ABSTRACT

One of the biggest problems facing developing countries today is the deterioration of natural resources, as well as a lack of renewable ones. As natural resources continue to be consumed at an alarming rate, the need for alternative forms of energy is becoming more and more predominant. It is widely believed that solar energy is one of the greatest, and underutilized, forms of renewable energy available today.

Alternative energy programs exist at many levels in developing countries, but they are least prevalent in rural village areas of the Third World. Solar energy is abundant in many parts of the developing world, especially in Africa, and these four simple types of devices could easily be incorporated into village life: ovens, stills, boxes and puddles. Rather than tackling the high technology of photovoltaics, which requires extensive initial capital rarely available to the average villager, there are a number of ways that simple solar technologies can be used at little expense to local villagers, and with extremely effective results.

The extreme rate of deforestation occurring in many countries in Africa, along with soil erosion and an increasing rate of respiratory infection caused by cooking with wood, is reason enough to be concerned about an alternative to using wood for fuel. There is such an incidence of parasites in the water in most rural areas that there never seem to be enough methods of providing clean and healthy water systems. Devices such as solar ovens, solar stills and puddles, solar

water pasteurizers and food dryers are all excellent forms of low cost, highly effective energy production.

Women are of primary concern in this study, since they are those who are responsible for most of the tasks involved in dealing with such devices. A significant portion of this paper will concern women in the village regions of Africa and will elaborate on why they are a crucial component to the success of rural solar energy projects.

The goal of this project is to provide a feasible rationale as to why these types of alternative solar energy projects would or wouldn't be successful in a rural village in Africa, and to justify these findings in terms of sustainability and cultural awareness.

ACKNOWLEDGMENTS

I would like to express my sincere thanks and appreciation to those very special people who helped to bring this project to fruition. To my advisors at Humboldt State University; Llyn Smith, professor of Anthropology and Women's Studies, it was your Women and Development class that started me thinking about what an important and underrecognized role women play in developing countries. Thank you for all of your insight and intuitive suggestions. Dan Ihara, your editing skills are beyond compare, thank you for all of your time and support. Bob Gearheart, you have been a wonderful mentor and advisor, thank you for taking time out from your busy schedule to help me through.

I could not have finished this project in such a timely manner if not for the support of my wonderful and amazing friends in Humboldt County and the Bay Area: Shawn, you're still the one, thank you for supporting me financially and emotionally, and for countless hours of therapy with the New Zealand radio show. Michelle, this would never have gotten finished without your unwavering friendship, support and Apple expertise. Thanks for being so good at what you do. Andy, thanks for the bitching and drinking sessions so badly needed.
Jason and Devon, for always having a home for me, for keeping me warm, and for being my family behind the Redwood Curtain. Morgan, thanks for getting me into the IDT program & for your always unconditional friendship. Darrell, for

knowing I could do it, & for waking up. And last but not least, Jake, thank you for making the right decision for both of us and still staying my friend.

Finally, a big and loving thanks to my family, Mark and Renee (Doni, too), Dad & Mary, The Bulettes, Dews & my long lost Rileys (Coto & Bev especially), for supporting me from afar and always accepting me for who I am, and who I want to be. And, most of all, thanks to my Mom, Carylon J.; you more than anyone else made me who I am, supported and encouraged my ideas of travel and exploration, and gave me the drive and motivation to pursue my dreams. You will live in my heart forever & I will always try to make you proud.

PREFACE

Much of the argument in this paper derives from my research and experiences as a Peace Corps Volunteer in West Africa. From June of 1997 to July of 1999 I taught high school English in the small village of Diapangou, located in Burkina Faso, a francophone country in West Africa. For two years I lived with and much like the local villagers of Diapangou, without running water or electricity or any of the modern conveniences that people are accustomed to in industrialized countries.

It was living in a small village in Burkina Faso, and observing how hard women work at daily tasks that would take us mere minutes here in the United States, that inspired me to explore options that are both practical and warranted for these types of communities. In addition to the extreme levels of labor, it was hard to ignore the intense amount of sunshine that falls on the African soil almost every day of the year. After repeatedly wondering how it was humanly possible for all of us to get through another sweltering day, I then began to imagine ways to effectively put all this sun and heat to work for the people who have to endure it every day of their lives.

Sustainable development has been a highly emphasized focus of both my Peace Corps experience and my graduate studies in International Development Technology at Humboldt State University. What I have learned, both in my studies and from first hand experience, is that in order for a project to be effective, it must be seen and treated as an important and needed part of local life by local people, and not as something deemed useful by another culture and merely dumped and donated by an outside organization.

There is a classic story that every Peace Corps Volunteer has heard, that of the donated water pump (or insert device here) tragedy. A Non Governmental Organization installs a much needed water pump in Anytown, Africa, and not long after this generous contribution has changed the lives of the majority of the villagers for the better, it breaks and becomes a monument to failure because no one in the village was ever taught how to fix it. These monuments litter the landscape of rural Africa, and every other developing country in the world.

What I have come to understand sustainable development to mean is this: a project that aids in the development of a certain region or culture in which the local people are the primary participants and enthusiasts and are involved with every aspect of its evolution. The project must not only be something that the outside developers consider necessary for the community at hand, but something that the people who live there will use and appreciate. In order for a project to sustain itself, the people it is meant to aid must be the primary concern.

To the best of my knowledge, an analysis and comparison of these types of simple solar technologies has not been previously attempted. The purpose of this paper is to provide a framework for appropriate and culturally sensitive methods to introduce and orchestrate small-scale development projects in rural regions of the Third World.

TABLE OF CONTENTS

ABSTRACT………………………………………………………………...iii

ACKNOWLEDGEMENTS…………………………………………………….v

PREFACE…………………………………………………………………..vii

TABLE OF CONTENTS……………………………………………….....ix

LIST OF TABLES…………………………………………………………..xi

LIST OF FIGURES…………………………………………………..….xii

INTRODUCTION…………………………………………………………..1

LITERATURE REVIEW OF ALTERNATIVE AND RENEWABLE
ENERGIES IN THE DEVELOPING WORLD………………………………..3

DESCRIPTION OF FOUR SIMPLE SOLAR TECHNOLOGIES AND
THEIR APPLICATION………………………………………………………..9

Solar Ovens……………………………………………………………....9
Technology need…………………………………………………….....9
Description…………………………………………………………….13
Application ……………………………………………………………17

Solar Stills………………………………………………………………… 22
Technology need……………………………………………………....22
Description ……………………………………………………………24
Application…………………………………………………………….26

Solar Boxes ……………………………………………………………...30
Cookers………………………………………………………………..30

TABLE OF CONTENTS (Continued)

Pastuerizers……………………………………..………….31
Technology need……………………………………....31
Description…………………………………………….31
Application…………………………………………….35
Dryers………………………………………………………35
Technology need……………………………………....35
Description…………………………………………….36
Application…………………………………………….38

Solar Puddles…………………………………………………40
Technology need……………………………………...40
Description ……………………………………………...41
Application…………………………………………….43

EVALUATION AND COMPARISON OF TECHNOLOGIES………………...44
Ovens……………………………………………………….....50
Pasteurization………………………………………………….52
Dryers………………………………………………………......53
Stills…………………………………………………………...…54
Puddles………………………………………………………...54
Summary………………………………………………………55

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH……………………………………………………………..57
Orientation to Community……………………………...…..58
Education…………………………………………………….…..59
Brainstorming………………………………………………....61
Materials and Construction………………………………………62
Operation and Follow Up………………………………………..63

REFERENCES……………………………………………………………..65
Website References……………………………………………69

LIST OF TABLES

TABLE

1: Definitions of Technologies…………..……………………………………..45

2: Categories of Appropriateness…………………………………………...….46

LIST OF FIGURES

FIGURE:

1: Diagram of basic construction of a solar oven…………………………..15

2: Description of operation of solar oven……………………….……....16

3: Process of a solar still……………………………………………...24

4: Diagram of a solar still…………………………………………..… 25

5: Diagram of a solar box…………………………………………….…32

6: A WAPI……………………………………………………………34

7: A solar box angled towards the sun……………………………...…..38

8: A solar puddle……………………………………………..……42

INTRODUCTION

This project critically analyzes four forms of simple solar technology in order to determine which are most practical and appropriate for women in rural African villages. Simple solar devices are those which can be easily constructed and at very little expense. Staying away from complex solar technologies, which are costly and better suited to large and industrialized areas, the focus of this project is small-scale, simple solar technologies more suited to everyday life in a rural village.

This project is one tool to assist in the introduction of solar energy devices to small, rural areas in Africa. These devices are ones that can be made with local materials at little or no expense, that people can understand, and that will greatly benefit local people in these regions. The value of alternative energies such as these needs to be recognized and embraced, especially by local villagers participating in the project, or the effort and changes required to incorporate these new ideas into traditional village life will never be met.

Women are the target population for this project because their everyday duties are the ones most directly related to these simple solar devices. In rural Africa almost all cooking and food preparation, as well as the arduous task of gathering and transporting water and fuel-wood, falls upon the women. The solar cooking, drying and pasteurizing devices being analyzed in this study will be used primarily by women who perform these tasks.

Four devices are the main focus of this study: the solar oven, the solar still, the solar box and the solar puddle. These devices have been chosen because of their low-cost construction, ease in obtainment of local materials and simplicity of design[1]. Simplicity of construction and operation is important in order to better assure the devices can be repaired if they are damaged or destroyed. Also, if the devices are easy to construct and local materials are available, then it is more likely that villagers will be inclined to initiate construction of future devices independently.

The introduction of any kind of new or different technology can sometimes be met with resistance. New technologies tend to disrupt an ingrained and finely tuned daily routine. Consequently, it is very important that traditions and cultural boundaries be seriously considered before attempting to introduce new technologies to a community.

[1] In addition to these four, there are many solar applications that are not included in this study because of either their high cost or complex design. Photovoltaics (PV) or solar panels are a brilliant technology that I would like to see incorporated throughout the world in both developing and developed countries. However, due to its highly advanced design and the current high cost of installation, PV is not a feasible energy source for the rural development project being analyzed for this project. Parabolic cooking devices are also not included because they cook on a much larger scale than is appropriate for the small-scale village use that is the focus of this study.

LITERATURE REVIEW OF ALTERNATIVE AND RENEWABLE ENERGIES IN DEVELOPING COUNTRIES

The idea of using solar energy rather than fossil fuels is not a new one. Fossil fuels such as oil and wood are non-renewable resources, and therefore their utility is finite. Solar energy is a realistic alternative to the overuse of earth's non-renewable resources. People have benefited from, employed and even worshipped solar energy in different ways for thousands of years. The sun is a colossal furnace that pours out a tremendous amount of energy, of which we on earth receive and use only a small portion (Cheremisinoff & Regino, 1978). As Goldin (1988) notes,

> in one year the sunlight falling on our planet delivers about 130 times as much energy as is contained in all the coal, oil, and natural gas deposits in the world. On one sunny day it delivers the equivalent of 4.69 million horsepower per square mile (20 square blocks or 2.59 square kilometers), enough to run 1/2 a million limousines.

Each day more solar energy falls to the Earth than the total amount of energy the planet's inhabitants would consume in 27 years. It is possible and necessary to use only a small portion of this resource, and we've only just begun to tap the potential of solar energy. Only in the last few decades – when growing energy demands, increasing environmental problems and declining fossil fuel resources made us look to alternative energy options – have we focused our attention on truly exploiting this tremendous resource (NREL, 2001).

> Almost two billion people in developing countries, one third of the world's population, have no access to electricity. Fuelwood, agricultural residues, human power and draught animals continue to be the primary energy resources for the majority of millions of rural families (F.A.O., 2000).

