The Burden of Thirst

Team 14

Project Proposal and Feasibility Study
Calvin College ENGR339/340 Senior Design Project

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Abstract:
Senior Design Team 14, Burden of Thirst, has undertaken for the scholastic year 2010–2011 the opportunity of providing a process /design that is capable of filtering and sanitizing 3000 gallons per day (gpd) of water without a dependence on fossil fuel derived power. The primary objective of the design is to provide filtered and sanitized, potable, drinking water in remote areas and also to those in need during an instance of natural disaster. The process is not designed to draw water from a well; its intended purpose is to clean and disinfect raw water from an existing source at grade level. Portability, rugged integrity, dependability, and ease of use are design norms that predicate the project’s function and form. We have determined that a design producing an on-demand style utility, with a flow rate of 10-20 gallons per minute, will be superior in use and practicality to that of a continuous flow system producing the specified 3000 gpd (equivalent to 2.1 gpm for a 24 hour period). The on-demand utility of the process will reduce the instance of re-contaminating the processed water and alleviate the need of providing for a storage and possible post-processing. The filtration/sanitization process design has been organized around tried and true components and processes that have been proven dependable and effective. The innovation of the design is in coupling together these standard practices and components of water filtration/sanitization with a non-traditional power source, not requiring fossil fuels.

A hand operated raw water pump is the entrance and starting place for the water flow. A piston type displacement pump with an extendable handle (capable of being pumped by two persons) has been selected and can provide a max flow of 20 gpm with 20’ of head and a NPSH of 40’. Beyond the pump, a 3 stage cartridge filtration system has been selected for its ease of use, dependability and consistent results. A 10 micron filter, followed in line by a 5 micron filter and then followed in line by a 5 micron Carbon Block filter is the preliminary design spec. A pre-screen filter screen can also be added onto the raw water pick-up tube to strain out large debris, before the pump depending on the quality of the raw water source.

Exiting the Carbon Block filter, the water is subsequently sanitized by a UV Disinfection System capable of removing any biological or viral contaminants not reduced in the filtration process. The UV light source has a power consumption of 15 amps of continuous, electric power that will be provided by a solar panel and the aid of a battery with a minimum of 75amp/hours available. The Solar Panel will be large enough to provide all the power needs of the purification system given adequate sunlight, and the battery supplied power is to be used only as a supplement in the event of the Solar Panels not gathering enough sunlight to furnish the necessary demand. An onboard failsafe control structure with a power draw of less than 1 amp will be monitoring the electrical system for power supply and that the UV function is operational: protecting end users by means of a lockout valve in-line between the pump and filter, effectively blocking all water movement in the absence of UV purification.

Potable water will be excited by means of an open spigot, delivered into a vessel provided by the end user.

A complete business plan is under development (to accompanying latter issues of this ppfs), setting up the designers and process in a 501-c-3 corporation. The non-profit will be for the manufacture and distribution of ready to use filtration/sanitization systems throughout the World.
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1. Introduction

1.1 Problem Statement
Team Burden of Thirst is electing to compete in a design competition at New Mexico State University (NMSU) to complete the requirements of the Senior Design course at Calvin College. There are roughly one billion people that do not have access to clean drinking water across the globe and NMSU has charged senior engineering students across the United States to design a self-contained, portable, and reliable water treatment system that has the capacity to treat 3000 gpd to bring clean drinking water to these people. The design competition mandates that no fossil fuels be used in the entire process. This means that renewable energy alternatives must be sought out for the needed power. The designed water treatment system will be tested at the competition to ensure all the design specifications have been met and that the water is treated to the proper standards. Having a design that only runs if the system is in proper working order is important to ensure that no lives are endangered that will use the treatment system to get drinking water from. As Calvin students the welfare of other comes first in this project.

1.2 Design Norms

1.2.1 Transparency
This design will be very transparent in its design and operation. It is important for ease of use that the finished product looks like the process it is providing: simple, straight-forward with ruffed dependability.

1.2.2 Stewardship
The aim of this project is not for the economic advance of its designers and builders, the goal is born strictly out of compassion for our fellow man. We wish for no financial reward from this endeavor, just the opportunity to use our collective talents in service to others. It was Jesus who spoke on compassion in Mathew 25: 37 “Then the righteous will answer him, ‘Lord, when did we see you hungry and feed you, or thirsty and give you something to drink? 38 When did we see you a stranger and invite you in, or needing clothes and clothe you? 39 When did we see you sick or in prison and go to visit you?’ 40 “The King will reply, ‘Truly I tell you, whatever you did for one of the least of these brothers and sisters of mine, you did for me.’

1.2.3 Integrity
The intent of the design is to provide a means of delivering water suitable for direct human ingestion. Integrity of this design remains of continuous concern in that the health and safety of those it is intended to assist needs to be protected.

1.2.4 Cultural Appropriateness
The final deliverable product, the actual filtration/sanitization unit must be easily and dependably used in the areas of the World with the fewest resources. Language and technological barriers will not impede or restrict the ability of this design from its purpose. The stand alone nature of the design; its transparency and integrity also contribute to its appropriateness for differing cultures.
2. Project Management

2.1 Senior Design 339, 340
Calvin College has an engineering program that is well respected in both the academic and professional fields. Their students have gone on to do great things in industry. The Senior Design course at Calvin is created to get students ready to go into the workforce by requiring them to group up into teams, pick a project, and meet the project goals by using the knowledge they have gained throughout the past few years of learning. It also is design to push the students past points usually found in a Calvin classroom to encourage the students to do something great. This has happened many times in the past as students that have received the same $300 to $500 budget at Calvin for many years compete against and have prevailed with better projects than public universities that have vast resources and connections.

2.2 Team 14 Personnel
Team Burden of Thirst is a multi-concentration group comprised of two civil/environmental engineers and two electrical engineers. This helps diversify the group’s level of expertise allowing for a more practical and better designed system. These four students are Randall Venema, Nick Van Klompenberg, Jonathan Lotton, and Jonathan Gelderloos. Randall Venema is a nontraditional student advancing toward a BSE with a Civil/Environmental concentration. He has more than 25 years of professional experience in engineering related services, and has numerous designs and business models still in productive service. Nick Van Klompenberg is studying to earn his BSE with a Computer/Electrical concentration at Calvin College. He enjoys working with, understanding, and designing computers and other electronics. Jonathan Lotton is working towards a BSE with a concentration in International Civil/Environmental engineering. He has experience in land development, surveying, and project management. Jon Gelderloos is earning his BSE with a concentration in Computer/Electrical engineering. He enjoys working with embedded systems that deal with the interfacing of hardware and software.

2.3 Work Break-Down Structure
The project team is split up into two main focuses that come together to produce a final product. These focuses are the water treatment/environmental aspect and the power/control aspect. Many of the requirements for this project come from the environmental and water treatment side of the project. Some of these specifications come directly from the design competition requirements and others are unique decisions based on how the design should function. These decisions once made, often add to the requirements of the electrical side of the project. This includes requirements for power, safety, and ease of use. For the most part Randal Venema and Jonathan Lotton are focused on the water treatment and environmental aspects due to their study in the civil engineering field. Meanwhile, Jon Gelderloos and Nick Van Klompenberg are focusing on the power and controls side of the project due to their studies in the electrical concentration. This unique team structure allows for expertise in all of the areas needed while not being limited to one specific train of thought. Utilizing this multidiscipline advantage, the team is able to come up with creative solutions to complete the project tasks.
2.3.1 Formal Team Meetings

The team meets with the team advisor, Professor Wayne Wentzheimer, once a week on Tuesday at 12:30 for updates on task statuses and to get everybody in the team up to date on the other’s progress. This allows for easy delegation of tasks that may have been added recently and need to be finished fairly soon. The team meets unofficially 3-4 times per week for what usually is a one hour brain-storming session shortly after senior design class to discuss progress on current tasks and what is to be done next.

