME) development of the SHB?

It was decided to choose a community in the Valley of Thousand Hills in KwaZulu Natal as the demonstration site. The name of the community is Mabedlane. It is a remote rural area 20 km's north of Botha's Hill and is situated along the Umgeni River. The community is dependent on the river for domestic water. Most families are headed by women. The area has low levels of infrastructure, poor roads, a high unemployment rate and poor health facilities.

The first survey, which was conducted before the test period started, showed a very positive response from potential users. From 112 questionnaires that were given to the people of Mabedlane, all indicated that they were interested in a product that can transport and heat water for domestic use. The socio-economic study has shown that the price per unit needs to be adapted as 85% of the people who participated in the survey indicated that they would

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only pay less than R100 for the product. 15% indicated that they would pay between R100 and R200.

From the second and third questionnaires it was clear that the users were satisfied with the heating performances of the SHB. The community was very interested in purchasing a SHB. They have realised that a SHB will improve their standard of living and regard it as a necessity in their day to day activities.

It is apparent that people, who will benefit from a SHB most, are those who will not be able to pay the full retail price. Therefore, new business strategies have to be researched when implementing the SHB to the target market in South Africa. The idea of considering ways to sponsor/fund the SHB must also be investigated.

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# SAMEVATTING

<b>TITEL:</b>	ONDERSOEK, ONTWIKKELING EN TOETSING VAN DIE LAE KOSTE SON WATER DRAER EN SUIWERAAR.
<b>OUTEUR:</b>	DANIEL FRANCOIS LE ROUX
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<b>SKOOL:</b>	MEGANIESE EN MATERIAAL INGENIEURSWESE
<b>FAKULTEIT:</b>	INGENIEURSWESE
<b>GRAAD:</b>	MEESTERS IN INGENIEURSWESE
<b>SLEUTEL TERME:</b>	SON WATER DRAER (SWD), WATER PURIFIKASIE BEREIDER, WATER DRAER, PLATTELANDSE GEMEENSAPPE, ENERGIE EFFEKTIWITEIT, SOSIO EKONOMIESE STUDIES, BESIGHEIDS POTENSIAAL

Verskeie plattelandse gemeenskappe in Suid Afrika het nie lopende water of elektrisiteit nie. Die verkryging en verhitting van water is dus 'n tydrawende daaglikse ritueel. Energie bronne soos hout en steenkool is nie geredelik beskikbaar nie en veroorsaak ook besoedeling.

Alhoewel water sonverhitters algemeen beskikbaar is in Suid Afrika, word dit selde gebruik in plattelandse gemeenskappe. Die rede hiervoor kan hoofsaaklik toegeskryf word aan die hoë koste van son energie stelsels. So ook is die ontwerp van son verhitters is nie spesifiek gemik op die probleme van plattelandse gemeenskappe nie, naamlik die vervoer en suiwing van water.

A prototipe model, ontwerp met die bogenoemde probleme in gedagte is alreeds daar gestel deur Temm International (Pty.) Ltd. Die Son Water Draer (SWD) is ontwikkel oor 'n periode van elf jaar (1992 – 2003) met die spesifieke doel om sekere funksionaliteit te kombineer teen lae kostes. Die spesifikasies was as volg:

- lae kostes
- 'n geskikte ontwerp en materiaal vir hoë volume produksie
- 'n duursame produk, inagenome die omstandighede waarin dit gebruik word.
- geskiktheid vir gevalle waar geen binnenshuise lopende water beskikbaar is nie.
- die gebruik van geskikte tegnologie en
- die verbetering van lewenskwaliteit.

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Die eenheid kombineer die absorpsie van sonkrag, die verhitting van 'n relatiewe klein hoeveelheid water, die vervoer van water vanaf die bron en die stoor van die verhitte water tot en met gebruik.

Onbehandelde water bronne soos grondwater (afvoer water, riviere, damme ens.) of onbeskermdes oop water bronne, is draers van water gevormde bakteriële siektes soos byvoorbeeld Cholera en Buiktifus. In gevalle waar water verkry word van hierdie bronne het die Son Water Draer 'n ingeboude Water Purifikasie Bereider wat die water reinig van hierdie water gevormde bakteriële siektes.

Sekere navorsings vrae moet beantwoord word. Dit sal gedoen word deur die gebruik van die SWD in twee gemeenskappe waar geen binnenshuise lopende water beskikbaar is nie vir 'n bepaalde toets periode. Verder sal die sosio-ekonomiese reaksie van gebruikers ook gemeet word. Die navorsings vrae is as volg:

- Wat is die reaksie van SWD gebruikers in vergelyking met 'n gekontroleerde toets groep rakende die produk se hantering, duursaamheid, gebruiklikheid en bevrediging van behoeftes?
- Wat is die daaglikse gebruik van verhitte water en die vermindering van energie verbruik en kostes?
- In watter mate sal die teiken gemeenskap die SWD aankoop teen handelsprys en/of gesubsidieerde kommersiële prys?
- Is daar 'n besigheds moontlikheid wat ontwikkel kan word vir die grootskaalse produksie, bemaking en finansiering van die SWD binne Klein, Medium en Mikro Besighede?

Die Mabedlane gemeenskap in die Vallei van 'n Duisend Heuwels in KwaZulu Natal is gekies as demonstrasie gebied. Dit is 'n afgesonderde area 20 km noord van Botha's Hill en is geleë langs die Umgeni Rivier. Die gemeenskap is van die rivier afhanklik as bron vir huishoudelike water. Die meeste families word gelei en onderskraag deur die vrou. Die area se infrastruktuur, paaie en gesondheids dienste is swak en die werkloosheids koers hoog.

Met die eerste ondersoek vraelys, wat voltooi is voor die toets periode begin het, is positiewe terugvoer ontvang van die potensiele gebruikers. Al 112 vraelyste het getoon dat die mense van Mabedlane belangstel in 'n produk wat water vir huishoudelike gebruik kan vervoer en verhit. Die sosio-ekonomiese studie het getoon dat die prys per eenheid verlaag moet word

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aangesien 85% van die mense aangedui het dat hul slegs minder as R100 vir die produk sal betaal. 15% het aangedui dat hulle tussen R100 en R200 vir die produk sal betaal.

Uit die tweede en derde ondersoek vraelyste het dit geblyk dat die gebruikers tevrede was met die SWD se verhittings vermoë. Die gemeenskap het beslis belangstelling getoon in die aankoop van die SWD. Verder het hul ook bewus geword van die SWD se potensiaal om hul lewens standaard te verhoog en dat dit noodsaaklik is vir hulle dag tot dag aktiwiteite.

Dit is duidelik dat die mense wat meeste baat sal vind by die SWD nie die volle handelsprys sal kan betaal nie. Dit is dus noodsaaklik om 'n nuwe en innoverende besigheids strategie te implementeer om die SWD beskikbaar te stel aan die teiken mark in Suid Afrika. Metodes ter befondsing asook die verkryging van borge vir die Son Water Draer moet ook ondersoek word.

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## SECTION 1: INTRODUCTION

*In this section, the background, mission statement and vision are given for the potential business emanating from this research and development programme. The impact of the product on the target market is also listed.*

### 1.1 BACKGROUND

Although the electricity supply industry in South Africa has exceeded the electrification targets of the Reconstruction and Development Programme (RDP), more than 54% of rural communities are still without electricity<sup>1</sup>. When required, water is therefore usually heated in these communities by burning fuels such as wood or coal. This leads to deforestation and considerable local air pollution, which has a negative effect on both the health of rural people and the environment.

Another policy of the RDP<sup>2</sup> states that '*Energy efficiency and conservation must be a cornerstone of energy policies*'. The use and promotion of solar water heaters are specifically mentioned as a strategy to be adopted in such policies.

In many developed countries, the solar hot water industry is driven by the means to find highly efficient systems. This is particularly true of Europe, where solar radiation levels are relatively low.<sup>3</sup> In addition, the high energy costs of developed countries as well as the need to conform to strict safety standards makes imported systems very expensive.

Such systems are therefore unsuitable for and unattractive to developing countries such as South Africa. Fortunately, our country is blessed (for the purpose of solar water heating) with high solar radiation levels<sup>4</sup>. This makes it possible to develop an inefficient, in absolute terms, but still useable, solar collector to provide hot water at a more affordable cost.

Of course, low cost is not the only factor that should be considered. By making the system multi-functional, it would be far more attractive to the end user. For example, few rural and/or disadvantaged communities have in-house running water. Small children and women often spend long hours fetching relatively small amounts of water from a community tap, river or borehole some distance away<sup>5</sup>.

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Spending time in a rural community it would be apparent that there is need for a device to transport and heat water for domestic use<sup>6</sup>. This device must be designed to be hassle free for the user in terms of filling water at a source, moving it to the vicinity of the house, leaving it facing the sun during the day to heat the water and storage at night. The warm water could then be used for personal hygiene, laundry, washing of dishes, food preparation, etc. Having been disinfected at least partly from various pollutants through heating, the water will also be healthier for personal use.

An industry ready model, designed with such an approach in mind, was developed, tested and constructed by TEMM International (Pty.) Ltd. in the 1992 to 2003 period with the intention of combining the different functions at low cost<sup>7</sup>. Laboratory tests have been completed to determine the heating performance of this unit.

A second part to the research and development project is implementing the industry ready model in a rural community with no in-house piped water supply. This project concerned the manufacturing of 15 Solar Heat Barrow (SHB) units and implementing them for a test period of 2 months in a rural community with no in-house piped water supply. The contract period was from August to December 2002. Together with the implementation of the units the socio-economic response of the users were monitored to determine the need for this product in rural communities.

In this report business scenarios are developed for the manufacturing and distributing the SHB in large volumes. These scenarios are only a starting point, in discussing the viability of exploiting the business potential of the solar heat barrow in rural communities.

## 1.2 RESEARCH SCOPE

The scope for the potential business emanating from the Solar Heat Barrow research is the following:

- *To demonstrate the Solar Heat Barrow in a community in KwaZulu Natal where no in-house piped water supply is available and to establish the socio-economic response of the users.*
- *To investigate the feasibility of a purification dispenser as part of the Solar Heat Barrow to combat cholera.*

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The aim is:

- *To support sustainable development in rural areas,*
- *improve health and quality of life,*
- *reduce energy use and subsequent environmental degradation.*

From the above project statement, the following objectives were established:

- *To ensure that the needs of the target market are met by focussing on all relevant socio-economic issues (e.g. awareness, acceptability, affordability and accessibility).*
- *To exploit the full potential of commercialising the solar water heater to the benefit of the country.*

### 1.3 IMPACT OF THE PROJECT ON THE TARGET MARKET

- Once the heat barrow is commercially available, it will assist in meeting some of the aims of the RDP by improving the quality of life in underprivileged communities.
- People who live in areas without running water will be able to spend less time and effort fetching as well as heating water for daily use.
- The health of disadvantaged communities will also be improved by
  - a. decreasing local air pollution caused by wood and coal burning and
  - b. purifying contaminated water through the build in purification dispenser against waterborne bacterial diseases such as cholera.
- People in disadvantaged communities may spend less money on purchasing coal or other fossil fuels
- The manufacturing and distribution of the solar water heater may create new job opportunities.

### 1.4 NEED FOR THE SOLAR HEAT BARROW

South Africa sells electricity more cheaply than any other country in the world to industrial and residential users<sup>8</sup> – yet every month many thousands have their electricity cut off because they can't pay their bills<sup>9</sup>. The impacts of fossil fuel use include billions of rands in annual public health care costs, compromised childhood development for countless youth

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and degradation of our natural resources. South Africa has one of the most carbon – intensive economies in the world (no. 8 in the world)<sup>10</sup>.

About one third of the population does not have access to grid electricity<sup>9</sup>. When required, domestic water is therefore usually heated in these communities by burning fuels such as wood or coal. This leads to considerable air pollution, which has a negative effect on both the health of rural people and the environment.

To boil 1 litre of water consumes approximately 1 kilogram of wood, coal or charcoal<sup>11</sup>. From personal experiences that claim is probably a bit exaggerated. From the 1996 Census it became apparent that 24% of all households in South Africa are dependant on wood for cooking and space heating, almost the entire amount having been consumed by 3,2 million rural households.

Wood fuel is the basic fuel for these households and provides for approximately 65% of their energy needs<sup>12</sup>. This fact significantly contributes to deforestation and air pollution and is clear for anyone travelling in the Southern Africa. In Africa alone, the fuel wood and charcoal consumption was estimated at 502.2 million m<sup>3</sup> in 1994, with an increase of 3.3% per year for the preceding decade<sup>13</sup>.

Speaking at the Coal and Sustainable Development Conference in Johannesburg, researcher Yvonne Scorgie of Matrix Environmental Consultants pinpointed domestic coal use as the main culprit for the high levels of air pollution affecting large sections of the population in certain areas of South Africa<sup>14</sup>.

All these statements show the importance of the use and promotion of solar energy in South Africa. This fact together with the fact that energy efficiency and conservation must be a cornerstone of the RDP only shows one thing. The use and promotion of solar energy is an important issue in South Africa.

Because of the radiation levels and financial background of the majority of people in developing countries there is a need for a relatively inefficient but still useable solar collector to provide hot water at a more affordable cost.

Most of the people who collect water from a community tap are not sure about the health situation of the drinking water. Untreated water sources are the vehicles for waterborne

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bacterial diseases such as cholera. From August 2000 to date 128450 cases of cholera were reported in South Africa<sup>15</sup>.

Disinfection of water collected from untreated sources dramatically reduces the incidence of these diseases. Thus, if a water purification dispenser could be build into the SHB the system will purify the collected water, safe to drink.

The SHB system could then be used by simply filling it with water at the source, moving it to the vicinity of the house and leaving it facing the sun during the day. The water is purified against bacteria by the water purification dispenser and heated by the sun. It could be used for personal hygiene, laundry, washing of dishes, food preparation and drinking.

## 1.5 OVERVIEW OF REPORT

The sections in this report have been written so that they may be read independently of one another. Each has their own abstract, introduction, conclusion and list of references. The intention is to enhance the readability of the document. The following points give a brief overview of each section.

- **Section 2: Solar Heat Barrow design.** This section specifies the design specifications for a prototype SHB. The SHB is not only designed for water heating purposes, but also as a water transporter and water purifier.
- **Section 3: Water purification.** Background of the cholera bacteria in South Africa is given. A water purification dispenser is designed as part of the SHB to purify the water in the SHB against waterborne diseases.
- **Section 4: Socio economic study in the Valley of Thousand Hills.** Investigates the socio-economic issues (e.g. requirements, awareness, acceptability, affordability and accessibility) relevant to the target market. From this information, valuable business insights have been obtained.
- **Section 5: Possible business scenarios.** Two different business approaches are discussed in this section. Implementing a solar water heater into rural communities brings a new dimension to the research investigation. The scenarios will give a good indication about the business potential for the SHB.

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- **Section 6: Conclusions and recommendations.** Provides recommendations and conclusions regarding the design, socio economic study and business potential. The section concludes with an overall summary concerning recommended future work on the SHB.

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## SECTION 2: SOLAR HEAT BARROW DESIGN

*More than half of the people in rural communities in South Africa do not have access to electricity. This chapter identifies the basic needs people in rural areas have. This is used to state the design specifications for the development of the Solar Heat Barrow.*

### 2.1 DESIGN SPECIFICATIONS

#### *2.1.1 Overview of the solar water heating industry in South Africa*

The domestic solar water heating industry in South Africa has had a minimal impact on the economy and on improving the quality of life of disadvantaged communities. Reasons for the sluggish industry include high unit costs<sup>16</sup>, the relatively low price of electricity<sup>17</sup> and the absence of government incentives.

The focus of the South African solar water heating industry has been largely on the middle to high-income sector. This sector has largely rejected the idea because of poor reliability of commercial systems and the high capital outlay.

There are 3 typical solar water heater-system configurations available for domestic use:

- Integral systems – the storage tank also acts as the absorber.
- Close-coupled systems – the collector and storage tank are mounted adjacent to one another on the roof.
- Split collector/storage systems – the storage tank is mounted inside the house and the collector on the roof.

The typical costs of domestic solar water heater - systems are presented below:

Description	Capacity	Cost
Integral batch heater	10 litres	R100
Close-coupled batch heater	30 - 60 litres	R750 – 1200
Integral roof-mounted system	100 - 150 litres	R2500 – 3500
Close-coupled system (indirect)	100 - 300 litres	R5000 – 10000
Split collector / storage system (indirect)	200 - 300 litres	R8000 - 12000

*Table 1: The typical costs of domestic solar water heater – systems available in South Africa<sup>18</sup>*

However, the high cost required for efficient systems is completely unnecessary for South African conditions. The interior of our country experiences the clearest skies at the coldest time of the year<sup>3</sup>, enabling a solar water heater to still operate well in winter<sup>19</sup>. We should therefore be able to develop a much cheaper system, with lower efficiency, but which still achieves a desirable result.

Also, the products available in the market today, although all are plausible, do not provide an integrated approach to the South African situation. The biggest shortcoming of the systems is that they are dependant on in-house plumbing.

It is not enough to simply provide a means to heat water using solar energy. The issues of *ultra low-cost*, *water transportation* and *water purification* were therefore addressed in the SHB design. There is not another product in South Africa that combines the features of a water transporter, water heater and water purifier at low cost in one unit. This provides potential customers with a product that has far wider business and market potential than the competing products currently available in South Africa.

