ESHRAB

Collecting potable water from thin air

by

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Abstract

Considering the numbers of people suffering to find water along with having these numbers increasing every day, Eshrab could be a very efficient device to support the hydration needs for people who lack access to potable water. It is a mobile atmospheric water generator that collects moisture from the air and turns it into potable water. The device could also run on solar power making it completely sustainable and more usable by people who do not have power connected to their houses. Eshrab works with a very simple technique which is basically cooling the stainless steel sheets and allowing them to get to the dew point to collect the water. The device will be in the shape of a hexagonal prism and it could be stacked in any order as long as the water and power are connected properly. Also the six sides facing outside will have a place where one could slide in the solar panel. This way it will give flexibility to the user onto which of the six sides does what function along with which of the solar panels or power plug should be used.

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Introduction

There are many problems in this world that appear to be very hard to solve. Yet there are some issues that could be resolved with minor tricks and discoveries. Having the surface of our planet being composed of 71% water, it is just sad to hear that someone is suffering from dehydration. The rivers and groundwater are doing a great job for the people living around them, but the people who live where there are no similar sources of clean water are having a really hard time adapting. The UN Water Inter-Agency discusses this unfortunate circumstance: “According to the WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation, at least 1.8 billion people worldwide are estimated to drink water that is faecally contaminated.” Moreover, 85% of the world population lives in the driest half of the planet and 6 to 8 million people die annually due to water-related diseases. These numbers appear to be getting bigger every day along with population of people on the planet, which means the problem will probably not resolve itself. In addition, these areas that are home to 85% of the world’s population also have high rates of poverty, illiteracy and exponential population growth making it only worse socially, economically and politically. There might be a direct relationship between all of these factors and the increasing scarcity of water, but until these factors are resolved the water issue will still be there. Consider that people form habitats in areas where there is some source of water. Where there is water there is greenery, animal life, and possibly other humans seeking an oasis. Either there is a river, a lake or dwelling around the people; there is almost no way people could live in places that do not have at least one of these elements. Even the people living in coastal cities that are surrounded by salt water found sources of potable water nearby due to many reasons like the water of the sea spreading into groundwater and having the salt reside at the bottom or be part of the rocks, allowing the rest of the water to be drinkable. Yet with the exponential population growth these sources appear to be not enough for the people who are living around them to survive on. People have tried many solutions to figure it out including building dams, for example, which was the most successful solution to prevent excess water from being wasted. Yet another strategy tried by the people who do not have rivers or rain and are becoming a population too big for the local dwells to support them was purifying salt water. This does result in potable water, however it is a very expensive process and required the consumption of a lot of energy.

A very effective piece of art that was in the Museum of Natural History (figure 1), explains the amount of potable water (figure 2) in a clear manner. It was in an exhibition called "Water: H2O= Life". In the figure 1, we can clearly see the whole planet, while in figure 2 the blue line represents the amount of potable water compared to the actual size of the planet.

Figure 1

Living most of my life in Egypt and working with NGO's on areas of extreme poverty I have come to see how many elements contribute to making life harder for everyone there; some are easy to solve while others need to be rebuilt from scratch. The problem with the cycle of poverty is that one has an insufficient amount of income or fund, which leads to the person not being able to buy what they need to make life easier, making them time-consumed with problems that prevent them from breaking through the glass ceiling. There needs to be an interruption of the cycle to allow more time for learning more, working more, resting more, being healthier and hence advancing more in every aspect of life. If we can imagine the time, money and health wasted of a person who lived for thirty years walking every other day for miles while carrying buckets of water that is not even safe to drink, it would be easy to imagine how intense the daily challenges in his/her life are. So the solution to this problem appears to be the need of a source of water that will save time, money and effort along with not being dangerous to people's health or lives. And this is exactly what I had to do.

Figure 2

Concept Statement

My thesis project, Eshrab, is a mobile atmospheric water generator that collects moisture from the air and turns it into potable water. The device could also run on solar power, making it completely sustainable and more usable by people who do not have power connected to their homes. Approach, iterative problem solving and fabrication of the device, Eshrab, will be analysed in the chapter on methodology.

Ironically the higher the temperature the higher levels of water the air can carry (this will be explained further) so the device should actually work better in the summer than in the winter, which is when people need the water most to avoid dehydration most. The device is supposed to be as cheap as possible so that it is affordable to people who lack the ability to build their own infrastructure or get access to water. However, it could also count as an investment because it is something that the person would buy once and then have it supply water for as long as it is in its place. Each device is ideally supposed to generate a minimum of 2 liters per day and, which is the minimum consumption for a human being.

