WATER • OUT • OF • THIN • AIR

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Table of Contents

Problem Definition

The worldwide water crisis is a widely-acknowledged problem. According to UNICEF and the World Health Organization, over 780 million people lack access to clean water.[1] The resulting problem is two-fold: not only do people lack access to water, but even if they do have access to a water source, it is often unsanitary, which leads to water-related diseases. Every year, there are more than 3.4 million deaths due to diarrheal diseases such as cholera and typhoid.[2] The impacts of these diseases are most striking in children. It is estimated that 801,000 children under the age of five die each year from diarrhea alone, which accounts for 11% of the total deaths of children under the age of five worldwide.[3] According to the United Nations Millennium Project Task Force on Water and Sanitation, improvement of the quality of drinking water can lead to a 45% reduction in diarrheal episodes.[4]

After speaking with Professor Judi McLean Parks[5] and Dr. Joaquin Barnoya,[6] it was clear that our solution must meet a few key requirements to make a significant impact in the affected regions. Electricity is nonexistent or unreliable in many of these target regions, so it is paramount that our solution be grid-independent. Many regions lack a stable centralized government, and even in countries where a stable government does exist, it often does not have the funds necessary to establish reliable water infrastructure, so our solution must not require costly infrastructure. Conditions in these regions can be harsh, with both weather and animal interference, so our solution must be weatherproof and durable. WOOTA's solution takes each of these obstacles into consideration when addressing the world's water problem.

WOOTA, LLC began investigating a solution by looking into the climate in the regions with the greatest need for clean water. **Figure 1** shows a map of the percentage of the population that lacks access to clean water.[7] **Figure 2** shows a map of global annual average relative humidity.[8] Although it may seem counterintuitive, there is significant overlap between countries that are very humid and countries that have a great need for clean water. WOOTA saw great potential in this overlap because it indicates that the water these people need so desperately is already there- it is just in the air around them.

WOOTA, LLC is a global health venture that utilizes a simple, grid-independent process to produce water from humidity in the air, providing clean drinking water to developing countries. Our target market consists of the 39 countries seen in **Figure 3**. Each of these countries has both greater than 18% of their population with a lack of access to clean water and regions with greater than 60% average annual relative humidity. Because WOOTA produces water from the air, we not only can provide clean water to people who are at risk for water-related diseases due to unsanitary water, but WOOTA can also provide water for those who currently lack access completely.

Impact in the Developing World

As mentioned above, improvement of the quality of drinking water can lead to a 45% reduction in diarrheal episodes. While the health benefits of providing clean water may seem obvious, the benefits extend far beyond the realm of health alone. The time saved by providing a single-family solution implemented right outside each home has an enormous impact. **Figure 4** shows a map of the percentage of the population that must travel at least 30 minutes to the closest water source.[9] Research shows that even those spending such time collecting water still fail to meet their families' minimum daily drinking-water needs.[10] Globally, women and children in developing regions spend 125 million hours each day collecting water, which results in significant social and economic costs associated with a water source that is miles away, if present at all.[11]

A key example of the social impact is seen in education. 443 million school days are lost each year due to water-related diseases.[12] Moreover, studies show that a 15 minute reduction in the distance to a water source increased girls' school attendance by 12%.[13] Allowing increased access to education, especially for girls, has the potential to increase skilled labor in these regions and begin to narrow the social gap between men and women. These intangible benefits lead to economic benefits as well. Currently, 72% of water collection responsibilities are designated to women and girls, as shown in **Figure 5**.[14] With WOOTA's help, time previously spent collecting water has the potential to create jobs and boost the local economies of these developing regions, particularly increasing the presence of women in the workforce. In summary, with just one device, we can revitalize developing societies by improving the quality of life while also promoting education and increasing contribution to the local economy.

WOOTA's substitute/competitor analysis is found in **Figure 6**. Current water collection methods are shown in the top section. These methods are not sufficient solutions, mainly attributed to their need for a nearby water source or existing infrastructure. In addition to these substitutes, two main classes of competing water condensing solutions exist. The first class consists of grid-independent solutions that are very large structures, requiring significant infrastructure and laborious installation. These solutions are implemented on a village scale, and the central village location can still be miles from individual households. This class is represented by SkyWell and Warka Water in **Figure 6**. The second class consists of household solutions that rely heavily on electrical input. These solutions are not feasible in the majority of our target areas due to nonexistent or unreliable electrical grids. This class is represented by EcoloBlue in **Figure 6**.

Unlike any of the existing solutions, WOOTA is unique in its cost-effective, portable design that requires neither electrical input nor a nearby water source. Our grid-independent process allows developing countries with unreliable or nonexistent power grids to benefit from our device. Furthermore, since it does not require a local water source, our device can be implemented successfully across a much broader geographical area.

Required Performance Specifications

While WOOTA has the potential to impact a global target market, we are focusing our initial implementation on Madagascar due to our university's close connections in the village of Mahabo. Madagascar is an ideal site, as it has both an exorbitant need for water with 92% of rural populations lacking access to a clean water source and a high average relative humidity above 80% year-round.[15] Thus, our initial performance specifications are designed to specifically meet the needs of the Malagasy people, but can easily be extrapolated to other countries as well.

Our general performance specifications are summarized in **Figure 7**. According to the World Health Organization, the minimum drinking water required per person per day is 2.5 liters.[16] Given that the average household size in Madagascar is 4.6 people, a successful single-family solution should provide at least 12 liters of drinking water per day.[17] Our solution must also be grid-independent, as only 15.4% of the Malagasy population has access to electricity, and even then it may be unreliable.[18] As previously noted, just having access to a water source is not enough. A beneficial device must provide safe water with a dissolved solids content below the standard of 150 parts per million suggested by Kent RO Systems, a commercial supplier of water filtration systems headquartered in India.[19] The water must also appear clear to be adopted. Lastly, a successful solution must be portable and require no labor-intensive assembly or infrastructure for implementation on a single-family scale.

As is addressed in greater detail in the following section, WOOTA's solution utilizes a system in which a desiccant intermediate is used to absorb humidity from the air and regenerate upon solar heating to produce water vapor which then condenses as potable water. The technical performance specifications for this method are summarized in **Figure 7**. According to performance data published by our desiccant provider, Sorbent Systems, the maximum weight percent absorbance of silica gel exposed to an environment of 80% relative humidity is approximately 33 weight percent as shown in **Figure 8**.[20] For an effective absorption cycle, our desiccant should be able to absorb to at least 20 weight percent. Assuming absorption is the limiting process, a volume of 0.057 cubic meters of desiccant must be regenerated per day to provide the minimum 12 liters of water, as calculated in **Figure 9.** Therefore, our device design must regenerate this volume of desiccant to provide an effective solution. However, this volume is not indicative of the capacity of the device, as multiple cycles per day is possible depending on the length of the absorption and regeneration cycles. As seen in **Figure 10**, the absorption capacity of silica decreases rapidly between 100 and 200ºF.[21] In order to achieve significant regeneration of the desiccant, the internal temperature of our device must reach at least 150ºF. Our design must be both air-tight and water-tight to effectively maintain this internal temperature and efficiently collect the water produced. The device must also be made of durable materials to withstand both weather and potential animal interference.