## **2.1.2 Design and build of the Solar Water Heater**

### **2.1.2.1 Design specifications**

A typical scene found in rural and/or informal communities where people are dependant on polluted water is given in Figure 1. The following two problems can easily be identified by looking at this scene:

- The health level of the water from the source.
- The method of transporting the collected water from the source to the point of use.

Many people living in rural areas in South Africa are dependant of water from a natural source or a community tap. When people use water for domestic use from sources such as surface water, rivers or boreholes the probability of cholera outbreak is very high.

This was the case in August 2000 when a cholera outbreak was reported in KwaZulu Natal. The total cholera cases reported in South Africa from August 2000 to date were 128 450 and the number of fatalities were close to 400<sup>15</sup>. This shows that there is definitely a need for a water purification dispenser as part of the SHB design.



*Figure 1: A typical scene of collecting water from polluted sources.*

Furthermore, 54% of rural South African households do not have access to electricity<sup>1</sup>. Therefore many people are dependant on often undesirable means of heating water. The using of open wood and coal fires leads to other environmental issues such as deforestation, erosion and air pollution.

When designing a Solar Heat Barrow, the following specifications must be covered to solve the problems stated above:

1. Low cost to be affordable for people in rural areas.

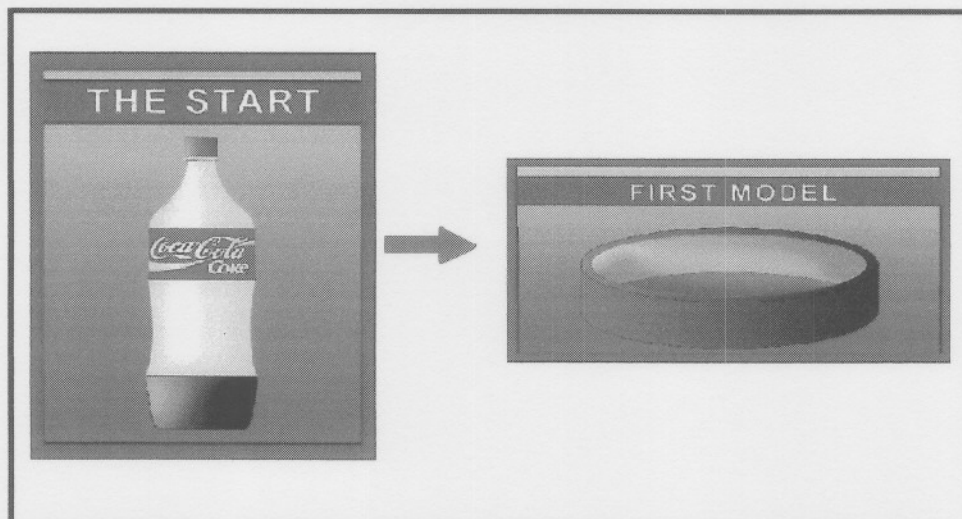
2. Water transporter to solve the problem of transporting the collected water from the source to the point of use.
3. Heat the water in the container by means of sun power to a temperature of 30°C above the daily average tap water temperature at 20h00, regardless of season. This hour was chosen, as it is just after the time when most people have returned from work and require hot water.
4. Combine a water purification dispenser into the SHB unit to purify the water against bacteria. The aim for the dispenser is to combat cholera and purify the water for drinking purposes.

Another important specification when designing a SHB for South African conditions is the shortcoming of the currently available solar heater systems to be independent on in-house plumbing.

The issues of *ultra low-cost*, *water transportation* and *purification dispenser* lead to the development of the first prototype “heat barrow”, which is dealt with in the following section.

#### 2.1.2.2 Development of the first prototype

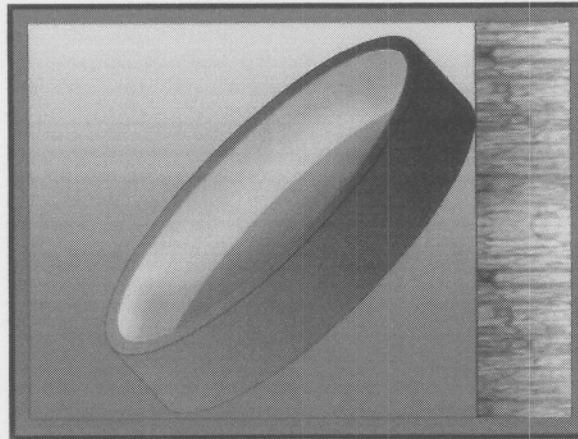
The heat barrow had a humble beginning in 1994. The idea originated from a previous design of a 2l Coke bottle, as shown in Figure 2. The first test model consisted of a black plastic base acting as a water container with a solar collector on top and a transparent plastic sheet as a shield to prevent heat loss. Preliminary temperature measurements showed that the idea would work well to heat water.



*Figure 2: The first test model was derived from a previous Coke bottle.*

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In South Africa, the optimum solar radiation is received at an angle of  $35^\circ$  from the horizontal<sup>20</sup>. The idea therefore came about to lift the solar water heater to take full advantage of the solar energy, as illustrated in Figure 3.



*Figure 3: An inclination of 35% is optimal for the absorption of solar energy in winter for South Africa.*

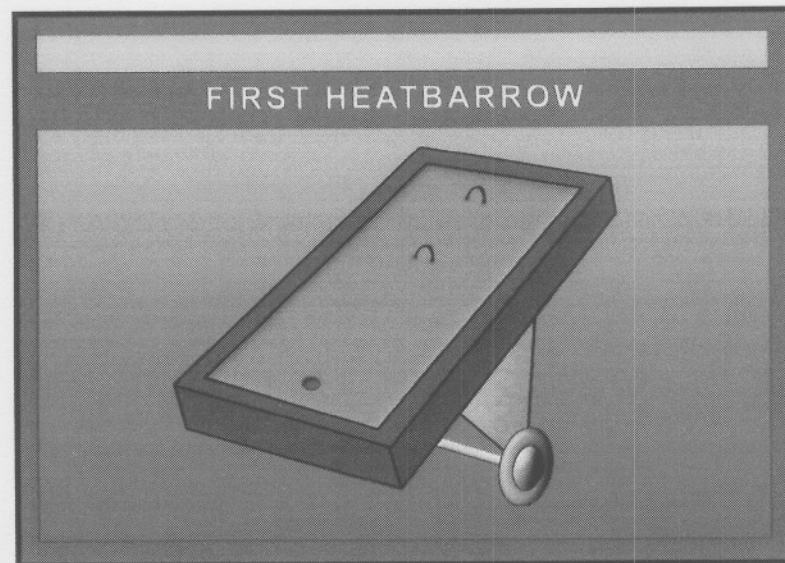
The idea then came about to use a wheel to incline the solar heater at the correct angle. This solved a further problem of rural communities, namely the transport of water. The “heat barrow” was therefore born.

The main focus of the development then shifted to manoeuvrability. The initial concept had a flat rectangular shape with two small wheels, making it very difficult to manoeuvre (especially for children) through the sand and grass as well as rugged terrain.

The first improvement made was therefore to change the two small wheels to a single, large ball wheel. This would decrease the pressure on the ground, making the heat barrow easier to move around. It would also help prevent the formation of erosion furrows while being pushed along the ground.

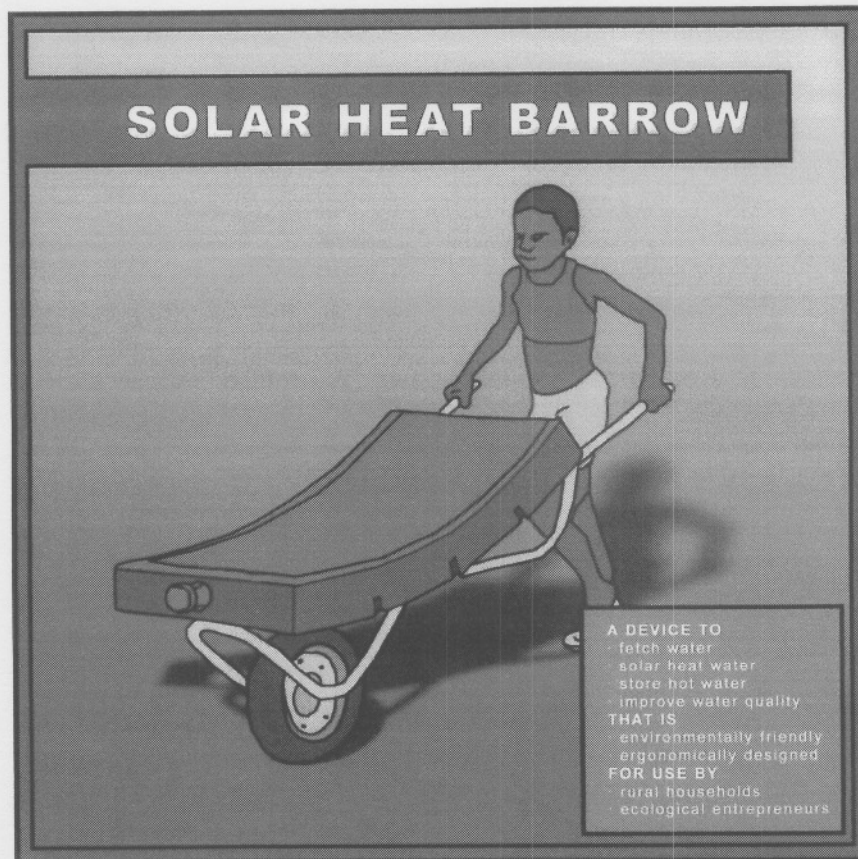
The flat rectangular shape of the water tank was also changed to a concave shape. This has the advantages of a lowered centre of gravity (making the heat barrow easier to pick up) and increased rigidity (thus lowering material cost). A preliminary sketch of the first “heat barrow” is given in Figure 4.

Because children and women often spend long hours fetching from a community tap, river or borehole some distance away the volume of the SHB could not be made too large<sup>5</sup>. It was decided to design the SHB to carry 25 litres of water.



*Figure 4: An early illustration of the first SHB prototype.*

Initial tests have already been performed on this prototype. For example, a study showed that the thermal performance of the system would deteriorate by only 3% if the collector glass becomes scratched. Investigations also indicated the necessity for side and back insulation to limit thermal losses<sup>20</sup>. A schematic demonstration of the first prototype is given in Figure 5.



*Figure 5: Demonstration of a child manoeuvring the first solar heat barrow prototype.*

A prototype of the purification dispenser was also developed. The design of the dispenser is discussed in Section 3.3.

## 2.2 RESULTS AND ANALYSIS

### 2.2.1 Thermal performance test results

The initial goal was to supply water at 30°C above the daily average tap water temperature at 20h00, regardless of season. This hour was chosen, as it is just after the time when most people have returned from work and require hot water.

Thermal measurements were conducted over a two week period in August. The tests were conducted to ascertain whether the SHB design would meet the heating specification as stated in section 2.1.2.1.

The solar heater was placed at a position of rest for all measurements to measure the following:

- Water temperature of the SHB from 7:00 am for a 24 hour period.
- Tap water temperature for the same period of time. To simulate tap water, a 1 litre cylinder was filled with tap water and placed in the shade.
- Air temperature for the same period of time.

The average results of all the measurements taken are given in Figure 6. It can be seen that the water temperature inside the heat barrow peaks at about 15:00, which is the time that the water is completely mixed by stratification. The peak temperature achieved is almost 60°C, more than 45°C above the daily average tap water temperature.

At 20h00, the heated water temperature is more than 30°C above the “tap water” temperature. The thermal performance test results for the SHB are according to specifications and thus successful.

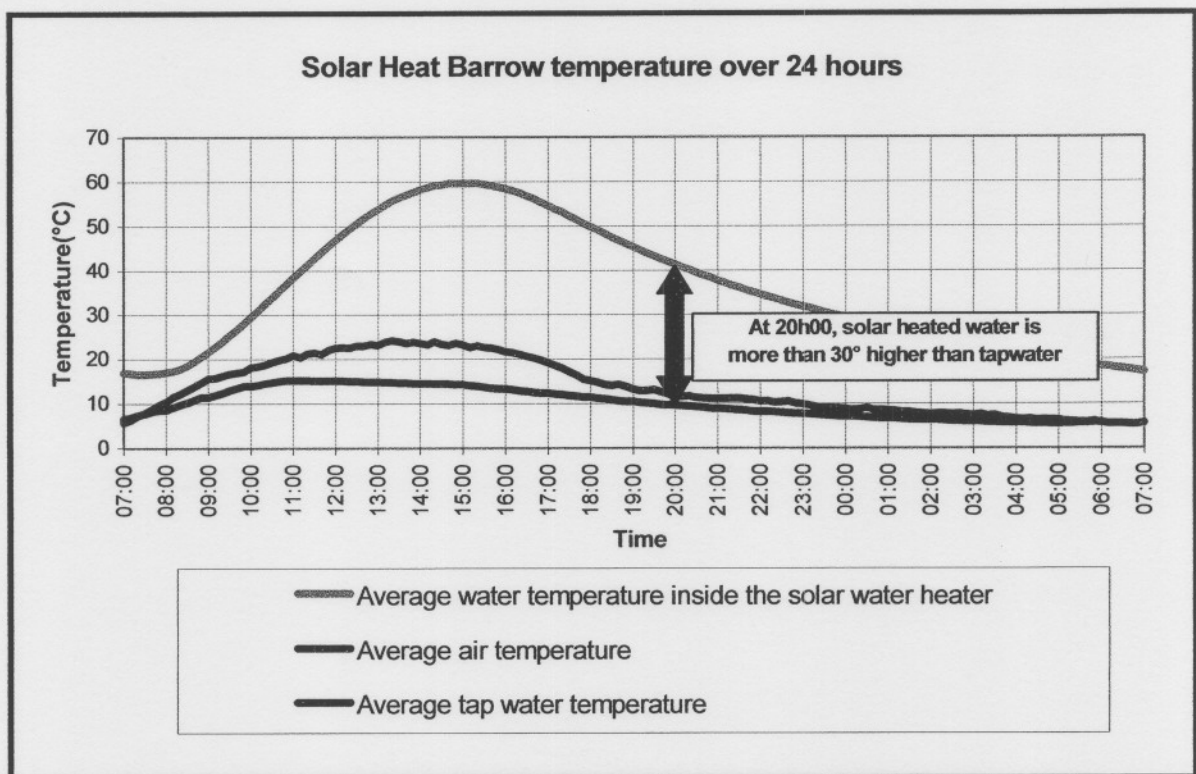


Figure 6: Results of 25 litre water temperature measurements for the SHB prototype.

## 2.2.2 Cost results

Table 2 summarises the manufacturing costs for the SHB unit. The total of R802.50 consists of R150 labour costs and R70 tooling cost. This may sound very expensive when compared to the monthly income of the target market. One of the main specifications of the SHB is to keep it affordable for people in rural areas. It must be kept in mind that the unit price of R802 is obtained when the manufacturing process is for a small volume (between 1 and 1000) of SHB units.

When the SHB is manufactured in large volume (more than 1000), the manufacturing price will definitely be reduced. For example, the outer housing and absorber tank is manufactured with a rotomould process. When manufacturing the in large volume the costs of these two components will be reduced by using a different process. The process of blow moulding will be used then.

Manufacturing Estimate for Solar Heat Barrows					
No	Component / Activity	Material	Process	Tooling Cost	Component Cost
1	Outer Housing	CL LDPE UV Stabilised	Rotomould	R 15,000.00	R 150.00
2	Absorber Tank	CL LDPE UV Stabilised	Rotomould	R 15,000.00	R 150.00
3	Standard Lid		Buy-in Component		R 2.50
4	Glazing	PC Clear 1mm	Vacuum Form	R 20,000.00	R 75.00
5	Frame	Tubing Steel 32mm	NC Bend / Weld		R 100.00
6	Wheel Assy		Buy-in Component		R 40.00
7	Isolation Materials	PU Foam	Mix / Pressure Pour	R 20,000.00	R 50.00
8	Fasteners	Bolts & Screws			R 10.00
9	Consumables Assy	Rags, Rivets			R 5.00
10	Labour Assy Mechanical				R 100.00
11	Labour Assy Isolation				R 50.00
			Tooling total	R 70,000.00	
			Cost/unit		R 732.50
			Tooling/unit		R 70.00
			Total cost/unit		R 802.50

*Table 2: Estimated cost for the SHB unit when manufacturing in small volume.*

## 2.3 CONCLUSION REGARDING THE DESIGN OF THE SHB

The Reconstruction and Development Programme (RDP) of the South African government has specifically mentioned the promotion of solar water heaters in adopting energy conservation policies. This chapter discussed the research and development behind a SHB for South Africa's specific circumstances.

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Although solar water heaters are available in South Africa and a limited amount of research on the subject is being conducted, South Africa is far behind other developing countries<sup>4</sup>. This can be attributed to the high cost of imported systems, the relatively low cost of electricity in South Africa and a lack of governmental support (despite the above-mentioned RDP policies).

Two important factors that must not be ignored are the problem of water transportation and water health quality from the source in rural and/or informal areas. From August 2000 to date 128 450 cases of cholera were reported in South Africa. This illustrates the importance of an add-on purification dispenser to the SHB. Also, a great burden is placed on rural women and children who carry containers filled with domestic water over long distances every day.

A new multi-functional "heat barrow", addressing the issues of low-cost, water transportation and the purification of water was therefore researched and developed. The device is simply filled with water at the source and left outdoors during the day. The water purification dispenser purifies the water inside the SHB and the warm water can be used at night for personal hygiene, washing of dishes, etc.

A prototype was developed, based on the results of previous socio-economic study. The study showed that most people in disadvantaged communities were satisfied with the basic design and felt that it would well suit the purposes of heating and fetching water.

