SUMMARY OF PHASE I

1. BACKGROUND AND PROBLEM DEFINITION

Although potable water is critical in sustaining human life, according to the World Health Organization (WHO) and UNICEF water assessment there are over one billion people without access to safe water [1,2]. Every year more than five million people die because of the lack of safe water and improper sanitation. The most profound impact of unsafe water occurs among children below the age of five. A substantial portion of the more than 10 million children who die each year is directly related to unsafe water and poor sanitation [3]. At the 2002 World Summit on Sustainable Development, it was recognized that access to safe water is a severe problem to sustainable growth, so much that the Johannesburg Sustainability Plan of Implementation set a target of halving the proportion of people without access to safe water by 2015 [4]. Although there has been significant progress increasing safe water accessibility in urban areas over the past decades, there is still significant shortage in rural areas of the developing world. According to UNICEF, 50% of the children living in rural areas of the 50 least developed countries do not have access to improved drinking water sources [5]. These less centralized areas are more challenging to address because the disperse nature of the population makes it difficult to utilize centralized water systems and the limited access to the utility grid limits potential technology options. Decentralized water treatment technologies will have to be deployed to satisfy much of this rural need.

Not having access to safe water not only leads to higher death rates but also causes significant debilitating problems such as weakness, blindness, and respiratory illnesses. This lack of access hinders people's ability to focus on the development of their families and communities, which ultimately reduces their chances of improving their economic prosperity. There has been considerable work done on community sized water treatment systems for the developing world where ideally a community could protect a pure, safe source of water by capping a spring or well. Then by utilizing gravity or a pump to deliver the water supply a source of water is available. If a safe source is not available, or if the source is suspect, a treatment process must be employed. Treatment technologies normally include some type of pretreatment process such as sedimentation and/or roughing filtration followed by one or more treatment processes. Some of these treatment processes include boiling, chemical disinfection (chlorination), slow sand filtration, ultraviolet disinfection, or solar disinfection. These treatment methods may not always be appropriate because of high costs, diminishing fuel supplies, potential environmental degradation, limited access to vital chemicals, significant maintenance, or not having guaranteed disinfection.

The practice of gathering and burning wood for treating water and cooking has an enormous human and environmental toll each year. Deforestation of carbon sequestering trees is greatly influenced by this practice. According to FAO's 2005 State of the World Forest report [6], the change in the world's forest cover in the 1990-2000 decade was -0.2% (or a decrease of 9,391,000 ha.), with worldwide fuelwood consumption totaling 1,795,496 m^3. This also accentuates the problems derived from soil erosion, habitat losses, and contamination of waterways. Biomass fueled fires also pollute the air and contribute to global warming. Additionally, the rapid depletion of fuelwood forces people (primarily women and children) to spend many hours each day in an increasingly nonproductive foraging process. It is reported that the average person living in a rural area in a developing country walks between 3 to 10 miles to gather enough wood to cook for a day. This situation is likely to get worse as forests continue to be depleted.

The negative environmental and economic consequences of firewood for water treatment and cooking are matched by the adverse health impacts (primarily respiratory ailments and eye diseases) associated with long-term exposure to smoky fires. Firewood stoves are major sources of concentrated indoor pollution from smoke. In homes without ventilation, exposure levels to particulate matter, along with carbon monoxide, formaldehyde, benzene, nitrogen dioxide, and other gases can reach 1000 $\mu g/m^3$ over a 24 hour period [7], which is more than 20 times higher than the standards set by the U.S. Environmental Protection Agency. Indoor air pollution is the fourth leading cause of premature death in the developing world and, overall, kills over 1.6 million people, predominantly women and children, every year. This represents a death toll almost as great as that caused by unsafe water and sanitation, and greater than that caused by malaria. Finally, skin burns in children are also frequent when cooking with fuelwood and fires can readily get out of control causing damage in the surroundings.

Since energy from the sun is readily available in most locations where unsafe water is an issue, developing a solar water treatment technology is a viable option for small water supply systems that does not have many of the people and planet issues associated with several of the current alternative water treatment options. One solar technology that has gained recent attention is solar water pasteurization. Pasteurization works on the principal that pathogenic protozoan, bacteria and viruses are destroyed as water temperatures are elevated. Water can be pasteurized at much lower temperatures than boiling, therefore reducing the potential emission associated with boiling water for treatment. The pasteurization of water is a function of temperature and exposure time. The most thermally resistant pathogens for short time periods of less than one hour are the viruses. Most viruses are inactivated in less than one minute above 70°C according to Backer [8]. Hepatitis A appears to have greater thermal resistance than other viruses. Parry and Mortimer found that Hepatitis was fully inactivated within four minutes at 70°C and 30 seconds at 75°C in a phosphate-buffered saline solution [9].

Solar pasteurization emerged as a means of treating water in the mid 1990's. Earliest development utilized a batch process for heating the water to pasteurization temperatures. Theses systems tended to be low cost, but suffered from relatively small production rates (<5 liters/day) [10-13]. The batch systems tend to be simple and are reliable as long as the users are trained properly. The disadvantage of these types of systems is that they require the operator to monitor them throughout the day and replace the water with untreated water once pasteurization temperatures are reached in order to get optimal performance. The entire system must also reach the pasteurization temperature which may be extremely difficult on partly sunny days with larger systems.

To increase performance, flow-through systems were developed, which use a thermostatic valve or other temperature control to regulate a continual flow through the system while ensuring pasteurization temperatures are reached. A natural extension of this design is to add a small heat exchanger to recover heat from the treated water to preheat incoming untreated water. This improvement dramatically increases throughput of systems by a factor of four or more [11]. There are a few off-the-shelf systems that use two separate primary components [14], the solar collector and heat exchanger, which limits options for cost reduction.