Implementation of Prototype

WOOTA's device provides clean drinking water without the need for electricity or a nearby water source. As alluded to above, our device utilizes a proprietary two-phase process involving a desiccant intermediate that requires minimal user input. These two phases can be seen in **Figure 11.** The first phase is a simple, passive process: a desiccant absorbs water from the humidity in the air. The second phase is also simple: solar radiation heats the base of the device, causing a temperature gradient to develop between the base of the device and the top panel. When absorbed desiccant is placed into the device, the high temperature of the base and internal environment of the device causes the absorption capacity of the desiccant to decrease, and the desiccant releases its absorbed water content into the air inside the device as water vapor. This vapor then condenses onto the inside of the top panel due to the temperature gradient developed, where the top surface is relatively cool compared to the heated base. The condensation process is similar to that of water droplets condensing on a bathroom mirror during a hot shower. As water continues to condense, droplets run down and collect in a storage container, which can be buried in the ground beneath the device to keep the water cool and prevent re-evaporation. The collection container is securely connected to the spout on the base of the device to create a closed system and prevent contamination in the containment system such as dirt and insects. Because energy is utilized from the sun directly in the form of heat, this simple process successfully meets the critical performance criterion of grid-independence and does not require the use of expensive solar panels.

The user interface of the device is even simpler than the process itself. The device must be placed in a sunny location, where it can remain permanently or be easily moved at the user's convenience. Phase one requires the user only to place the desiccant tray in an area exposed to external air. The tray must be left to absorb for at least five hours for maximum absorption, but there is no upper limit for the time the tray can remain in the absorption phase. The desiccant tray contains a small section of non-toxic orange self-indicating silica gel, which can be used as a visual indicator for the saturation of the desiccant. The orange silica gel turns from a bright orange color when dry to a dark green color upon saturation. We believe that this indicator will aid in the adoption of the device, as it provides visible proof that the absorption phase is functioning correctly, since clear silica gel does not have any visible change as it absorbs water. Once the desiccant has absorbed, the tray is placed in the device via a removable door in the back panel of the device. Once the device is closed, the desiccant will begin to heat, and water droplets will be visible on the top panel. The device will autonomously continue to produce water until the desiccant is fully regenerated, which will again be made visible by the section of orange indicating silica gel. The water is then available for consumption or continued storage, and a second cycle can begin. Multiple desiccant trays can be alternated to eliminate down time between phases and allow for continuous production of water.

There are currently two identical WOOTA prototypes in use for research and development. The first is located at our university and is available for laboratory simulations. The second was recently constructed in Houston, Texas, to test the full process in temperature and humidity conditions very similar to those of Madagascar. The prototype is shown in **Figure 12.** This prototype was designed as a half-scale model to be more compatible with laboratory equipment. While the width and height are set to give the top panel an angle of 30º from the horizontal to maximize solar exposure and water runoff efficiency, the 16 inch length is scalable to linearly increase the water output. A greater length allows the device to contain more desiccant, which is directly proportional to water output. As will be shown in the following section, the length of the device must be approximately 34 inches, or slightly more than twice that of the current prototype, to produce the target water output of 12 liters. The length can be increased even more if needed to accommodate greater water output in other regions, while still providing a portable solution.

The materials of this prototype were carefully selected to fulfill the requirements of durability as well as achieving a high internal temperature. Important properties of these materials can be found in **Figure 7.** Polycarbonate was selected as the material of the top panel because it provides high solar transmittance as well as low risk of cracking or shattering. Polypropylene was selected as the plastic casing due to its strength and high melting point required to resist the internal temperatures produced within the device. The walls and base consist of three layers as detailed in **Figure 12a**: outer polypropylene casing for stability and an air-tight and water-tight seal, 1" mineral wool insulation to reduce heat loss through the walls of the device, and a black steel sheet to provide a surface of high heat capacity and high thermal conductivity that produces and maintains a high base temperature when exposed to the sun. The water collection system consists of two aluminum v-shaped tubes that direct all of the runoff into a centralized spout in the base of the device that will connect to the storage container. All pieces were cut to size using simple machining equipment and outer pieces were adhered with silicone adhesive. The metal and insulation layers were adhered with a common spray adhesive, and simply slid into the device.

Using what we've learned from testing with our initial prototype, we have designed the next iteration of our device, which will be in testing in Houston by mid-June. The new model shares many similarities with the initial prototype, as it is essentially two of the initial prototypes back to back as shown in **Figure 13**. Because this iteration doubles the internal volume of the initial prototype by doubling the width, this new prototype will be a full-scale model for the target water output. There are many important changes that we believe will greatly enhance the efficiency of the device. A chart of the improved material properties is found in **Figure 7.** The new prototype contains shorter polystyrene side walls, which will greatly reduce the shadow within the device. The house-shaped front and back panels will be transparent to allow greater solar exposure of the base. Adjustable feet have been added to the rear of the device to adjust the angle of the entire device depending on local geographic longitude to maximize the perpendicular solar exposure as the sun travels across the sky, which also increases the temperature achieved within the device.

Proof of Performance

WOOTA, LLC has completed extensive testing of each part of the process. The absorption phase was tested with our desiccant and desiccant tray in a chamber in our university's greenhouse with a controlled environment of 80% relative humidity and 80ºF, representative of the climate conditions in Madagascar. An initial dry mass of 250 grams of desiccant was monitored over an 8-hour period, with weight measurements taken every 10 minutes. The results are found in **Figure 14.** The silica gel in our desiccant tray absorbed approximately 25 weight percent over 8 hours, with no indication of plateauing within that time period. This result exceeded our target absorption of 20 weight percent.

Additional tests were conducted to investigate the effect of the surface area to volume ratio of the silica gel on the weight percent absorbed. Three sections of silica gel were tested with ratios of 1:1, 1.5:1, and 3:1. The results are found in **Figure 15**. Higher surface areas greatly increase the absorption rate of the silica, and we expect they will increase the regeneration rate as well. The current desiccant tray is a simple aluminum cooking tray, covered with a sheet of wire mesh to prevent spillage of the desiccant. Using these results, we are currently designing a desiccant containment system to maximize the surface area to volume ratio while also maximizing the volume of desiccant in the device per cycle. One potential solution is seen in **Figure 16**. This containment system will cause both the absorption and regeneration processes to be more efficient, allowing more cycles per day and an overall more efficient device.

The regeneration phase was tested first using a laboratory oven at a constant temperature of 200ºF, which we believe to be a reasonable internal temperature of our device once the efficiency is improved, as solar focusing devices such as solar cookers commonly function between 250 and 350ºF.[22] This testing was completed with the same sample of absorbed desiccant immediately after the 8-hour absorption outlined above. The results are found in **Figure 17**. The silica gel achieved 100% regeneration in under 4 hours. Thus, 4 hours was determined as our target length for the regeneration cycle for maximum water production per day. Therefore, there can be three regeneration cycles per day. If a three tray system is used, the three trays can be rotated so each tray has 8 hours in the absorption phase and 4 hours in the regeneration phase. Alternatively, leaving the trays in the absorption phase overnight will satisfy the time required as well as potentially be more effective due to the lower moisture capacity in the air, while not interfering with the daylight hours for regeneration.

Given our absorption and regeneration phase results, we used a single desiccant tray volume capacity to calculate the potential water output of the device per day. The tray volume capacity is the internal volume of the device to the top of the rear door. The calculations are shown in **Figure 18.** Given three cycles per day as determined above, our initial prototype is capable of producing 5.42 liters of water per day, or roughly half that of the target water output. Given that this prototype is a half-scale model, it meets the required performance specifications. When doubled, the desiccant volume capacity of the device also exceeds that of 0.057 cubic meters of desiccant set forth in the performance specifications.