2.4 Official Documentation

All team documents, notes, and research can be found in either the scratch drive on Calvin’s network or the team project binder found at the team station. This allows any member of the team access to the most updated version of all documents and information. The team also communicates through email on the weekends so that recently updated documents can be circulated without the use of Calvin’s network.

2.5 Schedule

The scheduling for this project is done in Microsoft Project and included in appendix: a. This allows for events to be planned a long distance into the future while still maintaining neatness and accuracy. Microsoft Project allows for tasks to have critical paths between them so that tasks with other tasks depending on them are emphasized. This also allows for simple schedule modifications if a task is finished ahead of time or late. By using a file stored on the shared drive to store the schedule all team members have access to the same schedule. This allows for team members to modify the schedule and the other team mates can easily view the changes. A weekly task template has also been constructed so that all completed tasks from the week before and tasks to be completed in the following week are organized and brought to every advisor meeting. This helps to manage all he team members by keeping everyone on task with goals to complete each week.

2.6 Budget

The budget for this project is a group effort among all four members of the team. The budget is updated whenever a major design decision is made or updated. The budget is used to manage the project very effectively, many aspects of the design for this project will be purely design and never implemented because of the limited budget.

2.6.1 Design Competition Expenses

The cost to compete in the Design Competition $ 895.00, this fee is exclusive of any materials and research for the actual design prototype. Travel to NMSU (approximately $500 per attendee) is also not included in the contest fees. At the time of this publication we have no funding options for these expenses.
Table 1: Materials Budget

<table>
<thead>
<tr>
<th>Team 14 Materials Budget.</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Drive Pump.</td>
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<tr>
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<tr>
<td>Tank</td>
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<tr>
<td>Filters: housing 3 @ 24.50</td>
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<td>Sediment 5 micron</td>
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</tr>
<tr>
<td>total</td>
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2.6.2 Complete Prototype

Table 1 outlines the basic expenditures needed to complete a working prototype. The prototype will be actual size; able to produce the design specified 3000 gpd. The solar panel may be simulated with a proxy current supply equal to that of a specified solar panel. While component type and style have been studied; and decisions made as to size and specifications for the prototype, fixed suppliers have not yet been decided upon. The costs outlined in Table 1 are estimates compiled from non-explicit research. $ 1,250 is a reasonable estimate at the present time to produce a working full scale prototype.

3. Design Component Considerations

3.1 Water Treatment Criteria

This project requires a water treatment system that is effective and reliable. There are many treatment types out there a few of the most likely process candidates are discussed below by their advantages and disadvantages.
3.1.1 Treatment Options

3.1.1.1 Boiling

Boiling kills pathogens that are in the water when the boiling duration is long enough. It is successful at killing most living things in the water including cysts, bacteria, and viruses. The acceptation to this rule is microorganisms that live in very hot water, such as ones found in volcanic vents or hot springs in Yellowstone. The act removes some volatile organic compounds because they may evaporate during the process. The act of boiling is a widely know process. Almost all cultures have the ability to boil water as it can be done over a small fire.

Boiling should not be used when toxic metals, chemicals, or nitrates are in the water. It is hard to predict if these materials will or will not be in source of the pretreated drinking water, so boiling should not be done in areas were the content of the water is unknown. Contaminants in the water do not vaporize and will therefore be left in the drinking water at a higher concentration after being boiled. This is due to the pure water boiling off during the process and the contaminants remaining in less water than was started with. Boiling on a larger scale will require a constant energy source of either a large fire in a more primitive setting or electricity. This can be a problem as wood or electricity might be scarce.

3.1.1.2 Distillation

Distillation creates a finished product of very pure water. The water the distiller produces will be consistent in quality no matter the characteristics of the water inputted into the system. This form of treatment removes nitrates, chloride and other salts that other treatments cannot. It also kills pathogens which are not transferred into the drinking water because they do not vaporize and therefore are left in the untreated water creating greater protection to the recipients. With this option there are not parts such as filters that need to be replaced on a regular basis. Although similar to boiling, distillation provides higher quality water than boiling because only the pure water evaporates to be condensed into another collection basin. Where with boiling the contaminants remain in the drinking water at higher concentrations than originally started with because some of the pure water has boiled off.

The distillation process takes a long time to complete. It can take two to five hours to produce a single gallon of water in countertop systems as they treat about a quarter of a gallon per hour. Although the system does not need parts replaced it does need to be cleaned on a regular basis so the contaminants removed from the drinking water do not build up in the system. Distillation is also a very expensive treatment option as it requires high levels of energy. This is normally electricity and is therefore subject to the kilowatt-hour cost for electricity in that area. If electricity is not available the process could be done with fire, but this fire would need to be maintained at the proper temperature as to not waste resources by having a fire that is too hot as well as be sustained for a long period of time with little treated water for all the effort put forth.

3.1.1.3 Reverse Osmosis

Reverse osmosis filters out many parasites including viruses, if the pore size is small enough, which often prove difficult to treat by other methods. This process significantly reduces salts
and most other inorganic material suspended in the water along with some organic compounds. Reverse osmosis can achieve a very high level of water quality that approaches that of distillation when it is coupled with a carbon filter to remove the bulk of the organic materials.

Reverse osmosis wastes a substantial amount of water when compared to the amount of drinking water it produces. The process often wastes 20% of the raw water available for treatment and therefore should not be used in situations where the raw water source is scarce. Treated water production is low for small scale systems treating only a few gallons a day. This treatment option does not remove all of the pesticides, solvents, and other volatile organic chemicals and therefore should not be used for water treatment near agricultural runoff or situations where the aforementioned contaminants are regularly found without additional treatment to remove these contaminants. If the membrane used in the reverse osmosis process is compromised in any way, such as a small tear or rip, harmful pathogens are not filtered out and are in the drinking water. There is no easy way to tell if the membrane has been compromised leaving people vulnerable to drinking untreated water. This is a complex system that requires maintenance as the pre and post membrane filters as well as the membrane itself must be routinely changed in accordance to the manufacturer’s specifications to insure a properly treated product.

### 3.1.1.4 Ultra Violet (UV) Light

Ultra Violet light requires a short time of contact with the untreated water to render pathogenic microorganisms inactive and remove some organic contaminants. The required contact time is on the order of seconds as opposed to minutes when using chemicals. Water exposed to the UV light has better smell and taste because the UV destroys the organic contaminants and microorganisms which are causing these undesired effects in the water. This treatment option has similar results to that of others, but does not introduce any byproducts to the drinking water. This ensures that no adverse effects will happen to the treated water consumer due to the treatment process chosen. This option is effective at removing the danger of untreated water by rendering inactive many things, but it also does not remove minerals from the water which are often beneficial and necessary to the health of the human body.

Water that has high levels of turbidity, suspended solids, or soluble organic matter is not effectively treated. This is due to the materials in the water making it difficult for the radiation to penetrate the water which can lead to shadows in the water allowing pathogens to slip through unaffected. UV rays are only effective against treating living organisms meaning it has no effect on non-living contaminants such as chemicals, lead, asbestos, and so on and these contaminants pass right through into the drinking water. Cysts are also resistant to the effects of UV light and must be dealt with by usually filtering or another treatment option. A UV system requires electricity to light the bulb. Without a constant source of electricity the system will not properly treat the water endangering those drinking it.

### 3.1.1.5 Ozone

Treating water through exposing it to ozone is a good way to kill off biological contaminants. Ozone can be used to oxidize and subsequently precipitate iron, sulfur, and manganese which allows for them to be filtered out of the water greatly increasing the purity of the effluent water.
This process also oxidizes most organic chemicals many of which are attributed to odor and taste problems. This leaves the end user with water that is free of odor and has a clean taste.