If the solar collector and heat exchanger could be integrated with little sacrifice to system performance, the cost and simplicity of the system could be greatly improved. A simple cartoon of solar pasteurizer with an integral heat exchanger is depicted in figure 1. An integrated system can be built by attaching a heat exchanger surface on the underside of an absorber. This approach would eliminate all the components associated with an external heat exchanger such as insulation, housing, and piping material. Because the water is in full contact with the absorber and at low pressures, a wide range of materials and fabrication techniques can be considered to reduce system cost. Preliminary experimental work on merging the collector with an integral heat exchanger for small water treatment systems has been done [15, 16] but little has been done to design deployable prototype systems, which could potentially be manufactured within the country of use.

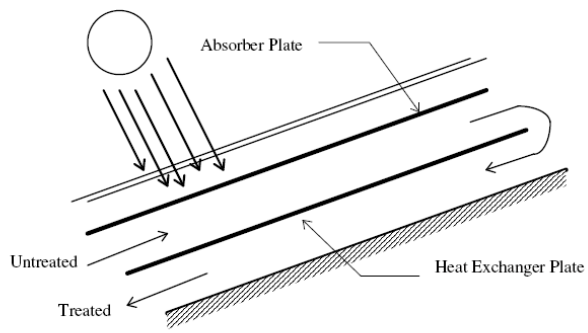


Figure 1: Schematic of solar pasteurizer with integral heat exchanger.

To tackle this next generation of solar pasteurizer, a multidisciplinary team of seven senior engineering students from RIT's Mechanical and Industrial and Systems Engineering was formed in the fall of 2007. Students enrolled in the two quarter design courses work through a formal engineering design process to complete their project. In the proposed project, students evaluated their conceptual designs against both traditional cost and productivity criteria as well as against broader sustainability criteria. Standard methods and metrics which ignore environmental and social externalities may not be appropriate for a project or product that is to be evaluated against broader sustainability criteria. An important step forward in increasing the awareness of students with respect to the impacts of their designs on people, prosperity and the planet will have been made once awareness of sustainability issues has been assimilated into the standard design process.

This project also serves as one of the first design projects specifically initiated to enhance the new Energy and Environment Option being developed in the Mechanical Engineering department and the first of six in the newly formed sustainability project family in the College of Engineering at RIT. This new family of projects supports the College of Engineering's growing programs in sustainable engineering.

The student project has applied the knowledge from preliminary work on solar pasteurizers with integral heat exchange systems to develop a simple and inexpensive prototype that could potentially be mass produced in the developing world, therefore creating the possibility of a cottage industry while meeting the fundamental needs of people using a renewable energy source.

2. PURPOSE, OBJECTIVES, SCOPE

The primary purpose of the solar pastuerizer project is to develop a viable alternative for treating water for the rural populations in developing areas using a renewable energy source while reducing the impact on the environment associated with other treatment options and improving the quality of life of the end users. The developed technology should predominantly use locally available materials and practices and be relatively simple to use while being robust and durable. The primary objectives for the project are:

- To design and develop a working prototype solar pasteurizer with an integral heat exchanger to treat adequate quantities of water for a typical rural Latin American family.
- To minimize the use of imported and environmentally harmful materials and specialized fabrication techniques in the pasteurizer construction.
- To test both thermal and water treatment effectiveness of the prototype pasteurizer under a range of conditions.
- To minimize the cost of providing safe water to rural families.
- To expose undergraduate students to sustainable design practices, while sensitizing them to the relationship between engineering and both the environment and people.

3. DATA, RESULTS, FINDINGS

At the Rochester Institute of Technology's Kate Gleason College of Engineering, graduating engineering students are required to participate in the two-quarter "Multidisciplinary Design Experience" (MDE). During this experience, students from all Engineering disciplines form teams to work on projects for a wide variety of clients. Within this context, students enrolled in the MDE work through a formal engineering design process to complete their projects, which is outlined in Table 1. The solar pasteurizer multidisciplinary team was composed of seven undergraduate students from Mechanical and Industrial Engineering: Sang Lee (team leader), Elaine Aiken, Kellen Bucher, Drazen Hadzialic, Nathan La Croix, Sulen Gonc, and Alexander Kinlock.

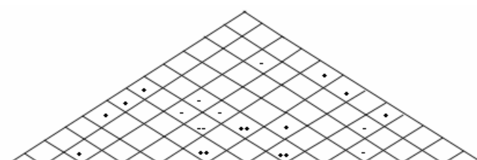
Table 1: Stages of the design process

1) Sensitization, recognition, and quantification of the need
2) Process mapping, concept development, and preliminary designs
3) Engineering analyses and models
4) Testing and redesign iteration, material selection
5) Final detailed design, performance analysis and cost estimation
6) Impact analysis: economical, environmental and health
7) Fabrication of design
8) Performance testing

3.1 Sensitization, recognition, and quantification of the need

During the first phase of the design project the team focused on gaining insight into the people needs by conducting research on both water issues and past work on solar pastuerizers. The teams also did benchmarking, where they collected data on existing pastuerizers and other water treatment technologies. The student team met with Sarah Brownwell, who has had extensive experience with low cost water treatment technologies in Central America. In order to better understand many of the social and cultural of the rural population of Central and South America, the student team also interviewed Andres Cerrano and Brian Thorn who have visited many areas in rural Venezuela. Based on the team's interviews and research, the team developed a list of the "customers" needs. These needs were then mapped into a set of 24 engineering specifications and prioritized. From this a Quality Function Deployment (QFD) matrix was developed, shown in figure 2.
This method analyzes the case at hand from several dimensions: 1) Identification of the customer needs/requirements; 2) Ranking of the customer needs/requirements by using a 1-3-9 scale, 1 being low importance, and 9 being the high importance need/requirement; 3) Development of engineering attributes to address the mentioned needs; 4) Identification of the strength of the engineering attributes to the corresponding need/requirement; 5) Recognizing the relationship among the engineering attributes; 6) Benchmarking of engineering attribute values; 7) Development of target values for each engineering specification after benchmarking; 8) Stating and ranking the technical difficulty of each