According to estimates of the Food and Agriculture Organization of the United Nations (2000),

> by the end of the 20th century, 2.4 billion people will have been either unable to obtain their minimum energy requirements, or forced to consume wood as fuel faster than it can be replaced.

Approximately 43% of energy consumption in the developing countries comes from biomass: mostly wood, dung and crop residues. On a heat-supplied basis this is the equivalent of over 8 million barrels of oil each day, globally (Tidwell, Riddoch & Grainger, 1983).

Lack of adequate energy sources is only one of the developing world's many problems. More than two million children die each year because one billion of the earth's people lack access to safe drinking water (Earth Island Journal, 1995). Microbiologically contaminated water places a tremendous burden on the lives and the health of the world's poorest people and causes needless illness and death where the struggle for life is the hardest (Safe Water Systems, 1996). In countries lacking utilities, water must be boiled by burning firewood or coal, but this process is rarely carried out because doing so would consume nearly one third of a poor household's income. Because it takes a kilogram (2.2 pounds) of wood to boil a liter (1.1 quarts) of water, boiling water with wood fires contributes significantly to deforestation (Earth Island Journal, 1995).

Scarcity of energy resources and an abundance of contaminated water in many areas around the globe are also contributing to alarming rates of deforestation. This is a serious problem that should be examined in detail before any more irreparable damage is done.

> Once a tropical rainforest is logged or clearcut, it is very difficult if not impossible to replace, by definition, a nonrenewable resource (Russo, 1999).

The global fuelwood deficit was expected to reach almost1 billion cubic meters per year by the end of the 20th century (UN Chronicle, 1996). The need for fuelwood exacerbates the tendency towards deforestation in Africa, and therefore the environmental crisis of the entire continent. The risk of complete forest destruction on the African continent has to be considered critical (Duhamel, 1987).

> For countries fortunate enough to have forests to support a substantial lumber industry, it behooves them to use their forest waste efficiently in order to maintain, or even improve, their present resources. However, the deforestation of many parts of the world resulting from the incessant search for cooking fuel is an issue of worldwide concern (Brown, 1978).

It is increasingly clear that our current dependence on fossil fuels is endangering our environment, our economy and our health. To avoid the risk of potentially catastrophic climate shifts in the middle of this century, the world needs to achieve a rate of carbon emissions per dollar of gross world product that is roughly a 60% – 70% reduction below the current level. This essentially means an end to the fossil fuel-based energy economy, and a gradual transition to an entirely different energy system – one that ultimately relies on renewable sources of energy (McIntyre, 1997).

> Health and energy are interdependent factors, which have great influence on one another in determining the progress of rural development. An alternative energy strategy for rural areas is critical in achieving lasting health improvements. Developing a reliable and affordable source of energy that is well suited to meeting the low demand of traditional peoples' activities remains a challenge, but the World Health Organization believes solar energy can play an important role in improving health energy infrastructure if integrated with a broad array of end uses (UN Chronicle, 1996).

The proponents of decentralized renewable energy recognize the notion that the vast majority of people in the Third World still depend upon wood, animal and vegetable wastes, and animal power to earn their daily livelihood. These sources of energy are running short, so primary focus should be placed upon assuring an ample supply of those energy sources that are fundamental to life itself before emphasizing modern energy (Ganapathy, 1981).

The Harare Declaration on Solar Energy and Sustainable Development considers cheap, clean, renewable energy essential in improving the quality of life and in creating income-generating activities (UN Chronicle, 1996). In the Harare Declaration in 1996, world leaders recognized that

> there is a need to increase access to energy in developing countries, and (to recognize that) the provision of adequate energy services can improve living conditions, alleviate poverty, improve health and education, promote small-scale enterprises and create other income-generating activities, especially in rural and isolated areas, thereby reducing rural to urban migration (UN Chronicle, 1996).

Awareness of energy problems facing the world is greater now than at any other period in history. It is now widely accepted that the growth in energy consumption that has been experienced for many years cannot continue indefinitely, as there is a limit to our reserves of fossil fuel. Solar energy is by far the most plentiful alternative energy source for the future, as, apart from its non-polluting qualities, the amount of energy available for conversion is several orders of magnitude greater than all present world requirements (McVeigh, 1977). Finding alternative sources of energy that are both economically and environmentally friendly is crucial for increasing local productivity and improving the quality of life in rural communities (F.A.O., 2000).

> Sources of energy obtained directly from sunlight, solar energy, constitute, by far, the cheapest way to generate electricity in rural and remote areas (UN Chronicle, 1996).

Solar energy systems could significantly improve health care, education, supplies of consumable water, and food preparation and preservation (F.A.O., 2000).

Solar technology is environmentally benign in terms of global warming or destruction of the ozone layer. Simple solar devices have long life spans since they have no moveable parts that can wear out. They are economically viable and competitive, largely due to their low life-cycle costs and high reliability. Maintenance is low since no fuel is consumed. Properly installed, simple solar technologies are safe, usage risks are minimal and dangers related to other rural appliances using gas or kerosene are non-existent. Solar energy techniques are capable of significantly enhancing the quality of life of the end users (Karekezi, 1997).

Since most of the population in less developed countries living in rural areas is isolated from central power distribution, they would particularly benefit from development of technologies to exploit renewable energy resources of the sun, wind and flowing water. There is almost unlimited solar energy potential in regions between 40 degrees north and south latitude, and Africa is especially well situated (Duhamel, 1987). If simple solar applications could be implemented in over-populated or under-resourced areas of the world, a major burden of life's energies, as well as resource depletion and pollution, could be alleviated (Wells, 1980).

The goal of this project is the introduction and examination of simple solar technologies as a culturally practical alternative energy resource suitable for everyday village use. Small-scale solar devices such as ovens, stills, boxes and puddles are a rational and feasible approach to reducing the burden of the hardships that the people of rural Africa endure on a daily basis.

DESCRIPTION OF FOUR SIMPLE SOLAR TECHNOLOGIES AND THEIR APPLICATIONS

Solar Ovens

Technology need

Globally over two billion people rely solely on wood or other traditional fuels for the energy they need. (Three quarters of the annual primary energy consumption in Africa is in the form of fuelwood, and this consumption has gone beyond the natural regenerative capacity of forests). Use of wood for fuel intensifies deforestation, soil loss and severe respiratory problems that, by World Health Organization estimates, kill more than four million people per year (Tyson, 1997). Deforestation leads to soil erosion, floods and climate change. As has been noted by Addison (1999), this kind of severe environmental degradation can greatly contribute to poverty and hunger.

In developing countries forests are being reduced by more than 15 million hectares annually. Deforestation is known to contribute between 25 and 40 percent of global greenhouse emissions. By protecting the soil from erosion, forests lessen the risks of landslides and avalanches. They not only increase the rate that groundwater is recharged by rainwater, but also help regulate the rate that watersheds release water and thereby provide a sustained supply of freshwater. Climate is also greatly affected by forests, and the occurrence and strength of floods and droughts increase when they are eliminated (Syed, 2000).

Only in the last couple of decades has the magnitude of wood and charcoal consumption in Africa been recognized (Duhamel, 1987). Wood is the only source of energy for many African farmers, accounting for more than 90% of energy consumption in many rural areas (Duhamel, 1987). In addition, many rural villagers cook indoors, and the people living in these smoky huts can experience pollution that is the equivalent of smoking several packs of cigarettes a day. Acute respiratory infection, which is caused by inhaling wood smoke, kills more children every year in Kenya than dysentery (Tyson, 1997). Smoke also seems to have the ability to keep pesky mosquitoes at bay. Daniel Kammen, Director of Renewable and Appropriate Energy Laboratories (RAEL) at Berkeley, has watched women in Kenya close the door & stuff the windows with cloth before cooking in their indoor huts.

> We're not sure why they do this," he says. "They may be following long-held traditions or driving away insects that infest wood stored indoors (Tyson, 1997).

A child in the Gambia strapped to a mother's back over a smoky stove is found to be six times more likely to develop an acute respiratory tract infection than a child protected from smoke (Nishimizu, 2001).

Women of developing countries can spend anywhere between two and nine hours each day in fuel collection and cooking chores (Nishimizu, 2001). Most women in rural Africa are known to spend up to eight or ten hours a day walking great distances to gather wood. This is a phenomenal amount of time that could very easily be spent on more productive activities, or to better attend to the needs of their families. A survey conducted in Maphephethe, a rural community about 80 kilometers to the west of Durban in KwaZuluNatal in South Africa, found that collecting firewood was one of the greatest burdens for many women, and that it had a significant impact on their quality of life (Green & Wilson, 2000). The search for fuel consumes more than the time, energy and health of women and their children. As local wood supplies grow scarce, women risk spinal column damage and uterine prolapse from carrying heavier loads over longer distances. Girls are often kept home from school to help their mothers gather wood, depriving them of essential educational opportunities. Where wood is unavailable, women will cook with inefficient fuels such as animal dung or crop wastes, depriving livestock of fodder, soils of natural fertilizer, and endangering both the nutritional and respiratory health of women and their families (Addison, 1999).

Energy use for cooking in the rural areas of developing countries is higher than in most U.S. households because the energy is used inefficiently. Fuel is burned partly in open fires and partly in inefficient mud or stone stoves; the fire is started before the pot of food is placed on it, and the fire keeps on burning after cooking has been completed. Only a small fraction of heat actually serves to boil the food, most of it escapes outside the cooking pot. As a result of this, the amount of energy going into the cooking process is about 10% of the total energy in the fuel, in contrast to about 30% of that in a gas stove. This inefficiency of fuel use is likely to have serious consequences for many developing countries if their rural populations continue to increase because the principal source of domestic energy is wood, trees and other vegetation, all of which are being destroyed for fuel faster than they can grow (Brown, 1978).

People's habits with respect to energy use rarely change. This is the case of those who, because of low population density in the past, have remained under the illusion that fuelwood resources were inexhaustible. The rapid urbanization in Africa continues to aggravate the exhaustion of wood resources as it results in widespread commercialization of firewood (Duhamel, 1987).

For energy conservation, perhaps one of the most important developments would be a better way of cooking food rather than a new source of energy: an inexpensive, easily used device that would enable the efficiency of fuel to be raised from 10% or less, to 30 or 40% or above (Brown, 1978). A complete conversion from the customary mode of cooking to a new and alternative one will probably not happen, not quickly anyway. The most any environmentally aware development agent can hope for is to introduce a supplement to current cooking methods, one that works and will feasibly be used by the community.

Simple, easy to use technologies such as solar ovens are practical substitutes for firewood in much of the Third World. The solar oven has met with success in many areas in Africa and throughout the developing world. Assuming a family uses 2 kilograms of coal for one meal, 10.7 tons of coal could be saved during the 15-year lifetime of a solar cooker (Parikh, 1980). This type of savings would be substantial to a village family in a rural setting, and could make a significant difference in the way their daily lives are lived.

In light of the fact that the majority of energy use in most rural areas is for cooking (more than 70% for low-income group countries), solar ovens are possibly the single most important application of solar energy in developing communities (Parikh, 1980). There is no doubt that one of the most effective ways to reduce the denudation of forests for firewood is by improving the efficiencies of traditional wood-burning cookstoves (Brown, 1978). Supplementing wood stoves with solar ovens could take care of a major burden on one of the major natural resources of the developing world, as well as improve the health and overall quality of life for the majority of women and children in rural areas.

Description

The technology for a solar oven is simple; it is a box made from a heat retaining material (plywood, cardboard or a basket will work best, since bricks and metal do not have insulating properties). The top of the box consists of one to two layers of clear glass or plastic, and on the bottom is a black collector plate made ideally of metal (but alternatively of cardboard or wood) upon which a cooking pot rests. Aluminum foil or an equally shiny material sheathes the inner walls, in addition to a protective front lid that swings open above the oven. The lid serves as a reflector, which guides the sun onto the pot inside of the oven. The lid should have a prop, which can be adjusted with the angle of the sun. It is best to have a layer of insulation between the black plate and the bottom of the box in order to retain heat. The foil or shiny material attracts the heat of the sun and directs it to the black plate, which in turn absorbs the heat and allows it to be retained by the pot of food being cooked.