Ozone needs to be constantly replenished by bringing new cylinders of it onsite or creating it yourself through the use of electricity to keep the treatment process steady and reliable. The process of using ozone is not effective at removing minerals and salts that are dissolved in the water. Although it is a good primary treatment, killing microorganisms at the treatment point, it does not prevent the future growth of microorganisms. This results in the need for a secondary treatment to disinfect the water. The disinfectant historically chosen is chlorine.

3.1.1.6 Chlorine Dioxide

Chlorine was chosen as a representative for chemical treatment options as it is a time tested process especially on large scale systems which can be scaled down if necessary. Chlorine can be used as a primary treatment option, but it works well as secondary treatment option ensuring the water does not get contaminated again during distribution. Chlorine kills off many pathogens in the contaminated water and yields very predictable results.

Chlorine has some adverse effects such as changing the taste and odor of the water if the concentrations are too high. Chlorine poisoning can occur if the chlorine concentrations are exceedingly high. Prolong use of this water for drinking water can result in death to the user.

3.1.1.7 Filters

Filters vary greatly in the material they are comprised of and the contaminants they remove from the fluid moving through them. They can be used to remove debris, sediment, pathogens, chemicals, and other harmful things by choosing the proper pore size and filter media to extract the desired contaminants.

The use of a single filter for treatment is very unlikely. In most cases there is a multi-stage filter design that removes the biggest contaminant first and the smallest last. These filters must be routinely replaced. The more filters in the system the more money it will cost to maintain.

3.1.2 Treatment Conclusion

This project requires a fairly substantial amount of water treated per day. Boiling, distillation, and reverse osmosis are unlikely to meet this demand while remaining within the other design requirements and should therefore not be implemented. Chlorine has the possibility to poison the user if not properly monitored and should not be used because of this. Ozone has many benefits, but it is unlikely that a steady supply of it could be found where the system will be used or that there would be enough electricity to produce it onsite and should not be chosen for these reasons. Ultra Violet light is a compact alternative and lasts one year without the bulb needing to be replaced. It is a good eliminator of living organisms and works well for the design requirements. It is therefore recommended that UV light be coupled with a three stage filter system. The filter system will remove the sediment, chemicals, and cysts which are the weaknesses of the UV treatment option. The filters will need to be replaced on regular intervals.
as dictated by the manufacturers. The combination of these two treatment types should yield a reliable source of clean drinking water.

### 3.1.3 Filter/Purification Options Decision Matrix

A decision matrix was employed to aid in the choice of possible options in the production of clean water. Table 2 is the actual matrix used.

Table 2, Filter/Purification Options Decision Matrix

|                  | Removal of Living Contaminants | Removal of Non-living Contaminants | Feasibility for location | Safety | Culturalappropriateness | Portability | Simplicity of use | Design Feasibility | Redundancy | Totals |
|------------------|--------------------------------|-----------------------------------|--------------------------|--------|--------------------------|-------------|-------------------|-------------------|------------|
| Boiling          | 10                             | 2                                 | 10                       | 10     | 7                        | 8           | 7                 | 10                | 10         | 2      | 76     |
| Distillation     | 10                             | 10                                | 2                        | 5      | 9                        | 2           | 6                 | 8                 | 6          | 8      | 66     |
| Reverse Osmosis  | 10                             | 9                                 | 3                        | 6      | 8                        | 3           | 4                 | 6                 | 5          | 9      | 63     |
| Ultra Violet Light| 10                            | 2                                 | 10                       | 8      | 9                        | 9           | 10                | 9                 | 5          | 8      | 82     |
| Ozone            | 10                             | 1                                 | 10                       | 6      | 6                        | 5           | 6                 | 7                 | 6          | 3      | 60     |
| Chemicals        | 10                             | 7                                 | 10                       | 6      | 3                        | 7           | 8                 | 6                 | 7          | 8      | 72     |
| Sedimentation Filters | 6                      | 9                                 | 8                        | 10     | 6                        | 10          | 10                | 8                 | 10         | 7      | 84     |
| Granulated Block Carbon Filters | 8                          | 8                                 | 6                        | 10     | 8                        | 9           | 10                | 8                 | 10         | 6      | 83     |
| Solid Block Carbon Filters | 9                          | 10                                | 7                        | 10     | 9                        | 10          | 8                 | 10                | 8          | 8      | 90     |

### 3.2 Fluid Transport

Water needs to be transported both to the raw water pump and throughout the filter/purification to the end user waiting for a drink. The choice of materials must be food grade acceptable of proven components and sensitive to the rigors of: transport and exposure to the elements while being easily serviceable in the instance that field repairs are mandated. Pipe materials inline before the raw water pump will be a separate consideration from those after the pump, as one will be for suction from an open source, and the latter a closed and pressurized system.
3.2.2 Pressurized Piping Considerations

3.2.2.1 GIP

Galvanized Iron Piping (GIP) has been used in the last century for domestic water systems with moderate success. Seeing that the nature of an iron pipe is to rust in the presence of water, GIP has not been the choice of plumbing professionals in the last 45 years. Although GIP is still commonly available in the marketplace, and it is dependable for interior or exterior use, this report cannot recommend its use. Of the options considered, it is the hardest material and therefore the most brittle, rendering it the most susceptible to fractures and breaking.

3.2.2.2 PVC

Polyvinyl chloride pipe (PVC) is made from a plastic and vinyl combination material. The pipe is durable, hard to break, and enduring. A PVC pipe is suitable for interior or exterior use: it does not rust, rot, or wear over time. For that reason, PVC piping is commonly used in water systems and sewer lines. PVC is easy to work with an inexpensive. PVC piping is commonly joined with adhesives that contain VOCs and it not recognized universally as acceptable for domestic potable water systems. In the absence of joints utilizing adhesive, PVC pipe is joined together by durable compression fittings, each situate specific. PVC piping has also been known to cause a conspicuous odor and taste in water, leaving users suspicious of its integrity.

3.2.2.3 PEX

PEX is cross-linked polyethylene pipe. The material is durable for extreme temperatures, hot or cold. PEX is relatively a lesser expense plumbing pipe option, and easy to use because of its flexible nature; however it does require some custom tooling to modify or repair if needed and is NOT approved for use outside and therefore cannot be considered feasible in this design.

3.2.2.4 Copper Tubing

Copper tubing has been used in domestic plumbing applications for more than 50 years and is still the popular choice of plumbing professionals. Copper is durable and flexible, making it easy to install, especially compared to iron pipes. Copper piping also provides a biostatic atmosphere, making it difficult for bacteria to grow inside of it, which is an important health consideration. Copper also resists corrosion and is unaffected by ultraviolet rays, which means it can be used for outside needs. The world wide acceptability and availability of the knowledge and parts required to modify and or repair copper plumbing make copper tubing the preferred choice for this design. Copper is also 100% recyclable making it a sound environmental choice.

3.2.3 Suction Hose

A flexible reinforced PVC material is the most commonly used material for liquid suction lines. It can field cut to fit the application and secured on the suction end of a pump with a simple hose compression clamp. Due to the flexible nature of the hose, joints, couplings and fittings are not necessary. The wide acceptability and time proven service of this style of hose make it the
dominant choice in the marketplace and an easy fit for this project. The rigid piping options outlined: sections 3.2.2.1 – 3.2.2.4, are acceptable for suction use; however, in light of the culture appropriateness design norm, a flexible and easily modified style of hose is the appropriate design choice for this project.

3.2.3 Raw Water Pump

The energy needed to transport water from open source at grade level and push it through the filter/sanitizing process has been considered and optimized. The design requirement of 10 gpm water flow without the aid of a fossil fuel power source can easily be obtained through the operation of hand driven pump. Two different styles hand operated pumps have been assessed for their feasibility. Most other human powered fluid pumps are a derivative of these two kinetic principles.