The temperature of the device was monitored over a 9-hour time course with a thermocouple probe attached to the base surface to observe changes in the internal temperature. The device was exposed to conditions of 84ºF at our university. As shown in **Figure 19**, the shape of the temperature curve mirrors the arc of the sun. The device exceeded the target 150ºF from the period of 10 am to 2 pm, which is the period of most direct sun exposure overhead. The temperature does not reach the 150ºF threshold earlier or maintain it longer due to the large amount of shadow caused by the solid side walls in our initial prototype. With the new iteration of our prototype with transparent side walls and twice the top panel area, we will be able to achieve temperatures above 150ºF throughout the course of the day. Additional testing was carried out to find the minimum base temperature required to see significant regeneration of the silica. These tests were performed on a hot plate, so the added air heating of an enclosed environment was not present. With base heating alone, the silica achieved significant regeneration at a temperature as low as 120ºF.

The safety of the water produced by our device is our number one priority. WOOTA, LLC must not only provide water to those who need it, but we must ensure that the water we provide is safe and void of any potential pathogens. According to silica's material safety data sheet (MSDS), silica gel is non-toxic, non-flammable, and inert, with a very high melting point.[23] Silica gel packets found in consumer packaging such as coat pockets and shoe boxes are labeled 'do not eat' due to the choking hazard of the small packets, not due to concerns related to the silica itself. According to a 2012 study, fog water was found to exceed the World Health Organization standards for potable water.[24] In addition, the process of expelling and re-condensing the water in the device is similar to the process of solar distillation, where the evaporation process allows separation of dissolved solids and larger particles such as dirt and bacteria.[25] In a laboratory test, water collected from our device had a ppm reading of 012, which showed a marked decrease even from the tap water with a ppm of 067. This process will greatly surpass the goal of 150 ppm.

Moving forward, we are running tests to maximize the efficiency of the water collection process after condensation. A laboratory simulation was completed to test the effect of hydrophobic treatment of the inner surface of the top panel. The results shown in **Figure 20** indicate improved beading in runoff with the treated surface. We are also considering a potential tapping mechanism or magnetic squeegee which could aid in water collection. Additionally, we have designed a solar focusing component that can be added as a removable element to the device to further increase the amount of solar radiation absorbed by the device. This addition can be seen in **Figure 21.** We are also considering using montmorillonite clay as the desiccant in our process. Montmorillonite clay has a lower temperature range for regeneration as seen in **Figure 11**, which may be useful for implementation in areas of lower temperatures or less solar exposure. We also believe that its more natural appearance could promote adoption during initial implementation.

Business Plan

Customer

It is important to make a clear distinction between WOOTA's customer and end user. Our distribution channel is depicted in **Figure 22.** The end users of the device are the people in developing regions who need it most. However, the wages in these countries are often extremely low, making it infeasible for the end user to pay for our product directly. For example, 61% of the Malagasy population lives on less than $1 USD per day.[26] WOOTA, LLC plans to sell our device instead to likeminded nonprofits that are already focused on solving the world's water problem through other methods. These nonprofits already have extensive funding sources established to fund their efforts, as well as established relationships with villages, local governments, and organizations with a similar mission headquartered on the ground. For example, WATERisLIFE has an entire sector devoted to new technology. Their goal is "to understand, research, help develop and ultimately deploy new technology that works."[27] WOOTA aligns perfectly with this mission, making WATERisLIFE an ideal initial customer. There are countless other water-focused nonprofits in the United States alone that have a similar interest in implementing promising novel technologies.

Cost

The raw materials for our initial prototype cost $57, including the cost of desiccant required for the device to function. We expect the raw material cost to increase to $110 for our new prototype due to the larger size and improved materials. WOOTA is currently working with Objex Design, a manufacturing firm focused on taking startup ideas from the prototype stage to mass production, to determine the most cost-effective method for mass production and packaging.[28] The methods for manufacturing will be discussed in the following section. According to their estimations for our new prototype design, Objex would be able to produce a small order of 100 units for approximately $100-150 per unit, with continued price reduction for larger orders. These estimations take into account the costs for raw materials, estimates for the machining/forming costs of individual components, and estimates for assembly cost. WOOTA, LLC would price our device at $145-215 to maintain a 30% profit margin. This cost is miniscule compared to the average $8000 required to build a well in developing regions, which is currently the most common method for improving water access.[29]

Manufacturing and Distribution

The manufacturing process for our device is quite simple. Our prototype requires only a common silicone adhesive to connect the pieces once the parts are cut to size. After discussions with Objex Design, WOOTA has determined that the most effective method for manufacturing and distributing our device is to package the pieces in a pre-shaped and pre-drilled manner requiring minimal assembly at its destination, similar to an IKEA model. Upon arrival, these pieces could be either simply snapped together or require a common local adhesive. This method of distribution minimizes the open-air space during shipping and allows many more units to be shipped at once, which is key for shipping internationally. WOOTA plans to take on distribution costs of shipping only to our customer nonprofits, so WOOTA will not be directly involved in foreign distribution. Our partner nonprofits will then be responsible for establishing local partnerships to distribute the device to developing regions throughout the world. The design is also simple enough and the materials common enough that it could be feasible to produce locally in some of the target countries, requiring only simple machining equipment to cut the parts to size. WOOTA will work with local organizations to establish local manufacturing channels where possible.

Current Funding

WOOTA, LLC has received start-up funding from a variety of sources thus far in support of our technology. WOOTA received approximately $1000 of seed funding from IDEA Labs, a dynamic biogenerator founded in 2013 focused on making medical entrepreneurship attainable for students and contributing to the growing entrepreneurial spirit in St. Louis.[30] We also received just over $1000 from the Engineering Projects Review Board at our university.[31] This April, WOOTA, LLC placed first in the final round of the Engineering Discovery Competition at our university, winning $25,000 for continued research and development of our venture.[32] For further funding, WOOTA plans to apply to additional startup competitions locally and on the national scale to share our idea with a broader audience and gain support and connections nationwide.

Sustainability Model

Since our device does not require any electrical source, there are no costs associated with the ongoing production of water. The only substantial costs associated with our product are manufacturing and delivery costs. We are interested in pursuing a three-pronged strategy for establishing a sustainable business while making the greatest possible impact. First, we would like to partner with like-minded nonprofits. WOOTA provides these nonprofits with a novel, effective technology that would add to their current scope, while these partnerships provide WOOTA with valuable connections and ability to implement our solution across the world. Second, we would like to partner with for-profit companies, particularly in the dehumidifier, solar energy, and other related industries. WOOTA provides these companies with a channel for social contribution, while these partnerships provide WOOTA with funding and infrastructure to increase efficiency and expand our value proposition. Third, we would like to partner with local governments. WOOTA provides an increased quality of life for people in the region, while the governments could potentially aid in subsidizing our device directly to the consumers. With this model and the necessary seed funding, we believe that we can achieve a financially self-sustaining business within the next three years.

Marketing Strategy

Because our target market consists of nonprofit organizations rather than individual consumers, we do not anticipate using traditional marketing channels to market our device to the general public. However, this form of publicity could be useful if we decide to solicit funding form the general public in the form of donations in the future. Currently, we intend to start expanding WOOTA's professional network by attending conferences focused on the global water problem, such as the Sustainable Water Management Conference, the International Water Conference, and the Global Water Conference. Doing so will allow WOOTA to connect with funding organizations with the same passion and purpose and make connections with likeminded nonprofits. This greatly increases WOOTA's market visibility and leads to an increase in customers and partners. We also plan to increase awareness of the world's water problem and our solution through social media campaigns, as well as direct outreach to potential partners and advertisement in nonprofit-centered publications.