The SHB's thermal performance is within design specifications. The peak temperature achieved is almost 60°C, more than 45°C above the daily average tap water temperature. At 20h00, the heated water temperature is more than 30°C above the "tap water" temperature.

The water purification dispenser will purify the water in the SHB unit. This is an important add-on to the SHB unit. The design and build of the dispenser is discussed in Section 3.

It is important to note that the issue of extreme weather conditions was not included in this section. There is definitely a need to investigate whether the design of the SHB should be altered for extreme weather conditions, such as hail and temperatures below 0°C. When the user stores the SHB outdoor the design specifications must be robust against extreme weather.

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## 2.4 REFERENCES

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## SECTION 3: WATER PURIFICATION

*Since the early 1970's, cholera has been endemic in the Southern part of the African region. Since then, South Africa has been actively involved in the prevention, control and treatment of cholera. Cholera outbreaks in the early 1980's were used as training grounds for the South African Health System in so far as prevention and control of infectious diseases is concerned. Various strategies and outbreak response mechanisms were employed at various levels of care.*

### 3.1 BACKGROUND

Untreated water sources such as surface waters (streams, rivers, lakes, etc.) or unprotected open wells are the vehicle for waterborne bacterial diseases such as cholera and typhoid fevers. Disinfection of water dramatically reduces the incidence of these diseases. Untreated waters may also play a role in the transmission of water-washed viral enteric diseases such as hepatitis (hepatitis A virus and non-A non-B hepatitis agents), gastroenteritis (rotaviruses, Norwalk and Norwalk like viruses), as well as an unknown number of ill-defined diseases caused by the other enteric viruses (adenoviruses, astroviruses, coxsackieviruses and echoviruses).

The fecal-oral route is probably the major route for transmission of these bacterial and viral diseases as well as of many parasitic diseases in poor sanitary conditions. An improvement of water quality and water usage for improving sanitary conditions should result in a decrease of waterborne as well as water-washed diseases<sup>21</sup>.

Cholera has been prevalent worldwide since the early 19th centuries. This disease has been prevalent also in Sub-Saharan African countries, including South Africa. The World Health Organisation (WHO) has confirmed that cholera had always been endemic but under control in South Africa, although the worst cholera epidemic was seen in the early 1980s, particularly in the rural areas<sup>15</sup>.

Research has contributed a great deal in providing health practitioners with knowledge on the etiology and epidemiology of the disease, including the clinical management of patients. Both public and clinical research contributed the following light in understanding cholera:

- In approximately 90% of cholera cases, the disease is mild; and it is difficult to differentiate it from other diarrhoeal diseases;

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- Oral dehydration therapy is important in case management and can reduce the case fatality;
  - Vaccination and other chemoprophylaxis are ineffective in preventing and controlling cholera; and personal hygiene on drinking and eating habits, safe disposal of human waste have proven to be effective in controlling the disease.

Cholera epidemics are public health problems and could claim up to 50% of its victims. It is therefore important for all the stakeholders in cholera prevention and control to use correct intervention strategies useful in curbing the epidemic.

### 3.2 SOLAR DISINFECTION OF THE SHB

The proposed configuration of the *SHB* does not make the use of solar UV assisted disinfection in the device possible. The black surface of the solar collector will not allow any UV to reach the water. This method could however be of some assistance if small settlement ponds are used with the pre-treatment of the water.

An obvious method of water disinfection that can be utilised with the *SHB* is pasteurisation. Measurements on similar integral collector/storage (ICS) solar water heaters have shown that the required temperature for pasteurisation is within the capability of the proposed *SHB*.

This method would be ideal to apply to the *SHB*, as no additional infrastructure requirements are necessary. If *Vibrio cholerae* is the only pathogen of concern, pasteurisation of the water alone could have a significant effect on the users health outcome.

From Figure 7 it can be seen that the *Vibrio cholerae* bacteria is not a very strong organism. If the bacteria is present in water and the water temperature is kept above 45°C for longer than an hour, the bacteria will die. Figure 6 showed that the *SHB*'s water temperature is above 45°C from 12:00 to 19:00. Comparing this information to the trend of the *Vibrio cholerae* bacteria in Figure 7 it is clear to see that cholera will not survive in the *SHB*.

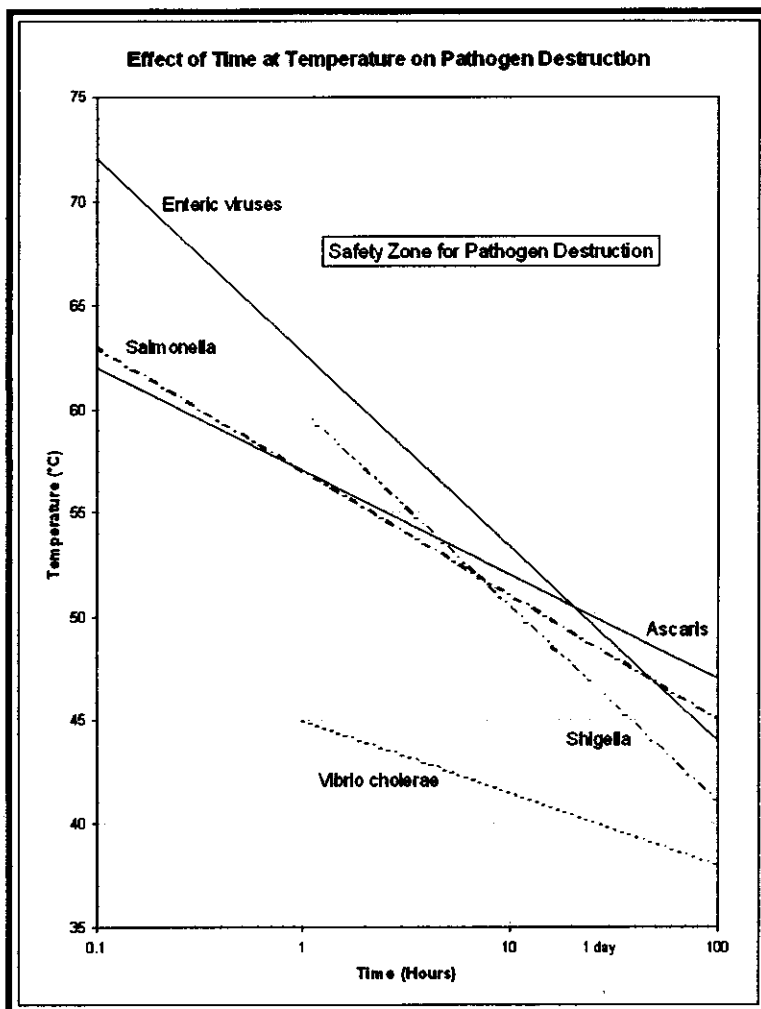


Figure 7: Temperature – time relationships for safe water pasteurisation. The temperature is on the vertical axis and the time is on the horizontal logarithmic axis<sup>21</sup>.

It would however be too high a risk to depend on pasteurisation as the only method of water disinfection. Too many common pathogens require higher pasteurisation temperatures (see Figure 7) for destruction. On days with reduced sunshine the water temperature would not necessarily reach this temperature, but it could still reach an acceptable temperature for domestic hot water use.

Just ensuring that the water has in fact reached the pasteurisation temperature would require a temperature measurement device. The water would then still have to be kept at high temperature for a minimum required period before it could be deemed safe for use.

The best method of water disinfection to use with the elevated water temperature of the SHB would be a chemical method. Iodine and iodine compounds are disqualified because of the

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possible long term health effect, while special short lived, high potency disinfectants place a high premium on the distribution infrastructure.

### 3.3 PROBLEM WITH BLEACH AND DISCUSSION OF NEW PRODUCT

#### 3.3.1 *Problem with bleach*

The chemical disinfection method of choice is chlorination. Its wide use, proven capability of disinfection and low cost are attractive. Preference would have to be given to sodium hypochlorite because of its general availability as household bleach. Chlorine, in both granular or tablet form, is susceptible to moisture damage if not properly stored. Granular calcium hypochlorite also poses a danger due to its temperature sensitivity.

The drawback of commercially available sodium hypochlorite solutions (3% to 6% concentration) is its tendency to decompose at temperatures from as low as 25°C. Its shelf life is limited to less than a month unless the concentration is reduced to 0.5% and the solution is stored at temperatures preferably below 20°C<sup>22</sup>. The bleach may also already be of dubious concentration when bought at the ever present 'spaza' shops of rural Southern Africa. This is due to a low turnaround and the absence of storage temperature control.

If a 5% sodium hypochlorite solution reaches a temperature of 40°C it starts to 'boil'<sup>23</sup>. This is not boiling in the true sense of the word, but a rapid decomposition of sodium hypochlorite into common salt and oxygen. Depending on conditions and the users' storage diligence, they may in the worst case thus end up with a mild salty solution of water that will be of little use in the disinfection of water.

#### 3.3.2 *Discussion of steripure*

*Steripure* is a new South African product that uses the ability of some metal salts to disinfect water, effluent and sewage without causing harm to the environment. The product is presently in the process of being patented worldwide and as such very little published data is available.

In an interview with the technical director of the company GES Environmental Services<sup>24</sup> some information about the product came to light.

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*Steripure* is a complex acidic solution of metal salts, mainly copper and zinc, in water. It has a faint smell of nitric acid, is translucent green in color and boil at 100°C. It has an unlimited shelf life, however decomposition starts at approximately 80 to 90°C. It may lead to slightly irritating gases and vapors being released from the solution. Concentrated solutions should not be heated above this temperature as it loses its disinfectant properties.

The CSIR, the University of Natal, the Umgeni Water Board, the Transvaal Sugar Board and the Mbabane (Swaziland) City Council tested *Steripure* as a disinfectant for drinking water. While independent published data would help to substantiate claims, viewing of some of the test results during the interview showed a full removal of all coliform bacteria, including *Escherichia coli*. No results were available for viruses and helminths or oocysts of parasites, nor were any claims to this regard made.

Further claims of the product is that it helps to remove turbidity from water by reacting with the materials suspended in the water. This result in a reaction product that rapidly settles out of the water. The sludge is not harmful to the environment and any unreacted *Steripure* remaining in the water has residual disinfectant qualities.

*Steripure* will be available in different stable concentrations suitable as a disinfectant from mixing ratios from as low as 1 part per million to 1 part per 10000. It is classified according to the European directive on the classification of hazardous preparations, 90 / 492/ EEC and does not need to be labeled as a hazardous substance in any concentration supplied.

Thus, *Steripure* meets most of the requirements for a suitable disinfectant for distribution in Southern Africa. The high concentration that is feasible reduces the volumes of *Steripure* that have to be distributed and stored. The stability of *Steripure* concentrations at elevated temperature makes it suitable for nearly all storage conditions that could be expected. It even makes it possible to integrate within the *SHB* a storage container with sufficient disinfectant for a reasonable period's usage. This route will thus further be followed for implementation with the *SHB*.

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### 3.3.3 Dispenser concept

Not all users of the *SHB* will require a disinfection device. Some may have access to already purified water, in which case additional disinfection is not required. Others may select to use a different disinfection method such as manual dosing with sodium hypochlorite solutions.

A concept for a disinfectant dispenser to be used with the *SHB* was thus developed by Mr. MN. Nieuwoudt<sup>25</sup>. It works on the basis of an add-on device that will dispense an adequate volume of *Steripure* into the water container every time it is filled. In concept this can be done with a disinfectant dispenser that takes the place of the standard spout screw lid on the *SHB* water container. The *SHB* is envisaged to only have one 50 mm spout for both filling and pouring. This would mean that the dispenser must dose the water in the *SHB* on filling, but not every time that water is poured from it.

Filling of the *SHB* will require the spout to be fully opened for insertion of a hosepipe, funnel, or whatever means will be used for filling. The dispenser was thus further conceptualised to be removed from the spout during filling and to dispense an adequate volume of *Steripure* on replacement.

The dispenser must however be prevented from dispensing *Steripure* every time that water is poured from the *SHB*. While this would not have detrimental health effects, it would prematurely deplete the stored volume of disinfectant in the dispenser. A second pouring lid or valve must thus be provided on the dispenser. It should be easy to operate, in order to promote its use in preference of removal of the whole dispenser for the pouring of water. It should, however, not be possible to fill the *SHB* water container through this route.

The container for the storage of *Steripure* will be integrated with the dispenser unit. It should store sufficient disinfectant to ensure a reasonable period of operating without replenishment. Temperatures exceeding 80°C are not expected in the *SHB*. It should thus be possible to store sufficient *Steripure* for up to a month's supply in the dispenser without the product decomposing prematurely.

This concept of the dispenser also allows it to be used with water containers other than that of the *SHB*. This should be a feasible goal if a standardised thread system is used for the dispenser / container interface.

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## 3.4 DESIGN OF WATER PURIFICATION DISPENSER

### 3.4.1 Design specifications of the Water Purification Dispenser

- **Steripure concentration**

Steripure will be available in different concentrations suitable as a disinfectant for mixing ratios from as low as 1 part per million to 1 part per 10 000. If we count in drops and assume 20 drops per  $\text{cm}^3$ , 1 drop of the strongest solution will disinfect up to 50 litres of water. Dispensing 1 drop at a time is however relatively difficult and the storage volume in the dispenser would be so small that the smallest leak or evaporation of *Steripure* would go unnoticed.

If the dilution strength were 1 part per 100 000, 5 drops, or  $0.25 \text{ cm}^3$ , would be required to disinfect a *SHB* container with 25 litres of water. This concentration of *Steripure* will thus be used for this application.

- **Dispensing volume**

If allowance were made for inaccuracies of manufacture and other uncertainties, it would be prudent to design the dispenser part of the unit for reliably dispensing between 6 and 7 drops ( $0.3$  and  $0.35 \text{ cm}^3$ ) per cycle. The extra *Steripure* dispensed into the water will not harm people, but will ensure that at least the minimum dosing requirement was satisfied. The unit was thus specified to dispense between  $0.3$  and  $0.35 \text{ cm}^3$  per dispensing cycle.

- **Dispenser storage volume**

The *SHB*, with a storage volume of 25 litres of water, could be used to heat two and on a good day up to three, loads of water. This could result in the unit being used for approximately 60 loads of water per month. If the dispenser can store sufficient disinfectant for these loads of water, the user only has to replenish the unit once a month.

Sixty *SHB* loads of water would require a volume of at least  $15 \text{ cm}^3$  of *Steripure* to be stored in the dispenser. This is indeed a small volume of fluid and the requirement for the dispenser disinfectant storage was set at double this volume, or  $30 \text{ cm}^3$ , to allow for spillage and evaporation losses and variations in dispensing doses. The storage volume must also be transparent, or at least translucent, for the user to easily evaluate the level of the aquamarine coloured *Steripure*.

- **Materials**

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*Steripure* is not as sensitive to the materials of construction as chlorine disinfectant compounds are. It is, however, an acidic water based solution and it would thus be prudent to design the dispenser to be manufactured in polymer materials. This would also have the advantage that injection moulding could be used as manufacturing process for the relatively small components envisaged for the dispenser. The use of metals will be limited to the minimum. Where required, only austenitic stainless steel will be used.

- **Cost target**

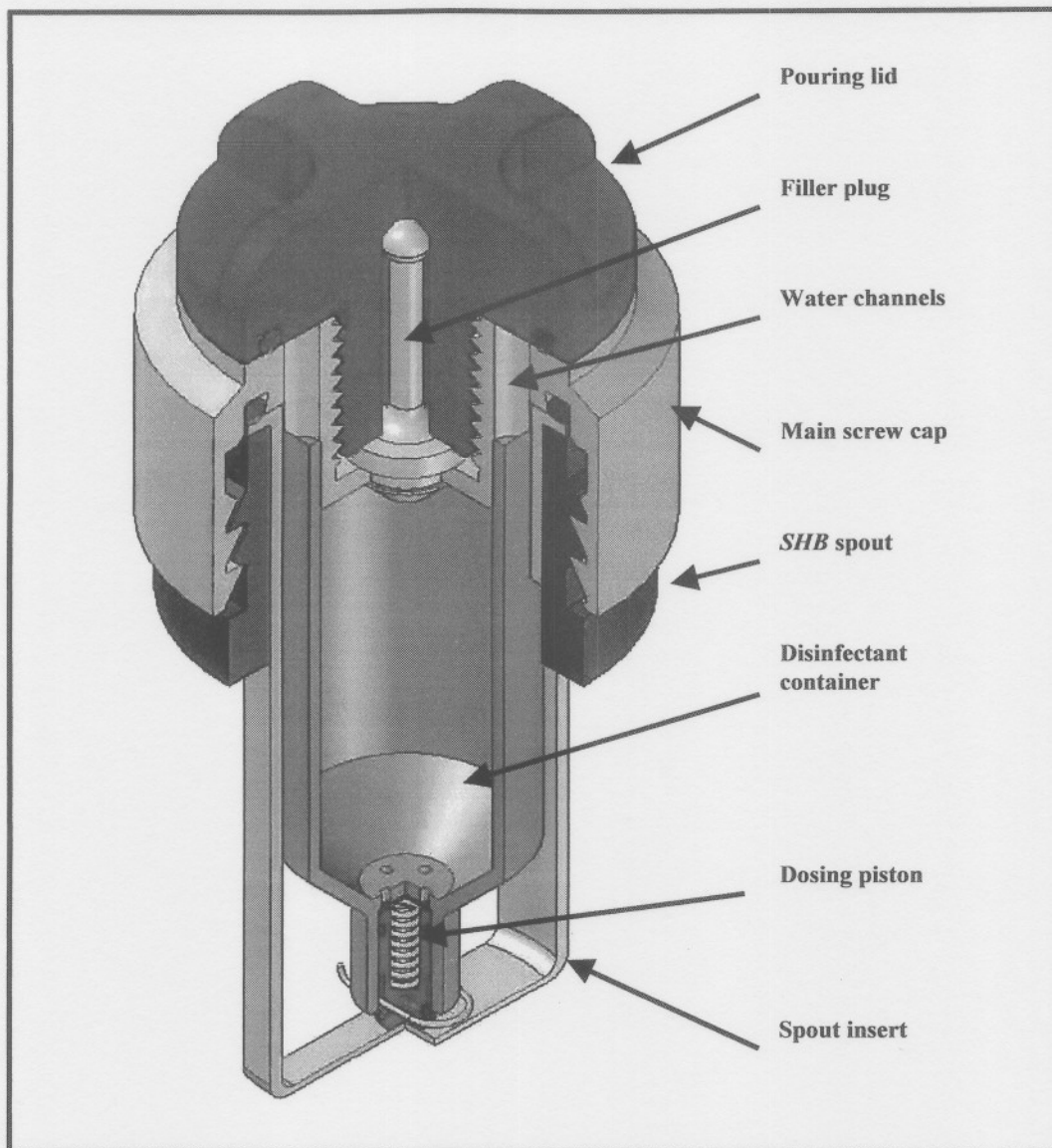
The cost target for the *Steripure* dispenser should be set independently of that of the *Solar Heat Barrow*. It could be sold as a separate unit and the actual numbers will heavily influence manufacturing volumes and costs.