Solar Pasteurizer with Integral Heat Exchanger (SPHIX)



		Customer Requirements / Needs	Relative Importance	Cost per Unit	Achievable Temperature	Time to reach Pasteurization Temperature	Duration of Pasteurization	Volume of the Pasteurizer	Weight	Thermal Efficiency	Daily Potable Output	Tamper-Proof	# of Moving Parts	Filter	Collection Area
End User	1	Low Cost	9	9				3							1
	2	Easy to maintain / clean	3					1	1				3	3	
	3	Durable	3						1			3	9		
	4	Capable of fabrication locally	9	9											
	5	Provide drinkable water	9		9		9			3	1			3	
	6	Indication of pasteurized Water	1		9										
	7	Effective in different settings	3							3					
	8	Made from readily available materials	9	9											
	9	Easy to operate	9										3		
	10	Easy to store / portable	1					3	9						
	11	Sufficient output	3					3		9	9				
	12	Quick pasteurization	1			9				3					
Technical Difficulties				9	3	1	1	1	1	3	9	3	1	1	3
Measurement Units				$	°C	min	min	m³	Lbs.	%	L/day	y/n	#	y/n	m²
Object Target Values				<65	70	300	5	0.07	50	80	20	y	2.0	y	0.387
Objective Measures		AquaPak		20	67	180	15	0.004	0.5	76%	15	y	0	y	0.17
		AquaCone		200	n/a	n/a	n/a	0.002	5	n/a	2	n/a	0	n/a	0.018
		WaterCone		26.17	n/a	n/a	n/a	0.042	n/a	40%	1.7	n/a	0	n/a	2.01
		Solar Oven		32.33	84	95	n/a	0.075	38.5	n/a	(*)	y	0	n	0.914
		Sol Saver		3700	n/a	n/a	n/a	0.705	460	n/a	800	y	1	y	3.7

Correlation Code	
++	Very Positive
+	Positive
-	Negative
--	Very Negative

Figure 2: Quality Function Deployment (QFD) / House of Quality Matrix

engineering attribute. This approach is instrumental for observing if the design has fulfilled the needs/requirements and to what extent. The team then utilized this information to help guide the concept design development process while paying close attention to the end user needs and design attributes.

3.2 Process mapping, concept development, and preliminary designs

During this second stage of development, the team mapped out the energy and material flow into a function diagram, figure 3, of a general solar pasteurizer to help identify the subsystems for design. During the process the team identified seven subsystems: i) sediment control, ii) feedwater handling, iii) solar collection, iv) heat exchanger, v) flow/temperature regulation, vi) air regulation, and vii) heat loss management. The team then brainstormed possible concepts for each of these subsystems. Figure 4 depicts one of the concepts for the flow/temperature control along with the final design and prototype. They also looked at existing products and did benchmarking to see if there were potentially other concepts that could be borrowed upon. The subsystem concepts were then assessed and ranked using the customer needs and specifications and ultimately narrowed to a few concepts for each subsystem.

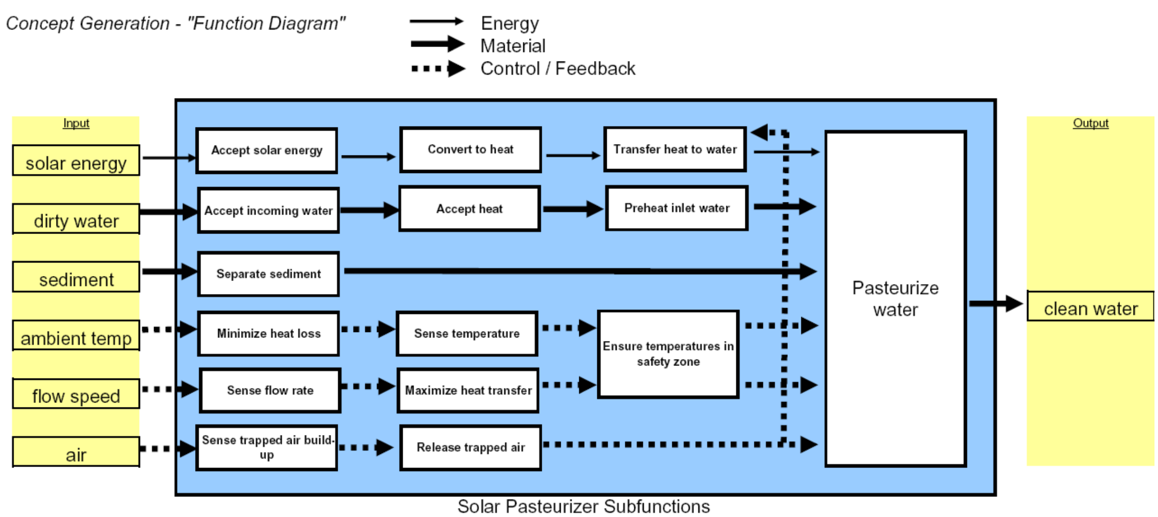


Figure 3: Energy and Material Function Diagram of Solar Pastuerizer

The team then brainstormed different options for combining the subsystems into a single pasteurizer system. These concepts were discussed and assessed with the customer needs in the forefront. Out of this process, five system concepts were selected for the team to pursue further. The concepts were refined and then the team ranked each concept using a Pugh chart, figure 5, ranking each concept against one another for each of the key specification/needs used as the selection criteria. The team then narrowed their scope to the three plate concept for further analysis and design. The team held a concept review where the team shares their understanding of the needs and proposed concepts with faculty and experts and solicited their input into the design.