3.2.3.1 Rotary Pump

A crank driven rotary pump as shown in Figure: 1, is a rotary vane pump operating on the principle of positive displacement and is a common fixture in industry. The most common uses of a rotary vane pump is in a constant velocity application where pressure varies at the point of application. The pump is simple in it operation and has very few moving parts providing for durable and dependable operation. Rotary pumps are commonly manufactured with a brass housing and composite lobes or rubber style vanes. Rotary vane pumps are not commonly used in clear liquid transport, and not typically manufactured to food grade specs. The possibility of the pump being operated in reverse is also a draw-back of these style pumps, and an external flow control valve would need to be incorporated to protect the integrity of upstream processes. Head and flow of the system is dependent on the speed at which the pump is operated. Cost of this style pump ranges from $350-$500 per pump for the needs of this project.

Figure 1: Rotary Vane Pumps

3.2.3.2 Piston Type Displacement Pump

The piston type displacement pump is one the oldest styles of drawing water with dependable flow and head. This style of pump shown in Figure 2, is most commonly associated with the long handled farm style picture pump. The pump handle and the vertical piston used to provide displacement are the only moving parts intrinsic to its design. The modern design of this style pump has a check valve incorporated into its design, ensuring consistent piezometric head with each stroke of the pump handle. Modern displacement pumps are also self priming, adding to ease of use. Pump handles can be easily modified to accept 2 or more persons working in concert to provide the needed energy for moving the water. The history of these style of pumps is that of being used mainly for potable water use. Form has continued to follow function in that most of the commercially available piston type hand pumps are design for the safe handling of drinking water. The limited number of moving parts also predicates a very dependable and long term service life. Cost of this style pump ranges from $125-$300 per pump for the needs of this project. The piston type displacement pump is the choice decided upon for the project prototype. The transparency of its function, acquisition cost, and time proven dependability make it a clear choice to draw water into the process and provide the needed head to propel the raw water through the filtration/purification process.

![Figure 2: Piston Type Displacement Pump](http://www.lehmans.com/store/util/enlarged_images?Args=&imgsrc=291682.jpg)

3.3 Power supply

3.3.1 Design Criteria
The project needs to have an adequate supply of power in order to power the UV filtration, control monitor system, and water pumps. The ideal power supply should be inexpensive and self-sustaining. The design must be robust enough to survive in a third world country. The design must also be not based on an electrical grid, because that power may be produced using fossil fuels which violates the terms of the competition. The current power requirement that the supply must meet is 300 watts.

3.3.2 Power Supply Design Alternatives
The predating principle of this project is a non-fossil fuel power source. Several options to answer this concern have been addressed.

3.3.2.1 Bike
One option that could be used to supply power to the structure is the electricity produced from a bicycle attached to a generator. The setup would have a basic electrical generator attached directly to the bicycles rear wheel. The parts needed for this option would include a standard bicycle, a 300 watt power inverter, some attachments and other mounting equipment, a voltage regulator and a generator. Some advantages for this type of power supply are that it is relatively inexpensive, between $150 and $400 for all of the equipment. Another advantage for this type of power supply is that it is relatively simple technology and uses many parts that can be acquired around the world. Bicycles have become part of many third world cultures and the generator to convert from mechanical to electrical power could be as simple as a car alternator. There are some disadvantages for this type of power supply. First it requires that a human rider be using it to produce any electricity. It requires an active person to spend time powering the station and maintaining the equipment. The cost of this person’s time must be considered when comparing to other power options which do not require a rider. The typical cost for a rider varies greatly between locations but is a significant compared to the price of the overall unit.

3.3.2.2 Hand Crank
Another option that could be used to power the structure is a simple hand Crank attached to a generator. This setup would be very similar to the Bike power option only less complex. The parts needed would include a hand crank, a 300 watt power inverter, and a generator. One major advantage to this power supply is its simplicity and lost cost. The price for all the parts is less than $300. This type of supply does have some disadvantages, while the design may be simple it does not allow for as easy and consistent power generation as a bicycle generator. It also has many of the same disadvantages as the bicycle. It requires a worker to actively using it to provide power and the cost of this persons time must be considered when comparing to other power options.
3.3.2.3 Solar
A third option for a power supply is a photovoltaic solar panel. The solar panel would be mounted on or near the structure and provide 300 watts to power the system. There are many advantages to this type of power supply. Many of the countries where freshwater are scarce have an abundance of sunlight and a solar panel would make use of this energy. Solar panels are also easy to maintain and operate; they require no active workers to provide the energy. Many solar panels come packaged with a voltage regulator and all of the electrical components to operate it. This would make installation and replacement relatively easy. Also solar panels require relatively little maintenance. There are some disadvantages. The solar panels will only be able to collect power during the daylight hours. Also ease of use and efficient use of power comes at a higher dollar price. Solar panels with the wattage needed for this structure are in the range of $800 to over $1000. Also the availability of replacement solar panels in third world countries is very low. If any panels were to break it may take days to weeks to provide new ones.

3.3.2.4 Wind
Another option for a power supply is a wind turbine generator. This option would place a turbine at an optimal position to capture wind relatively near the filtration structure. This power option has a few advantages. First it is able to capture energy and produce electricity with only a slight breeze and require no human effort. Also a wind turbine generator provides the needed wattage for the structure for lower price than solar; the price for a 300 Watt wind turbine is between $400 and $700. Also most wind turbine package come with all the equipment to provide a steady power source including regulators and power inverters. There are some disadvantages to using a wind turbine. It requires a source of wind to provide any power. It must be installed in an optimal location that may not be near the filtration structure. It requires maintenance to keep the blades in optimal condition. Replacement parts for a wind turbine are not easy to come by in third world countries.

3.3.2.5 Hydroelectric
Another option for a power supply is a hydroelectric generator. This option would place a turbine propeller in a fast moving water source. This option would require a large source of water (several hundred gallons a day) in order to provide the required 300 watts of energy. It is also very expensive, well over $1000. This option has some advantages. It does not require human input to provide power. This option has many disadvantages. It is complicated and expensive. It also requires large quantities of fast flowing water which might not be available in many locations in the third world.

3.3.2.6 Onsite power
Another option for a power source would be to use the onsite power. Many places in the 3rd world to have electricity and making use of this supply would be an inexpensive and relatively simple process. Some advantages to this type of power source would be its low design requirement and its inexpensive initial cost. It does not require any human maintenance or effort to supply. It can be run day and night and is not affected by weather. There are a few disadvantages to this type of power source. It does not provide its own electricity so the cost of supplying energy is based entirely on the price of electricity in the village, which may be expensive. Also not every village has a power line running to it.
3.3.3 The Cost of Power
Table: 3, just below is a breakdown of the power cost related to different design alternatives. Appendix: B is complete detailed cost breakdown for the individual power elements.

Table: 3, Power Costs

<table>
<thead>
<tr>
<th>Cost to Power</th>
<th>Min $/W</th>
<th>Max $/W</th>
<th>Avg $/W</th>
<th>300 W</th>
<th>200 W</th>
<th>100 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike Cost</td>
<td>$0.50</td>
<td>$1.85</td>
<td>$1.18</td>
<td>$352.50</td>
<td>$235.0</td>
<td>$117.5</td>
</tr>
<tr>
<td>Solar cost</td>
<td>$2.70</td>
<td>$4.44</td>
<td>$3.18</td>
<td>$955.20</td>
<td>$636.8</td>
<td>$318.4</td>
</tr>
<tr>
<td>Wind Cost</td>
<td>$0.88</td>
<td>$2.43</td>
<td>$1.71</td>
<td>$511.88</td>
<td>$341.2</td>
<td>$170.6</td>
</tr>
</tbody>
</table>

3.3.4 Power Supply Design Decisions
For our proposed design a solar panel system meets the design requirement criteria the best. For the full scale design a 300 watt array of solar panels would be optimal. Solar panels do not require much human maintenance. They have a decent cost to power ratio. They are very feasible for many locations because it only requires sunlight. Solar panels are easy to use. They also do not use up fossil fuels. For our prototype because of budget constraints it may be simulated using an AC source. A decision matrix was used to aid in the determination of the best power alternative and is displayed below in Table: 4.