Intellectual Property and Regulation

WOOTA, LLC currently has a provisional patent on file to protect the intellectual property of the novel features of our technology. As we look into implementing our solution into developing regions, we will be looking to file a PCT application for international protection before the provisional patent expires. Before global implementation, we must prove that our device meets the standards for dissolved ions and heavy metals. Given that fog water from the air has already been proven to meet these standards along with our process's similarity to the widely-accepted solar distillation process, we should not face significant difficulties in proving that our solution will provide safe water to those in the world who need it most.

Conclusion

WOOTA's device has the potential to have an incredible impact on the water crisis in developing regions. We believe that if we can improve the quality of life of a single child, family, or community, WOOTA, LLC is a success. Our favorite story to consider is that of Solo, a 13-year-old girl in rural Madagascar.[33] Solo is unable to attend school because she is responsible for traversing a dangerous trail while carrying her body weight in water to provide for her family. Even after obtaining the water, Solo said that "the water is yellow and sometimes there are bits in it… When you are thirsty, you just drink it and sometimes it makes you sick." Our device will change Solo's life. With a clean source of water right in her backyard, Solo will no longer have to risk injury to provide water for her family. Solo will no longer have to accept illness as a side effect of quenching her thirst. Solo will be able to attend school and have countless opportunities unlocked for her future. WOOTA, LLC has the potential to empower Solo and millions of other children across the globe.

Appendix

Figure 1. *Geographical representation of the percentage of the population lacking access to clean water. Areas with the greatest need are represented by the yellow, orange, and red areas.*

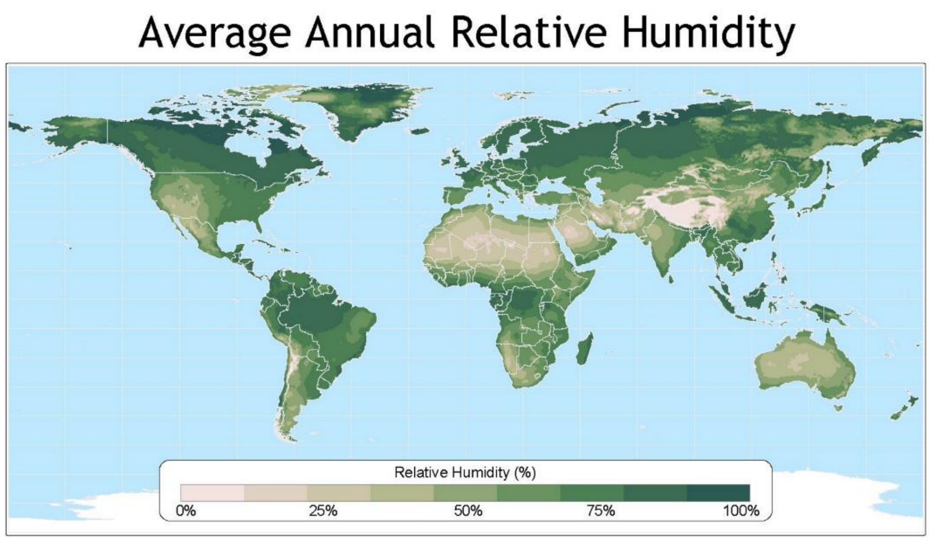


Figure 2. *Geographical representation of global average annual relative humidity. Humid areas are represented by darker shades of green.*

Figure 3. *Countries with >18% of the population lacking access to clean water and >60% average relative humidity year-round. This represents WOOTA's target market of 39 countries.*

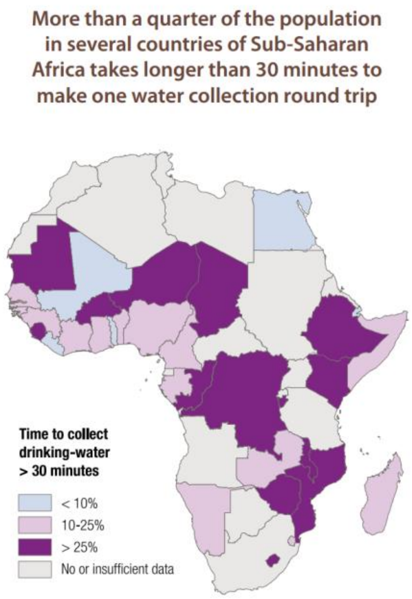


Figure 4. *Geographical representation of the percentage of population in African countries with a significant distance to the closest water source. The purple regions show countries where this number is >25%.*

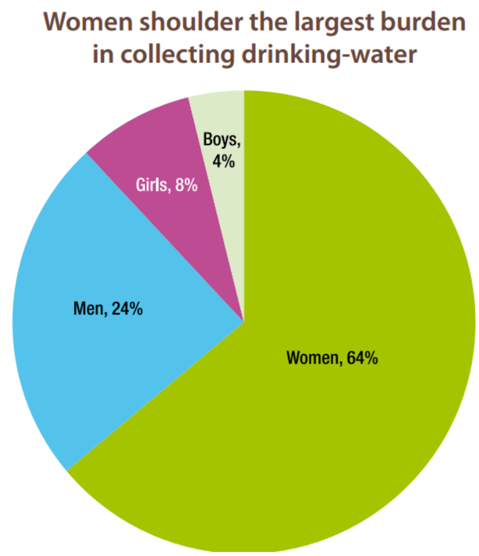


Figure 5. *Breakdown of the water collection responsibilities in a typical community. Women and girls bear nearly ¾ of the burden.*

	Cost Effective	Safe	Grid-Independent	No Source Required	Portable
Substitutes					
Wells	X		X		
River	X		X		
Bottled Water		X	X	X	X
Competitors					
Skywell		X	X	X	
Warka Water		X	X	X	
EcoloBlue	X	X		X	
WOOTA	X	X	X	X	X

Figure 6: *A comparison of WOOTA to its most direct competitors. Based on our extensive market research, a solution must meet all of these criteria in order to be successful. WOOTA is the only solution that is able to address all five standards.*

	Current Prototype	Performance-enhanced Prototype
Performance Specification	**Implementation**	
At least 12 liters of drinking water per day	• Half-scale model • Dimensions allow for 3 cycles of 10,324 cm^3 of desiccant to produce half the desired 12-liter output	• Full-scale model • Dimensions allow for 3 cycles of 25,000 cm^3 of desiccant to produce the entire desired 12-liter output
Grid-independence	• Supply of energy comes directly from the sun	• Same as current
Safe/Free of contaminants	• Uses nontoxic building materials and desiccant • Water from the air is free of contaminants	• Same as current
Portable with minimal required labor	• Passive process • Dimensions make it easy to assemble and carry	• Same as current
At least 20 w.p. water absorption	• Silica gel absorbs maximum of 25 w.p.	• Shape of desiccant container better maximizes surface area to promote maximum absorption
Achieve temperatures of 150 degrees or higher	• **Transmittant material:** Polycarbonate ○ Transmittance: >80%[34] • **Insulating material:** Mineral Wool • **Heat-absorbing material:** Galvanized Steel ○ Specific heat: 511 J/(kg-K)[35]	• **Transmittant material:** Temperature Glass ○ Transmittance: >90% • **Insulating material:** Polyurethane Foam ○ Improved water resistance • **Heat-absorbing material:** Aluminum Alloy 1100 ○ Specific heat: 921 J/(kg-K)
Durable	• Polypropylene casing	• Polystyrene casing ○ Enhanced assembly capabilities