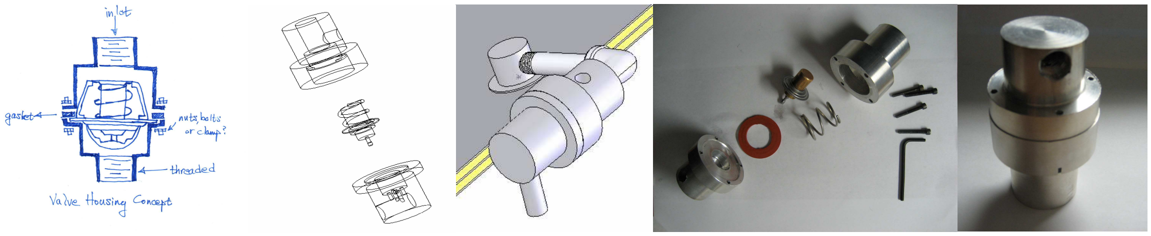


Figure 3: Concept, final design, and prototype of flow/temperature regulation subsystem.

		Concepts									
		A Dimpled		B Tube / Baffle		AB Baffle / Baffle		D Evac. Tube		E Mirrored	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Cost	17%	4	0.68	2	0.34	3	0.51	0.5	0.085	4.5	0.765
Easy to fabricate	13%	4.5	0.585	2	0.26	3	0.39	0.5	0.065	4	0.52
Easy to use	10%	3	0.3	3	0.3	3	0.3	3	0.3	1	0.1
Durability	10%	2	0.2	3	0.3	3	0.3	4	0.4	2	0.2
Maintenance	5%	1.5	0.075	1.5	0.075	1.5	0.075	3.5	0.175	3	0.15
Flow Distribution Complexity	5%	3	0.15	3	0.15	2	0.1	5	0.25	4	0.2
Output	15%	3	0.45	3	0.45	3	0.45	5	0.75	2	0.3
Heat exchanger effectiveness	10%	2.5	0.25	3	0.3	3	0.3	5	0.5	4	0.4
Air formation	5%	2.5	0.125	1	0.05	3	0.15	3	0.15	2	0.1
Design adaptability	10%	3	0.3	2.5	0.25	3	0.3	0.5	0.05	1	0.1
	Total Score	3.12		2.48		2.88		2.73		2.84	
	Rank	1		4		2		3		5	
	Continue?	YES		NO		YES		NO		YES	

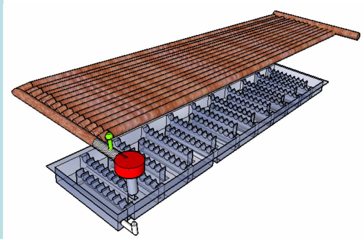


Figure 4: Pugh chart with one of the system level concepts.

3.3 Engineering analyses and models

To analyze and begin optimizing the selected concept, the team adapted an engineering model developed by Stevens *et al.* [16] to simulate the performance of the solar pasteurizer using hourly weather data. The model allowed the team to explore the impact of key design parameters such as heat exchanger material, solar coatings, glazing materials, and dimensions of collector and heat exchanger subsystems on the overall performance as well as their environmental impact. During this phase of design and optimization, special attention was paid to the manufacturability and durability of the pasteurizer.

The team made improvements to the thermal model by incorporating a transient model. Figure 6, shows a sample simulation of the pasteurizer for three typical days. Because solar pasteurizer is a highly transient problem, the model uses hourly solar data. Since reliable hourly solar data was not available for Venzuela, the team compared average solar data and found that using hourly data for Puerto Rico, which the team had access to, resulted in similar solar radiation monthly averages. The team then did multiple simulations where the design parameters were varied and finalized on a design that ensured that during the worst month of the year, on average the solar pasteurizer would treat 150% of their pasteurizer specification of 20 liters per day. A pasteurizer of 80 cm x 50 cm with 5 mm deep channels would ensure pasteurization of water and meet the required flow through to meet the daily needs of the users and minimize material cost.

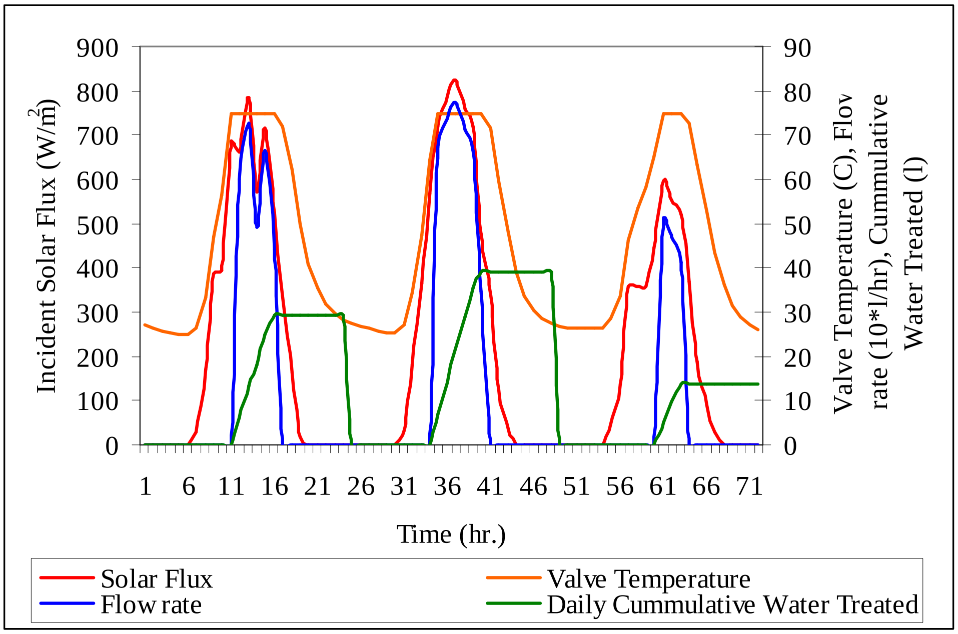


Figure 6: Three typical days of solar pasteurizer output for a given set of design parameters.