Table: 4, Power Source Decision Matrix

<table>
<thead>
<tr>
<th></th>
<th>Use of human resources</th>
<th>Cost to Power ratio</th>
<th>Feasibility for location</th>
<th>Safety</th>
<th>Cultural appropriateness</th>
<th>Portability</th>
<th>Simplicity of use</th>
<th>Design feasibility</th>
<th>Use of Fossil Fuels</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bike Crank</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>464</td>
</tr>
<tr>
<td>Hand Crank</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>453</td>
</tr>
<tr>
<td>Solar Cell</td>
<td>10</td>
<td>3</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>494</td>
</tr>
<tr>
<td>On site Power</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>379</td>
</tr>
<tr>
<td>Wind Power</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>10</td>
<td>375</td>
<td></td>
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<tr>
<td>Hydro-electric Power</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>8</td>
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<td>1</td>
<td>7</td>
<td>3</td>
<td>10</td>
<td>318</td>
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<tr>
<td>Weighted</td>
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<td>10</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
3.4 Power Storage Design Criteria

The structure needs to store electricity and energy for times when the filtration and water pumps are operating but electricity is not being collected directly from the power supply. A simple array of batteries will be able to provide this storage.

3.4.1 Batteries Design Alternatives

3.4.1.1 Starting

Starting batteries are found in most vehicles and are widely available around the world. This type of battery could be implemented for this use but generally this type of battery is not used for applications where power in the battery is drained very much. This misuse of application would cause the lifespan of the battery to decrease greatly.

3.4.1.2 Deep Cycle

Deep cycle batteries are designed to be charged and discharged. They have a long lifespan but may not have as high “instant” power like starting batteries. This type of battery would work well for our application given its longer lifespan and ability to be discharged greatly.

3.4.1.3 Marine

Marine batteries are a mix of Starting and deep cycle batteries. They have the ability to be greatly charged and discharged but also provide the “instant” power needed for high power startups. This type of battery would also work for our application of power storage.

3.4.2 Power Storage Design Decisions

Deep cycle 12 volt batteries meet the design standards for this project and therefore have been selected to be implemented in the design.

3.5 Control System

The control system of this machine will ensure that everything is working properly and that no water is dispensed that has not been fully treated. This will be accomplished by creating a control system that monitors and manages parts of the treatment system that directly affect the end product. This includes power generation and storage, flow and pressure control, in addition to special control systems for unique treatment options. This control system will also manage displaying any important information generated by these systems. Although the technology running the control system is fairly modern it is also very robust and reliable. To ensure that this system does not fail all the comments will be checked so that they meet specifications for the target area of use. For example all parts in this system must fall within a given temperature range of operation so that they do not overheat due to the climate. Also although the operation of the system may be complex to the average user, the interface will make the system simple to understand and use so that people in third world countries will be comfortable using it. Figure: 3 shows a block diagram of a possible control system arrangement.
3.5.1 Control Options

There are many different options that can be used to control all of this information. When deciding which hardware to use one of the first decisions is to use combinational logic or a clocked device such as a microcontroller. All of these systems will defined by input and output systems rather than loop systems. The controller will make a decision based on an input and output that signal to make the correct change. This is different than a traditional system with a summing loop. Sensors for flow and pressure have been found from different suppliers for prices around $5 to $25 dollars and will be purchased once decisions such as pipe diameter and expected pressure are known for sure.

3.5.1.1 Combinational Logic

In order for combinational logic to be used all the signals must be digital, appearing as a 1 or 0 to the system and all decisions must be based on a specific input from a given sensor. This will
happen in real time as soon any input is changed. This has the advantage of being very affordable and simple but it is not as reliable as other methods. For example it is possible for a given sensor to have an error and produce a signal that is incorrect for a fraction of a second before reverting to the correct signal. This would cause the system to respond to that change in signal and possibly shutting off the machine when it does not need to be shut off. This method requires all setting to be final and changing anything will require new hardware for the system.

3.5.1.2 Clocked Device
However, with a clocked unit the controller can sample information from different sensors and interpret that information better than a combinational logic device can. A clocked device can examine data of a span of time to ensure that the sensors output has actually changed and is not an error that will only last for a very short time. This also allows for other features such as memory which will be very important so that settings can be changed as needed. By using a system with memory the thresholds for certain loops to trigger can be adjusted as necessary.

3.5.1.3 Software
Using all hardware makes the system much simpler but offers very little flexibility and needs to be replaced if any changes are to be made to the controls. Software allows for continual flexibility throughout the design process which will be needed as the system is fine tuned to the point where it is working properly. Using software allows for the controls to be easily changed and tested without replacing any parts. The disadvantage of this is a slight increase in cost and increased complexity of the system. However, since this system will only be monitoring a small number of things a system using software is not out of the scope of this project and would be an advantage to the design process. It should also be noted that a system utilizing software requires clocked hardware. Currently most devices that have been looked at use C or C++ language. This offers an advantage as the electrical engineers in the group are already familiar with this and therefore there will be no need to learn a new programming language.

3.5.1.4 Microcontroller
There are currently many affordable microcontroller development systems intended for smaller system such as this. After searching products from a number of manufactures development systems were found for as little as five dollars for a 16-bit system and going up to around one hundred dollars for a 32-bit system. This offers a great amount of flexibility within the given budget and the requirements for the controls. There is a tradeoff between what can be accomplished by the system and how affordable it will be. Another deciding factor in the development tools is the programming language that is used. Development tools using software that the team is familiar with will allow for a shorter design time. Currently the team is looking at the MSP430 line of microcontrollers from Texas Instruments and researching whether or not their specifications will be adequate to handle our system.

3.5.2 System Design
The designing of the control system will depend heavily on the final choices of combinations of hardware and software. A very effective way of controlling a system is by using a state machine design. This only allows for certain parts of the machine to be running if the control system is in the correct state. For example, The UV light would not be able to turn on unless the state machine was in the water treatment state. Alternatively the microprocessor could control all of
the individual control systems together so that they all are incorporated into the correct operation without using a state machine.

All of the individual control systems will be modeled in Simulink. This allows for modeling of how the system will perform before it is actually implemented. This will help in the design process by helping to reduce the number of problems that are run into once the building and testing of the system starts. By catching these problems in a simulation it takes less time, money, and effort to fix a mistake. This software will also allow for other aspects of the system that are not controls to be tested. Simulink allows for modeling of the flow of water through the system as well as the performance of different types of batteries. Utilizing this software will greatly increase productivity of the design phase. Currently the pressure monitoring system is around 90% completed. The model has been simulated successfully with expected results and only requires actual component values such as pump displacement, pipe diameters, and filter resistances. The model for the power management is around 50% completed as there have been problems simulating the charging of batteries correctly. These two system should be complete by the end of the semester and any remain systems will be modeled over Christmas break or interim.

3.5.3 Power Management

Ensuring that every part of the system has power is critical so that the process will operate effectively. This means that the system must always have adequate power or the system must be shut down to prevent and untreated water to come out of the system. This will be accomplished by monitoring the batteries voltage and current output capabilities through sensors. This data will be sent to a microcontroller that will decide whether or not the system should be shut down. A preliminary model of this system is shown in Figure 4.

![Figure 4: Power Management System](image-url)
3.5.3.1 Power Shut Off
System shutoff can be implemented fairly easy with some basic programming and a pre-determined shut off point. However, the system could be shut off in a number of ways. By closing off the entry and exit point of the system before shutting off the UV system it is ensured that no bad water will exit the system. This would leave water inside of the system which may be of some concern. This remaining water would then need to be flushed out before the machine could start treating water again. Another option for system shut down is to close the system inlet and let the remaining water in the UV treatment section to flow out. With this method in place the system would most likely not need to be flushed before treatment started again.