Within the oven, a greenhouse effect occurs, wherein light enters through the transparent roof and strikes the black metal floor, or bounces off the reflective walls until the surfaces absorb it as heat energy. The heat is radiated as infrared light and then trapped inside the oven because its long wavelength cannot penetrate the double-glazed ceiling, much as infrared radiation trapped in the atmosphere cannot escape through clouds or smog (Tyson, 1997).

Dark colored pots are necessary for the solar oven to work efficiently as the dark pots absorb more heat than light colored pots, which actually reflect the heat away (Wilson & Green). Dark pots change the light from the sun into heat energy. Lids are important because they hold steam inside the pot. If a lid is not used the steam will dissipate much of the heat. Shiny aluminum pots and pans

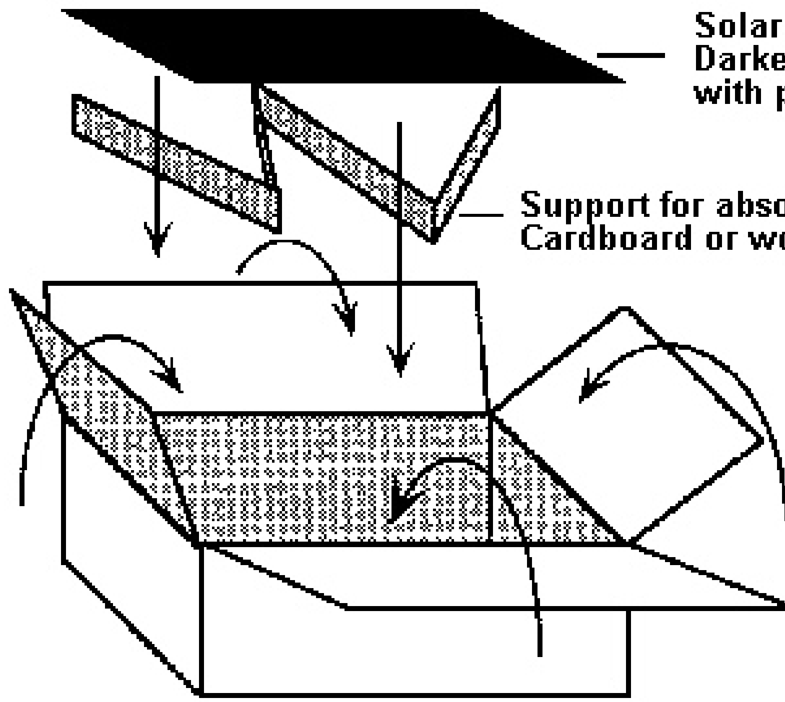

Figure 1: Diagram of basic construction of a solar oven

cause light to be reflected out, thereby reducing the oven's temperature. Glass dishes with lids also work well. For baking, dark sheets and baking tins work well (Sunoven.com).

Stirring to prevent scorching is not required when cooking with a solar oven due to the fact that no hot spots develop. The temperature of the food rises evenly, making it almost impossible to burn food in a solar oven (Sunoven.com). Because of this, it is quite feasible to set a pot of food cooking in the morning, and have it ready by lunchtime. The same is possible for evening meals, which would solve the problem of night time cooking, though this is highly dependent on the time of evening dinner is normally eaten.

Solar cooking allows many of the natural flavors of food to remain. The slow, even rise in temperatures in a solar oven gives the complex carbohydrates time to break down into simple sugars allowing subtle natural flavors to emerge. Sun baked foods stay moist because the natural internal juices do not bake out, resulting in a superior taste and much less shrinkage (Sunoven.com).

Solar ovens are beneficial to the environment and superior to traditional methods of cooking, such as stone stoves and open campfires commonly used in

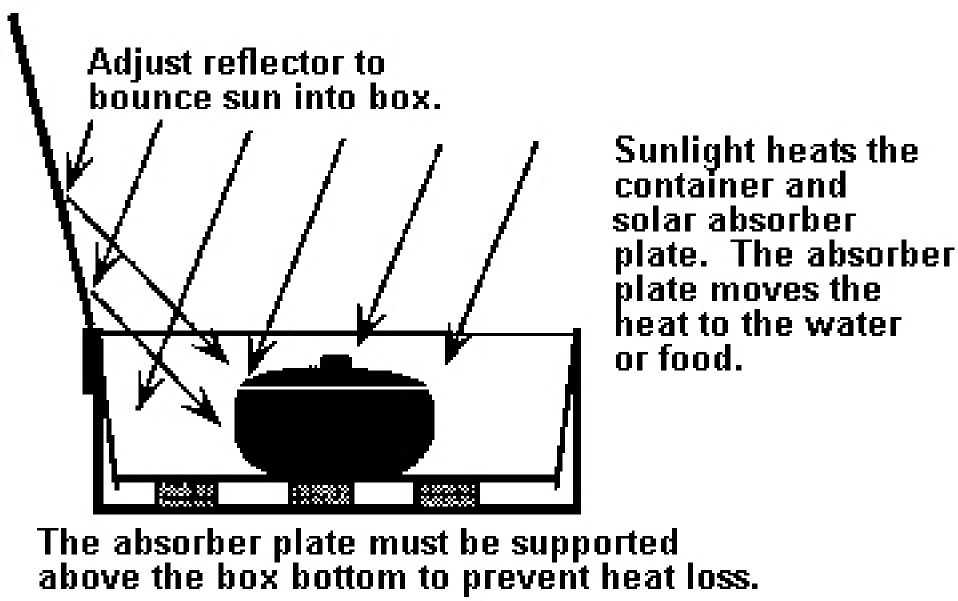

Figure 2: Description of operation of solar oven

rural areas in developing countries. The ovens do not burn food over an open flame, but simmer meals inside the covered containers, requiring less stirring or water, and retaining more nutrients and vitamins. More importantly they produce no smoke, which is important to cultures whose practice is to normally cook indoors (Tyson, 1997).

Solar cookers work best in developing countries because they can be constructed out of a variety of materials, including aluminum foil, cardboard, bamboo and other woods, and even mud with glass placed on top (Cloutman, 2001). It is such a simple concept that there is a lot of room for local improvisation, depending on the types of materials available. An oven made out of plywood and glass will predictably be more sturdy and last longer, but if these materials are too expensive or are not locally available, a cardboard box and clear plastic works just as well.[2] Black bags are plentiful in Africa, scraps of cardboard and wood are present in many areas, and there is normally some sort of artisan or carpenter who is willing to contribute 'know how' and expertise. Communities in Africa are inclined to come together for a common cause, and there is little doubt that, if a technology is wanted in any given society in Africa, a successful project is possible.

---

[2] Granted, these materials are not always readily available in every developing country, but from my experience living in 'the bush' in Burkina Faso, these types of items are not hard to come by.

<u>Application</u>

In 1960 200 solar ovens were distributed and evaluated in several Mexican communities, with remarkably consistent results. However, the cooker was a technical success and a social failure: the idea failed because people didn't like to cook in an unfamiliar way. Even though people in some areas did not have enough money to buy food, they preferred to spend their money on kerosene for cooking what little food they had. Social customs, traditions and ideologies clearly must be reckoned with before a routine altering project can be considered (Brown, 1978).

The major issue of cooking with solar ovens lies with the empiricism of the changing of traditional and ingrained behavior. African women are as accustomed to managing wood-fired kitchens as Americans are to their microwaves. Often, even when a project appears to make sense practically or environmentally, the change of traditional customs is not easy to accomplish (Home Power, 1997).

Long touted as ideal candidates for cooking in sun-splashed tropical countries, solar ovens have experienced only modest success. The reason is not technological, says Daniel Kammen, director of the Renewable and Appropriate Energy Laboratory at U. C. Berkeley, who conducted sun workshops on building and using solar ovens in Central America and Africa in the mid-1980s. Rather, the ovens often failed because, in an era of massive development projects, aid agencies did not encourage local people to build their own devices and thus understand how they operate. Agencies have also targeted the wrong sex, says women perform 80 percent of subsistence agriculture and virtually all domestic tasks.

> It seems obvious that women should be involved in the programs, says Kammen, but that hasn't been the tendency for a lot of past projects (Tyson, 1997).

Women are at the very center of rural life in the provision and use of household jobs and energy, yet tend to have little voice in how things might be changed or improved (Nishimizu, 2001).

> People don't like to abandon the way they're used to doing things, but they'll adopt new ideas if they see the use of them (Kammen/Tyson, 1997).

Considering how accustomed we, in the developed world with all of our conveniences and culinary luxuries are to our routines in the kitchen, then it isn't hard to imagine the difficulties of changing a routine to which people have few alternatives. There are so many cultural differences to be taken into consideration with any sort of development project, and this is the most important element of any type of assistance, and one that can easily backfire. Money and donations are not what is needed from one community to another. What is needed is an understanding of what the community to be helped wants and needs, and it is the job of a responsible developer to learn the ins and outs of a culture and community and to plan his or her development project accordingly. The community targeted for this project is women, and their culture of cooking is what must be understood.

The acknowledgement of women as the most substantial factor in the equation of domestic solar assistance is critical. It is not surprising that women have been overlooked in development processes for so long, considering their secondary standing in African society; men have, as in many other cultures in history, been in charge of decision making and in control of most matters of significance. This mode of thought has changed in many societies, and is slowly beginning to change in the developing world as well. Therefore, until men are willing to haul wood and water and cook an equal number of meals, they are going to have to accept that women need to be directly involved with these processes.

It is clear that women need to be the target group for a small-scale solar oven project, since they are the ones primarily involved with domestic tasks involving cooking and the gathering of fuel. It is important that the women are consulted throughout the process of the project on every aspect of tradition, custom and opinion regarding cooking and daily routine.

A Returned Peace Corps Volunteer, while serving in Africa organized a project to build latrines in his village because he often observed the women going out into the fields to relieve themselves. The latrines were of the highest quality, with dual composting bins, hinged doors and a roof. The volunteer was very excited to see what the villagers all thought of their new luxury, but he was disappointed to observe the women back out in the field again the next morning, squatting in the field as usual. After some discussion with local people about this perplexing situation, the volunteer began to understand that the time that women shared in the field every morning was their social hour, and some of the small amount of time that they were able to get together and talk. Performing mundane tasks like hauling water or wood on their heads for long distances during the day are also social times for women, and sometimes their only refuge from a less than perfect home life. It is social and cultural factors like these that need to be taken into consideration when attempting to implement a development program of any type, especially one in which women are the primary participants.

With the goal of reducing deforestation and improving the health and quality of life of women and children in rural Africa, it is important that women and children are the ones most involved in the application of the project. It is not the job of the developer to tell people what they need, but to listen to what people want, and to provide the most appropriate assistance possible according to these requests.

Stills

Technology need

Ninety-seven percent of the Earth's water mass lies in its oceans. Of the remaining 3 percent, 5/6 is brackish, leaving a mere 0.5 percent as fresh water. As a result, many people do not have access to adequate and inexpensive supplies of potable water. This leads to a concentration of populations around existing water supplies, less than adequate health conditions, and a generally low standard of living (McCracken & Gordes, 1985). One of the biggest problems in many parts of the world is the scarcity of fresh water, making the development of inexpensive solar distillation units increasingly important (McVeigh, 1977).