To quantify the impact of the designed pasteurizer would have on the environment a cradle-to-grave life cycle analysis (LCA) was conducted. The analysis was made using Sima Pro®. For disposing of the pasteurizer, different types of disposition scenarios including land-fill, recycling and a low percentage of municipal waste disposals were selected due to the materials used for the pasteurizer. Figure 7 shows the environmental impact of the pasteurizer for key environmental indicators. The product was evaluated according to the Eco-indicator 99(H) method for environmental impact. 1000 eco-points is the yearly environmental load of one average European inhabitant. The pasteurizer gained an overall score of 3.37 eco-points. Upon disposal, the solar pasteurizer will be beneficial to the environment in terms of resp. organics, inorganics, radiation, ozone layer, mineral as well as fossil fuels.

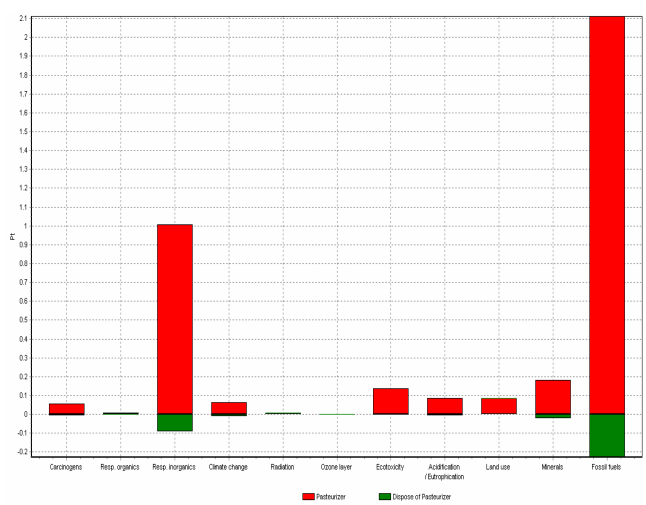


Figure 7: Life-cycle assessment of Solar Pasteurizer with Integral Heat Exchanger

The team prototyped several of the subsystem components and did tests followed by redesign of the subcomponents. Several fabrication technique were tried in order to reduce the overall complexity of fabrication to ensure the final design could be manufactured without the use of highly specialized tools. Figure 7 shows team members using a simple mechanical crank to create ribs to improve lateral structural rigidity and forming a simple z-bends on the edges on the top and back plates allowing for a one weld pass around the entire system to dramatically reducing fabrication cost/time.

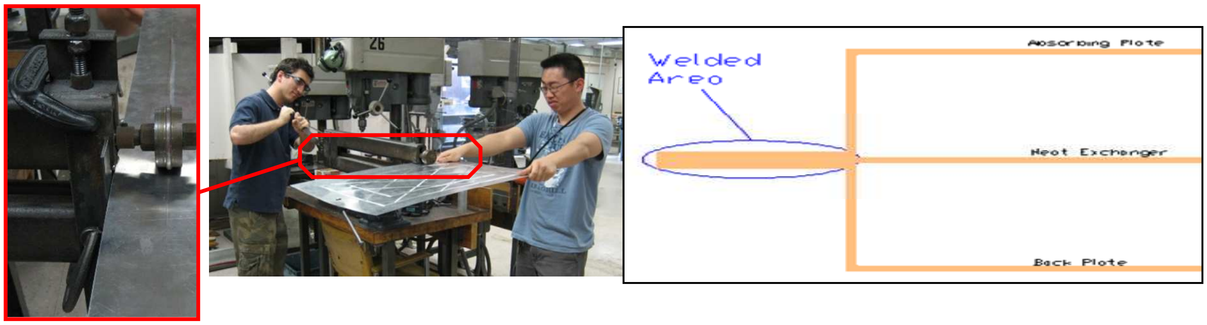


Figure 7: Simple mechanical crank used to make z-bends on edges and ribs for lateral support. A cross section of the collector and heat exchanger edge using the mechanical crank, which enabled a one weld pass for the entire system.

<u>3.4 Final Design, Fabrication, and Testing</u>

After testing, the team developed a final design plan and then invited local engineers to review the plans and give comments during a formal design review. The team took the input from these local experts and finalized the plan. Part of the final design plan includes a testing procedure for determining whether the final system will meet the specifications the team developed earlier in the design process. The team is currently fabricating the final prototype and plan to begin testing during the months of April and May. The testing includes thermal testing of the system and biological testing to determine the log kill rate of pathogens. Both set of tests will be conducted at RIT.

4. DISCUSSION, CONCLUSIONS, RECOMMENDATIONS

The RIT multidisciplinary Solar Pastuerizer team successfully achieved the objectives of designing a low cost solar pasteurizer for developing countries while using materials and processes that are less damaging than alternative water treatment options such as boiling water or chlorination. All team members from both the mechanical and industrial engineering programs greatly contributed to the project Furthermore, the team members will graduate this spring having been exposed to environmental issues and developed certain sensitivity towards them that, undeniably, most other students do not experience.

A solar pasteurizer has significant potential to improve the quality of life for many people. The world's need for clean water will have to be satisfied by a combination of several differing technologies. A tabulation was made of people without access to safe drinking water from the UNICEF Information Statistics [17]. The greatest percentage of people without access to safe water is found in Africa, with almost 50% of the population not having access to safe drinking water.