3.5.3.2 Charging
The other aspect of power management is managing the charging of the batteries. For most batteries over charging is damaging to the batteries. Even if this is not the case it would be inefficient to continue to charge the batteries once they are full. A system of controls will be used to make sure that this does not happen and the batteries are not damaged. This will be done very similarly to the system for system shut off due to low power. In fact, these two systems will heavily overlap in that they will be using the same set of sensors but just controlling something different. In this case when the microcontroller receives data from the sensors telling it that the batteries have reached an optimal charge level the incoming power will be shut off. If the case of bike or hand powered generator is used a notification will also be sent to the user so that they know the work is no longer required.

3.5.4 Flow control
While the water in the system is being treated it may be necessary to control the flow of the water so that the correct ratio of treatment per water is met. The flow of the water will be monitored by a simple flow sensor or Hall Effect sensor. In the case of a chemical treatment of the water this sensor would be used to synchronize the dispensing of the chemicals into the water at the proper rate. This can be accomplished by using a microcontroller to control the rate of chemicals being released into the water and base that off of the rate of water flow in the system. Flow control may be used to control the flow of water through a UV treatment system. However, this may not be necessary as the UV lamp will most likely be selected so that it can treat the maximum flow of water through the system with ease. Also with UV treatment applying more treatment time will not have any negative effects, but in a chemical dispensing system higher levels of chemicals in the water may actually make the end product less safe than properly treated water.

3.5.5 Pressure Control
Certain filters in the system have a specific operating pressure and an increase in that pressure will indicate that the filter is near the end of its useable life and must be replaced. It is also possible for some of the finer filters to be damaged from too great of a pressure on them. For these filters it is then important to monitor and control the pressure of the water being forced through the filter. The pressure would be measured before every filter which has pressure limitations. The data from the sensors would be then sent to a microcontroller. One way to alleviate this pressure is to use a device such as a solenoid to shut off the flow of the water to
reduce the pressure. However, this will likely cause frequent opening and closing of the solenoid during operation. Another way to reduce the pressure is to reduce the amount of water coming into the system. This will be done in different ways depending on the method that is used to put the water in the system. If a hand pump is being used a warning light or message will be used to notify the user to slow their pumping. This could cause problems if the user is not paying attention and the filters were damaged. If the water is being pumped into the system through an electric pump the microcontroller will control the rate of this based on the data from the pressure sensors. This option will most likely be more accurate than the previous method but puts a larger requirement on the overall power needed by the system. Alternatively a simple mechanical pressure release valve could be used to alleviate pressure while a warning is sent to the user. There should also be a method for the control system to decide if the pressure is due to too much water being forced through the system or due to a filter being clogged and needing to be replaced. Figure 5 shows the current top level simulink model of the pressure control system.

![Simulink Model of Pressure Control System]

**Figure 5: Pressure Monitoring System**

### 3.5.6 UV Lamp Control Monitor Alternatives

The UV lamp is a very important part of the system as it is responsible for cleansing the water of all remaining bacteria that gets past the filters. Ensuring that this lamp is always running properly is critical to the quality of the water exiting the system. It is possible to implement this system in a number of different ways.

#### 3.5.6.1 Photo Sensitive Diodes

One option is to use one or more photo sensitive diodes to check that the light is always on when it needs to be. A photo sensitive diode works by allowing current to flow through it while light is shining on it and no current to pass through when light is not shining on it. The flow of current, or the lack of it, through the diode would be measured by a microcontroller that can make the
decision to shut the system down if the UV lamp is not working properly. This shutdown would be very similar to the case when the power becomes too low to run the system.

3.5.6.2 Current Monitor
Another option for monitoring the UV lamp is by measuring the current or voltage being applied to the lamp. When the lamp burns out these values will change and will be read by the microcontroller. Again, this will cause the system to shut down. This method has the advantage of using fewer parts than the photo sensitive diode method but may prove to be less accurate depending on the scale of the change seen over the lamp. Further testing will be needed to see just how accurate this method is. The disadvantage of this case is that there is no redundancy in checking for a burnt out lamp. With the photo sensitive diode method multiple diodes could easily be implemented to monitor the lamp so that if one fails the other will remain working.

3.5.6.3 UV Conclusions
Since a lamp failing will cause the entire system to shutdown there are advantages to having an estimate of when the lamp will burn out. This would be implemented by using one of the two previous methods as an indicator of the time that the lamp is on. A counter can be created in the microcontroller to count the time the lamp is on or equivalently, the time the system is running properly. Comparing this with the manufacturers given bulb life an estimate of hours of lamp life remaining can be calculated and displayed to the user so that they know if extra supplies will be needed. Research indicates that typical UV lamp life can be anywhere between 1,000 and 9,000 hours depending on bulb style. With these large lamp life times it may be difficult to keep count of the hours on a simpler microcontroller.

3.5.7 Display
In most of the control systems used in this product it is important to display relative information to the user so that they know what is happening within the process. In some cases this display will be direct parts of the control system, letting the user know that they need to change what they are doing in some way. Examples of this are telling the user to slow the rate of the hand pump or to stop generating electricity with the bike powered generator or hand generator. In other cases the information displayed simply provides extra knowledge to the user. Examples of this are displaying the remaining lamp life or the remaining charge in the batteries. This information is not important until either becomes fairly low but it is still useful for the user to be able to view them at any point in time.

3.5.7.1 LED Lights
The most basic form of displaying this information is by using a number of warning lights or LEDs to inform the user that something needs to be changed in the system or that something is not working properly. This is relatively simple and cost effective to implement but requires the user to learn what each different light is for and may make the process of using the machine difficult.

3.5.7.2 LCD Text Display
Another option is a simple LCD text display. This will allow the user to easily read any important information about the system. This method has the disadvantage of being slightly more complicated to implement. This also assumes that the user can read English which may not be a
safe assumption considering the target users. The power requirement for this will also be slightly larger than a display system of LEDs but will not be very large compared to the power required by the UV lamp, and therefore should not be a problem unless there is trouble supplying the system with the required power.

### 3.6 Block Diagram of Design Alternatives.

![Block Diagram Image]

- Preliminary filter will stop any larger debris from getting into the system.
- Elevated plastic tank. Hand driven pump will supply the flow of the system.

10 micron sedimentation filter pulls dirt and other “large” particles from the water.
- 5 micron filter removes smaller contaminants from the water.
- Solid block carbon filter removes VOCs, PCB, cysts and turbidity.

- UV kills virus, bacteria, and mold threats
- Chlorine kills living Organisms, but could cause problems if it was administered too liberally.
- Ozone destroys living organisms, but could be problematic to get in most places the system would be used.

Figure 6: Process Block Diagram of Three Stage Filter with UV, Chemical, or Ozone Treatment.
Figure 7: Process Block Diagram for Slow Sand Filter Treatment Option.
4. Water Quality Analysis

4.1 Analysis Criteria
The end goal of this project is to provide water safe for human ingestion; that is, water free from harmful containments. Alternatives to have the water processed by the prototype system are as important as the design itself. Without empirical evidence to support the design claims, the project cannot meet its own design norm of integrity. Three possible alternatives have been outlined below.

4.2 Analysis Alternatives

4.2.1. Calvin College
Team 14 has investigated the option of using student, personnel, faculty, and the resources available at Calvin College to analyze the effluent water from our prototype. The college is not
currently equipped or in the practice of performing this type of analysis; it does not presently appear to be a feasible option for the analysis.

4.2.2 Kent County Board of Health
The Kent County Board of Health (in which Calvin College resides) has an establish lab for the analysis of drinking water; primary for private water wells throughout lower Michigan. Test sample bottles are distributed from any local Department of Health office. Processing is done for fifteen dollars per sample. Turnaround time for this service is routinely one week.