Figure 7. *Summary of WOOTA's performance specifications and how they are implemented in the design of our current prototype in addition to our upcoming performance enhanced prototype.*

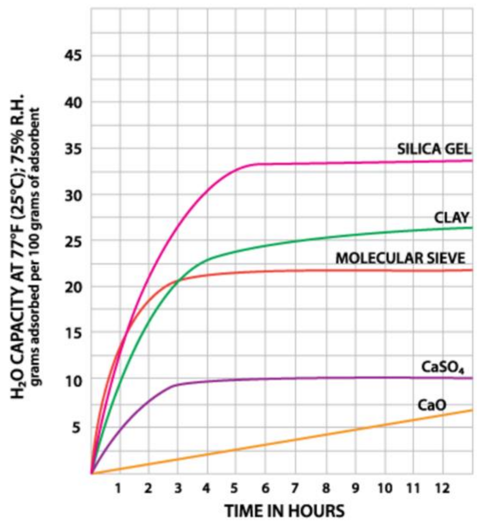


Figure 8. *Weight percent absorbance of common desiccants over time. Silica gel is represented by the pink curve and plateaus at approximately 33 weight percent.*

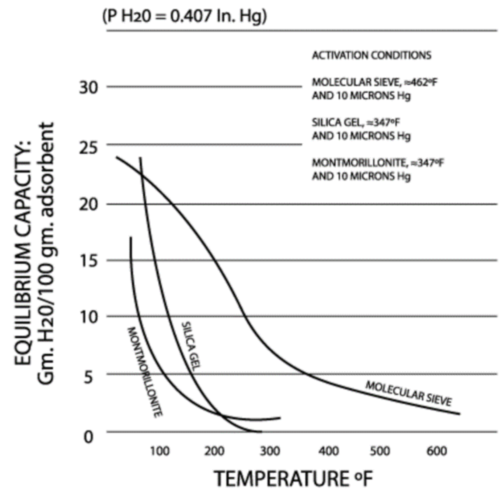


Figure 10. *Absorption capacity of common desiccants at high temperatures. Silica gel's capacity decreases significantly between 100 and 200°F.*

$$12\ L\ of\ water \times \frac{1\ kg}{1\ L} \times \frac{100\ kg\ of\ silica\ gel}{30\ kg\ of\ water} \times \frac{1\ L\ of\ silica\ gel}{0.7\ kg\ of\ silica\ gel} \times \frac{0.001\ m^3}{1\ L} = \mathbf{0.057\ m^3}$$

Figure 9. *Calculation of the volume of desiccant required to provide the minimum 12 liters of water per day.*

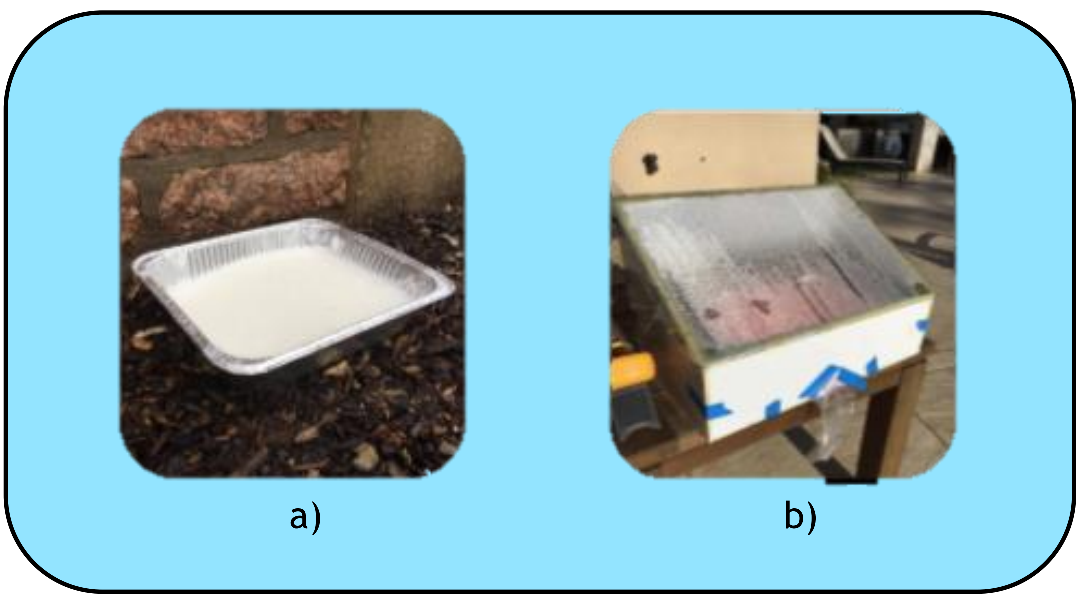


Figure 11. *Images of the two phases required to produce water. a) The desiccant tray is left outside to absorb. b) The tray is placed into the device and left in the sun to extract the water.*

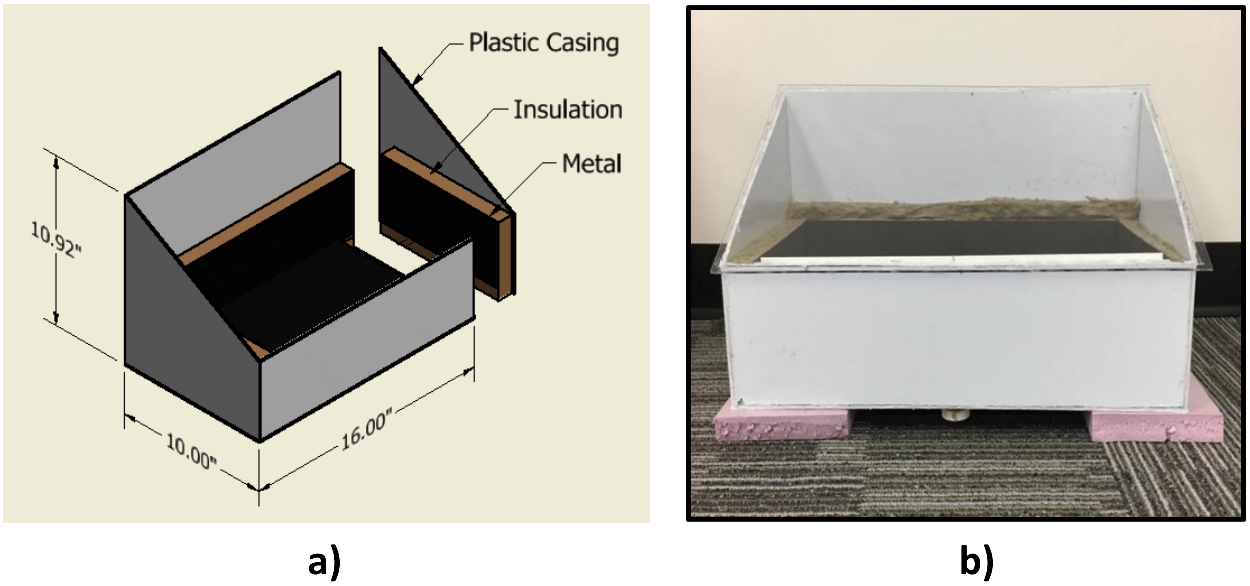


Figure 12. *WOOTA's initial prototype. a) CAD model with major dimensions labeled. b) Front view.*