Table 2 World Access to Safe Water NEED TO GET NEW NUMBERS FOR THIS TABLE

Region	Population	Without Safe Water	Percentage
Americas/Caribbean	441,174,000	105,465,000	24%
South/East Africa	283,240,000	130,681,000	46%
Mid East/No Africa	289,121,000	49,517,000	17%
West/Central Africa	289,172,000	147,429,000	51%
South Asia	1,267,442,000	252,773,000	20%
East Asia/Pacific	1,792,208,000	587,564,000	33%
Industrialized	442,532,000	3,761,000	1%
Total (not Europe)	4,362,357,000	1,273,428,000	29%

These figures include both urban and rural areas. Assuming an average of 8 people per household in the non-industrialized countries shown above, 159 million households do not have access to safe water. Conservatively assuming one percent of these households as the potential market for this size of solar water pasteurizer, a market potential of 1.6 million units exists worldwide. Burch and Thomas [10] estimated the market at close to 8 million, most of which was urban and peri-urban dwellers, who distrust municipal water supply. The market potential is obviously greater than 1.6 million and continues to grow each year.

PROPOSAL FOR P3 PHASE II

1. CHALLENGE DEFINITION AND RELATIONSHIP TO PHASE I

Phase I in this project addressed proof-of-concept development. It concluded with a prototype designed for rural use in developing countries. Phase II of this project proposes work in three areas:

- Prototype design optimization
- Field testing
- Business plan development

2. INNOVATION AND TECHNICAL MERIT

As demonstrated in Phase I of this project and in previous work [10-16], solar pasteurization has significant potential to provide a passive way of treating water, which requires no addition energy source or ongoing chemicals. Solar pasteurization also appears to be well suited for the small family or community applications for rural areas where water quality may be questionable. The novel approach of this project is to integrate the solar collection and heat exchanger of solar pasteurizers into a single unit and to focus on the choosing materials with low life cycle costs and that are easy to manufacturer using technique readily available in the developing world. The concept is described in more detail in the Phase I report section of this proposal.

3. P3 SUSTAINABILITY

The fact that a large portion of the Earth's population lacks access to safe water presents a challenge to sustainability. According to the World Health Organization (WHO) and UNICEF, there are over one billion people on the planet who do not have access to potable water [1, 2]. Every year more than 5 million people die due to the lack of safe water and improper sanitation. The most profound impacts associated with the scarcity of clean water fall to children below the age of 5. More than 10 million children die each year, and a substantial portion of these deaths can be tied to unsafe water and poor sanitation [3]. Lack of access to safe water not only leads to higher death rates but also causes significant debilitating problems such as weakness, blindness, and respiratory illnesses. This lack of access hinders people's ability to focus on the development of their families and communities, which ultimately reduces their chances of improving their economic prosperity. At the 2002 World Summit on Sustainable Development, it was recognized that access to safe water is a severe problem to sustainable growth, so much so that the Johannesburg Sustainability Plan of Implementation set a target of halving the proportion of people without access to safe water by 2015 [4].

This project directly benefits each of the three dimensions of sustainability described in the RFP (people, prosperity, and the planet). People will benefit from the successful completion of this project. Using passive solar methods for water pasteurization will help provide a reliable source of potable water even in very remote areas of the undeveloped world. Access to safe water will reduce the mortality rate for children under the age of 5 and reduce morbidity in other age brackets. Additionally, the use of solar energy to pasteurize water will help diminish the practice of boiling water in order to sterilize it. This will free people from their dependence on fuelwood and the foraging required to collect it.

Passive solar pasteurization does not emit soot or smoke so health benefits will accrue to those able to adopt solar pasteurization methods as well.

The planet benefits by substituting solar energy for the fuelwood routinely used to boil water. Though, strictly speaking, both fuelwood and solar energy are renewable resources, there is great merit in this substitution. In most developing nations, the rate at which wood is consumed far outstrips the rate at which it is renewed. Widespread use of solar energy for water pasteurization will reduce the pressure on forests to provide fuelwood. Further, by using solar energy rather than combustion energy from fuel wood, the byproducts of that combustion are eliminated, or more correctly, never generated. Health problems associated with long term exposure to smoke should be reduced. Finally, the greenhouse gases that would have been released as a byproduct of fuelwood combustion are never generated.

Finally, the manufacture, distribution, and servicing of solar water pasteurization systems presents an opportunity to enhance the prosperity of a community. The appropriate design of these devices can ensure that local manufacture and repair is feasible. This provides a platform for small entrepreneurial efforts to develop in the remote communities that will use the devices.

4. MEASURABLE RESULTS, EVALUATION METHOD AND IMPLEMENTATION

Track # 1: Field Testing

In this track, it is proposed that the final design developed by the team during Phase I and with the improvement made during the optimization from track #3 described below, be produced in quantities, delivered to poor areas in a developing country, and its use monitored throughout a summer season. It is anticipated that a team of three people (two students and one faculty) will accomplish this portion. The specific objectives of this track are

1. Study and quantify the utilization of the technology, rate of adoption, and other statistics on the usage.
2. Document the changes in water use habits, diet, etc. due to introduction of a new technology
3. Document the end-of-life practices
4. Develop the production standards and manufacturing data for a mass production environment,
5. Capture user feedback on existing design features
6. Develop a general understanding of the cultural barriers impeding wider adoption

It is anticipated that a pilot production of approximately ten solar pasteurizers will be manufactured using fabrication equipment resident in the Kate Gleason College of Engineering at RIT. During manufacturing, the industrial engineering techniques of work measurement will be used to develop the production documentation. This includes: work standards, time studies, operations charts, assembly charts, and bill of materials, among others. In addition, approximately ten more pasteurizers will be fabricated in Venzuela to get feedback from local manufacturers.