For the purpose of this study however, it is assumed that a dispensers will be sold with every *SHB*. A relative value of 1/6 of the *SHB* was decided upon, which leads to a cost target of not more than R 50 per unit.

The resultant specification for the *Dispenser* is summarised as follows:

1. Unit to be incorporated in *SHB* spout as replacement for existing cap.
2. Design to ensure dosing for every filling.
3. Design to prevent dosing for every pouring of water.
4. *Steripure* in a dilution strength of 1 part per 100 000 will be used as disinfectant.
5. Volume between 0.3 and 0.35 cm<sup>3</sup> to be dosed per dispensing cycle.
6. Minimum *Steripure* storage capacity of 30 cm<sup>3</sup>.
7. Only polymers and austenitic stainless steel to be used as materials of construction.
8. Cost target of about R 30 or less, for a target selling price of around R 50.

The layout of the *Dispenser* converged relatively quickly to that shown in quarter section view in Figure 8. The complete unit, except for the spout insert, is removed for filling the *SHB* with water. This interfaces with the same thread as the standard screw cap.



*Figure 8: Quarter section view through dispenser with insert for water container mouth.*

When the *Dispenser* is unscrewed from the *SHB* spout, the spring inside the piston pushes it out to the retaining stop. The flap valve, kept in place by the spring, allows fluid (*Steripure*) to flow from the storage volume and the volume behind the piston is sucked full with disinfectant.

A second lid is provided for pouring water from the *SHB*. A circular array of narrow water channels allow water to flow out and air to simultaneously enter when this lid is only partially unscrewed. It thus create a preferential method, easier than removing the complete unit, for

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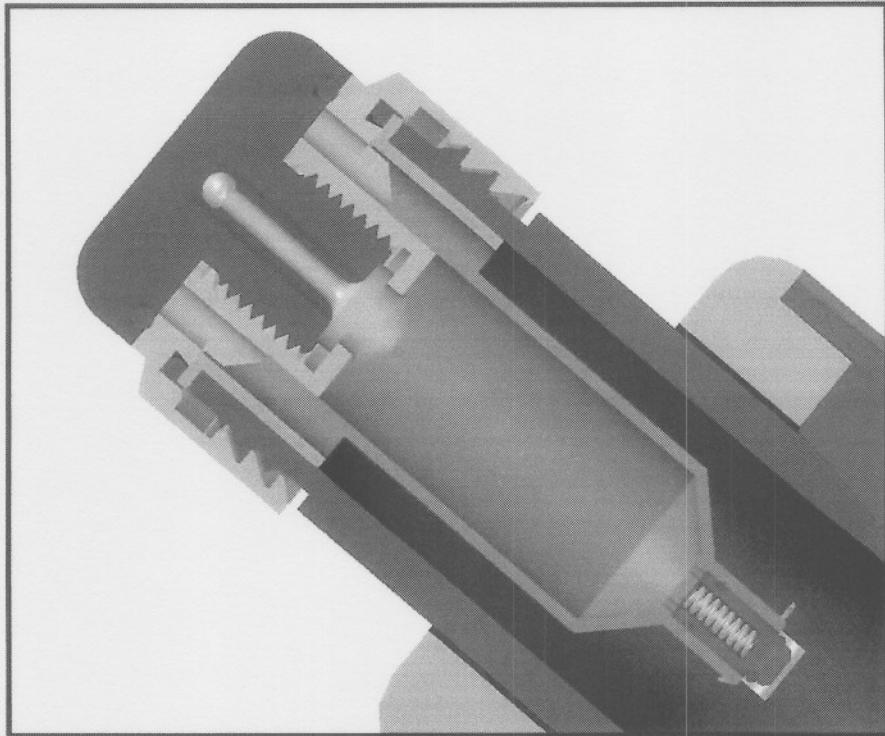
water to be poured from the *SHB*. It also prevents the *SHB* to be easily filled with water even if this second lid is fully removed.

Integral with the main screw cap is a disinfectant storage container. It can be filled by removing the secondary screw lid and a rubber plug, for example, by using a long spouted storage bottle for the *Steripure*. At the bottom of the disinfectant container is a dosing piston with a double valve arrangement.

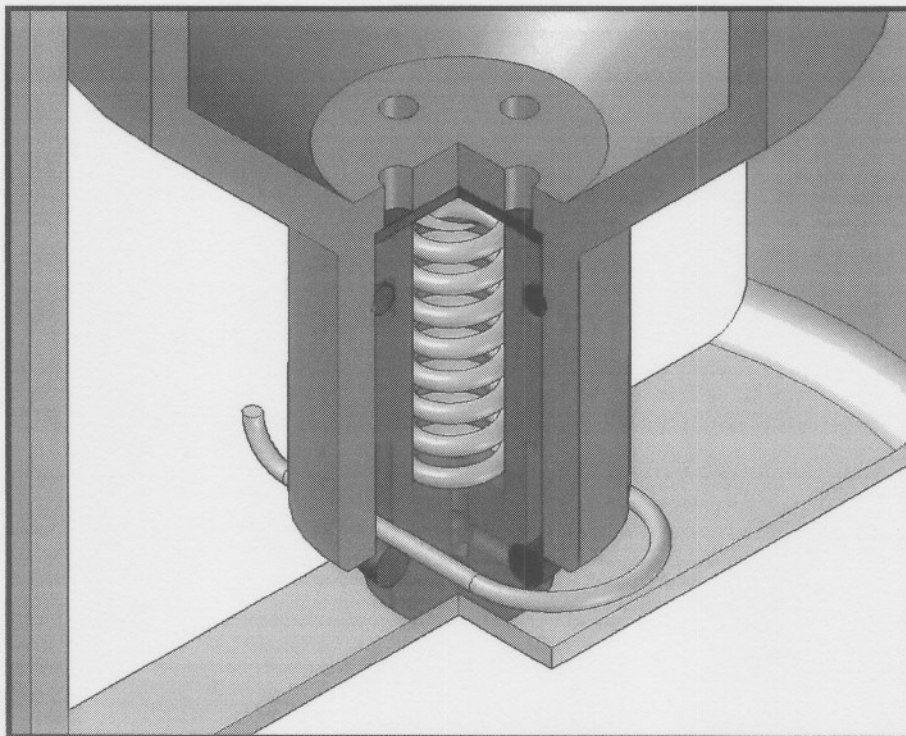
When the *Dispenser* is in place on the *SHB* spout, the spout insert pushes the piston up against the rear of its cylinder where a thin elastomer flap valve is situated and seals the disinfectant container outlet ports. The spout insert is a permanent installation in the *SHB* spout, sealed at the spout lip. Its bottom crossbar is sufficiently flexible to both allow the piston to be properly seated and the screw cap to seal on the upper spout surface of the insert. This arrangement is shown in Figure 9.

After filling the *SHB* with water, the *Dispenser* is screwed onto the spout. The flap valve prevents the disinfectant behind the piston to be forced back into the storage container. The pressure build-up then pushes the disinfectant through small holes to an elastomer O-ring on the lower piston circumference. The O-ring stretches and allows the disinfectant to be released in the *SHB* water storage volume. Figure 10 shows an enlarged view of the bottom of the storage container with the dosing piston arrangement, its spring, retainer and seals.

The design of the *Dispenser* was done for manufacturing of a single prototype unit only. A standard COTS stainless steel spring and standard *Viton*<sup>™</sup> fluoro-elastomer sealing components were selected. The material for the spout insert was specified as 304L stainless steel. All other components were specified to be machined from rigid unplasticized polyvinyl chloride (uPVC) because of its good machinability.



*Figure 9: Section view showing prototype disinfectant dispenser unit in place of standard screw lid.*



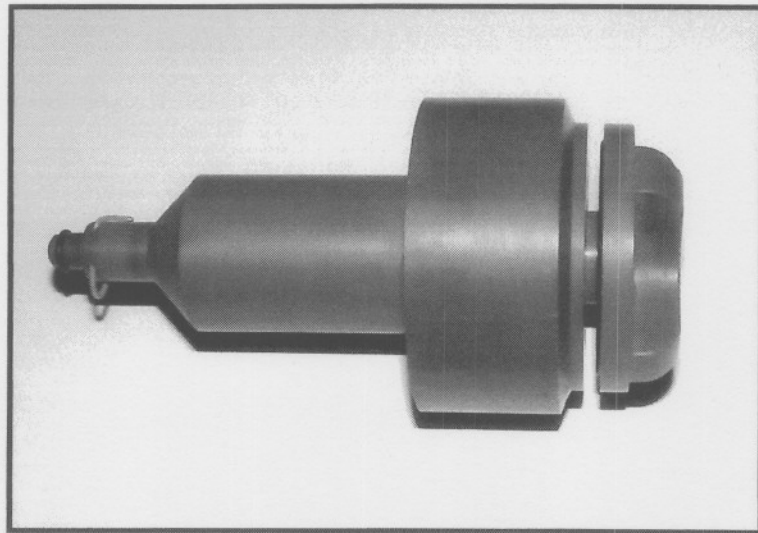
*Figure 10: Detail view of dispenser dosing piston arrangement.*

### 3.4.2 Development of the first prototype

The final functional parameters of the *Dispenser* prototype, as designed, are as follows:

- Cylinder diameter of 9 mm and piston stroke of 6 mm provide a dispensing dose potential of 0.34 cm<sup>3</sup> at an assumed volumetric efficiency of 90% maximum.
- Cylinder diameter of 9 mm and piston stroke of 6 mm provide a dispensing dose potential of 0.30 cm<sup>3</sup> at an assumed volumetric efficiency of 80% minimum.
- *Steripure* storage capacity of maximum 40 cm<sup>3</sup> is provided for.

A prototype model was built by M.N. Nieuwoudt<sup>25</sup> and can be seen in Figure 11.



*Figure 11: First prototype of the purification dispenser.*

### 3.4.3 Results of the purification dispenser

The prototype Dispenser fulfil to most of the design specifications. The specifications are given below with a short discussion of the results.

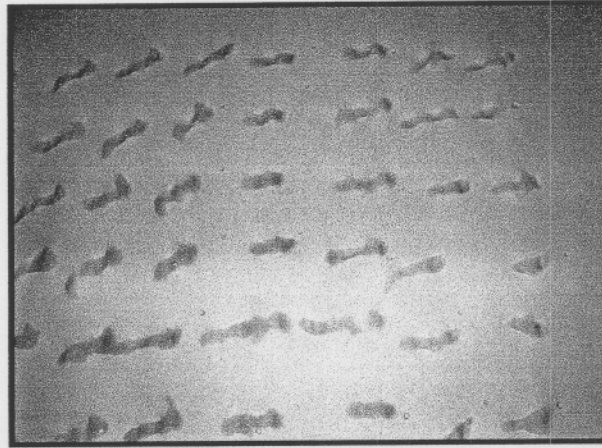
- *Unit to be incorporated in SHB spout as replacement for existing cap.*

This was successfully done and can be seen in Figure 13. When required the Dispenser can easily be replaced with the original cap. This may be the case in areas where disinfectant water is not a problem at it is required to sell the SHB unit without the add-in Dispenser.

- *Design to ensure dosing for every filling:*
- *Volume between 0.3 and 0.35 cm<sup>3</sup> to be dosed per dispensing cycle.*

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Every time, after filling the SHB with water, the Dispenser is screwed onto the spout. When this is done, Steripure is released into the SHB storage tank. The result of this specification can be seen in Figure 12 where liquid from the prototype Dispenser is dispensed on a white board. A volume of between 0.3 and 0.35 cm<sup>3</sup> is disposed.



*Figure 12: Individual dispensing volumes from prototype dispenser.*

- *Design to prevent dosing for every pouring of water.*

In Figure 13 the second lid of the Dispenser can be seen. It is opened to pour water from the SHB. A circular array of narrow water channels allow water to flow out of the SHB and air to simultaneously enter the SHB when the lid is only partially unscrewed. It thus create a preferential method, easier than removing the complete unit, for water to be poured from the SHB. The Dispenser does not dispose Steripure (as in Figure 12) when the second lid is closed or opened.

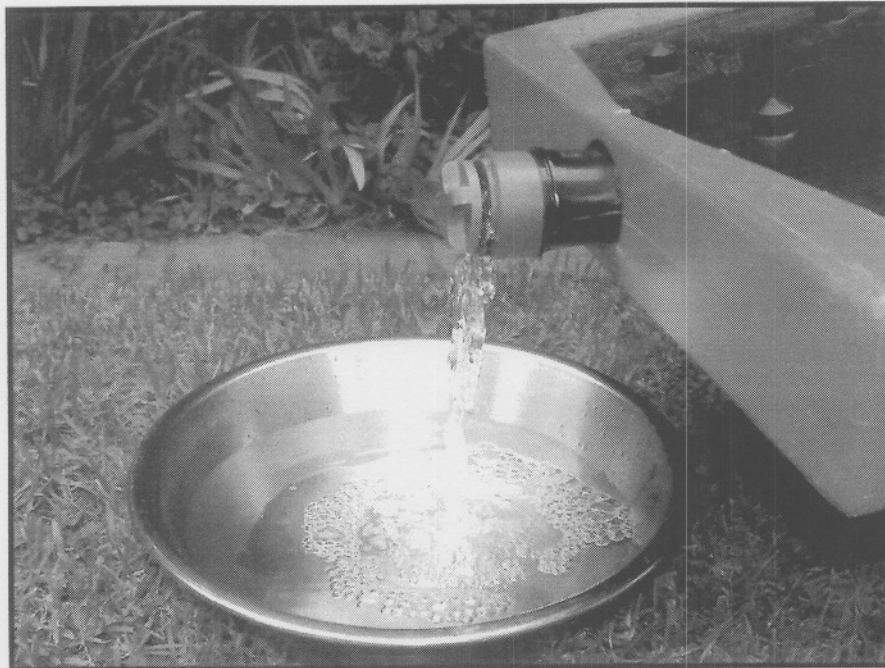


Figure 13: Demonstration of the water purification dispenser prototype.

#### 3.4.4 Cost implications

Table 3 summarises the manufacturing costs for the Purification Dispenser unit. The total of R598 consists of R10 labour costs and R11.10 tooling cost.

Manufacturing of Disinfectant Dispenser Prototypes					
No	Component / Activity	Material	Process	Tooling Cost	Component Cost
1	Screw Body	UPVC	NC Machining	R 2,000.00	R 250.00
2	Screw Lid	UPVC	NC Machining	R 2,000.00	R 125.00
3	Container	PP	NC Machining	R 2,000.00	R 50.00
4	Container Stopper	Si Rubber	Mold	R 1,500.00	R 0.50
5	Mouth Insert	Stainless Steel	NC Machining	R 1,500.00	R 125.00
6	Piston	PP	NC Machining	R 500.00	R 15.00
7	Spring	Stainless Steel	Buy out		R 0.50
8	Piston retainer	Stainless Steel	Buy out		R 0.50
9	Screw Body Seal	NBR O-ring	Buy out		R 3.00
10	Screw Lid Seal	NBR O-ring	Buy out		R 3.00
11	Piston Seal 1	NBR O-ring	Buy out		R 2.00
12	Piston Seal 2	NBR O-ring	Buy out		R 2.00
13	Piston Seal 3	Silicone Rubber Sheet	Punch Cut		R 0.35

14	Buying Components		16 hours	R	1,600.00
15	Assy Labour		0.1 hour by Hand		R 10.00
16	Consumables	Glue, etc			R 0.05
			Tooling total	R	11,100.00
			Cost/unit		R 586.90
			Tooling/unit		R 11.10
			Total cost/unit		R 598.00

Table 3: Estimated cost for the Water Purification Dispenser unit when manufacturing in small volume (1-1000 units).

### 3.5 CONCLUSION

Untreated water sources such as surface waters (streams, rivers, lakes, etc.) or unprotected open wells are the vehicle for waterborne bacterial diseases such as cholera and typhoid fevers. Disinfection of water dramatically reduces the incidence of these diseases. Untreated waters may also play a role in the transmission of water-washed viral enteric diseases

It was seen that the *Vibrio cholerae* bacteria is not a very strong organism. If the bacteria is present in water and the water temperature is kept above 45°C for longer than an hour, the bacteria will die. From the thermal results of the SHB it could be seen that cholera will not survive in the SHB.