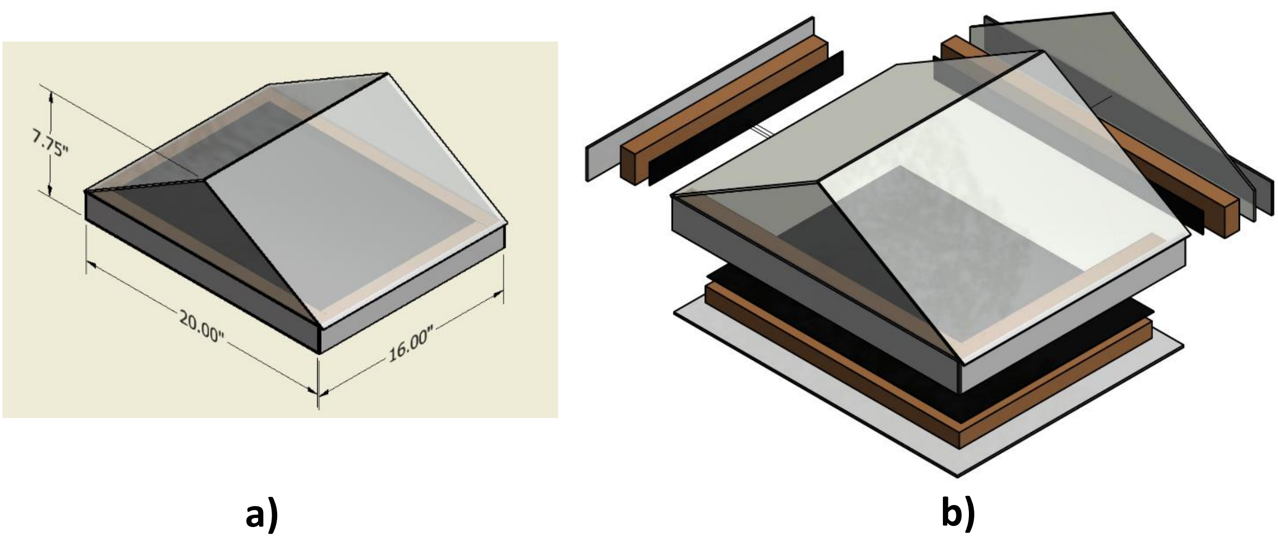


Figure 13. a) *A CAD rendering of our newly design performance enhanced prototype with major dimensions specified. b) An exploded view. Testing to begin in mid-June.*

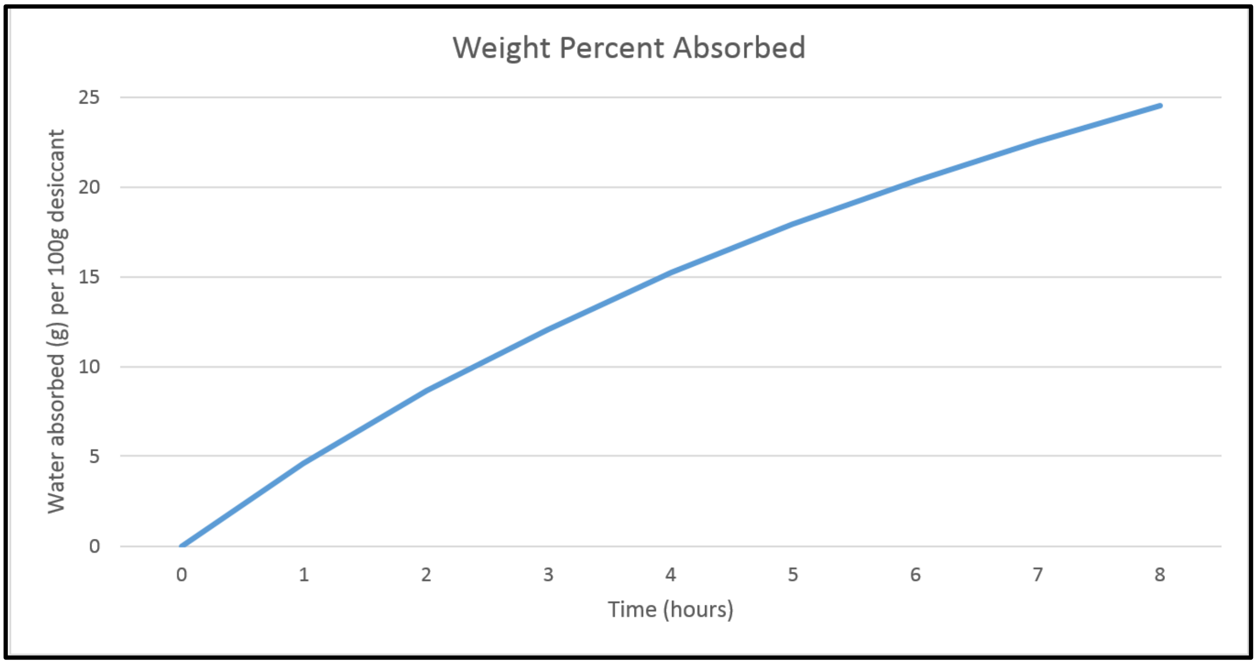


Figure 14. *Experimental data for the weight percent of silica absorbed over time in 80°F and 80% relative humidity conditions. The silica exceeds our 20 weight percent threshold for effective absorption.*