Eighty percent of all diseases in developing countries are transmitted through contaminated water; each year over a million children die from drinking unsafe water (Journal of Environmental Health). Diarrhea is caused by microbes entering the mouth and is, more often than not, caused by contaminated water. According to the United Nations Children' Fund (UNICEF) diarrhea is the most common childhood disease in developing countries. Dehydration resulting from diarrhea, usually brought on by drinking unsafe water, is the leading cause of death in children under the age of five, and annually kills an estimated five million children. Diarrhea is also the most common cause of child malnutrition, which can permanently impair mental and physical development, and lead to death (SolarCooking.org). Diarrhea and other deadly diseases caused by contaminated water need not be tolerated; there are simple and economical remedies to this serious problem, and one of them is the pasteurization and distillation of water.

UNICEF estimates that 60% of rural families in developing countries are without safe water (SolarCooking.org). One of the biggest obstacles to maintaining a steady supply of clean drinking water in developing countries is the cost of boiling contaminated water – an option not available to many who cannot afford to spare precious wood (Safe Water Systems). So much time and hard work is spent gathering wood for cooking, there is seldom any left over, especially to boil water that people have been drinking unboiled for all of their lives.

As has been established earlier in this paper, the altering of ingrained habits is one of the biggest obstacles to be overcome by any agency of change. It is difficult in any society to convince people to drastically change their ways of doing things, and close to impossible if any type of encumbrance is added to already burdened lives. But, if it is clear to the population that these changes can significantly improve current health standards and quality of life, even save lives, then hopefully that will be enough incentive for people to seriously consider it.

> Contrary to what many people believe, it is not necessary to boil water to make it safe to drink. Heating water to 149º F for six minutes, or to a higher temperature for a shorter period of time, will kill all germs, viruses, and parasites. This process is called pasteurization (SolarCooking.org).

This process is described in detail in the Solar Box section (p. 37). Pasteurization is easily accomplished with box-type devices the size of an oven, or with the larger device of a solar still.

Description

Basically, solar distillation uses the heat of the sun directly in a simple piece of equipment to purify water. The equipment consists primarily of a shallow basin with a transparent cover; the sun heats the water in the basin, causing evaporation, moisture rises, condenses on the cover and runs down into a collection trough, leaving behind the salts, minerals, and most other impurities, including germs (McCracken & Gordes, 1985).

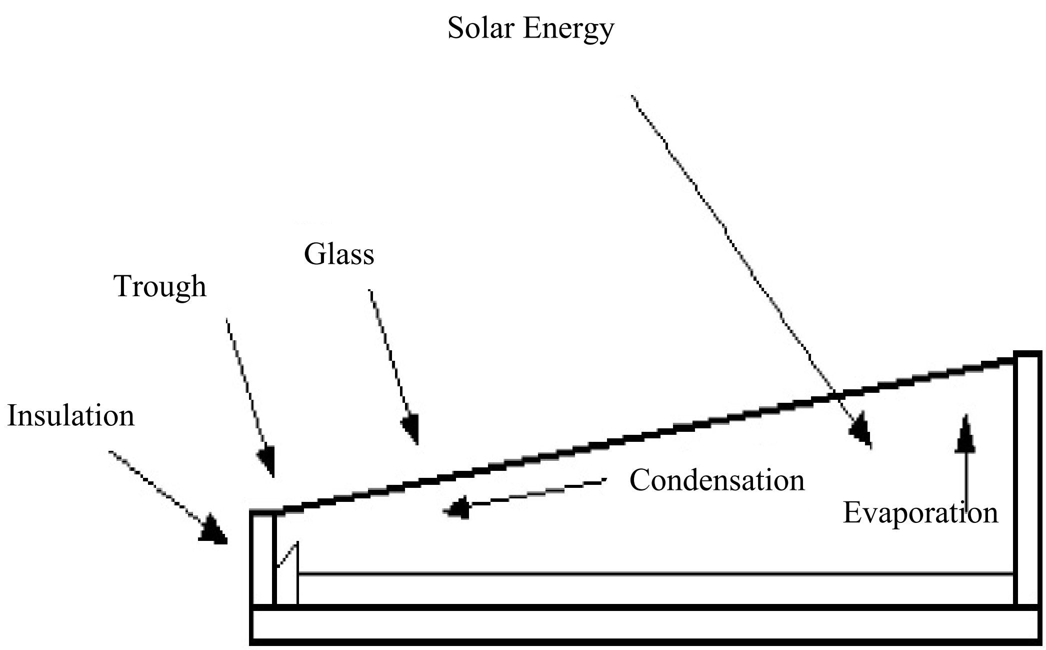

Figure 3: Process of a solar still

Solar stills hold considerable potential in isolated rural communities. Where less than 50,000 gallons of water per day is required, they are the cheapest source of fresh drinking water, and the simplest and easiest to construct of solar technologies (Deudney, 1983).

The concept of a solar still is familiar to anyone who has experienced a steamy greenhouse; a solar still usually consists of a large flat surface that can be mounted on legs or on top of a house. A short wall is built around the top of the table and is lined with impermeable material to make a small pool on the top of the table. A pane of glass, Plexiglass or similar sturdy transparent material is mounted at a slight angle above the table. As the water is heated, it forms water

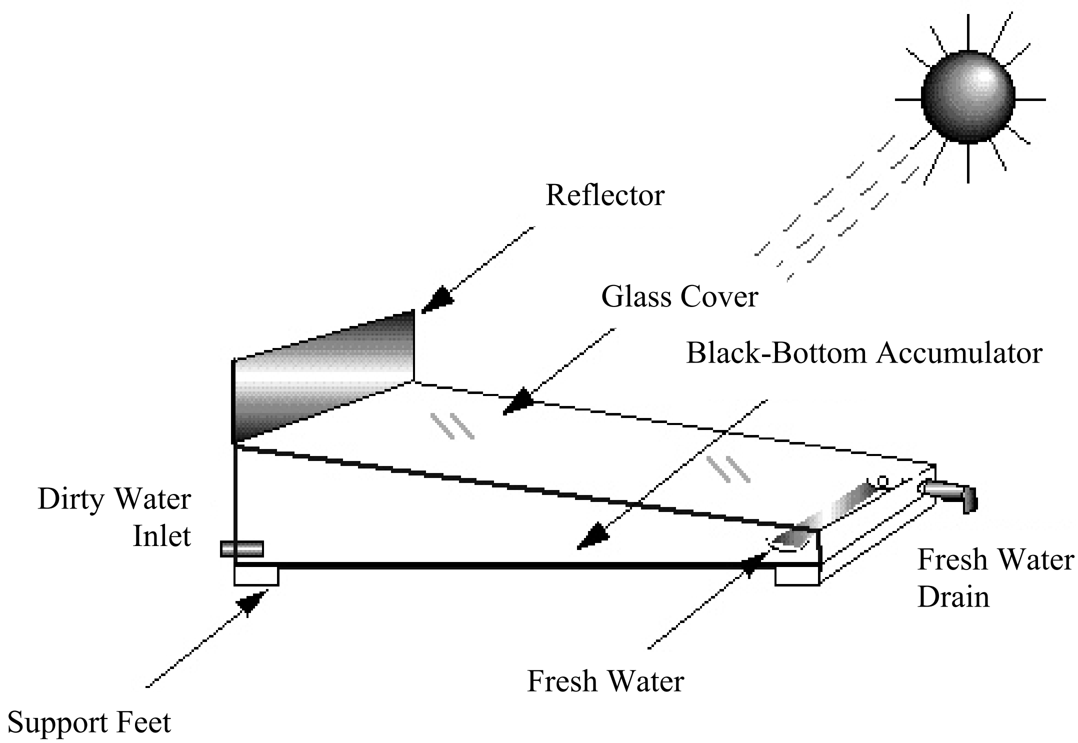

Figure 4: Diagram of a solar still

vapor, which condenses on the pane (Safe Water Systems). Gravity pulls the condensed water to the lower edge of the pane, which overhangs the pool, and drips into a trough, and then through a hose or tube into a collection jug. A still approximately 3 by 6 feet can produce about 3 gallons a day (Rolla, 1998).

As has been stated previously in regards to pasteurization, it is not necessary for the water to actually boil to bring about distillation. Steaming it away gently does the same job as boiling, except that, in the solar still it will usually turn out even more pure, because during boiling the breaking bubbles may pollute the product water with tiny droplets of contaminated liquid water swept along with the vapor (McCracken & Gordes).

Distillation operates by the escape of moving molecules from the water surface into the gases directly above it. Sensible heat--the kind you can measure with a thermometer--is caused by the movement of molecules, which zigzag about constantly, except that they do not all move at the same speed; add energy and they move faster, and the fastest-moving ones can escape the surface to become vapor. Solar energy, passing through a glass cover, heats up the water in a pan; this causes the water to vaporize, the vapor then rises and condenses on the underside of the cover and runs down into waiting troughs (McCracken & Gordes).

Application

Since solar stills are easily fabricated by low-skilled labor using locally available materials, their use is particularly appropriate in third world villages

(Deudney, 1983). Stills are one of the easiest and most economical methods of providing clean water to a group of people, and one that is both useful and practical for everyday use in a rural area.

The solar still is a larger device than an oven or box, and therefore requires more material, consequently at larger expense. Where an oven can feasibly be constructed of cardboard and plastic sheeting, a solar still needs wood or an equally sturdy material as its base material, and works best with a glass covering.

> While some plastics are cheaper than either window glass or tempered glass, they deteriorate under high temperatures and have poor wettability. Moreover, under temperature conditions typical of solar stills, the chemicals in plastics are likely to interact with the distilled water, possibly posing a health hazard (McCracken & Gordes).

Aside from the added initial cost, the changing of an age-old social behavior is a significant issue. The acceptance of solar distillation will depend greatly on how well a developing agent understands and handles the many social issues and cultural constraints that can hamper the introduction of a new technology. Some of the more important issues that may affect the acceptance of solar distillation are outlined below:

- Stills built for village use require community cooperation that can possibly be foreign to certain cultural groups. If the distilled water is incorrectly distributed, causing a family unit not to receive its fair share of water, this could become a source of conflict. For this reason a family-sized solar still unit over which a household has complete control may be more practical in some circumstances than a unit that serves an entire village.

- Potential users who anticipate finding distilled water tasteless or not in keeping with what they are accustomed to may become disappointed and possibly abandon the thought of drinking the water. The problem of taste must be dealt with early on so as not to give people a reason to respond negatively to the technology as a whole.
- In some societies, conflicts may arise concerning whether or not it is the responsibility of the man or the woman of the household to operate the solar still. Not dealing with issues of this type early on could result in frustration and the household's rejection of the technology.

If solar distillation is perceived to be any kind of threat to a community's traditional lifestyle, the community may reject the technology. Such concerns can be avoided if the technology is designed appropriately from the start and introduced at a proper time. Also, a community is more likely to accept the technology if it recognizes the importance of clean water and considers it a priority to the degree that it is willing to change certain aspects of its lifestyle (McCracken & Gordes).

This recognition of cultural boundaries regarding the importance of clean water is imperative to the success of a project and the health of the people. Drinking of contaminated water in most developing areas is commonplace, and in practice because there has been no alternative for as long as most people can remember. A tradition this ingrained into life and social behavior is very difficult to alter, even when good reasons for doing so are presented in a logical way. It is for this reason that education concerning contaminated water and its consequences is a very important factor in the implementation of a solar still development project. Knowledge, even though sometimes rejected at first, is a very powerful weapon against detrimental influences that can destroy a society.

Solar Boxes

The solar box can perform a number of functions without the use of dwindling natural resources or the excessive amount of labor that is currently the practice in many developing countries. A solar box can operate as an oven without the customary countless hours of foraging for wood or contributing to pollution, deforestation, soil erosion and respiratory infection. The solar box can also serve as a water pasteurizer, capable of purifying contaminated water without the need to boil it with wood or charcoal, or the addition of chemicals. And, it can function as a dryer to preserve food for extended periods of time, while preserving vital vitamins and minerals.