It would however be too high a risk to depend on pasteurisation from the SHB as the only method of water disinfection. Too many common pathogens require higher pasteurisation temperatures for destruction. On days with reduced sunshine the water temperature would not necessarily reach this temperature, but it could still reach an acceptable temperature for domestic hot water use. The best method of water disinfection to use with the elevated water temperature of the SHB would be a chemical method.

The drawback of commercially available sodium hypochlorite solutions (bleach) as a chemical disinfectant for drinking water, is its tendency to decompose at temperatures from as low as 25°C. The stability of *Steripure* concentrations at temperature makes it suitable for nearly all storage conditions that could be expected. This makes it possible to integrate within the SHB a storage container with sufficient disinfectant for a reasonable period's usage. This route will thus further be followed for implementation with the SHB.

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The Purification Dispenser was designed and a prototype was manufactured. The Dispenser fulfilled to most of the design specifications. The cost of the Dispenser prototype was close to R600 per unit. More research and new strategies are necessary to bring down the mass production price to a cost target of about R 30 or less. This will enable the manufacturer to achieve a target-selling price of around R 50.

### 3.6 REFERENCES

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## **SECTION 4: SOCIO ECONOMIC STUDY IN THE VALLEY OF THOUSAND HILLS**

*This section deals with market-related issues that are essential to the success of a business venture in manufacturing and marketing the Solar Heat Barrow. These issues include market requirements, awareness, acceptability, affordability and accessibility.*

### **4.1 PREAMBLE**

In order to finalise the business potential of the SHB, it is important to determine what the needs of the target market are. The best means to achieve this is by conducting an ab initio market and socio-economic survey. The SHB was tested for two months in a rural community in KwaZulu Natal with no in-house piped water supply. During this test period the socio-economic response of the users was closely monitored to determine the need for the product in rural communities.

In this section, market-related components of previous work done on the SHB are also compared to the results of this project. In comparing the socio-economic study of this project with previous work a more absolute result can be obtained, which will enable organisations to obtain a more accurate perspective of the business potential for the SHB.

### **4.2 DESIGN QUESTIONNAIRES**

Three types of questionnaires were given to the people of the pilot site:

- The first questionnaire (Appendix A, A.1) went out into the community before the two month test period started in October 2002. The questionnaire focused on biographical information, which included conventional ways of heating and transporting water for domestic use. The perception of the people about a product that can transport and heat water for domestic use was also tested.
- The second questionnaire (Appendix A, A.2) was only given to the 15 households that used the SHB. This questionnaire was completed one month after the test

period started, in November 2002. The aim of this questionnaire was to obtain feedback from the users about the quality and durability of the SHB.

- The third questionnaire (Appendix A, A.3) was also given to the 15 households, using the SHB, after the two month test period had been completed. The aim of this questionnaire was to get the opinion of the users about the product as well as to gather information about the quality and durability of the SHB. It was handed out and collected in January 2003.

#### 4.3 SOCIO-ECONOMIC SURVEYS IN MABEDLANE

It was decided to choose a community in the Valley of Thousand Hills in KwaZulu Natal as the demonstration site. The name of the community is Mabedlane. It is a remote rural area 20 km's north of Botha's Hill and is situated along the Umgeni River. The community is dependent on the river for domestic water. Most families are headed by women. The area has low levels of infrastructure, poor roads, a high unemployment rate and poor health facilities. Figure 14 shows a picture that was taken in the village. It gives a good perspective of the terrain where the SHB was tested for the two month test period.



*Figure 14: Typical settlement in the village of Mabedlane, the site for the field test of the SHB.*

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## 4.4 RESULTS OF THE STUDY

112 households participated in the first survey, which was conducted before the test period started. The detailed results obtained from this survey are given below. The verified and processed results of the second and third survey are also given in this section. These results include information about the quality and durability of the unit. This can be used to indicate the maintenance required by the unit and what the expected life is. It also includes the total perception of the user on the use and durability of the unit after the completion of the two month test period.

### 4.4.1 Results of first questionnaire

The first survey showed a very positive response from potential users. From the 112 questionnaires given to the people of Mabedlane, all indicated that they are interested in a product that can transport and heat water for domestic use. The socio-economic study has shown that the price per unit needs to be reduced as far as possible as 85% of the people who participated in the survey indicated that they would only pay less than R100 for the product. Only 5% indicated that they would pay between R100 and R200.

Further responses are:

- ***Water transport and heating***

In order to ascertain the usefulness of the heat barrow as a water transporter, it was important to determine the number of people with water taps inside their homes. After this was determined the people were asked how far they walked to collect water for domestic use. The survey showed that the average distance covered to collect water is more than 2 km. Figure 15 shows that 69% of the households collect their water for domestic use from the Umgeni River. 46 % of the respondents indicated that they have a water tap in the house. It is interesting to note that 15% of the houses have water taps in-house, but are also dependant on the river for water for domestic use. This may mean that the water taps may not be functioning all the time, or that the people collect water for other reasons than drinking from the river. This is indicated with a dotted line in Figure 15.

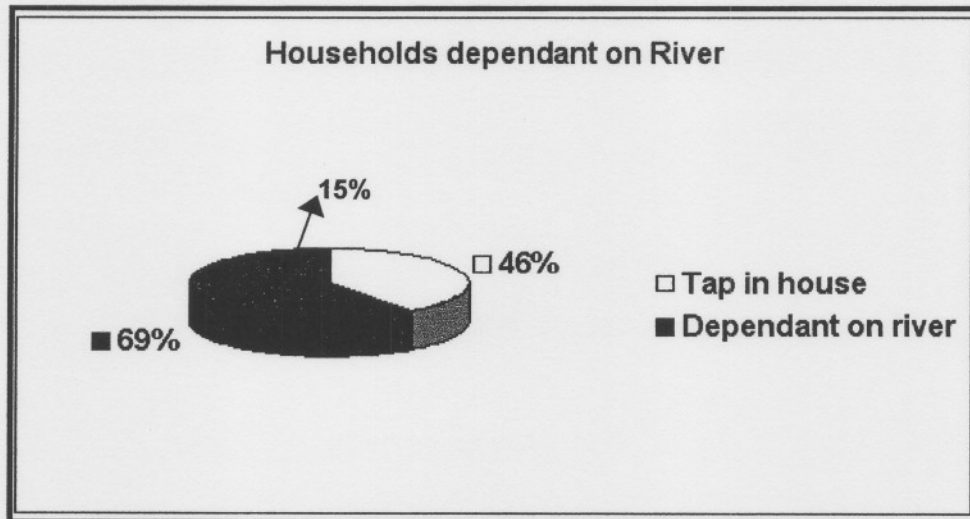


Figure 15: Percentage households dependent on water collected from the river.

The question about the method of heating water for domestic use was asked to determine the importance of the heat barrow in relation to the available energy sources that are used. The survey showed that more than 75% of the people are still using wood or coal. Only 11% of the households have access to electricity. The remaining houses utilise paraffin and LP gas in about equal proportions. This is showed in the pie diagram in Figure 16.

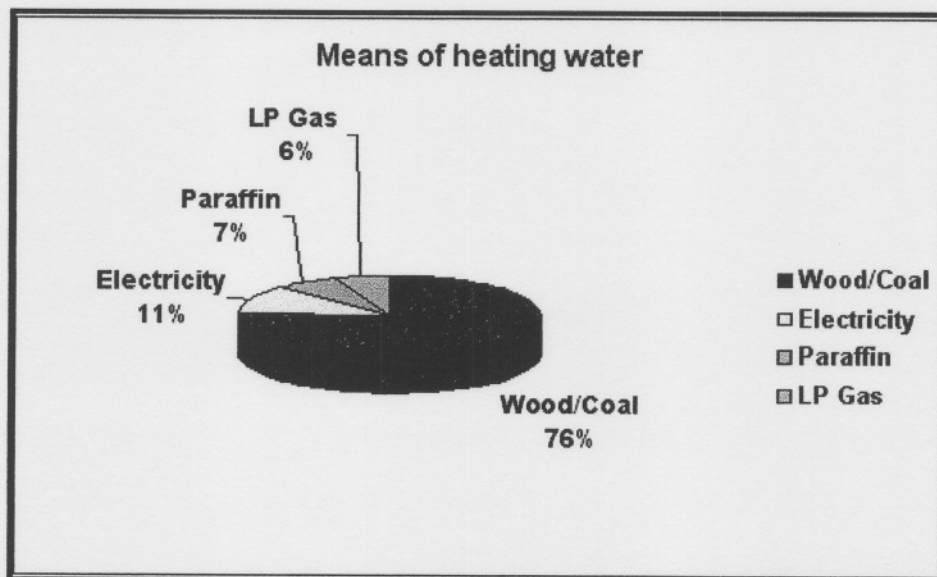


Figure 16: Methods of heating water for domestic use.

According to the 1996 Census more than 25% of all the South African households use wood and coal as a source of cooking<sup>26</sup>. When comparing the results of Figure 16 with Figure 17 it

is clear that the majority of people that use wood and coal as a source of energy live in rural areas. The households that fall in this class will be the potential users of the SHB unit.

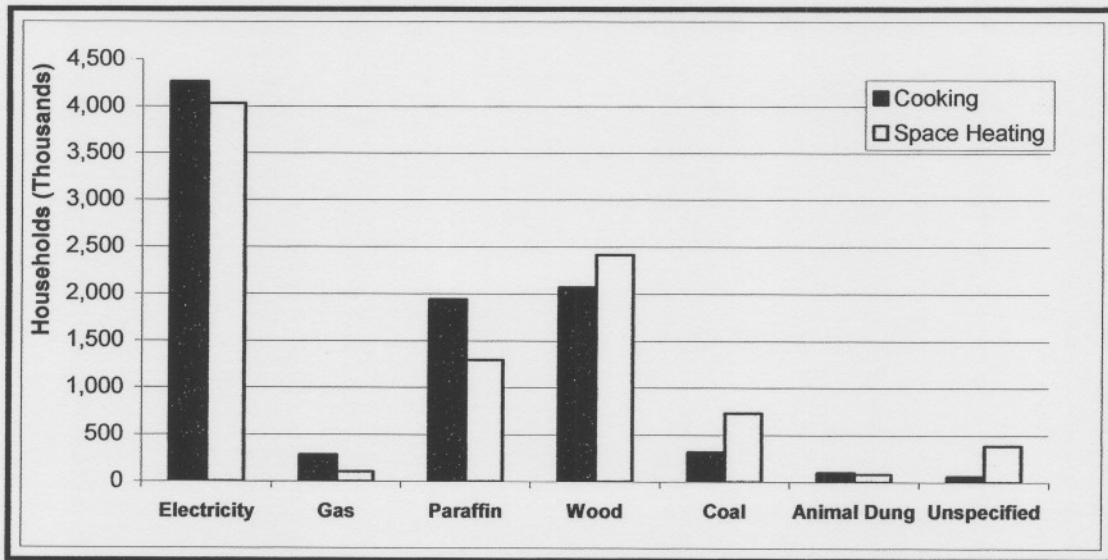


Figure 17: South African households using various sources of energy<sup>26</sup>.

- **Frequency of collecting water per day**

Figure 18 shows that more than 80% of the people collect water two times and more per day. Because women and children mostly collect water with portable containers, it can be said that between 15 and 20 litres of water is collected with every collecting. When wheelbarrows are used to carry the water, a higher quantity of water can be collected with every collection. Wheelbarrows are not generally used in this rural community. Thus it can be said that a average amount of 10 to 20 litres of water is collected per collecting.

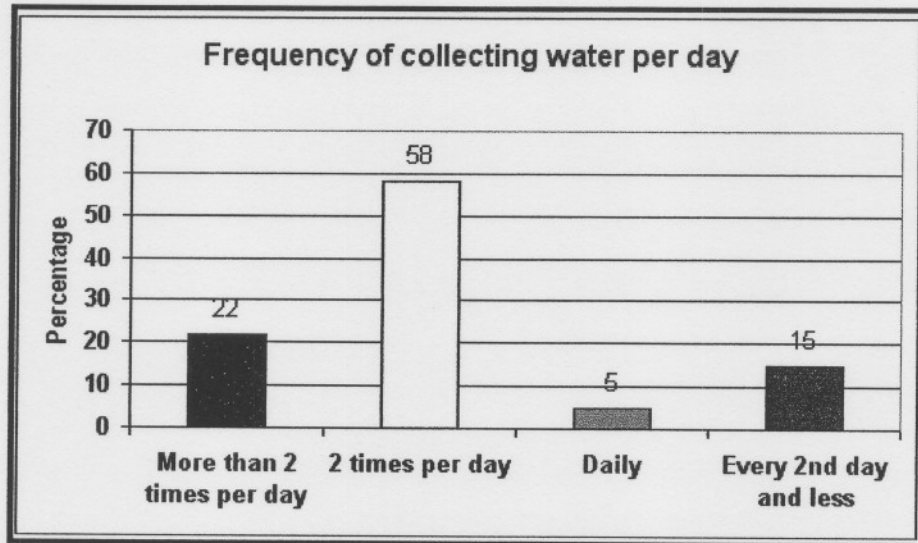


Figure 18: Frequency of collecting water per day.

To ensure the accuracy of the figures, the concept of 1 litre was explained to the participants. After this explanation 39% of the people responded that they use between 10 and 25 litres of hot water per day. 34% indicated that they use between 25 and 50 litres of hot water daily. It is of interest to note that this usage volume correlates fairly well with the design volume of the SHB of 25 litres.

- **Age Group**

The survey indicated that 64% of the people collecting water were teenagers, between the age of 11 and 19 years of age. 37% of the people were between the age of 20 and 29 years. Only 12% of the people were younger than 10 years and older than 60 years of age. This is shown in Figure 19.

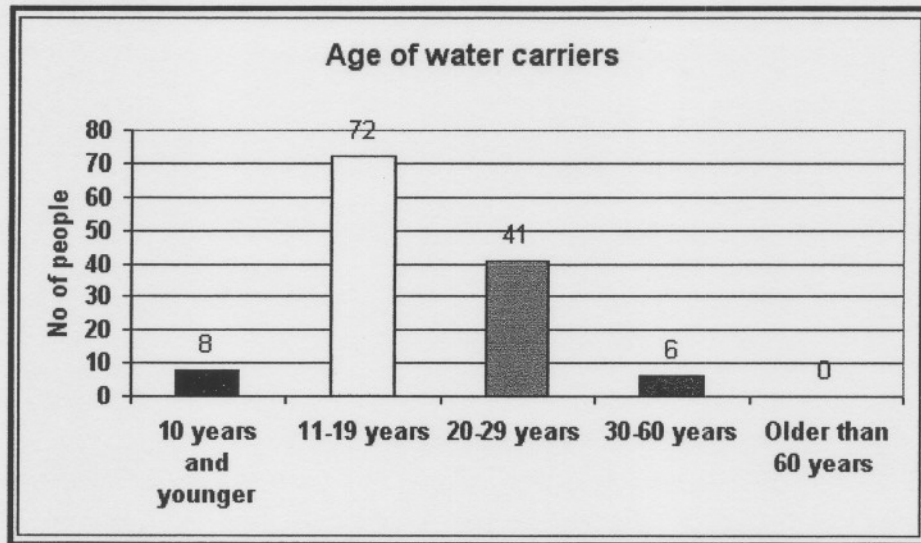


Figure 19: Age group of people collecting water.

- **Time of day using hot water**

The time that people use hot water is important to ensure that the original design specification (hot water 30°C above tap water at 20h00) is realistic.

It is shown in Figure 20 that from the 112 households, 90% indicated that they required hot water in the mornings, 34% in the afternoon and 57% in the evening. It can be noticed that these responses provide a total in excess of 100% as multiple responses were allowed.

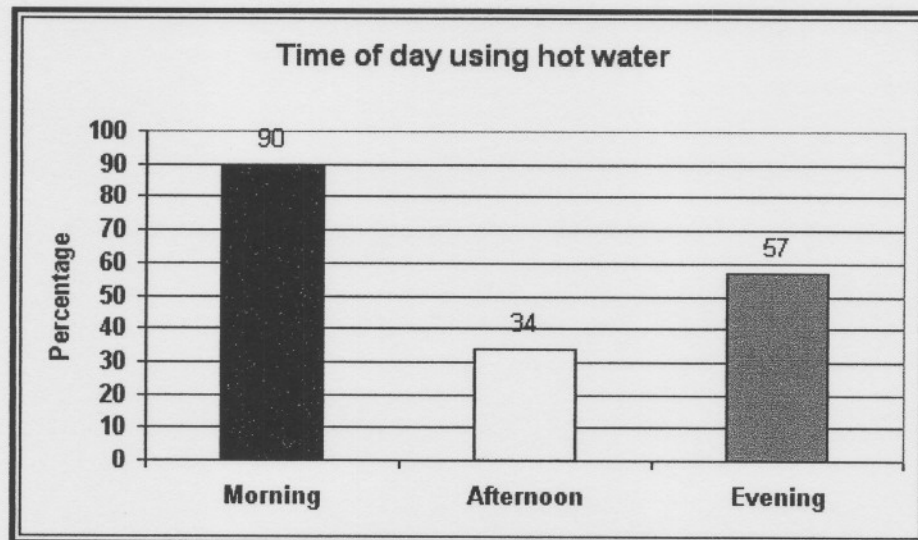


Figure 20: Times when hot water is used.