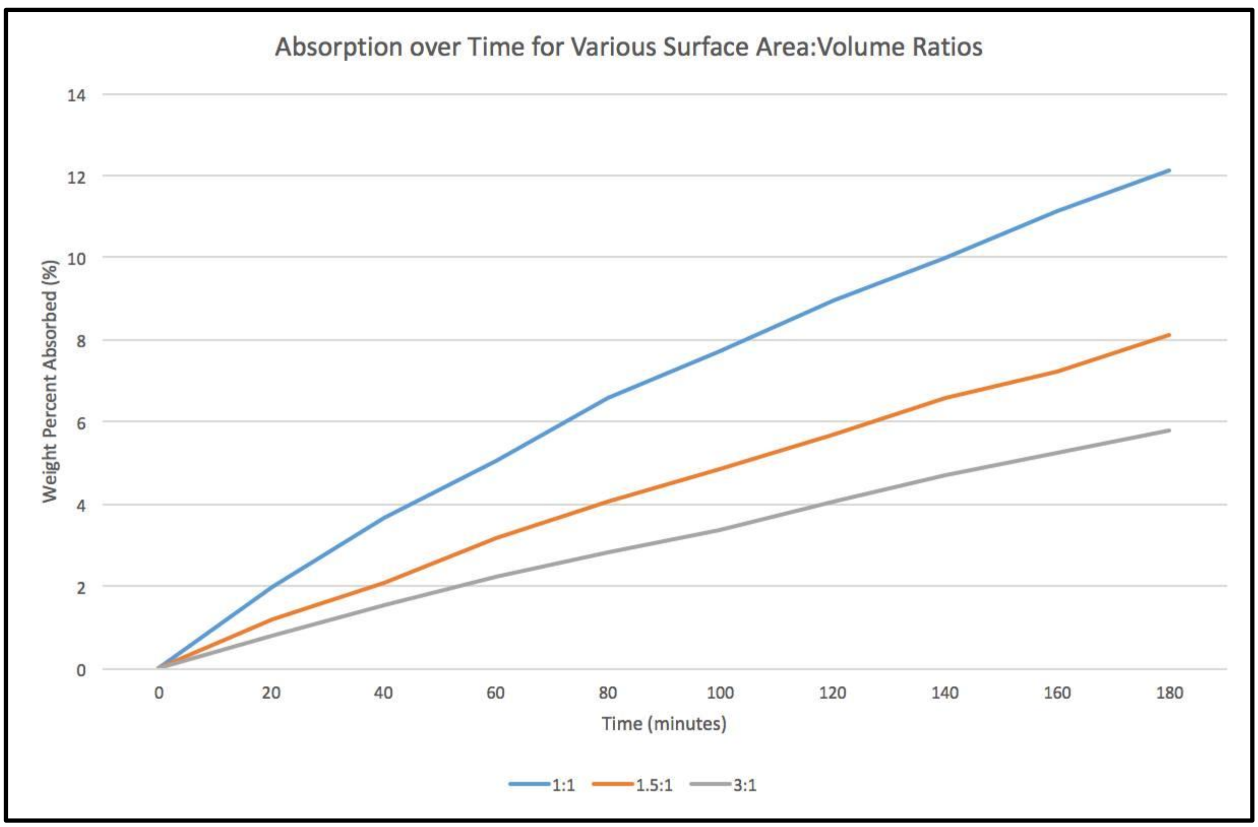
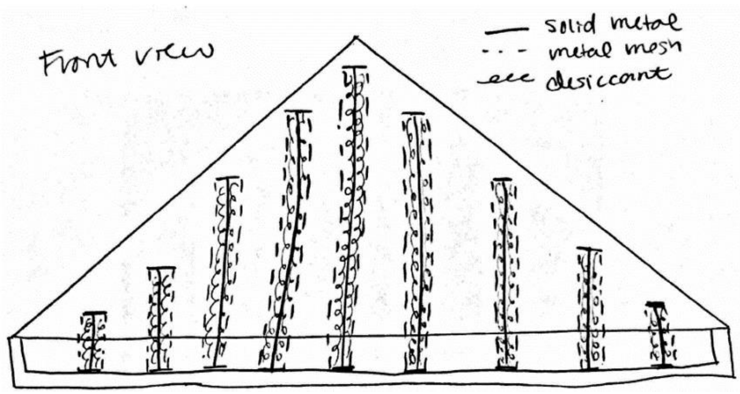
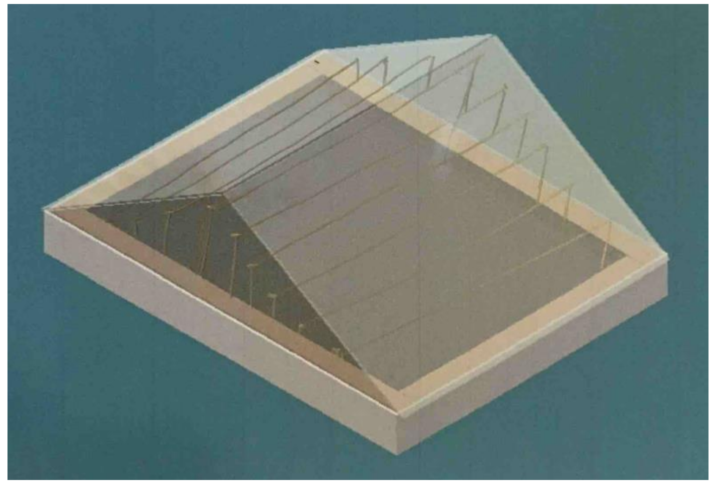


Figure 15. *Effect of a greater surface area to volume ratio on desiccant absorption. A greater ratio shows significant gains in absorption, indicating its importance in our design considerations.*





a) b)

Figure 16. *One proposed design of our desiccant container to enhance surface area for both absorption and regeneration. a) Front view. b) Perspective view of desiccant container in device.*

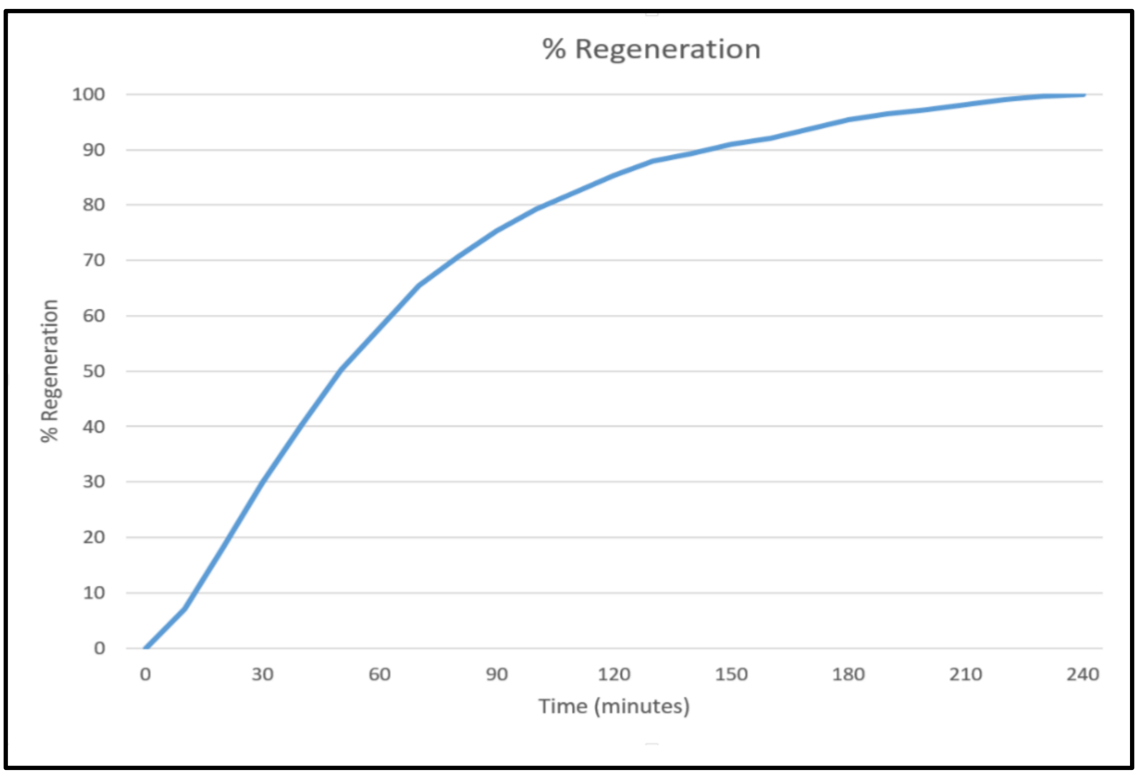


Figure 17. *Experimental data for the percent regeneration of silica gel over time when heated to 200°F. 100% regeneration was achieved within four hours.*

Prototype desiccant capacity: $9" \times 14" \times 5" = 630\ in^3 = 10324\ cm^3$

$$\frac{10324\ cm^3}{1\ cycle} \times \frac{3\ cycles}{1\ day} \times \frac{0.7\ g\ of\ silica\ gel}{1\ cm^3} \times \frac{25\ g\ of\ water}{100\ g\ of\ silica\ gel} \times \frac{0.001\ L\ of\ water}{1\ g\ of\ water} = \mathbf{5.42\ L}$$

Figure 18. *Calculation of potential water production per day of our initial prototype.*