Cookers

The solar box cooker is, in essence, a solar oven, which can perform the function of pasteurizing water and drying produce in addition to cooking food. The design and usage for each in this circumstance is identical. Since the need, description and application for a solar oven has been illustrated previously (see page 11), I will here focus on the need, description and application of the other two functions of the solar box; solar water pasteurization and the drying of food.

Pasteurizers

Technology need

As has been illustrated previously in the appraisal of solar stills, it is estimated that nearly 10,000 children die each day from dehydration caused by diarrhea, which is caused by germs carried in drinking water. The majority of diseases in developing countries today are infectious diseases caused by bacteria, viruses, and other microbes which are shed in human feces and polluted water which people use for drinking, cooking and washing. When people drink these live microbes, they can multiply, causing disease, and if shed again as feces into water, continue the cycle of disease transmission. World wide, unsafe water is a significant problem, and one of the ways to provide clean drinking water is to heat-pasteurize it (SolarCooking.org).

Description

Pasteurization is the process of disinfecting food or liquids by heat or radiation. Disinfection is accomplished by eliminating disease-causing microorganisms. The word ‘pasteurization’ was named after the French doctor Louis Pasteur; in 1864, Pasteur demonstrated that wine diseases are caused by microorganisms that can be killed by heating the wine to 65º C (149º F) for several minutes. It was soon after applied to beer and milk, and the process of pasteurization soon came into use throughout the world. Pasteur’s research proved that sufficiently heating a substance is able to destroy all disease causing germs.

Pasteurization is a function of time and temperature: if a low amount of heat is applied, the process of disinfection takes longer, at higher temperatures, disinfection occurs in a shorter period of time (Burch & Thomas, 1998). As a general rule, a solar box can pasteurize about a gallon of water in three hours on a sunny day (Rolla, 1998).

The solar box, used for pasteurization, is constructed in much the same way as a solar oven. It is a box made out of wood or cardboard, with a reflective

MIRROR

ADJUST THE REFLECTOR SO THAT SUN RAYS HITTING THE TOP OF REFLECTOR ARE REFLECTED TO THE FRONT OF THE BOX

‹Time™ and a
lecompressor
› see this picture.

Figure 5: Diagram of a solar box

material covering the inside walls and lid. In addition to this, it can also help to have a mirror placed at a certain point on the lid, to guide the sun's rays more directly onto the heat retaining materials inside the box. The sun's rays are caught by the mirror or shiny material on the lid of the solar box, then directed to the heat absorbing material on the inside of the box. This allows the box to absorb the maximum amount of sunlight available. The lid of the box can be adjusted to the position of the sun to ensure that the greatest amount of heat is directed into and stays within the compartment.

A covered pot containing water is placed inside the solar cooker, and needs to remain there until the water is at 150º F in order to pasteurize water. But how is one in a developing country with few resources (and even fewer thermometers) to know when the water has reached the recommended temperature? An ingenious solution is the Water Pasteurization Indicator, or WAPI. (A prototype of this device was developed by Dr. Fred Barrett (U.S. Department of Agriculture) in 1988). Dale Andreatta and other graduate engineering students at the University of California at Berkeley developed the WAPI currently used.

The WAPI is a polycarbonate tube, sealed at both ends, and partially filled with a blue soybean fat that melts at 156º F (69º C). The WAPI is placed inside the water container, with the fat end up. It is easy to tell when the water reaches 156º F (69º C) because the fat melts and runs to the bottom of the tube (Rolla, 1998). The tube itself is buoyant, and it is weighted with a washer so that it sinks

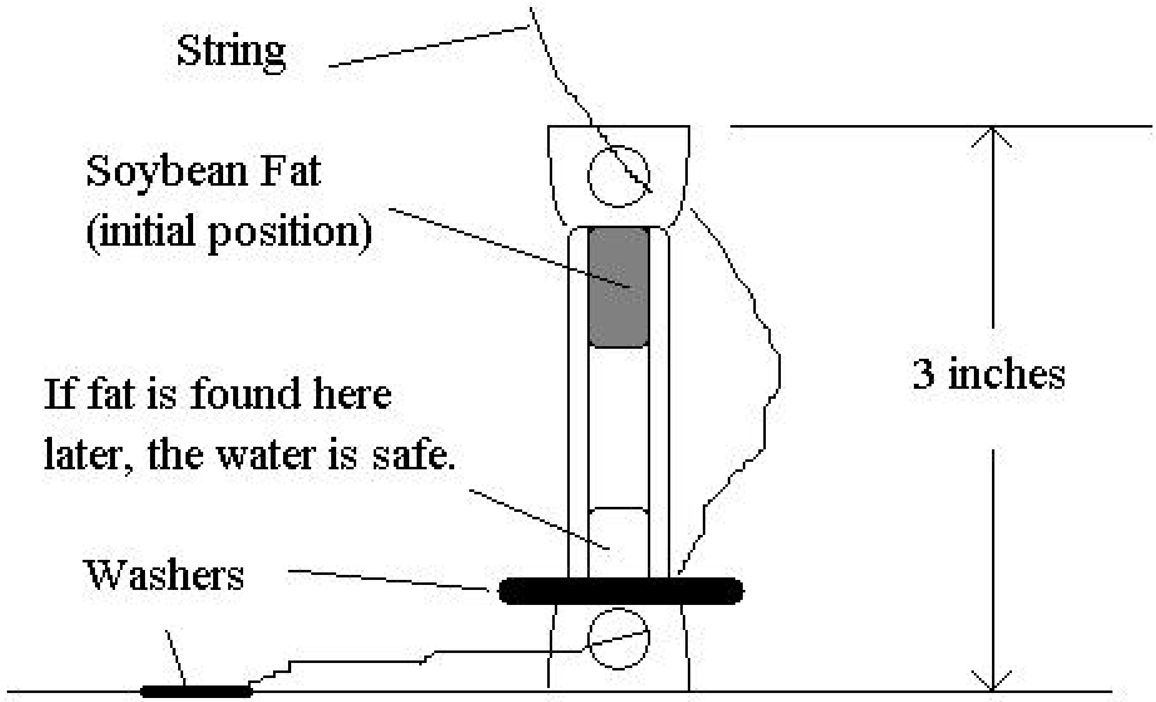

Figure 6: A WAPI

to the bottom (coolest) part of the water, with the fat in the high end of the tube. If the fat is found in the low end of the tube at any time after, the water has reached the proper temperature for pasteurization. A nylon string makes it easy to take the tube out without recontaminating the water. The WAPI can be used over & over by flipping it over and sliding the string through the other way (SolarCooking.org). The WAPI is reusable and durable, and can be used in a solar box cooker, a still or pond, or over a stove or fire (Rolla, 1998).

Application

Solar water pasteurization has been proven to be more than 99% effective in destroying water-borne pathogens. It destroys bacteria, viruses, protozoa and worms, as well as preventing air pollution, ozone damage, deforestation, and soil erosion. Pasteurizing water is a superior alternative to chlorine treatment, which is poorly rated at destroying worms & protozoa and leaves a chemical taste in the water. Pasturizers are low maintenance and there are no replacement parts costs (Safe Water Systems).

Solar water pasteurizers are one of the cheapest forms of water sanitation, and they are uncomplicated to construct. The solar box used as a water pasteurizer is a very effective means of sanitizing small amounts of water for drinking and cooking. It may be a very practical solution for a small family, but a solar still might be a better alternative for a larger family or even a small village. Because of size issues, appropriate applicability is very situational, making an accurate analysis of social customs, wants and needs particularly important.

Dryers

Technology need

Many at risk populations in developing countries are deficient in iodine, iron, and vitamin A, making them more vulnerable to illness, fatigue, blindness, and memory loss, and increasing the possibility of mental retardation among their children. Enhancing these micronutrients can inevitably result in improved well being and physical development. Infants and very young children could have greater chances of survival, better health, and increased intellectual capacity, and women would have improved pregnancy outcomes and increased productivity (Mulokozi, et al).

The current technique of drying food by laying it out on the ground or on mats carries a high risk of contamination by dust, birds and other animals and insects, and it changes the natural colors of the unprocessed food products, making it undesirable to some. Further, traditional drying results in excessive losses of carotenoids due to the food's vulnerability to oxidation that is accelerated by oxygen, ultra violet and visible light, heavy metals, and high temperatures. Compared to sun drying, enclosed solar drying provides high air temperatures and consequential lower relative humidities leading to improved drying rates and a lower final moisture content of the dried crop. As a result, the risk of spoilage during the drying process and in subsequent storage is greatly reduced. Drying in an enclosed structure also has the additional benefit of providing protection against rain and contamination. All of these factors contribute to an improved and more consistent product quality with increased market value (Mulokozi, et al).

Description

The difference between the construction of a solar oven or pasteurizer and a solar dryer lies in the circulation of air. If one were to build a solar oven and then add the appropriate holes and screening, it would then become a food dryer. Holes provide ventilation that is needed to allow warm air to move through and over the food, thereby extracting moisture and preserving vitamins and minerals.

It is best to cover the food with some kind of cloth or other obstacle so that it receives the warmth of the sun, but the sun does not contact it directly and begin cooking it. The cloth can go over the food itself, or be added to the structure of the box. The inside of the box should be reflective and the bottom black, as with a pasteurizer, and the flat plate collector is also necessary in order to retain maximum heat inside the box. Holes should be added to the box approximately one inch above the bottom in the front, and two inches above the bottom in the back, in order to ensure adequate ventilation. To be sure that the food is not contaminated by bugs, dirt or dust, screens over the holes are helpful. Old mosquito netting works well, as do old, thin t-shirts or gauzy strips.

There are two stages in the process of a solar dryer: first, solar radiation is captured and used to heat air; then comes the actual drying process during which heated air moves through, warms and extracts moisture from the product (Karekezi, 1997). As with a solar oven and pasteurizer, the solar dryer should ideally be facing the sun as often as possible, tracking the sun's progress throughout the day in order to assure the ultimate effectiveness.

The solar food dryer is a practical device for preserving certain foods for a longer duration than they would normally last without refrigeration, as well as maintaining levels of vitamins and minerals from the food that is normally lacking in many diets in developing countries.

QuickTime™ and a
GIF decompressor
are needed to see this picture.

TURN THE SOLAR BOX COOKER
TOWARDS THE SUN

Figure 7: A solar box angled towards the sun

<u>Application</u>

Solar dryers have the potential of increasing the efficiency and productivity of drying food, with the additional advantage of increasing availability of vitamin A-rich food sources. Therefore, it makes sense that the technology be targeted to women – given their roles as food processors, caregivers, and income earners – and that other community members be drawn into the process to support women in their decisions and actions (Mulokozil, et al).

The drying of certain foods and crops can not only improve the health of the people eating the food produced by it, but is also capable of providing additional income for women who choose to market these foods. Women in Africa have always made food in bulk to sell at market or on the streets. The drying of food makes it possible for them to make foods and keep them stored for an indefinite period of time, selling them in addition or in place of freshly cooked foods. This allows much more flexibility in marketing techniques and increases fiscal possibilities.

The drying of food is also beneficial in terms of preserving crops that cannot be eaten right away. Solar dryers can assist in reducing post-harvest crop losses because dried produce is less susceptible to natural deterioration and insect infestation (Karekezi, 1997). The drying of food is a good idea for any community, and one that can not only cut losses, but also provide a financial surplus with very little capital investment, along with requiring very little alteration once built.