4.2.3 Municipal Waste Water Treatment Plant (WWTP)
Industry technical advisor to the team, Wayne Langeland of fTC&h, provided the option that one of his many professional clients (WWTP) would at his request, be able to provide the needed analysis, free of charge.

4.3 Analysis Conclusions
The option of having the water analysis done by practicing water professionals at an operational WWTP, who routinely test water for public safety is the best alternative we have found. Mr. Langeland also seemed eager to contribute in this regard; insuring the integrity of our work.

5. Prototype Construction

5.1 Schedule
The completion of this ppfs represent only one portion of the work needed to be accomplished for this project. Actual construction of the prototype will be beginning part-time during Interim; and then proceeding to full-time at the advent of the spring academic semester. A prototype, capable of competency testing should be completed by the end of February 2011.

5.1.1 Make Final Design Decisions
After a final review of this ppfs by team members on December 10, 2010, final decisions will be made as to components necessary to build a full-scale prototype.

5.1.2 Secure Needed Parts
Before the end of this academic semester (Fall 2010) final decisions will be made as to suppliers for the decided upon materials, and appropriate purchase orders secured as funding is made apparent.

5.1.3 Start Date for Construction
A complete formal schedule as outlined in section 2.5 will be updated during Interim to reflect prototype construction in light of ppfs conclusions and attached to future project status reports.

5.2 Framework
In an effort to keep prototype costs as low as possible, the use of the existing steel inventory available at the Calvin College Engineering Building machine shop will be employed. A rigid base constructed of 1.5” mild steel angle iron, welded at the joints and seams will be fabricated on site in the Engineering Building. The base of the framework will be the size and standard
configuration of a 40” x 48” shipping pallet. Vertical members of the steel framework will be extendable to 6’ above the pallet base in such a manner as to support and secure a solar panel of appropriate dimensions. Steel outriggers will also be incorporated into the pallet base, made to extend horizontally 3’ in four directions: perpendicular and parallel to each other. The outriggers will have accommodations to accept stakes or screw type anchors to secure the extended outriggers to the ground. The outriggers will be primary for wind events, providing tip-over protection when a solar panel is employed in a canopy style over top of the filter/purification apparatus.

5.3 Filter and UV Positioning
A vertical cross member of the 1.5” angle iron will transverse the 48” length of the base, secured at 3’ above the pallet bottom. The angle face will be at 90 and 180 degrees to the horizon, providing a plumb or level surface capable of accepting the filter base applications. The filters are to placed in-line with each other, spaced just far enough apart to provide adequate serviceability and allow for the needed control elements. Positioning for the UV apparatus will be determined and fit as actual components are in hand, and best spacing practices become self evident. An effort will be made to reduce the number of potential changes in direction of the water flow when determining the best position of the components; as that each twist or turn in the subsequent piping adds to head loss in the water flow reducing the effectiveness of the raw water pump.

5.4 Electrical Component Routing/Positioning
Wiring will be shielded and attached to the inside of the angle iron. The National Electric Code (NEC) will serve as the standard in decisions regarding proper standards and practices for the electrical wiring of the prototype. A licensed electrical contractor experienced in solar power generation has made his services available as a technical advisor to this portion of the project. A cradle to support and securely anchor the batteries will be incorporated into the base pallet at the lowest point possible. Batteries will be enclosed in a manner sufficient to protect them from the elements as well as protecting users from a possible catastrophic battery failure.

5.5 Pump and Hard Piping
Rigid copper tubing has been decided as the pressurized piping material. After positioning the all of the filtration/purification components, the pump will be situated at the leading edge of the pallet base, at a height that best accommodates the human powered aspect of the displacement style raw water pump. All pipe and joints will be laid out soldered together employing best practices as dictated by the International Code Council (ICC-ES, Plumbing).

5.6 Testing of Operational Prototype
Untreated water from area WWTPs with known defects will be processed through the prototype and subsequently analyzed. Raw water from natural sources: rivers, ponds and storm water runoff will also be processed through the system and analyzed.

5.7 Review/Modifications
The results of prototype processed water will be the deciding factor for process modifications.
5.8 Technical Drawings
The completed, satisfactorily operating prototype will be measured, photographed and documented as to the position of components. Scale drawings will be produced with enough and proper detail, such that the prototype can be reproduced by qualified contractors.

6. Business Plan Overview
Calvin College Senior Engineering Design Team 14 is operating under the name: Burden of Thirst. The overview of this consortium of student engineers is to provide a stop gap measure in the ascertainment of clean drinking water. As the World continues to develop and advance technologically, one billion people are still in daily need of clean drinking water. The acquisition of potable water is commonly divided into three distinct areas of logistical concentration: source acquisition, filtration/purification, and distribution. The effort of the Burden of Thirst team is to focus solely on the filtration/purification process.

The Burden of Thirst is not being fostered as a platform for economic virility, a business model to bring gain to its principles; but rather as a benevolent effort to serve the needs of those who are victimized by their circumstance. The Burden of Thirst is therefore operating as a very transparent 501-c-3 corporation with each of the four technical contributors serving as officers. The main goal of the corporation is to make available a technical consortium from which to provide the basic essentials of water purification/filtration, utilizing the best off the shelf technologies: condensed to a dependable, trustworthy, durable, easily shipped and user friendly apparatus. Intrinsic to the bylaws of the corporation, the officers of Burden of Thirst will at their own expense, spend one week per year in the field: at the point of thirst, with their product, to best offer and provide continued product evaluation of the finished product.

The market for a product of this stature is not limited to developing and third world applications, but is also very relevant to situations both domestic and abroad affected by natural disasters as recently highlighted by the cholera outbreak just 750 miles southeast of the continental U.S. in Haiti.

The end user for this product is naturally the thirsty peoples of the World; however, these people are not normally in a position to pay for daily necessities, let alone new technology. Therefore, the market place for the Burden of Thirst product is the thousands of aid organizations already in place striving to situate goods and services where need arises. Through the direct sales efforts by the corporation’s officers in the direction of the NGO’s and Governmental agencies alike; Burden of Thirst will make its product known in the market place. Supported by the Burden of Thirst’s website, new advances in the product will be made available and marketed forward by the use of direct marketing and press releases.

Pricing for the product will be done on a cost plus method: cost + 20%, with the 20% going only towards the administrative and legal needs to facilitate the preservation of the Burden of Thirst Corporation. The goal of Burden of Thirst is not to manufacture, but to provide the technology in a manner that is easily understood and reproducible by a qualified contractor. The 501-c-3 corporation will maintain a local contractor under license to manufacture, store and ship ready to
use finished units. Corporate donations of materials and technical support will be sought from the manufactures of the components Burden of Thirst has delineated feasible for the finished product; from these capitol donations as well as cash donations from other venues, Burden of Thirst will maintain an inventory (by means of its contractor) of at least twenty finished filtration/purification units’ ready to ship anywhere worldwide. The actual capitol costs of the inventory will be determined by the contractor responsible for construction and distribution. Suitable cost of this endeavor will be a determining factor in Burden of Thirst’s choice in a contractor. Replenishment of inventories will come through the revenues received at time of fulfillment. Detailed product specifications and technical support will be provide for upon request of Burden of Thirst Corporation to those who may wish to seek product manufacture by a contactor of their own choosing, or fabrication/repair in a country of destination. Replenishment of expendable/renewable elements of the filtration/purification unit will be facilitated and contracted for by the product source of the specific resource. A comprehensive business plan will be made available and attached to subsequent reports; at time of this publication it is not completed.