People were asked to indicate the reason why water is heated during the morning, afternoon and evening. Figure 21 provides this information for the morning, afternoon and evening. It can be seen that most of the people are heating water during the morning.

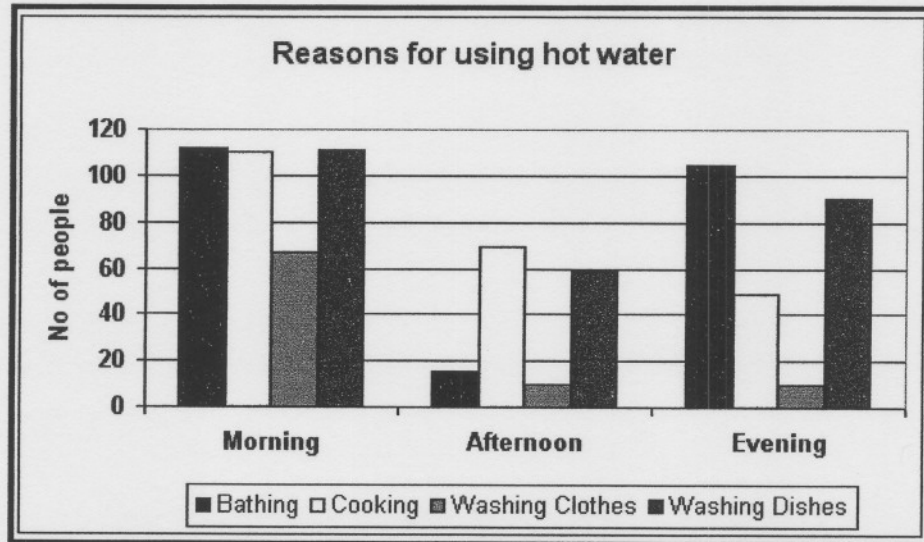


Figure 21: Reason for using hot water.

- **Price**

Respondents were asked what price they would be prepared to pay for the SHB. From the 112 interviewees, 85% indicated that they would only pay less than R100 for the product. 15% indicated that they would pay between R100 and R200.

It is important to note that there is a difference in what people say they are prepared to pay for a certain product and what they will do in reality. Some people will indicate a higher price than what they can actually afford. They will do this to pretend to have more money than what they really have. They will see it as a humiliation when indicating a lower price.

On the other hand people may state a lower price than what they really are prepared to pay for a unit, hoping it will lower the actual price. It can be seen that more research needs to be done regarding the price of a SHB unit.

Because of the above statement it is important to correlate the prepared price to pay with the annual income of the potential users. The survey showed that 42% of the households have a

monthly income of less than R200. 24% of the households have a monthly income of between R200 and R500 and 23% between R500 and R1000. Only 11% have an income of more than R1000 per month. These results are shown in Figure 22.

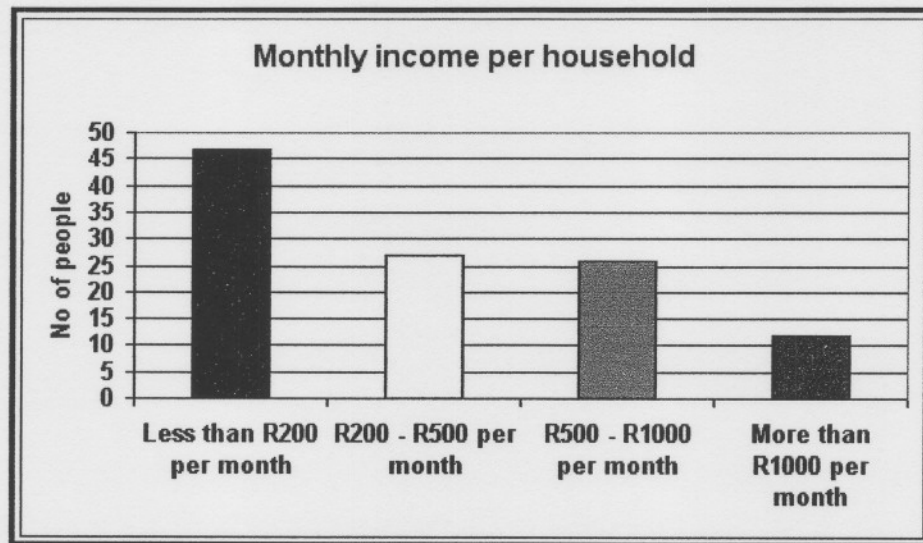


Figure 22: Monthly income per household.

#### 4.4.2 Results of second and third questionnaire

The second and third questionnaires were given to the 15 households that used the SHB. This second questionnaire was completed one month after the test period started, in November 2002. The aim of this questionnaire was to obtain feedback from the users about the quality and durability of the SHB. The third questionnaire was given to the 15 households, after the two month test period had been completed. The aim of the last questionnaire was to obtain the opinion of the users about the product as well as to gather information about the quality and durability of the SHB. It was handed out and collected in January 2003.

From the 15 households, all indicated that they were interested in purchasing a SHB. All off the households indicated that their neighbours and friends who have seen how a SHB unit works are interested in buying the product. When the people were asked what they were willing to pay for a unit, the answer was very much the same as the answer obtained from the first questionnaire. Two households indicated that they are only able to pay less than R50 per unit. The rest of the households indicated that they are willing to pay between R50

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and R100 per unit. From these results it is again apparent that the people who need a SHB most, will not be able to pay the full retail price.

The community was exceptionally happy with the heating and transporting performances of the SHB. All the households indicated that the SHB heat the water warm enough, in fact the people were amazed to see how warm the water from the unit was. All the participants indicated that they are definitely using less wood/coal for heating water.

From the 15 users, all indicated that the SHB fill easily. Eight users indicated that the unit leaks water while transporting it from the river. The rest of the users indicated that no water leaks while transporting it. Although the sealing mechanism of the barrow needs to be looked at, the results show that the users are satisfied with the design of it.

#### 4.5 COMPARISON OF SURVEY RESULTS WITH PREVIOUS WORK DONE

This sub section will compare the socio-economic results of this project with the socio-economic results of a project previously done on the SHB. The project that is used for the comparison was conducted by P. B. Taylor in fulfilment of the requirements for his PhD degree<sup>27</sup>. The methodology of this project was the gathering of data by means of a questionnaire from employees at the University of Pretoria that lived in Mamelodi, Hammanskraal and at the Marabastad bus depot.

There is a similarity in the socio-economic result of this project and the previous project and this correlation will be used to obtain a more complete opinion to determine the business potential for the SHB. The two socio-economic studies are similar in the following ways:

- Both determined a view of the need for the SHB in specific rural areas in South Africa.
- Both asked the respondents what they were willing to pay for the SHB.

These two points will be used to compare the results of the two market studies. The market survey of the previous project was conducted at the Mandela Village squatter camp in Mamelodi and at Makapanstad in Hammanskraal. A second market survey was also conducted at the Marabastad bus station.

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It is important to take into account that the survey of the previous project was conducted in two rural areas where most of the people work in the city. Whereas in this project, the survey was conducted in the Valley of Thousand Hills in KwaZulu Natal, where the people have a more agricultural way of living. Thus, there will be definite differences in the results, due to the geographical difference, but these disparities must also be considered when analysing the business potential for the SHB.

- ***Need for the SHB***

In the survey of this project it was shown that more than 75% of the people of Mabedlane village are still using wood or coal as a means of heating water for domestic use. Only 11% of the households have access to electricity to heat water. The remaining houses use paraffin and LP gas. This was shown in the pie diagram in Figure 16.

Results from the interviews in Mamelodi and Hammanskraal showed that 17% of the people used coal or wood to heat water, 16% used bottle gas, 43% used electricity and 60% used paraffin.

Respondents interviewed at the Marabastad bus station showed that 25% used coal or wood to heat water, 12% used bottle gas, 82% used electricity and 23% used paraffin. It can therefore be seen that the people interviewed at the bus station are more affluent as the major source of energy is electricity.

When comparing the results of the survey in Mabedlane to the results obtained in Mamelodi, Hammanskraal and Marabastad there is a definite difference in the people who are dependant on natural resources for heating water for domestic use. This is shown in Figure 23.

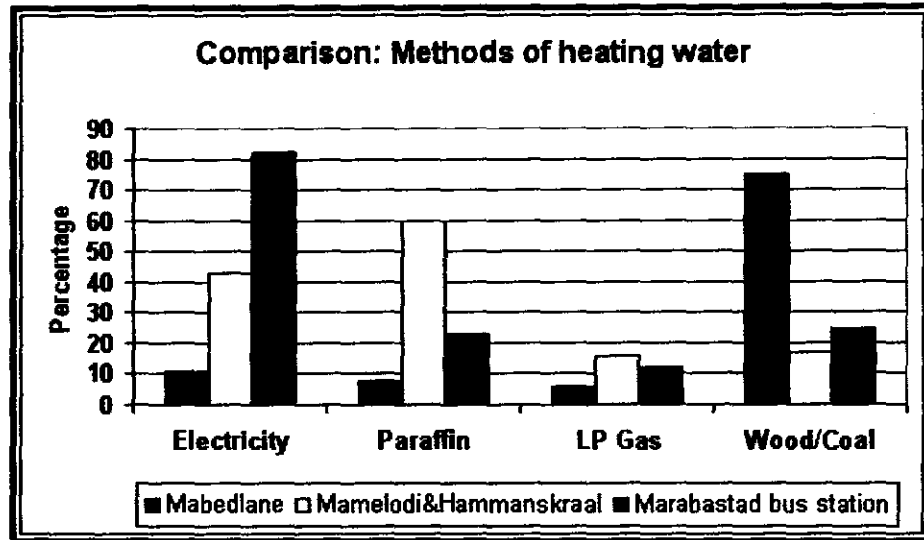


Figure 23: Comparison: Means of heating water.

From the comparison it is clear that the rural areas closer to cities use more electricity than the rural area that have a more agricultural way of living, however this number is still very low. It is important to point out that the largest majority is still dependant on fossil fuels such as wood, coal, paraffin and bottle gas for heating water.

Figure 15 showed the percentage of households in Mabedlane collecting their water for domestic use from the Umgeni River compared to those having a piped water supply in their houses. Results from Mandela Village (Mamelodi) and Makapanstad (Hammankraal) showed that 49% of the surveyed people had running water in their dwellings. At the Marabastad bus station, 87% of people stated that they had running water.

This fact again attests to the higher income of the people interviewed in Marabastad. The average distance that people travel to a water tap is 150 metres, which is in line with RDP standards. The comparison of people with and without running water in their houses for the two surveys is shown in Table 4. This shows that households living closer to cities have a higher percentage of running water in-house, however there are still a large number of households who are dependant on water for domestic use from sources such as rivers and springs.

	Houses collecting water from natural sources (%)	Houses with piped water supply (%)
Mabedlane	69	46
Mamelodi&Hammskraal	51	49
Marabastad bus station	13	87

*Table 4: Comparison: Households with piped water supply vs. households collecting water from natural sources.*

In both the surveys nearly all the respondents were positive about a product that will be able to transport and heat water for domestic use.

- ***The willingness to pay for the SHB***

Table 5 compares the results of the two projects when asked what the people were willing to pay for a SHB unit. It is clear that the people of Mabedlane will not be able to pay more than R100 for the SHB, while people living and working closer to cities will be able to pay more. It is important to correlate this result with the annual income of the potential users. The people of Mabedlane indicated that 42% of the households have a monthly income of less than R200. 24% of the households have a monthly income of between R200 and R500 and 23% between R500 and R1000. Only 11% have an income of more than R1000 per month.

There were no results available about the income of the people living in Mamelodi, Hammskraal and at the Marabastad bus station. Because they live and work closer to a city it can be said that their monthly income is higher than the people from Mabedlane.

	Less than R100	R100 – R200	R200 – R300	More than R300
Mabedlane	85%	15%	0%	0%
Mamelodi&Hammanskraal	43%	25%	21%	10%
Marabastad bus station	11%	35%	25%	29%

*Table 5: Comparison: What people are willing to pay for the SHB.*

The comparison between the two market surveys has shown that there is definitely a need for the SHB in rural communities in South Africa. The only thing that is still not clear is the price for the SHB. People in rural communities, living further away from the city will not be able to pay the same price as people living and working closer to cities. The large majority of people in Mabedlane have indicated that they will only pay less than R100 for a unit. Nobody in Mabedlane have indicated that they will be able to pay more than R200 for a unit, whereas in Mamelodi, Hammanskraal and Marabastad some people even indicated that they will pay more than R400 for a SHB unit.

It is important to note that the people of Mabedlane were shown a physical SHB unit when they were asked what they were willing to pay for such a unit. However, the people in Mamelodi, Hammanskraal and Marabastad bus station were only shown pictures and a description of a SHB unit when asked for an opinion. The more reliable information about the price of a unit will be the opinion of the 15 households in Mabedlane, after they have used the SHB for the two month period.

#### 4.6 REFERENCES

- <sup>26</sup> Energy Management News, "The safety of paraffin and LPG appliances for domestic use", Volume 8 Number 2 pp. 1, Winter 2002.
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## **SECTION 5: POSSIBLE BUSINESS SCENARIOS**

*Two different business approaches are discussed in this section. Implementing a solar water heater into rural communities brings a new dimension to the research investigation. The scenarios will give a good indication about the business potential for the SHB.*

### **5.1 INTRODUCTION**

#### **5.1.1 Production**

TEMM International has *researched* and *developed* an industry ready prototype Solar Heat Barrow. This unit functions simply by filling it with water and leaving it outdoors during the daytime. Ideally the unit should then be transported indoors in the late afternoon. The warm water can then be used for personal hygiene and washing of dishes at night.

The problem of collecting water from boreholes and rivers in the rural areas of South Africa is also addressed by this new design. The first survey showed that 81% of the people of Mbedlane collect water two times and more per day. The average distance covered to collect water for domestic use is more than 2 km. This harsh condition puts a burden on rural women and children who have to carry plastic containers filled with fresh water over these long distances. The new design exploits a synergy between a simple easily transportable water container and a solar water heater.

This project concerned the manufacturing of 15 SHB units. The 15 units were to be tested in a rural community in the Valley of Thousand Hills in KwaZulu Natal. The community has a high number of houses with no in-house piped water supply.

When manufacturing only 15 units the material cost and assembly time is high. The manufacturing of the plastic water collector of the 15 SHB units was done with the process of rotation moulding that is used when prototypes of a product are made. When the product is mass produced, injection moulding is used. The cost of the mould with rotation moulding is relatively low compared to injection moulding, while the time for producing the container is

much longer. This makes the cost of the plastic water collectors high when producing only 15 SHB units. The total cost for the materials per unit, when manufacturing 15 units, was R800. (This excludes the tooling cost.) Three engineers did the assembly of the 15 units over 2 days. The total man-hours to assemble one unit were 4 hours. A preliminary analysis indicated that when manufacturing the SHB in large volume, the production cost can be brought down to R350 per unit. Figure 24 shows a picture that was taken during the manufacturing process of the 15 SHB units.



*Figure 24: Picture that was taken during the manufacturing process of the 15 SHB units.*

It may be possible to decrease the production cost of R350 once the market size is known. Later in this chapter an estimate for the potential market size for the SHB is given. There is still work to be done concerning the issue of large volume manufacturing. At this stage only a preliminary analysis for manufacturing the SHB in large volume was done. When producing the SHB in the order of 5 million units, it may be possible that the manufacturing cost will decrease significantly. However, for the scenarios of this chapter we will be working with a large volume production cost of R350 per unit.

### *5.1.2 Distribution Channels*

When discussing the business potential of the SHB, one needs to look at every aspect that will contribute to the final price, the end user will see. Before manufacturing the SHB in large

volumes the distribution possibilities of the units, still needs to be investigated more thoroughly.

During this project the 15 units were manufactured in Pretoria and were transported to the Valley of Thousand Hills in KwaZulu Natal, where they were distributed to 15 households with no running water. For this project a 1 ton pick up truck together with a ¾ ton trailer were hired. Figure 25 shows a picture that was taken when transporting the units from Pretoria to Mabedlane.



*Figure 25: Transporting 15 SHB units from Pretoria to Mabedlane.*

Before consideration can be given to large volume manufacturing, certain aspects need to be investigated. One such aspect is to determine whether it will be feasible to distribute the SHB, in parts and then to assemble the unit where it will be used in the rural area. This will bring down the distribution cost, because more units can then be transported in one consignment. However, somebody needs to do the assembly in the rural area where it will be used and that will increase the market price that the end user will see.

Another point to remember is that the assembly of the units in the rural area might be an opportunity to create work in these areas. This will be an ideal opportunity for people to start small factories in the rural areas. These factories might even be used as the premises to sell the units from. But this issue will bring a new dimension to the project and as was said, this needs to be further investigated to determine whether it will be feasible.

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Let us assume for the business scenarios in this chapter that a fixed distribution cost of R35 per unit will be added to the manufacturing cost for distributing the units to the rural areas where they will be used.

### 5.1.3 Marketing

When considering marketing strategies for the SHB, the question of how much marketing cost may be added to the final price, must be answered. One of the aims of the SHB is to manufacture a low cost solar heater that can be used to transport water for domestic use. The aim is thus to keep the cost for the end user as low as possible. Because this product is not a luxury, but can be seen as a necessity for people without running water, marketing is not that important. When the 15 SHB units were delivered to Mabedlane village, it was clear that most of the people, especially the women, saw the advantageous of the product immediately. This can be seen in Figure 26.