Puddles

Technology need

A solar pond and a solar puddle are essentially the same thing, with the principal difference of scale. In the concept of a solar pond, a large and shallow body of water is exposed to and heated by the sun. In a mass of water of low depth, solar radiation falling on the surface will penetrate and be absorbed at the bottom, raising the water temperature (Mhathwar.tripod). In a natural pond when solar radiation heats the water below the surface, the action of convection currents causes the heated water to rise to the surface and the pond's temperature normally follows the mean temperature of the surroundings (McVeigh, 1977).

The solar puddle is a smaller version of a solar pond. A solar pond is normally built as a very large body of water, and, though capable of pasteurizing water, is more often used to collect and store energy to be used at a later time for electricity. The purpose that we are interested in for this project is the purification of water for a small community or group of people, which will require only a small amount of space, and thereby the least amount of cost and materials. For this type of small community project, we will focus on the solar puddle, using the solar pond model for technical reference.

The solar puddle works to purify water much like the still and box, the difference being that, since it is set into the ground, the water heats to a pasteurization temperature at the highest levels and then eventually transfers this heat to the rest of the water over time. Using the natural insulation of the earth and raw materials, it is one of the most inexpensive ways to purify water for drinking.

Description

The following description of a solar puddle is from a study conducted at the University of California at Berkeley by Dale Andreatta in one of his many attempts to elaborate on water pasteurization techniques;

In the construction of a solar puddle, a shallow pit is dug in the ground and filled with a few inches of solid insulation (paper, straw, grass, leaves and twigs are all possible materials). The layer of insulation should be made flat, except for one low spot in a corner of the puddle. A clear layer of plastic and then a layer of black plastic (two layers are used in case one develops even a small leak) is placed over the insulation with the edges of the plastic extending up and out of the pit (SolarCooking.org).

Water is added followed by the flattening of the insulation so that the water depth is even to within about a half an inch throughout the puddle, except in the trough which should be about an inch deeper than the rest. More water is added so that the average depth is 1 to 3 inches, depending on how much sunshine is expected. A WAPI should go in the trough since this is where the coolest water will collect. A layer of clear plastic is placed over the water, again with the edges extending beyond the edges of the pit. An insulating gap should be formed by putting a spacer on top of the third layer of plastic (large wads of paper will do) and putting down a fourth layer of plastic, which must also be clear. The thickness of the air gap should be 2 or more inches. Dirt or rocks should be piled on the edges of the plastic sheets to hold them down. Siphoning the water drains the puddle, the siphon placed in the trough and having it held down by a weight. If the bottom of the puddle is flat, well over 90% of the water can be siphoned out (Solar Cooking Archive).

Once the puddle is built it would be used by adding water each day, either by folding back the top two layers of plastic in one corner and adding water by bucket, or by using a fill siphon. (The fill siphon should not be the same one that is used to drain the puddle, as the fill siphon is re-contaminated each day, while

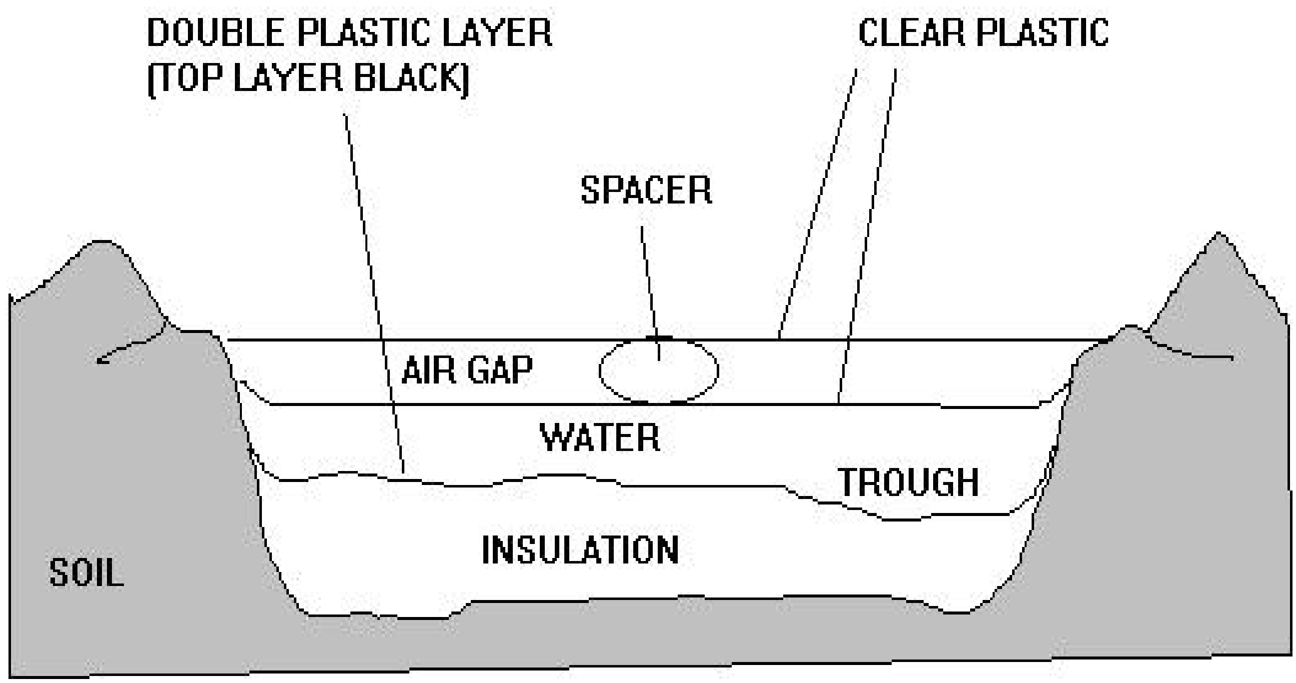

Figure 8: A solar puddle

the drain siphon must remain clean). Once in place, the drain siphon should be left in place for the life of the puddle (SolarCooking.org).

Application

Tests performed by Dale Andreatta in Berkeley, Ca. showed that, on days with good sunshine, the required temperature was achieved even with 17 gallons of water (2 1/2inches in depth). About one gallon is the average minimum daily requirement per person, for drinking, brushing one's teeth, and dish washing, etc. With thinner water layers, higher temperatures can be reached. The device seems to work even under conditions that are not ideal; condensation in the top layer of plastic does not seem to be a problem, though if a lot of condensation forms on the top layer, it should be pulled back to let the condensation evaporate. Small holes in the top layers do not tend to make much difference, and the device works in wind, or if the bottom insulation is damp (SolarCooking.org).

A solar puddle is an excellent form of simple water pasteurization that can be performed with few resources. A solar pond or puddle is merely a natural occurrence that can be elaborated upon to ensure that there is no contamination in the water being pasteurized. Being of such a simple and natural origin, a solar puddle is an appealing form of water pasteurization at the village level.

EVALUATION AND COMPARISON OF TECHNOLOGIES

It should now be clear that the rapid depletion of nonrenewable fossil resources need not continue, since it is now or soon will be technically and economically feasible to supply all of man's energy needs from the most abundant energy source of all, the sun (Williams, 1977). The reasons for employing alternative energies in rural areas of Africa are reflected in her rapidly deteriorating natural resources, high sickness and death rates, and inordinately high levels of manual labor. Solar technology is especially appropriate for this part of the world because of its hot climate and minimal cloud layer. In contrast to many high priced projects requiring substantial capital to get started and to develop, simple solar devices are designed to use local materials available in small communities, unpaid labor, and very little, if any, financial investment.

The four solar technologies that are being looked at for this study have basic and essential purposes for specific portions of the population in a rural community. Though most of these devices will be used by women because of the daily tasks they involve, the devices are appropriate for and ideally to be used by a family or small group of people. A simple chart depicting the uses for the simple solar technologies analyzed for the purposes of this paper are illustrated below.

Table 1: Definitions of Technologies

TECHNOLOGY	DEFINITION
Solar Oven	Small box used to cook food or boil water, suitable for a small family
Solar Still	Large device used to pasteurize water, suitable for a small community or group of families
Solar Box	Small box used for a variety of purposes: to cook food, pasteurize water, or dry food; suitable for a family or small group of women in business for the purpose of making and selling food or beverages
Solar Puddle	Small version of a solar pond; a shallow body of water set into the ground for the purpose of pasteurizing water, appropriate for a group of families or small community

There are some basic qualities that need to be addressed when attempting to evaluate how effective a technology will be in regards to development. Whether or not a project will be successful in a developing nation is highly dependent upon how appropriate it is in terms of local economy, available labor and/or expertise, and the benefits and/or disadvantages that will inevitably be proposed to the community. The following chart reflects some important categories that need to be considered when initiating a development project in a third world country. Measurement of categories will be referred to in terms of high, medium and low, but not uniformly representative of importance.

Table # 2: Categories of Appropriateness

	Ovens	**Stills**	**Puddles**	**Boxes**
Cost	Low	Low	Low-med	Low-med
Maintenance	Low	Low	Med	Low
Local materials	High	High	Med-High	High
Understanding of operation	High	High	High	High
Ease of repair	High	High	Med-High	High
Assistance in chores	High	High	High	High
Increase in time	High	High	High	High
Depletion of natural resources	Low	Low	Low	Low
Improvement of health	High	High	High	High
Save lives	High	High	High	High
Includes appropriate population	High	Med	Med	High
Ability to generate income	High	Low-med	Low-med	Med-High
Local labor	High	High	High	High
Appropriate for a hot climate	High	High	High	High

Depending upon location and local resources available, puddles and boxes may be slightly more expensive to construct than ovens and stills, due to the addition of materials. The plastic needed for puddles can be expensive if it is difficult to find, and the additional levels and meshing needed to turn a solar oven into a box cooker may also increase the price. Maintenance and repair of a puddle may be more laborious than the other devices due to possible deterioration of the plastic because it is set into the ground. Understanding of structure and process, assistance in time and toil, as well as the saving of lives and improvement of health are all rated as high due to simplicity and effectiveness of design. There is a minimal depletion of natural resources with all of the devices, and very great possibility of using the local population for all levels of construction and operation. The possibility to generate income is highest with the solar box and oven is since food and drinks are often made to sell on the streets or to transportation vehicles. Finally, appropriateness of climate to the devices are high on all counts, and mostly geared for use by women, though stills and puddles are equally suitable to the daily chores of both men and women.

There is a growing awareness of the importance of the way that energy is gathered and used, and an increased understanding on the part of the donor nations, of the necessity to focus seriously on the needs of rural populations of the less developed countries (Brown, 1978). That developing countries could benefit from assistance is not a new idea. What is new is the concept that assistance in the form of donations is not only not enough, it is rarely very helpful in the long run, and that local people need to be primary players in an assistance program. The ultimate goal of a self-sustaining project, such as a simple solar project proposed here, is to eventually do away with the ‘donor’ nation and guarantee that progress continues locally. The success of a development project depends on the participation of local people and the benefits they foresee as a result.

There are two primary reasons that solar energy has not been successfully applied in the developing world. The first reason, applicable also to the developed world, is that most solar technologies are expensive. A second reason for a lack of success in applying solar energy in the developing countries is a poor understanding of needs in those areas. Since appropriate needs have not been identified and assessed, assumptions pertaining to solar applications have been faulty (Brown, 1978). Expensive alternative energy technologies are practical developments for communities that can afford them, or have governments that are willing to support such an endeavor. This is not the case, however, in most of rural Africa, but this does not change the fact that there is a need for better health and for maintenance of resources. The donation of money or expensive projects rarely does much good in rural developing areas. The education and practical assistance of a community is what will provide a lasting foundation in the long run.