7. Conclusion

The following are the proposed designs for the various parts of the system. Copper tubing is the design choice for the pressurized fluid transport of the project with flexible PVC suction hose as the raw water intake hose. A piston type displacement pump will be driving force to draw raw water into the system and propel the water through the filters and purification process to the end user. Water treatment will be done by a combination of a UV light and a three stage filter process. The untreated water will be removed of sediment, chemicals, and cysts by the filters and the UV rays will kill the living pathogens that pass by the light. For our proposed design a solar panel in combination with a potential onsite power system meets the design requirement criteria the best. Deep cycle 12 volt batteries meet the design standards for this project and therefore have been selected to be implemented in the design.
Appendix: A  Project Schedule

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduled WDS (email to team Advisor)</td>
<td>1 day?</td>
</tr>
<tr>
<td>Project Brief to Industrial Consultant (with cc to team Advisor)</td>
<td>1 day?</td>
</tr>
<tr>
<td>Project web-site (posted)</td>
<td>11 days?</td>
</tr>
<tr>
<td>General Process Feasibility</td>
<td>16 days?</td>
</tr>
<tr>
<td>Power Requirements</td>
<td>10 days?</td>
</tr>
<tr>
<td>Hydraulic Requirements</td>
<td>10 days?</td>
</tr>
<tr>
<td>Control Requirements</td>
<td>10 days?</td>
</tr>
<tr>
<td>Certification Requirements</td>
<td>10 days?</td>
</tr>
<tr>
<td>Draft PFES to Team Advisor</td>
<td>7 days?</td>
</tr>
<tr>
<td>Preliminary Cost Estimate (email to team Advisor)</td>
<td>16 days?</td>
</tr>
<tr>
<td>PFES submit to Team Advisor and post on Web Page as PDF</td>
<td>11 days?</td>
</tr>
<tr>
<td>Preliminary Design Memo submit to Team Advisor (as required)</td>
<td>8 days?</td>
</tr>
<tr>
<td>Revisión updated project web-site (and new poster if major change)</td>
<td>15 days?</td>
</tr>
<tr>
<td>Registration for competition (Team)</td>
<td>22 days?</td>
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<tr>
<td>System Design (Randall and Jonathan)</td>
<td>20 days?</td>
</tr>
<tr>
<td>Structural/Thermal Design (Randall)</td>
<td>10 days?</td>
</tr>
<tr>
<td>Power System design (Nick and Jon)</td>
<td>10 days?</td>
</tr>
<tr>
<td>Controls Design/Modeling (Nick and Jon)</td>
<td>10 days?</td>
</tr>
<tr>
<td>Structural Construction (Randall)</td>
<td>7 days?</td>
</tr>
<tr>
<td>Add plumbing (Jonathan)</td>
<td>7 days?</td>
</tr>
<tr>
<td>Build or emulate power system (Nick)</td>
<td>7 days?</td>
</tr>
<tr>
<td>Build PCE for controls (Jon)</td>
<td>7 days?</td>
</tr>
<tr>
<td>Implement Controls and Power (Nick and Jon)</td>
<td>7 days?</td>
</tr>
<tr>
<td>Build Prototype (Team)</td>
<td>7 days?</td>
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<tr>
<td>Test Flow and general operation (Jonathan)</td>
<td>11 days?</td>
</tr>
<tr>
<td>Test Water Standards (Randall)</td>
<td>8 days?</td>
</tr>
<tr>
<td>Test User operation (Jon)</td>
<td>2 days?</td>
</tr>
<tr>
<td>End Product Testing and Modification (Team)</td>
<td>33 days?</td>
</tr>
<tr>
<td>Final Deadline</td>
<td>1 day?</td>
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## Appendix: B, Cost to Power

### Bike Cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Min</th>
<th>Max</th>
<th>$/Watt</th>
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<tbody>
<tr>
<td>300 Max, 200 Average</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>400 watt inverter</td>
<td>$30</td>
<td>$70</td>
<td>Max</td>
</tr>
<tr>
<td>bike and mounting</td>
<td>$50</td>
<td>$100</td>
<td>Min</td>
</tr>
<tr>
<td>car alternator/generator</td>
<td>$50</td>
<td>$150</td>
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<tr>
<td>Voltage regulator</td>
<td>$20</td>
<td>$50</td>
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<tr>
<td></td>
<td>$150</td>
<td>$370</td>
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http://www.econvergence.net/elec.html

### Hand Crank

same as bike only different mounting, no results so far as to Watts generated

### Solar cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Watts</th>
<th>Price</th>
<th>Size inch^2</th>
<th>$/Watt</th>
<th>Watts/inch^2</th>
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<tr>
<td>Kyocera KD135SX</td>
<td>135</td>
<td>$450.00</td>
<td>1600</td>
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<td>SW 245 MONO</td>
<td>245</td>
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<td>Kyocera KD185GX-LPU</td>
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<td>2100</td>
<td>$2.70</td>
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<td>Chicago Electric Power Systems</td>
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<td>$200.00</td>
<td>1400</td>
<td>$4.44</td>
<td>0.03</td>
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<tr>
<td>SUN-100</td>
<td>100</td>
<td>$300.00</td>
<td>1600</td>
<td>$3.00</td>
<td>0.06</td>
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<tr>
<td>Kyocera KD225GX-LPB</td>
<td>225</td>
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<td></td>
<td>$2.89</td>
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http://store.solar-electric.com/hiposopa.html

### Onsite AC

<table>
<thead>
<tr>
<th>Country</th>
<th>US cents/1kWh</th>
<th>$/kwh</th>
<th>$/300watt/year</th>
<th>US cents/1kWh</th>
<th>$/kwh</th>
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<tbody>
<tr>
<td>Australia</td>
<td>18.55</td>
<td>0.1855</td>
<td>487.494</td>
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<td>Belgium</td>
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<td>0.1143</td>
<td>300.3804</td>
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<td>Canada</td>
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<td>Croatia</td>
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<td>Denmark</td>
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<td>Finland</td>
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<td>0.0695</td>
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<td>France</td>
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<td>Germany</td>
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<td>805.7448</td>
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<td>Hong Kong</td>
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<td>Iceland</td>
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<td>Italy</td>
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<td>Malaysia</td>
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www.wikipedia.com

### Wind Cost

<table>
<thead>
<tr>
<th>Model</th>
<th>Watt</th>
<th>Cost</th>
<th>$/watt</th>
<th>Wind Speed mph</th>
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</thead>
<tbody>
<tr>
<td>AIR-LX-1</td>
<td>400</td>
<td>$560.00</td>
<td>$1.40</td>
<td>18-20</td>
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<tr>
<td>AIR-MX-1</td>
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<td>$720.00</td>
<td>$1.80</td>
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<tr>
<td>AIR-M4-1</td>
<td>400</td>
<td>$695.00</td>
<td>$1.74</td>
<td>18-22</td>
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<tr>
<td>WT312</td>
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<td>$600.00</td>
<td>$2.00</td>
<td>18-23</td>
</tr>
<tr>
<td>Model</td>
<td>Quantity</td>
<td>Price</td>
<td>Discount</td>
<td>Payment Plan</td>
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<tr>
<td>---------------</td>
<td>----------</td>
<td>-------</td>
<td>----------</td>
<td>--------------</td>
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<tr>
<td>Southwest Wind Power 1-ARBL-10-12</td>
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<td>$140.00</td>
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<tr>
<td>TPW-200-24</td>
<td>200</td>
<td>$485.00</td>
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</table>

http://telemetryhelp.com/solar_products_swest_air.asp
Resources


<http://www.werc.net/contest/>.


Acknowledgements

Team Burden of Thirst would like to thank the professors in the engineering department here at Calvin for donating their time and knowledge. A special acknowledgement would like to be given to Professor David Wunder for helping us decide on our project and to Professor Wayne Wentzheimer for being our team advisor. Professor Wentzheimer has helped us keep on track and think about ideas we would have pushed aside. He also set up our industrial consultant, Wayne Langeland, who we would also like to thank in advance for his help.