*Figure 26: Marketing of the SHB: How much effort should be put into this?*

When manufacturing the SHB in large volumes, a marketing cost of R5 per unit can be added to the final cost. Further studies on this issue will determine whether a marketing cost of R5 per unit is realistic, or not.

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#### 5.1.4 Affordability and selling price

We have to adopt a middle course between what the end price for the SHB will be and what the end user will be able to afford for the unit. In section 4 it was seen that for most people living in rural areas a unit price of more than R300 may be unaffordable. To make the SHB unit price affordable and attractive for most people in rural areas, the profit on a unit should be kept as low as possible.

The survey that was conducted in Mabelane has shown that 42% of the households have a monthly income of less than R200. 24% of the households have a monthly income of between R200 and R500 and 23% between R500 and R1000. Only 11% have an income of more than R1000 per month. These people have indicated that 85% will pay less than R100 for a SHB unit, the rest was willing to pay between R100 and R200. Nobody indicated that they are willing to pay more than R200.

Table 6 shows the calculations for the final price for a SHB unit, when manufacturing more than 12 000 units per year.

Manufacturing	R300
Purification dispenser	R50
Distribution	R35
Marketing	R5
Profit	R10
<b>Total</b>	<b>R400</b>

*Table 6: Wholesale price for the one SHB when manufacturing in large volume.*

This chapter provides a starting point for determining the business potential of the SHB product. The remaining sections of this chapter sketch business scenarios for the SHB, using the end price as stated in Table 6.

#### 5.2 SCENARIO 1: RSA MARKET AT A FIXED RETAIL PRICE.

In this scenario certain assumptions are made. One assumption that determines the market size of the scenario is to assume that all rural houses in South Africa without electricity have

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no in-house piped water supply. The opposite is also assumed. That rural houses with electricity have an in-house piped water supply and the electric appliances to heat water.

Thus, rural households *with electricity* will be unlikely to purchase a SHB unit. Rural households *without electricity* can be seen as the potential market. Because this base assumption is used to determine the estimated market size, it leads to the following scenarios. The structure of the scenarios can still be used when the quantum of the market size is altered.

### *5.2.1 Estimated market size*

It is estimated that 54% of rural South African households do not have access to electricity<sup>1</sup>. There is a total of 3 873 990 rural houses in South Africa<sup>28</sup>, giving a total market size for this scenario of 2 091 954 households.

### *5.2.2 Market penetration*

When estimating the market penetration of the SHB, the data in Table 5 must be analysed. It was seen that 0% of the people living in Mabedlane were willing to pay more than R200 for a SHB unit. People in rural areas closer to cities, showed more interest in a SHB for a selling price of above R200. In Mamelodi and Hammanskraal 31% of the people were interested to buy a SHB for more than R200. At Marabastad bus station 54% if the people were interested to purchase a SHB for more than R200.

A time frame of five years will be used for this scenario. If a nation-wide marketing and distribution strategy is followed, a market penetration of around 10% over this period can be expected.

The penetration model used to spread the sales over the 5 year period is given in Table 7 below. This is a typical "S-curve" for typical research and development products such as the SHB.

The percentages indicate the portion of the market penetration that can be expected every year. For example, in the first year, the total sales will be 8% of 10% or **0.8%** of the estimated market size.

Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
8%	28%	44%	16%	4%	100%

*Table 7: Penetration model used to calculate annual income.*

### 5.2.3 Estimated income

To determine the income for this scenario, there must firstly be decided for what price a SHB unit will be sold to the user. To determine this, certain aspects should be kept in mind. Some of these aspects are:

- **What can the users afford?** This must be correlated with the income profile.
- **What benefits do the unit have for the user?** These benefits should out-weigh the retail price, otherwise the user will see no need in purchasing a unit.
- **What benefits will there be for the environment?** This aspect can also be used to involve energy companies to support the implementation of the SHB. This can help to keep the retail price of a unit as low as possible.

Considering the statistics that were given in section 5.1.4, the retail price can not be more than R300 per unit. When selling the SHB for a higher price than this the market penetration will be lower. A part of the mission statement of the business is to provide a service to the community, thus the retail price should be kept as low as possible to attract the maximum number of customers.

Further research needs to be done to determine the best retail price for a unit, but for this scenario we will use a fixed retail price of R300 per unit. The estimated income for the 5 years is shown in Table 8 below.

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTALS
<b>Penetration</b>	0.8%	2.8%	4.4%	1.6%	0.4%	10%
<b>No units sold</b>	16 735	58 574	92 046	33 471	8 367	209 193
<b>Income</b>	R5 020 500	R17 572 200	R27 613 800	R10 041 300	R2 510 100	R62 757 900

*Table 8: Estimated income.*

#### 5.2.4 Estimated costs

In Table 6 the wholesale price for a SHB unit was given. This wholesale price can now be used to determine the total cost when manufacturing 209 193 SHB units over a period of 5 years Table 9 gives an estimation of the total cost.

Cost component	Year 1	Year 2	Year 3	Year 4	Year 5	TOTALS
<b>No of units sold</b>	16 735	58 574	92 046	33 471	8 367	209 193
<b>Manufacturing &amp; Dispenser</b> (R350/unit)	R2 510 250	R8 786 100	R13 806 900	R5 020 650	R1 255 050	R31 378 950
<b>Distribution</b> (R35/unit)	R585 725	R2 050 090	R3 221 610	R1 171 485	R292 845	R7 321 755
<b>Marketing</b> (R5/unit)	R83 675	R292 870	R460 230	R167 355	R41 835	R1 045 965
<b>Profit</b> (R10/unit)	R167 350	R585 740	R920 460	R334 710	R83 670	R2 091 930
<b>Totals</b>	<b>R6 694 000</b>	<b>R23 429 600</b>	<b>R36 818 400</b>	<b>R13 388 400</b>	<b>R3 346 800</b>	<b>R83 677 200</b>

*Table 9: Estimated cost.*

The marketing cost is proportionally distributed over the 5 year period. However, it may be necessary to use more than R83 675 in the first year. In the last two years less money may be needed for marketing the product. The total amount of R1 045 965 for marketing can thus be used over the 5 year period, but not in a proportional manner. A suggestion is to use 50% of the R1 045 965 in the first year, 25% in the second year, 10% in the third and 15% in the last two years.

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At this point it must be mentioned that there was not provision made for unexpected expenditures, such as defect units. More field studies are necessary to determine unexpected costs like these. A maintenance plan must also be determined. This will add to the cost analysis. For this scenario it is said that the units are sold with no maintenance guarantee. The user will thus purchase a unit as is.

#### *5.2.5 Scenario discussion*

As can be seen when comparing Table 8 and Table 9, the estimated income is less than the estimated cost. The units are sold at a loss of R100 per unit. When selling 209 193 units over a period of 5 years the total loss will be R20 919 300.

It is easy to say that the retail price should be increased to ensure that there will be no losses, but then certain rural communities in South Africa may not be able to afford the SHB. This scenario demonstrates the point when the SHB is distributed at a loss. The survey that was conducted in Mabelane showed that the market, for which the SHB was designed, might not be able to afford the full retail price.

If this is the case other ways to fund the SHB need to be considered. Earlier in this section it was mentioned that the benefits the SHB have for the environment need to be looked at. This aspect can be used to involve energy companies to support the implementation of the product. If the SHB can be promoted as a practical answer to sustainable development, there are organisations that can be approached to help with sponsoring it.

The use of the solar energy and wind generators are increasing rapidly, generating extensive interest. It will be an increasingly important topic in future. This was clearly seen at the World Summit on Sustainable Development (WSSD), which was held in Johannesburg earlier this year.

The following question is asked in the official brochure of the WSSD, compiled by the United Nations: *"How can we improve people's lives and conserve our natural resources in a world that is growing in population, with ever-increasing demands for food, water, shelter, sanitation, energy, health services and economic security?"*<sup>29</sup>

To add to this the Department of Minerals and Energy (DME) encourages the use of renewable energy, especially in rural areas that are not connected to the national electricity grid. A policy option is to adopt targets for the percentage of renewable energy to be

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achieved within a particular time frame. The DME has recently discussed a target of 5% renewable electricity by 2010<sup>30</sup>. The draft White Paper on Renewable Energy suggested that an additional 10 000 GWh of renewable energy contribution should be achieved over ten years, i.e. 1 000 GWh/yr, to be produced mainly from biomass, wind, solar and small-scale hydro<sup>31</sup>.

Dr. Steve Lennon, executive director of Resources and Strategy at Eskom, has said that “by 2020 renewables could account for about 4 000 MW of South Africa's generating capacity – which would be between 5% and 10% of the total output.”<sup>32</sup> A study by the University of Cape Town examined a range of targets for feasibility and recommended a target of 15% of renewable electricity generation by 2020<sup>33</sup>.

It is clear to see that products such as the SHB are practical answers to these questions and goals. It is a practical answer towards building a more sustainable future. Some of the organisations that can be approached for funding/sponsoring of the SHB are listed:

- **ESKOM:** In supporting the SHB it reflects that ESKOM is supporting the socio-economic development of rural people and exploring the increased use of renewable energies in South Africa.
- **UNDP** (United Nations Development Programme)
- **UNEP** (United Nations Environment Programme): Including the Global Environmental Facility, etc.
- **UN Programme for Refugees**
- **World Bank:** including the Prototype Carbon Fund, Community Carbon Fund for Poor Countries
- **SA Government:** Rural development funds, future use of a possible carbon tax<sup>34</sup>, SMME development funds
- **Developed countries support development in developing countries:** USAID, Canada, Japan, Australia, European Union, United Kingdom, Germany (GTZ), Denmark, Holland, Norway, other

### 5.3 SCENARIO 2: RSA MARKET AT A RENTAL PRICE.

This scenario is build on the same estimated market size as the first scenario. It also uses the same market penetration as the first scenario. Because these assumptions are difficult to

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make at this stage they will be left the same as in the first scenario. Again it is possible to alter these assumptions at a later stage and still use the structure of the scenario.

This scenario differs from the first in the way the user will pay for the SHB unit. In this scenario, the user will pay for the SHB in instalments over a certain period. It can be said that the user rents the SHB and after a certain period takes ownership of it. This way of paying for a SHB will make it easier for the user to afford a unit, but other aspects come forward that may increase the final price.

### *5.3.1 Estimated market size*

The same market size will be used as in the first scenario. This market size is **2 091 954** households.

### *5.3.2 Market penetration*

Again, a time frame of five years will be used as in the first scenario. The estimate for the market penetration is also 10% over this period.

The penetration model used to spread the sales over the 5 year period is given in Table 7. This is a typical "S-curve" for typical research and development products such as the SHB.

### *5.3.3 Estimated income*

When investigating the idea of renting the SHB over a fixed period, certain aspects need to be considered. One of these aspects is the payment period. When renting a SHB on a monthly bases, the monthly payment will be low enough for the user to pay, but the collection fees will be high, which will result in a high final price per unit. When renting a SHB on an annual basis, the annual payment may be too high and the users may not be able to afford the annual instalment. In this case the collection fees will be low, which will cut down the final price of a unit.

Thus a middle course between these two cases has to be adopted. For this scenario we will assume a quarterly payment frequency over a three year period. This means that the user will have to pay the total amount in 12 quarterly payments. This also means that the 12 payments have to be collected.

In the next section we determine the final price per unit, which includes the wholesale price obtained in Table 6 and the collection fee. This final price is determined at R530 per unit. When we use an interest rate of 25% per year Formula 1 determines the payment that need to be paid by the user quarterly over a period of 3 years. The interest rate of 25% per year needs to be converted to a rate per quarter. Thus, we are using 6.25% per quarter in the formula.

$$R530 = \text{payment} \times \left[ \frac{1 - \left(1 + \frac{6.25}{100}\right)^{-12}}{\frac{6.25}{100}} \right]$$

*Formula 1: Equation for determining the quarterly payment over a period of 3 years.*

When using Formula 1, the quarterly payment is determined at R65. Thus the user has to pay R65, four times per year over a period of 3 years. It can be seen that the user rents a SHB unit for a renting cost of R65 per quarter and after 3 years takes ownership of it. Table 10 indicates the total income for the SHB units that will be distributed during the first year. The market penetration for the first year was estimated at 0.8%, which results in 16 735 units.

	Year 1	Year 2	Year 3	TOTALS
<b>Income (R65 x 4)</b>	R4 351 100	R4 351 100	R4 351 100	<b>R13 054 080</b>

*Table 10: Estimated income for SHB units distributed in the first year.*

Table 11 summarises the estimated income for the 5 year period. It must be remembered that the total income for the units distributed in the first year will only be collected over a period of 3 years. This will be the case for all 5 years of distribution.

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTALS
<b>No of units sold</b>	16 735	58 574	92 046	33 471	8 367	209 193
<b>Income (R65x4)x 3 years</b>	R13 053 300	R45 687 720	R71 795 880	R26 107 380	R6 526 260	R163 170 540

*Table 11: Estimated income for SHB units distributed over five year.*

### 5.3.4 Estimated cost

The main expenditure that needs to be covered when renting the SHB units will be the collection costs. This cost need to be added to the wholesale price (transport, marketing) to determine the final price per unit. More research investigation is needed to determine the collection cost, but for this scenario an extra cost of R100 is added to the wholesale price.

When renting the SHB units on a quarterly bases over a period of 3 years, the payments need to be collected 12 times. The collection of the payments will mean that workers need to go into the rural areas and collect the money from the users. We must also keep in mind that on the day of payment the user may not be able to pay the payment. This means that the collector has to go back there again to collect the money. We therefore, add an extra administration cost of R30 over the three year period.

Table 12 below gives the total estimated cost over the period of five years.

	Year 1	Year 2	Year 3	Year 4	Year 5	TOTALS
<b>No of units sold</b>	16 735	58 574	92 046	33 471	8 367	<b>209 193</b>
<b>Wholesale price (R400)</b>	R6 694 000	R23 429 600	R36 818 400	R13 388 400	R3 346 800	<b>R83 677200</b>
<b>Collection fee (R100)</b>	R167 350	R585 740	R920 460	R334 710	R83 670	<b>R2 091 930</b>
<b>Administration (R30/unit)</b>	R502 050	R1 757 220	R2 761 380	R1 004 130	R251 010	<b>R6 275 790</b>
<b>Totals</b>	<b>R7 363 400</b>	<b>R25 772 560</b>	<b>R40 500 240</b>	<b>R14 727 240</b>	<b>R3 681 480</b>	<b>R92 044 920</b>

*Table 12: Estimated cost.*

### 5.3.5 Scenario discussion

In this scenario the SHB will be rented to the users at a quarterly cost of R65 per unit over a period of 3 years. The additional expenditures that have to be added are the collection fees and an administration cost over the three year period.

More research investigation is needed to quantify these numbers, but for this scenario we estimated the collection fee to be R100 for 12 collections and the administration cost to be R30 for the three year period. When asking the people R65 per quarter for three years the total income is estimated at R163 170 540. The total cost is estimated at R92 044 920. The difference is R71 256 620. An interest rate of 25% per year was used in the scenario.

This way of paying for a SHB unit seems to be more attractive for the users and has a greater business potential. The users need only to pay R65 per quarter, which may be more affordable than R300 or R350 at once.

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## 5.4 REFERENCES

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## SECTION 6: CONCLUSION AND RECOMMENDATIONS

*Conclusions and recommendations regarding the design, socio economic study and business potential are given in this concluding section. Recommendations for future planning are also briefly discussed.*

### 6.1 CONCLUSION AND RECOMMENDATIONS REGARDING DESIGN

A final prototype for the SHB as well as the add-on Purification Dispenser was designed and manufactured. In general, the performance of the prototypes designs fulfil to the design specifications.

When manufacturing small volumes, the manufacture price for a SHB is R800 and a Purification Dispenser is R600. This is very expensive if the monthly income of the target market is brought into consideration. However, the manufacturing costs will drastically drop if production rises to more than 12 000 units per year.

More research work is recommended regarding mass production of the SHB and the Purification Dispenser. For example, casting moulds and forms as well as tools must also still be designed for mass manufacturing. The idea of catering for different capacities should be remembered when designing this equipment. For example, it would be ideal if the same tools, forms and moulds could be used with special inserts to increase the capacity of the water tank. This would help to decrease manufacturing costs, resulting in a lower end-user price.

At this stage of the research it is estimated that the mass production price for the manufacturing of a SHB and Purification Dispenser is R300 and R50, respectively. For the SHB and add-on purification dispenser the total manufacturing costs is R350 per unit.

For most people R350 per unit sounds affordable, but people in rural areas may not be able to afford this. Therefore, more research regarding mass production is necessary to bring down the manufacturing costs.

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## 6.2 CONCLUSION REGARDING SOCIO ECONOMIC STUDY

It was decided to choose a community in the Valley of Thousand Hills in KwaZulu Natal as the demonstration site. The name of the community is Mabedlane. The community is dependent on the Umgeni River for domestic water. The area has low levels of infrastructure, poor roads, a high unemployment rate and poor health facilities. The SHB was tested at 15 households for a test period of two months.

Three types of questionnaires were given to the people at the pilot site. The questionnaires can be seen in Appendix A.

- First questionnaire (before the test period started): Focused on biographical information, which included conventional ways of heating and transporting water for domestic use. 112 households participated.
- Second questionnaire (one month after the test period started): Focussed on the feedback from SHB users about the quality of the SHB. The 15 households that used the SHB participated in the questionnaire.
- Third questionnaire (after the two month test period had been completed): Focussed on the opinion of the users about the product as well as to gather information about the quality and durability of the SHB. The 15 households that used the SHB participated in the questionnaire.