It is not merely a question of transferring technology to developing countries – all too often technology developed in the context of an industrialized society is irrelevant at best, or harmful at worst, to developing countries. What is needed, for the long run, are technologies suited to the needs and constraints of the country where they are to be used (Brown, 1978). Too many wells have caused desertification in Africa, and too many elaborate schemes for modern water supplies lie on the shelves in many developing countries (Cain & Dauber). One of the first things we learned in Peace Corps is that it does no good to give a community something that will not last a lifetime. The giving of money and expensive gifts is not helpful to a poor community, because soon the money will be gone or seized by someone in a higher station, as will a donated development project that cannot be assimilated to its immediate surroundings.

In order for a project to sustain itself, its ends need to be carried on by local people who have confidence in the project and the drive and ability to maintain its efficiency. Sustainable development is one of the fundamental focal points of a project of this kind, as is the involvement of the appropriate segment of the population. This is the group of people most inclined to use the technology, be able to contribute to it and have the most influence over its outcome. In the case of the solar devices presented in this paper, they are aimed at domestic tasks, with which women in Africa have the most involvement.

Development planning in the past has failed to recognize women as a principal factor in the success or demise of these types of projects. Even with an increased awareness of women and their impact within their communities, many development efforts fail to fully recognize women's actual and potential contribution to the development process, or the effect of the development process upon them. This failure has seriously limited development efforts, and their effects. If women are made aware of the possibility that their time could be better spent for the increased wellbeing of themselves and their families, then maybe solar devices will be adopted by these women as a way to better their lives. Since the particular solar devices that are being analyzed in this paper involve mainly the time and tasks of women, it is central to the focus that they be directly involved in all aspects of their introduction and implementation.

The use of alternative energy technologies in rural areas of developing countries should be aimed at the reduction of human drudgery, with a minimum capital investment and operating expense (Brown, 1978). Women work hard all over the world. Women in Africa have no choice. If there is a way to ease their load and make their lives a little bit easier, then this should be a decision that they have the ability to make. If the interest is there, there are devices that can help the average woman in rural Africa with very little capital investment. There are so many alternatives to a difficult lifestyle out there; African women should have a few available to them.

Ovens

From the solar cooking literature, it is clear that certain factors are essential for the successful introduction of solar cooking. Not only are the technical constraints important, but the social and cultural norms of the people must be considered. Many solar cooking projects have failed because the specific needs of the women were not taken into consideration, for example the need to cook at night rather than at midday when the sun is high (Wilson & Green). From beginning to end and on into the future, women need to be involved, consulted and listened to regarding a project involving solar ovens, or it will fail.

There is a history of attempts to introduce solar cooking that amply demonstrates that efforts to introduce such technologies must take into account not only the economics of a given situation, but also local customs (Brown, 1978). Customs and traditions are not easy to penetrate. For instance, how many solar ovens do you see in use in your neighborhood? Americans don't cook outside, why should Africans? Americans have everything they need to cook inside. People living in Africa feel the same way. They have been cooking in the same way for centuries, and it will take some serious influence to convince them that there is a better and more effective way for them to prepare their meals.

Women in Africa spend an exorbitant amount of time transporting wood for fuel on their heads. This takes up so much of the average woman's time that it would be considered a part or full time job in an industrialized country. At the risk of using the cliché American catch phrase 'time is money', this is time that could be spent making food, drinks or crafts to sell at the market, improving upon education or providing superior care for their children. By using solar ovens, women would have more time to help improve their family's quality of life.

> Women in Africa would be better able to feed their families if they had conveniences that lighten women's cooking chores (Mikell, 1997).

It is clear that the traditional methods of cooking in Africa, though effective, can have a negative impact upon both the lives and health of the women and their families. A solar oven is an example of a method to promote this process.

Wilson and Ramphele (1989) noted that the concept of development must include processes that facilitate the widening of opportunities for individuals and communities. The solar oven has the potential to contribute to such an outcome.

The link between improved household energy sources and possibilities for enterprise has great potential for the empowerment of rural women, as many projects in a wide range of countries have shown. Some stove projects in Kenya have indicated that improved stoves have had a direct effect on the emancipation and general development of women, and women with better cooking facilities were more likely to become involved in development projects and were more proactive in enhancing their living conditions (Wilson & Green).

Pasteurization

It has been shown that solar water pasteurization can kill disease-causing microbes, providing an effective way to purify contaminated water without boiling (Journal of Environ. Health). The pasteurization of water can reduce the amount of time spent hauling it in buckets from the well to the home, in addition to improving the health of people in the village. A water pasteurizer is capable of providing clean and sanitary drinking water when there is no other such resource. Wells are easily contaminated, and pumps have a history of breaking down, but if there is a source of water that is questionable, a solar water pasteurizer can quell doubts and bring peace of mind about the purity of the water being consumed.

Water pasteurization with a box cooker only provides a small amount of purified water. It is without a doubt a worthy endeavor in regards to the purification of contaminated water, but the quantity provided may not be practical for life in an African village. If water pasteurization is needed for an individual or small family, for instance, it would be fairly easy for a person to pasteurize a number of pots of water a day in order to store for drinking and cooking. But, this requires a person to be in the presence of the pasteurizer for a good part of the day, switching pots and water, etc. This approach would be perfect for a person who works at home or already has a solar oven.

In the United States, a device such as this would be ideal for a single person or a couple who was in need of purified water. But, unlike social circumstances in North America, people in rural areas in Africa rarely live alone and are extremely connected with their community. Given this, it is the opinion of the researcher that a solar water pasteurizer would be best used primarily in an emergency situation, or as a supplement to a larger source of clean water.

Dryers

Solar food dryers are strictly a supplement to a daily diet. They do not provide life saving services, but they are capable of improving nutritional intake, which is a more indirect but by no means less important approach to saving lives. A solar food dryer performs essentially the same function as setting food out in the sun, which is already practiced in most developing countries, it just performs it better and faster. Traditional drying techniques involve laying food outside where it is exposed to the elements, and thus contamination. A solar dryer provides an enclosed area for the food to dry in, and also assures that more vitamins and moisture are sustained, increasing nutritional value and reducing the risk of spoilage.

In parts of Eastern and Southern Africa, extensive research has been carried out to develop reliable solar dryers. Solar dryers of different types and designs suitable for use in such regions have been developed for drying agricultural products (such as grain, tea leaves and other crops), fish and timber. In general, research has shown that solar dryers perform well and produce better results than the traditional method of drying crops in the open sun (Karekezi, 1997).

Stills

Solar stills are one of the most practical methods of water sanitation for a rural area that I have seen. They can be made as big or as small as is needed for the community, and require no supervision in order to operate sufficiently. They are the most expensive of the devices portrayed in this paper, but if made correctly can last a very long time. Because of their simple design and project participation, there is little chance of one breaking down and sitting stagnant, waiting for repair. A solar still seems to be the most practical way to purify water for a small village.

Puddles

Puddles are the simplest and most natural way to pasteurize water. After all, solar puddles have been occurring in nature for as long as there has been sun and puddles of water. They also require the least amount of materials, except for an abundance of plastic. So, the feasibility of solar puddles in any given region depends solely on how much plastic is locally available. That, and the amount of time people are willing to dedicate to the process. Because a solar puddle is fairly small, it will require regular maintenance to safeguard against contamination, as well as to retrieve and to refill with water.

Summary

All components and materials used in a solar energy collector should be designed to operate satisfactorily under the worst conditions which could be expected in any particular installation. Materials should be capable of withstanding both the high temperatures, which could be encountered during periods of maximum radiation, and the low temperatures that could occur in mid-winter. Problems that could arise from cyclic variations in temperature, or temperature differences within the collector, should be taken into consideration in material selection and design. The estimated life of any component is important in determining the real life cost of the delivered energy (McVeigh, 1977).

Conventional methods of cost/benefit analysis frequently fail to give adequate weight to the social benefits that result from making energy available where it had not been and would not be available for some time to come if conventional sources were relied upon. But the long-term benefits in improvement of the quality of rural life are difficult to quantify and are easily glossed over in economic comparisons. The unique ability of solar technologies to provide power in isolated communities, without the necessity of building roads, providing transport, or constructing transmission lines – not to mention avoiding the burden of increasing costs and scarcity of petroleum-based fuels – must be given appropriate weight in national planning schemes (Brown, 1978).

I believe that passive solar energy and its application in developing communities in Third World countries is one of the most important and fundamental concepts of sustainable development today. The utilization of passive solar power in a village setting is capable of saving time, energy and resources that could greatly enhance the quality of life for countless villagers in rural communities. I would like to see the practical attributes of these concepts of solar energy management analyzed and practiced to a much greater extent in all developing nations, especially those with an untapped abundance of solar energy, and particularly in Africa.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

As a culmination to the study presented in this paper, the conclusion will contain suggestions for a tentative project plan involving simple solar technologies in a rural village in Africa. Following a synopsis of the fundamental requirements for a simple solar project, a more detailed set of recommendations will be outlined.

An effective development project should start by getting to know as much about the prospective community as possible, enabling the project planners to operate with an understanding of what will work, what won't, and why. Following an appropriate immersion into the community, the need of the project should be clearly described; in this way the community can decide for itself the project's level of importance. As a prelude to instruction about the devices, brainstorming between project planners and local participants is a good idea so that everyone shares a comparable focus and goals. Materials need to be locally obtained, inexpensive and confirmed early on in the project, and instruction should be a combination of expertise on the part of the project planners, and group participation. Operation needs to be supervised at the outset in order to prevent unnecessary problems and ensure productivity. A follow up schedule needs to be determined in order for problems to be assessed and resolved, and so that subsequent efforts are able to improve upon the design of the project.

Orientation to community

In order to implement any kind of successful project in a rural area of a Third World country, a sincere effort needs to be made to get to know the community. Not just for the duration of the project, but for a significant period of time before the project is initiated. Research should be undertaken, if possible, on the people who live in the village; their heritage, traditions, customs and beliefs. This information will be invaluable when societal problems arise, which they undoubtedly will. But only a certain amount of well-founded information can be gleaned from history. It is virtually impossible to know a community and the people in it, unless you live among them.

This is one of the development approaches that is to be commended about the Peace Corps. Peace Corps could easily be explained as more of an exchange program than a development organization; volunteers are placed in a village type setting, experiencing almost identical living situations to every other person in that village. (Unlike almost every other development organization that provides personnel with transportation, servants, and much nicer accommodations than their local neighbors). A Peace Corps volunteer is placed in order to perform a job that would not otherwise be fulfilled (teacher, health assistant, forester, etc.) due to lack of government funds, availability of qualified workers, whatever the case may be. In addition to executing this primary job, a volunteer lives in the village, shops at the market, goes to the local bars and restaurants, eats, drinks, converses and shares experiences with his or her neighbors on a day to day basis. In this way a volunteer gets to know how their neighbors think, what they want and how they do things. With this knowledge, it is the secondary job of a Peace Corps volunteer to establish what kind of a project their community needs and would do well with, and to get the materials, funding and assistance needed to make it happen.

This is one of the most effective ways to understand what it is that a community truly needs and will make use of. If it is not economically possible for a solar company to put a volunteer in a village for a period of time before the project begins, then an alternative may be to approach a village that has a Peace Corps volunteer living there already. If not a Peace Corps volunteer, then contact could be made with another development organization that is currently living there, or has lived there in the recent past. If a job is worth doing, especially a development job, then it's worth doing right, and the only way to effectively assist in the development of another community is to know how and *if* it wants to develop.

Education

After doing adequate research on a village in order to determine if simple solar technologies are warranted, the next step is to implement an education program. The first step of an education program is to interest participants in being educated. As has been established, people are busy everywhere, particularly the women of rural Africa. It needs to be made worth their time to sit and listen to a foreigner with foreign ideas when they have a busy life to attend to. A good way to accomplish this is to begin with a trusted member of the community, one who has the respect necessary to encourage people to listen. The idea of a new technology should be suggested locally, in this way it becomes a community enterprise, rather than an extrinsic imposition.