The next step is then to deploy the pasteurizers at a specific sites and instruct the user on their operation. The design team has established contact with a local church located in a poor rural area. This organization is well embedded in the sector and has offered a platform for demonstrations, education, as well as for collecting data from the people in the area. They also have identified and work with key people living in each of the neighborhoods that have, in the past, facilitated and disseminated some of the tasks typical of a religious organization. The facilitators will be instrumental to identify, in turn, those families presenting a profile (family size, responsible family head, etc) suitable for the study. In agreement with the church, the team proposes using both the church facilities and resources (people, building, etc) and the area facilitators for demonstrations, education and general dissemination of the solar pasteurizer practices. Educational materials will be developed combining pictorials (for the illiterate) as well as the language of the users (Spanish in this case). An initial trip during the first part of the summer will accomplish fabrication, education and delivery of the pasteurizers. At the end of this trip, approximately 20 families will walk away with a solar pasteurizer and the necessary instructions for its general use and maintenance.

The user families and their water use habits will then be monitored at discrete points in time. The team will stay at location for few days after delivery and to provide support to the product and to answer their questions. Two additional trips will be made to the location during the following year and to gather midpoint and final data. Observations and data collection in between these three trips will be left to the church personnel and facilitators. Some of the metrics of interest will include: frequency and volume of use per week, percentage of families still using the pasteurizers, changes in the local diet (success stories and failures), feedback of product features (what they like or dislike, robustness, etc.), reasons for discontinuing use, among others. These are to be gathered by means of personal interviews to both the facilitators and the users, observations, and visits to each site where a pasteurizer was deployed. Since the pasteurizers will be purposely distributed in high density in some areas (many in neighboring families) and very low density in others, some information on the peer effect, such as help and collaborative use, is expected.

During the final trip, and for those families that stopped using the solar pasteurizers, information on their end-of-life disposal of the product (landfill, some parts recycled, etc) is to be documented. This information will then serve to produce a more accurate Life Cycle Analysis (LCA) for the pasteurizers.

<u>Track # 2: Prototype Design Optimization</u>

For this track, it is proposed that a different multidisciplinary team of 4-6 undergraduates from Mechanical and Industrial Engineering research into optimizing the design feature and characteristics of the Generation III design. This team will work during the academic year 2007-2008 to perform a series of engineering analyses (thermodynamics, materials, etc.) aimed to improve functionality and reduce costs. Some of the design aspects to be optimized include:

- Channel thickness
- Insulation material and packing density

- Collector plate area
- Valve assembly
- Thermostat valve temperature rating
- Absorber plate material

All these will be contrasted and compromised with the respective cost curve. More complete experimentation should allow for the development of an effective pasteurizer within appropriate cost constraints.

<u>Track # 3: Business Plan Development</u>

An effective low cost, low maintenance, point-of-use water pastuerization device will be of use to millions in both the developed and undeveloped worlds. Key variables in determining the marketability of such a device are the availability of appropriate fabrication and repair materials locally, and the cost of the device. Much of the work being done by the Phase 1 design team is focused on reducing the costs associated with manufacturing, delivering, and servicing the devices. To the extent that cost can be reduced and durability enhanced, marketing opportunities will expand.

It is believed that the solar pasteurizer can be manufactured at low cost with widely available materials using relatively unskilled labor. Should this prove to be the case, widespread distribution of the devices could be practical, and entrepreneurial opportunities will arise to support the marketing, sales, demonstration, manufacture, distribution, and servicing of the devices.

With respect to the entrepreneurial component of the challenge, it will be necessary to understand the economic, social, and labor systems that exist in various South American contexts. During previous work sponsored by the EPA, the investigators worked with a community education center in a very poor neighborhood of Caracas that specialized in disseminating nutritional information to local residents. This platform will be used to pilot the introduction and demonstration of the pastuerization units in the surrounding community, and to evaluate their acceptance by local residents. However, we also propose to develop appropriate business plans that can guide the establishment of local, sustainable microenterprises that can perform the manufacture/distribution/sale/service functions that will be required on an ongoing basis.

The final deliverable of this Phase II will be a package that includes: (1) detailed design, performance specs, and manufacturing/distribution plans for a low cost solar pasteurizer; (2) the quantified economic, environmental, and health impacts versus number of pasteurizers adopted; (3) a proven deployment strategy; and (4) a business and marketing plan that can serve as a guide to those interested in pursuing the solar pasteurizer as an entrepreneurial opportunity. This package will be then readily available for a government, foundation, non-profit or even for-profit organization that might be looking for a sound opportunity to make a positive impact upon society and environment.

5. EDUCATIONAL TOOL

At the Rochester Institute of Technology’s Kate Gleason College of Engineering, graduating engineering students are required to participate in a “capstone” design experience. Many students elect to enroll in the two-quarter “Multidisciplinary Design Experience” (MDE). During this experience students from Industrial and Systems Engineering, Mechanical Engineering, and Electrical Engineering form teams to work on projects for a wide variety of clients. The teams may also attract students from disciplines beyond the College of Engineering. More details of this multidisciplinary experience can be found on the following URL: http://designserver.rit.edu

This project represents one of the few MDE that will be evaluated against both traditional cost and productivity criteria as well as against broader sustainability criteria. Standard optimization and costing methods and metrics which ignore environmental and social externalities may not be appropriate for a project or product that is to be evaluated against broader sustainability criteria. A very important step forward in increasing the awareness of students with respect to the impacts of their designs on people, prosperity and the planet will have been made once awareness of sustainability issues has been assimilated into the standard design process.