The first survey showed that there is definitely a market for a product that can transport and heat water for domestic use. However, the unit price has to be affordable for the specific users. 85% of the people who participated in the first survey indicated that they are only willing / can only afford to pay less than R100 for the product.

People living in rural areas do not have an energy conservation approach to life<sup>35</sup>. It may be hard for them to spend more than a month's salary on a device that heats up water for domestic use, ease the way of transporting the water and purifies the water. If wood or coal is available, they will use it to heat up water, compared to a device that costs a lot of money. Therefore, the cost of the SHB must be as low as possible to attract potential users.

A primary analysis indicated that when manufacturing the SHB in large volume, the production cost can be brought down to R350 per unit (including the purification dispenser). The conclusion is that there is definitely a need in rural areas for a water carrier that can heat

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the water for domestic use, but the unit price needs to be as low as possible and possibly subsidised to make it affordable for the users.

It was clearly established that most people would like to use the heat barrow both to collect water and also as a heating device. This implies that the initial concept of the solar water heater was successful in meeting the specified objectives.

From the second and third questionnaires it was clear that the users were satisfied with the heating performances of the SHB. The community was very interested in purchasing a SHB. They have realised that a SHB will improve their standard of living and regard it as a necessity in their day to day activities.

The third questionnaire focused on user information about the quality and durability of the SHB. This information was based only on the results from the two month field test. The quality and durability information was recorded, but because of the short test period there are still void areas on this part of the research. For example, the SHB has not been tested in extreme weather conditions like hail and temperatures below 0°C.

To obtain a more complete analysis of the quality and durability of the SHB the duration of the field test period must be at least one year. The unit must also be tested in different climatic regions of South Africa. This point is later recommended for future work on the SHB. However, the quality and durability information obtained from the third questionnaire was positive for this study.

The only area where most people differed was in the pricing. People living closer to a city and/or commuting to the city every day have a higher income and more exposure to urban development. They have less time available because of their fixed working schedule and time required for commuting. They will therefore be more willing to try new things that aid them in saving money, time or effort. As a result, the price that they will be prepared to pay will also be higher.

However, the less affluent people will probably benefit the most from using the heat barrow. The positive impact of the heat barrow would therefore be significantly reduced if the price were to be based on the results of surveys conducted in higher income communities. From the results of the three questionnaires that were given in Mabelane it was clear that the people will not be able to pay the full retail price of a SHB unit. The largest majority of people indicated that they can only afford to pay less than R100 for a unit.

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It is apparent that people who will benefit from a SHB most are the people who will not be able to pay the full retail price. Therefore the idea of considering other ways to fund the SHB must be investigated. This was discussed in the first business scenario in Chapter 5.

The socio economic study did not gather information about the amount of energy saved by the SHB. It is recommended in Section 6.4 that a future socio economic study should include a comparison in amount of energy used between households using the SHB and not. This information is important to form an idea of the amount of energy (wood/coal/etc.) that the SHB saves.

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### 6.3 CONCLUSION AND RECOMMENDATIONS REGARDING THE BUSINESS POTENTIAL

When bringing all aspects of the business potential in consideration, it seems that a rental price for a SHB is more favourable. The socio-economic survey, conducted in the Valley of Thousand Hills, showed that the users will not be able to pay more than R200. For people with a very low monthly income it is hard to pay an amount of R400 at one stage.

It may be easier for potential users to pay a rental price for a certain period. After the rental period the SHB becomes their property. This way of paying for the SHB unit brings implications forward. Workers have to go out into the rural areas four times a year and collect the payments.

The collection of the payments itself will be a difficult task. On collection day, the workers may find that the users are not at home, or that they are not able to pay the payment. This means that the workers have to return to those households again on a later stage. More investigation is needed on this idea to determine the feasibility of it, but at this stage it looks to have a greater business potential than paying the full amount at once.

It is clear from these two scenarios that there is a business potential in renting the SHB to users. After a specific rent-period, the user can then take ownership of it. Further investigation is needed on this to determine all aspects. More investigation is also needed on the topic of the distribution of the SHB units in large volumes.

When asking the question if there is a business case that can be developed for the large scale production, marketing, financing and SMME development of the SHB, it is important to note the following:

- From the socio economic study it is clear to see that the SHB can not be sold at the wholesale price of R400 per unit. People in rural areas can simply not afford to pay this amount for a device that ease the way of transporting water, heat the water and purifies the water.
- Therefore, financial help must be brought into consideration to subsidise the wholesale price. By sponsoring sustainable development projects such as the SHB, private companies can easily get local and international exposure. A good example of this is the sponsor that Sasol Pty (Ltd) made in taxi ranks around South Africa as a community

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development project. According to a media release made by them in August 2002, they commit more than R75 million a year on social investment on community development projects in under-resourced communities in South Africa<sup>36</sup>.

Thus, there is definitely a business case for large production, marketing, financing and SMME development of the SHB. But for this to be possible it may be necessary to get financial support to subsidise the wholesale price. This can be done in the form of sponsorships from private companies.

It is known the Government is busy planning a range of activities aimed at rural socio-economic development. This will most probably include a local development institution with an extensive branch structure in rural areas. Many of the issues in getting the SHB effectively into the hands of the user at an affordable price, including micro-financing, may be effectively integrated into this action.

In the Budget Vote Speech of the Department of Minerals and Energy, delivered by Minister Phumzile Mlambo-Ngcuka earlier this year, she was talking about Integrated Energy Centres.<sup>37</sup> "Integrated Energy Centres are designed to provide a one-stop service regarding access to affordable and reliable energy carriers for rural and peri-urban communities."

The centres are also intended to provide an economic push for community development, linking energy sector provision into local economic development. With the help of corporate sponsors the government will open seven this year. Total, Sasol and the Paraffin Safety Association of South Africa (PASASA) are currently contributing to these centres<sup>37</sup>.

There are several products available on the South African market regarding energy use in rural areas, for example the solar cooker<sup>38,39</sup>. If the SHB and other energy products can be attached to these energy centres, many of the problems will be solved, including the distribution to the rural areas. Research regarding the feasibility of energy centres in rural areas has already been done<sup>40</sup>. But it is recommended that further investigation regarding the aspect of connecting the SHB to these energy centres should be taken.

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## 6.4 RECOMMENDATIONS FOR FUTURE WORK

This project and previous projects have shown that the SHB design for heating and transporting water is near to complete. Also, a water purification dispenser prototype has been successfully built. From Section 5.1.4 we saw that the add-on purification dispenser increases the SHB selling price with R50 when manufacturing in large volumes.

Further research work still needs to be done to investigate whether the add-on water purification dispenser must be sold as part of the SHB unit, or separately from it. From the socio economic survey results we saw that the majority of people in rural areas will not be able to afford the SHB's retail price.

In general more research work needs to be done regarding the business aspects of the SHB. This includes marketing, distribution channels, maintenance of the unit etc. The following points conclude the future work that needs to be done:

- As mentioned the SHB design for heating and transporting water is near to complete, but data needs to be gathered about quality, durability and maintenance of the unit.
- The two month test period was insightful, but inadequate. A longer test period needs to be looked at that will cover all the seasons of the year and more climatic regions in South Africa.
- During the two month test period no information was gathered regarding the amount of energy saved by the SHB. When longer field tests (at least one year) is conducted, the energy use of people using the SHB and people not using the SHB must be monitored and compared.
- The question of selling the purification dispenser as part of the SHB unit or separately must be investigated.
- More investigation is needed on the distribution of the SHB units into rural communities in South Africa. There must be looked at the possibility of attaching the SHB to Integrated Energy Centres, which is being implemented by the government.
- Several business issues also remain outstanding. These were not dealt with here as they are detail issues that would depend greatly on the business approach that potential investors decides to take. Issues that must be investigated further include detailed sales and marketing strategies, manufacturing, storage, distribution and customer support.

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It might also be worth potential investor's while to investigate the option of obtaining a strategic partner. The ideal partner would have the manpower and infrastructure to set the business up as well as having excellent acquaintance with the disadvantaged community. Building contractors who build low-cost houses may be a possible option. Another option would be to launch initiatives with Government departments of housing, health, water affairs and energy.

## 6.5 REFERENCES

- <sup>35</sup> Gordon A., "Facilitating education in rural areas of South Africa: the role of electricity and other sources of energy", pp. 1-39, EDRC, University of Cape Town, 1997.
- <sup>36</sup> Sasol Limited Media Release, "60 000 Visitors expected at the Sasol Science and Technology Exhibition in Sasolburg", Sasol Limited, 1 Sturdee Avenue, Rosebank 2196, PO Box 5486, Johannesburg 2000, Tel.:+27 (0)11 441 3111, www.sasol.com, 14 August 2002.
- <sup>37</sup> "Budget Vote Speech of the Department of Minerals and Energy", by Minister Phumzile Mlambo-Ngcuka, Cape Town, 7 May 2002.
- <sup>38</sup> Bennett M. R., "Introduction and promotion of solar cooking - Phase 1", (EFD/1996/BEN/INT), 1996.
- <sup>39</sup> Suharta H., Sayigh A. M., Abdullah K., "The Solar Cooker HS 5521 and HS 5921 Tested in Indonesia", World Renewable Energy Congress VI, Elsevier Science Ltd., pp. 1143 – 1146, July 2000.
- <sup>40</sup> Robson P. M., "Feasibility study into the establishment of an integrated energy and development project/centre", (EFD/1996/ROB/FEA), 1996.

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**APPENDIX A**

**A1. QUESTIONNAIRE PRIOR TO THE TEST PERIOD**

**Questionnaire for Project : Solar Heat Barrow - Mabedlane 2002**  
**Information to be gathered before product is implemented in community**

Biographical data

1. How many people sleep in your home every night? \_\_\_\_\_

2. Where do you collect your water for domestic use?

Tap in house	<input type="checkbox"/>
Central point in house	<input type="checkbox"/>
River	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>

3. How (far/long)? do you walk to collect the water? \_\_\_\_\_

4. How often do you collect water?

Twice a day	<input type="checkbox"/>
Daily	<input type="checkbox"/>
Every second day	<input type="checkbox"/>
Every third day	<input type="checkbox"/>
Every fifth day	<input type="checkbox"/>
Weekly	<input type="checkbox"/>

5. What is the age of the person collecting the water?

younger than 10 years	<input type="checkbox"/>
11-19 years	<input type="checkbox"/>
20-29 years	<input type="checkbox"/>
30-60 years	<input type="checkbox"/>
older than 60 years	<input type="checkbox"/>

6. How do you heat your water?

Wood/Coal	<input type="checkbox"/>
Bottle Gas (LPGas)	<input type="checkbox"/>
Paraffin	<input type="checkbox"/>
Electricity	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>

7. How much hot water do you use per day?

Less than 10 litres	<input type="checkbox"/>
10 - 25 litres	<input type="checkbox"/>
25 - 50 litres	<input type="checkbox"/>
50 - 80 litres	<input type="checkbox"/>
more than 80 litres	<input type="checkbox"/>

8. What do you use hot water for and what time of the day are you using it?

<input type="checkbox"/> Bathing	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Cooking	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Washing Clothes	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Washing Dishes	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening

9. What is the income per household?

Less than R200 per month	<input type="checkbox"/>
R200 – R500 per month	<input type="checkbox"/>
R500 – R1000 per month	<input type="checkbox"/>
more than R1000 per month	<input type="checkbox"/>

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Opinion & Perception of Solar Heat Barrow



1. If there is a product available like the one in the picture, will you use it to carry water?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Not sure	<input type="checkbox"/>

2. If the water carrier, as in the picture above, has the ability to heat water with heat from the sun, will you use it?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Not sure	<input type="checkbox"/>

3. How much are you willing to pay for such a product?

Less than R100	<input type="checkbox"/>
R100 - R200	<input type="checkbox"/>
R200 - R300	<input type="checkbox"/>
More than R300	<input type="checkbox"/>

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## A2. QUESTIONNAIRE DURING TEST PERIOD

**Questionnaire for Project : Solar Heat Barrow - Mabedlane 2002**  
*Information to be gathered 30 days after the product has been implemented*

### **Contact details of Home Owner**

Name of Home owner: \_\_\_\_\_  
Surname : \_\_\_\_\_  
Home Address : \_\_\_\_\_  
Telephone Number : \_\_\_\_\_  
Cell phone Number : \_\_\_\_\_

### Use of Solar Heat Barrow for transporting/heating water

1. How many people sleep in your home every night? \_\_\_\_\_

2. How often do you fill the Solar Heat Barrow with cold water?

Twice a day	<input type="checkbox"/>
Once a day	<input type="checkbox"/>
Every second day	<input type="checkbox"/>
Every third day	<input type="checkbox"/>
Every fifth day	<input type="checkbox"/>
Weekly	<input type="checkbox"/>

3. What is the age of the person collecting the water?

younger than 10 years	<input type="checkbox"/>
11-19 years	<input type="checkbox"/>
20-29 years	<input type="checkbox"/>
30-60 years	<input type="checkbox"/>
older than 60 years	<input type="checkbox"/>

4. Does the Solar Heat Barrow fill easily when you collect the water?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>

If no, please describe : \_\_\_\_\_

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5. Does the Solar Heat Barrow leak water while you transport it?

Yes, a lot	<input type="checkbox"/>
Yes, but only a bit	<input type="checkbox"/>
No, not at all	<input type="checkbox"/>

6. For what are you using the hot water from the Solar Heat Barrow and when do you use the water?

<input type="checkbox"/> Bathing	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Cooking	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Washing Clothes	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Washing Dishes	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening

7. Is the hot water from the Solar Water Heater hot enough?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>

If no, please describe : \_\_\_\_\_

8. Does the Solar Heat Barrow heat enough water?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>

9. Do you use the Solar Heat Barrow to transport water?

Always	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>
No	<input type="checkbox"/>

If no, please describe : \_\_\_\_\_

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10. Are you using other ways for heating water?

Wood/Coal	<input type="checkbox"/>
Bottle Gas (LPGas)	<input type="checkbox"/>
Paraffin	<input type="checkbox"/>
Electricity	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>
None	<input type="checkbox"/>

10. Can you say that due to the Solar Water Heater, you are using less wood / gas / paraffin / electricity than before?

Yes, definitely	<input type="checkbox"/>
No	<input type="checkbox"/>
It's hard to say	<input type="checkbox"/>

11. Are your friends interested in the Solar Heat Barrow?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Maybe	<input type="checkbox"/>

11. What do they say?

They want to buy one	<input type="checkbox"/>
They may want to buy one	<input type="checkbox"/>
They do not want to buy one	<input type="checkbox"/>

12. How much are you willing to pay for the Solar Heat Barrow?

Less than R50	<input type="checkbox"/>
R50 – R100	<input type="checkbox"/>
R100 – R200	<input type="checkbox"/>
More than R200	<input type="checkbox"/>

Other comments : \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

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A3. QUESTIONNAIRE AFTER TEST PERIOD

**Questionnaire for Project : Solar Heat Barrow - Mabelane 2002**  
**Information to be gathered after the product has been implemented**

**Use of Solar Heat Barrow for transporting/heating water**

1. How often did you fill the Solar Heat Barrow with cold water?

Twice a day	<input type="checkbox"/>
Once a day	<input type="checkbox"/>
Every second day	<input type="checkbox"/>
Every third day	<input type="checkbox"/>
Every fifth day	<input type="checkbox"/>
Weekly	<input type="checkbox"/>

2. Did you use the Solar Heat Barrow to transport water?

Always	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>
No	<input type="checkbox"/>

If no, please describe : \_\_\_\_\_

3. Did the Solar Heat Barrow fill easily when you collect the water?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Partly	<input type="checkbox"/>

If Yes, please describe : \_\_\_\_\_

4. Did the Solar Heat Barrow leak water while you transported it?

Yes, a lot	<input type="checkbox"/>
Yes, but only a bit	<input type="checkbox"/>
No, not at all	<input type="checkbox"/>

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5. For what were you using the hot water from the Solar Heat Barrow and when did you use the water?

<input type="checkbox"/> Bathing	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Cooking	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Washing Clothes	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening
<input type="checkbox"/> Washing Dishes	<input type="checkbox"/> Morning	<input type="checkbox"/> Afternoon	<input type="checkbox"/> Evening

6. Was the hot water from the Solar Water Heater hot enough?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>

7. Did the Solar Heat Barrow heat enough water?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Sometimes	<input type="checkbox"/>

8. Were you using other ways for heating water while using the Solar Heat Barrow?

Wood/Coal	<input type="checkbox"/>
Bottle Gas (LPGas)	<input type="checkbox"/>
Paraffin	<input type="checkbox"/>
Electricity	<input type="checkbox"/>
Other (please specify)	<input type="checkbox"/>
None	<input type="checkbox"/>

9. Can you say that due to the Solar Water Heater, you were using less wood / gas / paraffin / electricity than before?

Yes, definitely	<input type="checkbox"/>
No	<input type="checkbox"/>
It's hard to say	<input type="checkbox"/>

10. Are your friends interested in the Solar Heat Barrow?

Yes	<input type="checkbox"/>
No	<input type="checkbox"/>
Maybe	<input type="checkbox"/>

11. What do they say?

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They want to buy one	<input type="checkbox"/>
They may want to buy one	<input type="checkbox"/>
They do not want to buy one	<input type="checkbox"/>

Other comments : \_\_\_\_\_

12. How much are you willing to pay for this product?

Less than R100	<input type="checkbox"/>
R100 - R200	<input type="checkbox"/>
R200 - R300	<input type="checkbox"/>
More than R300	<input type="checkbox"/>

13. Other comments : \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_