It may also be the case that people at a village level don't know that improved water quality or an abatement of deforestation is what is needed to improve the quality of their lives. From my experience living in Africa, I have to say that these are some of the happiest people I've ever had the pleasure to know. From observing the way that they live, they don't really seem to know why their children sometimes get sick and die; that's just the way it is. The way it's always been. How do you begin a change for the better when you don't have the realization that things are bad?

It is here that education becomes a crucial factor in the development process. Even if ignorance is bliss, it is still important for people to understand that their water may be killing them, the smoke from fires may be infecting their lungs, and there are alternatives to walking ten to twenty miles a day for basic necessities such as wood and water. Regardless of whether or not they choose to accept them, it is important for people to know that they have options, that it is possible to be healthier, to possibly make money and to definitely save lives.

Brainstorming

Brainstorming between project planners and local participants is an important aspect of a project like this. Without this interaction it becomes just another plan forced on a developing country and thrown away after the project planners have left. There are too many of these already, and an abundance of evidence that they don't work.

People living locally will have a much better idea of what types of materials will work best and why. (Tree sap and wheat paste are natural sticky substances that would not immediately pop into the mind of a westerner to use for glue). It is necessary to talk with locals about their daily routine and how this may influence the project. (People who normally cook indoors will have a much harder time adjusting to a solar oven than those who normally cook outside). Also, what about cooking at night or in the early morning? During the month long celebration of the Muslim holiday Ramadan, those who are devout are only allowed to eat one hour before sunrise & after the sun sets. If a solar oven is only able to be used for one meal a day, or not at all during certain times of the year, then even though this may provide a drastic reduction of deforestation and manual labor, it may not be feasible for this particular area.

Will a solar still provide the same active interaction between women that is provided them at the pump, well or river? Rituals of personal contact are very significant social structures that cannot be overlooked.

Are the women interested in supplementing their income with solar dryers, or is this not a priority in their particular community?

Is a solar puddle going to be just too weird? Is there too much participation involved in the pasteurization of water?

These questions will hopefully be matched by ones from the local people that project planners would never normally think about. It is the recognition of the differences in culture and reference that will open the doors of communication and allow this project a fighting chance.

Materials and Construction

Materials need to be locally attainable. Nothing should have to be shipped or obtained from a donor country or from too far away from the village of operation. The construction of these solar devices needs to be as economical as possible. If the materials needed for construction of the device are not readily available or are too expensive, then this is not an area where the application of this type of device is feasible. The adequacy and attainability of local materials is an area of research that needs to be done before a project is suggested to a given area.

Construction is to be directed by the project team, taking care that every aspect of production is understood and achievable by the local people after the planners have left. A guidebook can be provided, including diagrams and photos, or translated into the local language. Whatever process that local people think would be the most effective method of preservation and reference, should be made available.

Operation and Follow up

Much as with the idea of construction, operation should be demonstrated and supervised by the project planners, making sure to be open to ideas and suggestions from the local participants all the while. Issues such as what to do with the devices when they are not in use should be addressed, as well as schedules assigned to those in charge of maintenance, etc.

Project planners should stay until the devices are in use and there are no questions from the local operators. Following the departure of project planners, regular contact should be made throughout the first few weeks or month, by phone, letter or email. A follow up visit should be planned for three months after the devices have been adopted to see how they are working and if they are being used as much as estimated, and then another three months after that. Future follow up to be determined by the solar company itself and local operators.

During the follow up visits, discussion groups should be held to receive ideas and suggestions regarding operation successes and failures from the local participants. If it is possible for the local users to keep a logbook or record of some kind during operation, this would help to identify problems and aid in finding solutions in the future.

Further research into current projects should be conducted in order to determine which methods have been successful and which have failed.

Evaluation of product quality and the degree to which they have withstood local conditions is important to know for future project design. Most important, though, is a look at how these types of devices have affected the lives of local people; have they brought any kind of improvement to the community in general, have they bettered the lives of women and girls, augmented income, or provided better health to the community? These main points are the objectives of a project involving simple solar devices, so these are the outcomes that should be analyzed for future studies, along with possible future outcomes that may not have been anticipated or planned for. Most significant are the effects that these devices will have on the community at hand, most specifically women and girls, and the positive or negative impact they will have on their immediate and future lives.

REFERENCES

Beard, Jonathan D., & Gunther, Judith Anne, *More News on Photovoltaic Shingles*, Popular Science, July 94, Vol. 245, Issue 1, p.36

Beard, Jonathan, and Fritz, Sandy*, Corals Do It, So Why Can't We*?*,* Popular Science, Jan 1994, Vol. 244, Issue 1, p.42

Berger*,* Dave, *Lighting a Small Candle; A Renewable Energy Sabbatical*, Home Power #60, August/September 1997

Brower, Michael, Cool Energy, Renewable Solutions to Environmental Problems, Massachusetts Institute of Technology, 1992

Brown, Norman L., Renewable Energy Resources and Rural Applications in the Developing World, The American Association for the Advancement of Science, Westview Press, Inc., Boulder, Co., 1978

Burch, Jay & Thomas, Karen E., *An Overview of Water Disinfection in Developing Countries and the Potential for Solar Thermal Water Pasteurization,* National Renewable Energy Laboratories, 1998

Cain, M.L. Dauber, R., *Women and Technological Change in Developing Countries,* Colorado, Westview Press, Inc., 1981

Cheremisinoff, Paul N., and Regino, Thomas C., Principles and Applications of Solar Energy, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1978

Cloutman, Elizabeth, *Fast Hot Meals from here to Nepal with Solar Cooking*, The Town Crier, Los Altos, Ca

Deudney, Daniel and Flavin, Christopher, *Renewable Energy, The Power to Choose,* W.W. Norton & Company, 1983, pp. 74-Duhamel, Bernard, *Renewable Energies in Africa: Examples of Fuelwood and Solar Energy,* African Environment, 1987, pp.43-6

Dwortzan, Mark, *Something New Under the Sun?* Technology Review, Sept/Oct 2000, Vol.103, Issue 5, p.30

Earth Island Journal, *Off the Grid, Beyond the Border,* Fall 1992, Vol. 7, Issue 4, p.10

Earth Island Journal, *The Sun Can Save a Million Lives,* Winter 1995, Vol.11, Issue 1, p13

Food and Agriculture Organization of the United Nations, *Solar Energy: Power for Rural Development*, News and Highlights, October 24, 2000

Ganapathy, R.S, *Agriculture, Rural Energy and Development*, Division of Research, Graduate School of Business Administration, The University of Michigan, Sponsored by the International Association for the Advancement of Appropriate Technology for Developing Countries, 1981

Goldin, Augusta, Small Energy Sources, Harcourt Brace Jovanovich, Orlando, Fl., 1988

Hankins, Mark, *Home Power in Africa: PV Field Training in Karagwe District, Tanzania*, Home Power #41, June/July 1994

Harntett, James P., *Alternative Energy Sources*, Energy Resources Center, University of Illinois at Chicago Circle, 1976, pp.10, 149-150, 219

Hull, John R., Nielsen, Carl E., Golding, Peter, *Salinity – Gradient Solar Ponds*, CRC Press, Inc., Boca Raton, Florida

Journal of Environmental Health, *Safe Drinking Water Using Solar Energy Without Electricity or Pumps*, Jul/Aug 1997, Vol.60, Issue 1, p.46

Karekezi, Stephen, Renewable Energy Technologies in Africa, African Energy Policy Research Network and The Stockholm Environment Institute, Zed Books Ltd., London and N.J., 1997

McCracken, Horace & Gordes, Joel, Understanding Solar Stills, Volunteers in Technical Assistance, 1600 Wilson Blvd, Suite 710, Arlington, VA, 22209, vita@vita.org, 1985

McIntyre, Maureen, Solar Energy – Today's Technologies for a Sustainable Future, American Solar Energy Society, Boulder, Co., 1997

McVeigh, J.C., Sun Power: An Introduction to the Application of Solar Energy, Pergamon Press, Oxford, England, 1977

Nishimizu, Mieko, *Energy, Gender and Poverty Reduction*, Joint Strategy Business Meetings, 2001

NREL: National Renewable Energy Laboratory, *Solar Energy: Tapping into Earth's Largest Energy Resource*, 1617 Cole Blvd, Golden, Co., 80401; 2001

Parikh, Jyoti K., *Energy Systems and Development; Constraints, Demand and Supply of Energy for Developing Regions*, Oxford University Press, Bombay Calcutta Madras, 1980, pp.73-75

Presidents and Prime Ministers, *Solar Power Project,* Nov/Dec 1993, Vol. 2, Issue 6, p.52

Rolla, Trudy C., *Sun and Water – An Overview of Solar Water Treatment Devices*, Journal of Environmental Health, June 1998, Vol. 60, Issue 10, p.30

Russo, Ronald W., *Deforestation in Cost Rica: What are the Effects on the Environment and the Native People?* Colby College, 1999

Schwartz, Joe, *Tapping The Sun,* Whole Earth, Winter 99, Issue 99, p48

Syed, Tahira, *Solar Sustainable Development*, Sun Ovens International, Inc., www.sunoven.com

Taylor and Francis, *Energy Issues and Options for Developing Countries*, The United Nations, 1989, pp.158, 208-209

Tidwell, John, Riddoch, Fiona, and Grainger, Bill, Energy for Rural and Island Communities III, Pergamon Press, 1984, pp.239-242

Tyson, Peter, *Solar Ovens Heat up in the Tropics,* Solar Ovens; Renewable Energy Sources – Kenya, Kammen, Daniel; Technology Review, 1997, Vol. 97, Issue 4, p.16

UN Chronicle, *World Leaders Launch Global Solar Campaign*, 1996, Vol. 33, Issue 4, p.31

UN Chronicle, *World Leaders Launch Global Solar Campaign*, 1996, Vol. 33 Issue, p31, 2p, 2bw

Waltham, *Evergreen's Goal: Plugging in the sun Start-up Seeks to Tap into Vast Potential of Solar Energy Field*, Boston globe, January 18, 1998

Wells, Malcolm, *Notes from the Energy Underground*, Van Nostrand Reinhold Company, 1980, 44-48

Williams, Richard J., Solar Energy Technology and Applications, Ann Arbor Science Publishers, Inc., Ann Arbor, MI., 1977

Wilson, Merridy and Green, J Maryann, *The Feasibility of Introducing Solar ovens to Rural Women in Maphephethe*, Journal of Family Ecology and Consumer Sciences, Vol. 28, 2000

Women and Technological Change in Developing Countries, West View Press, Inc., 1981

Website References

Accessone.com, *A Summary of Water Pasteurization Techniques*, Figure 6 (A WAPI), Figure 8 (A Solar Puddle); Public Domain, obtained June 4, 2001

Epsea.org/stills.html, El Paso Solar Energy Project, *Solar Water Purification Project*; Figure 3, Public Domain, obtained March 25, 2001

Mhathwar.tripod.com*, Solar Ponds,* accessed September, 2002

SafeWaterSystems.com, *What is Solar Water Pasteurization*; *The Problem: Contaminated Drinking Water, The Solution: Solar Water Pasteurizers,* Figure 4 (Diagram of a Solar Still) – Public Domain, (model of a Sol*Saver) obtained Aug 15, 2002

SolarCooking.org, The Solar Cooking Archive, *The Solar Puddle: A New Water Pasteurization Technique for Large Amounts of Water; Improved Devices to Pasteurize Drinking Water*; Figure 1 (Basic Construction of a Solar Oven), Figure 2 (Operation of a Solar Oven), Figure 5 (Diagram of a solar box), Figure 7 (A Solar Dryer Diagram), Public Domain, obtained August 21, 2002

Sunoven.com, *Frequently asked Questions about Solar Ovens,* accessed August, 2001