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6. PROJECT SCHEDULE

ACTIVITY	Au 07	Se 07	Oc 07	No 07	De 07	Jan 08	Fe 08	Ma 08	Ap 08	Ma 08	Ju 08	Jul 08	Au 08	Se 08	Oc 08	No 08	De 08
Trip to Venezuela	■																
Prototype production		■	■							■	■	■					
Deployment and education				■									■				
Field monitoring					■	■	■	■						■	■	■	■
Optimization team startup				■													
Trip to Venezuela									■								
Analysis of field data								■								■	■
Engineering analysis				■	■												
Modeling and optimization					■	■	■										
Generation III Fabrication							■	■	■								
Final Trip to Venezuela																■	
Business plan Developmt.									■	■	■						
Trip to Washington										■							
Conference Dissemination																■	

7. PARTNERSHIPS

There are three partnerships in Latin America that will provide local support and expertise in the area of solar ovens and also two local partnerships in Rochester, New York that will provide fabrication assistance and expertise support. These are listed below

Universidad Catolica Andres Bello (UCAB)

College of Engineering (Professor Ing° Rafael Hernandez, Dean)
School of Civil Engineering (Professor Ing° Jose Ochoa Iturbe, Department Head)
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UCAB is a Catholic University located in Caracas, Venezuela. This university and the Rochester Institute of Technology have had agreements of understanding and student and faculty exchange relationships for the past five years and have collaborated in previous research effort in the past. Two of the co-PIs in this project (Dr. Andres Carrano and Dr. Brian Thorn) have used their water testing facilities and local expertise in the past. They have offered support in many aspects of Phase II, including field testing (instrumentation and monitoring of rural locations) and water testing. Prof. Ochoa is the department head of the School of Civil Engineering, which boasts excellent laboratories while Prof Rafael Hernandez (Dean, College of Engineering) main area of expertise is on business plan development. Additionally, the university has many contacts and branches into poor rural areas in Venezuela and the institutions embedded in these.

Shyam S. Nandwani, Ph.D.

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http://www.una.ac.cr/hoycampus/sol.html

Dr. Nandwani is a recognized expert in the field of solar energy, especially for applications in developing countries. He has been working with solar energy and solar ovens since 1976. He has written over 20 journal papers and one book in the area, and has delivered over 170 talks and seminars worldwide. Additionally, he organized the 2nd World Conference in Solar Cooking (1994). Dr. Nandwani has been researching on and educating people of Central America on the use and benefits of solar cooking and solar energy for water pasteurization. He has offered to collaborate with this proposal by providing technical expertise as well as with field testing in Costa Rica. He is very familiar with the work being done at RIT and has visited Rochester and advised the group in the past.

Ing° Sandro Baldini
Plant Manager
Fragolar C.A.
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Fragolar C.A. is a medium-size manufacturer of cabinets and wood furniture located in Caracas, Venezuela. They produce and delivere solid wood, composite-based as well as upholstered furniture of the highest quality for customers nationwide. In addition of a well-established line of products, they also manufacture custom designs and specialty items. Although his help is not anticipated in this project, Mr. Baldini has helped the RIT team in past projects with local fabrication and material suppliers. He continues to offer his support in this regard.

National Center for Remanufacturing and Resource Recovery (NCR^3)
Rochester Institute of Technology
Center for Integrated Manufacturing Studies
111 Lomb Memorial Drive
Rochester, NY 14623-5608
Phone: (585) 475-5101
Fax: (585) 475-5250
Website: www.reman.rit.edu

The National Center for Remanufacturing and Resource Recovery is located on the campus of Rochester Institute of Technology. Their mission is to deliver to industry advanced technologies and tools for efficient and cost-effective remanufacturing and the design of products that have no negative environmental impacts. This center boasts outstanding research facilities and personnel that can provide support to this project. One of the investigators (Dr. Brian Thorn) has successfully collaborated with this center in the past.

Brinkman Manufacturing Laboratory
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The Brinkman Manufacturing Lab is a 3000 sq-ft facility located on the campus of Rochester Institute of Technology in Rochester, NY. This facility offers CNC machine tool capabilities, resin casting, electro-discharge machining, and assembly capabilities. Additionally, design software and materials selection software are available in the laboratory. A 500 sq-ft wood shop complements this facility. One of the investigators (Dr. Andres Carrano – former director) is very involved with this facility. This laboratory is where most of the fabrication activities are expected to take place.

UNIVERSIDAD CATÓLICA ANDRÉS BELLO

FACULTAD DE INGENIERÍA

March 30, 2007

To Whom It May Concern:

We at Universidad Católica Andres Bello (Caracas, Venezuela) look forward to working with a Multidisciplinary Design Team from the Rochester Institute of Technology on the "Design and Development of a Solar Water Pasteurizer with Integral Heat Exchanger for Treating Water in Rural Areas" project submitted to the Environmental Protection Agency EPA-P3 proposal by Drs. Stevens, Carrano, Thorn, and Bailey. The services we can provide include a wide range of water tests in our laboratories, field testing of prototypes with data collection, usability tests, as well as with local expertise in the field. Additionally, we will help in developing a business plan for the micro enterprises that would develop from commercializing these water pasteurizers. Faculty within the College of Engineering and Business will provide the expertise in this area

This effort will extend our ongoing partnership with the Industrial and Systems Engineering Department at the Rochester Institute of Technology, and successful development of the devices will help alleviate the need for safe water that is most urgent in many of the areas of our country.

Sincerely,

Decano

Ing. Rafael Hernandez
Dean
College of Engineering

UNIVERSIDAD CATOLICA ANDRES BELLO · FACULTAD DE INGENIERIA · DECANATO · CARACAS

Ing. Jose Ochoa
Department Head
Civil Engineering

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