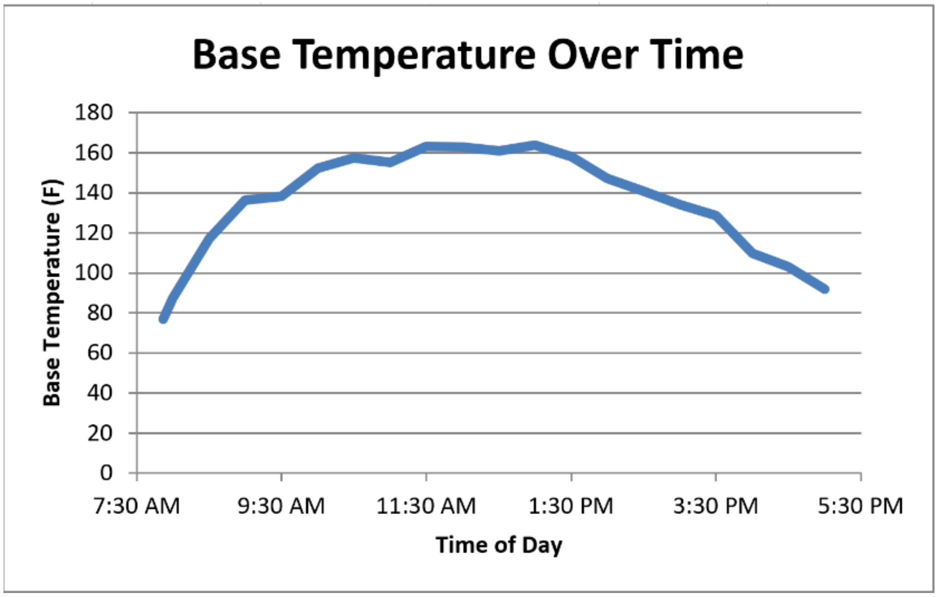


Figure 19. *Change in base temperature when left outside on a day with a high of 84°F. The temperature climbs to well over performance specification of 150°F during the peak hours of sunlight exposure.*

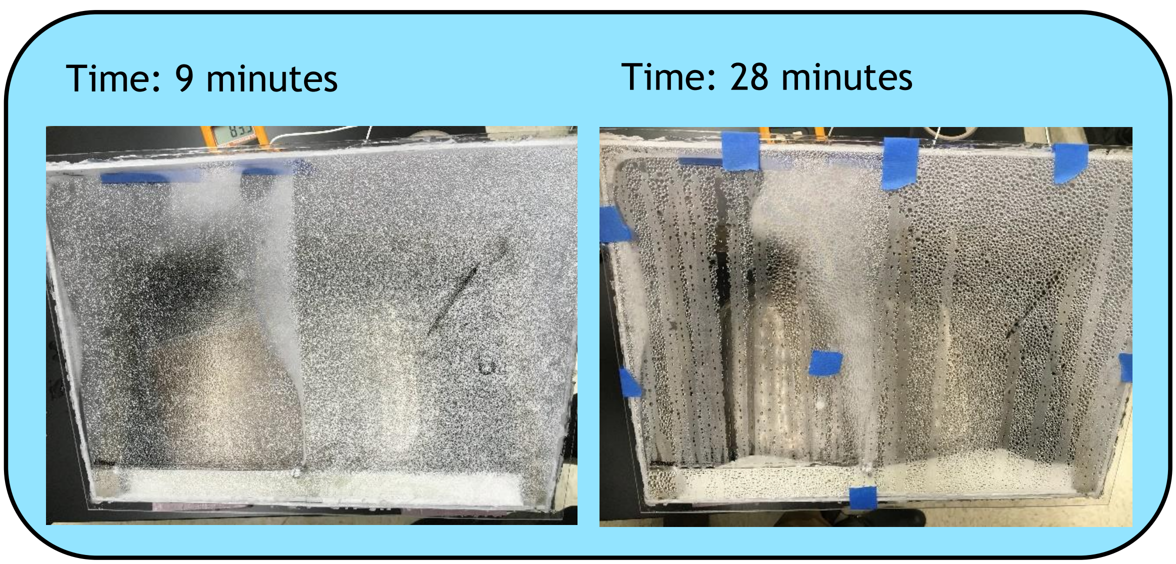


Figure 20. *Effect of hydrophobic treatment of the condensing surface on water collection. In the pictures above, the left half of the device was treated and shows a significant increase in runoff.*

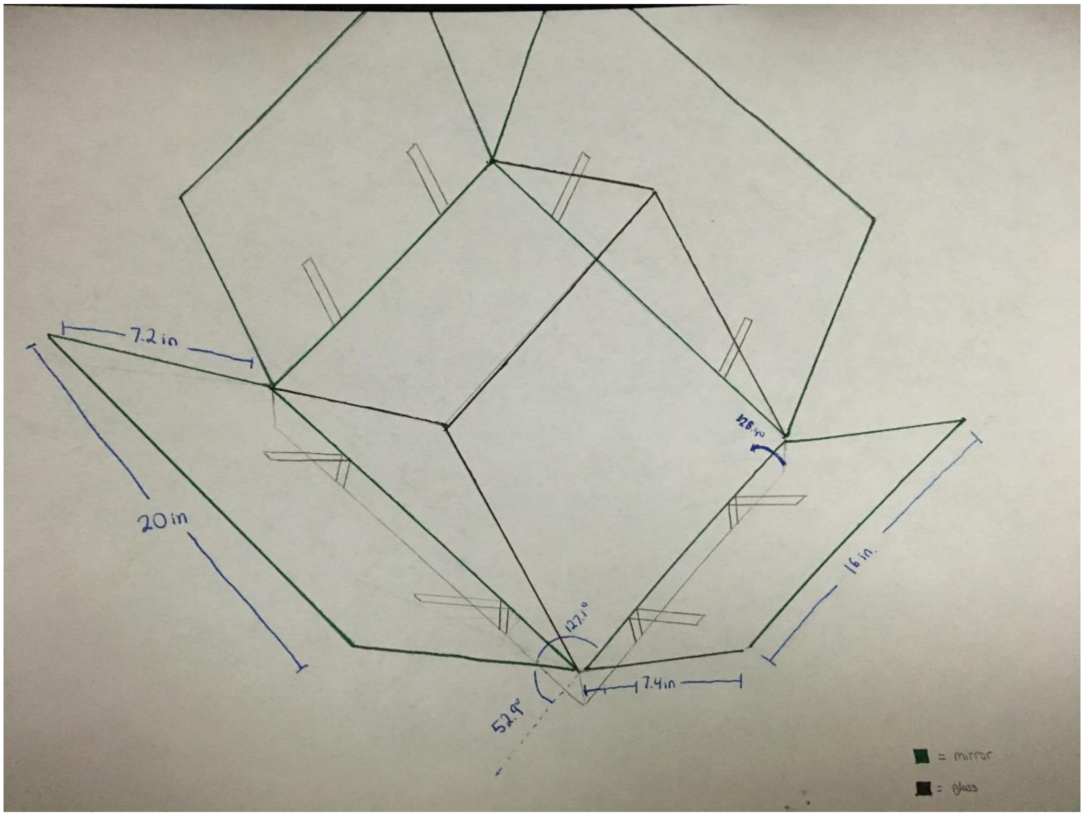


Figure 21. *Proposed solar focusing addition. Addition consists of an array of strategically positioned mirrors that ensure the device captures maximum solar radiation.*

Figure 22. *A depiction of WOOTA's primary distribution channel. It is important to distinguish between our end users and our customers. We anticipate nonprofits purchasing and then distributing the product to those in need of it.*

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