The device should be very easy to assemble and activate and it will be accompanied with a manual on how to do it, which will also be explained further. The importance of this project is not only to prevent people from dehydrating, but also clear the burden they have every day of how they will get the water off their minds. In the areas where the demand for water is becoming very high along with the supply being low, the water is getting more expensive every day. And it is a cycle that is destroying many cities because it is squeezing the people living there every day more than the day before, causing many of them to migrate or sell many of their belongings to get more supply.

Influences

Lately there has been a lot of research being done about water scarcity, especially with global warming happening and the planet being subject to severe geographic changes. This research has lead us to be able to predict what will happen in ten or twenty years from now and this allows us to take better precautions that we had in the past. One of the major critical issues we were able to understand is when and where there will be water scarcity, which is expected to lead to water wars happening.

Opportunities

Rijsberman addresses this issue in his article but focusing more on the future showing how some areas will be drastically affected by the water shortage in the next decade (figure 3).

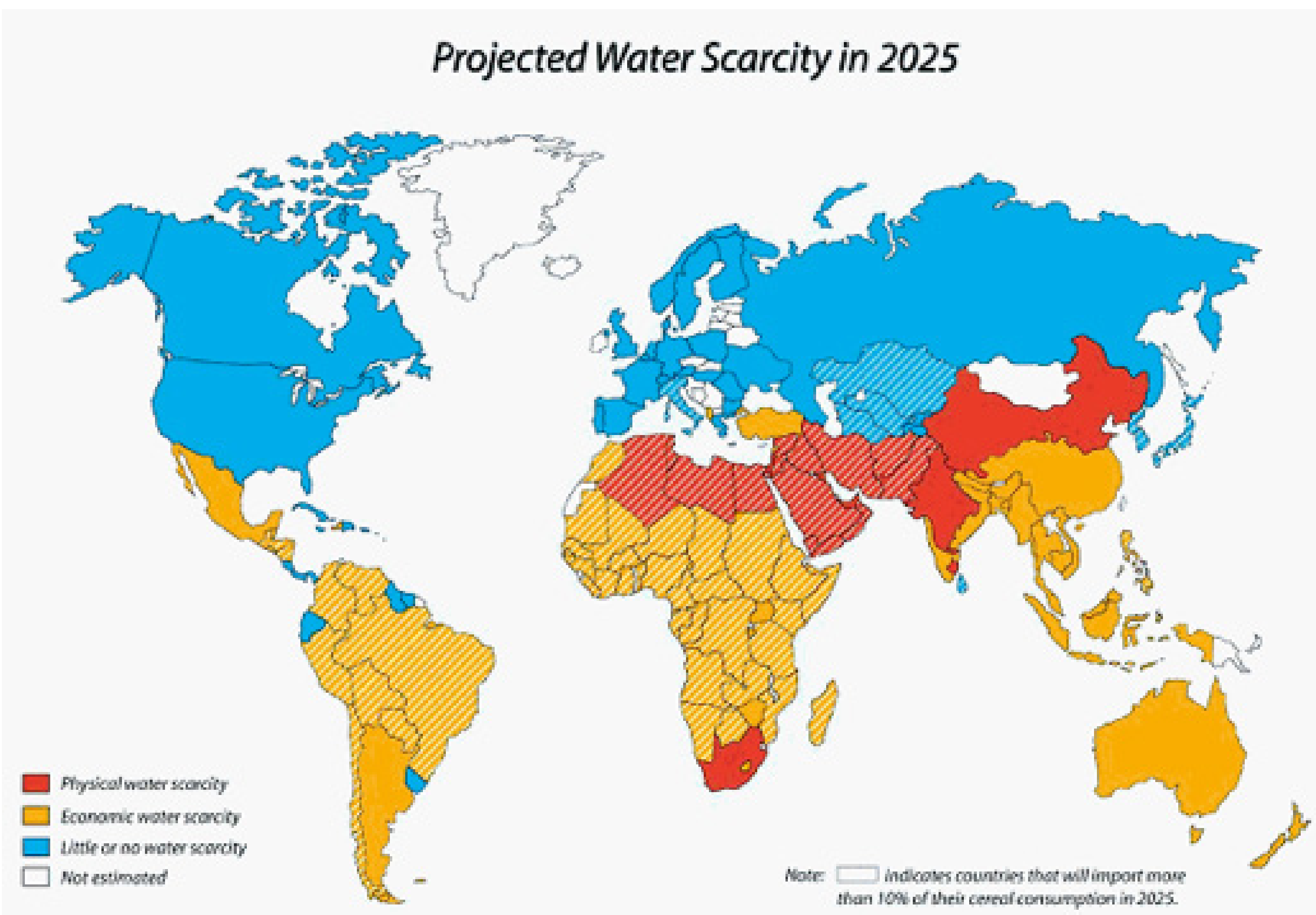
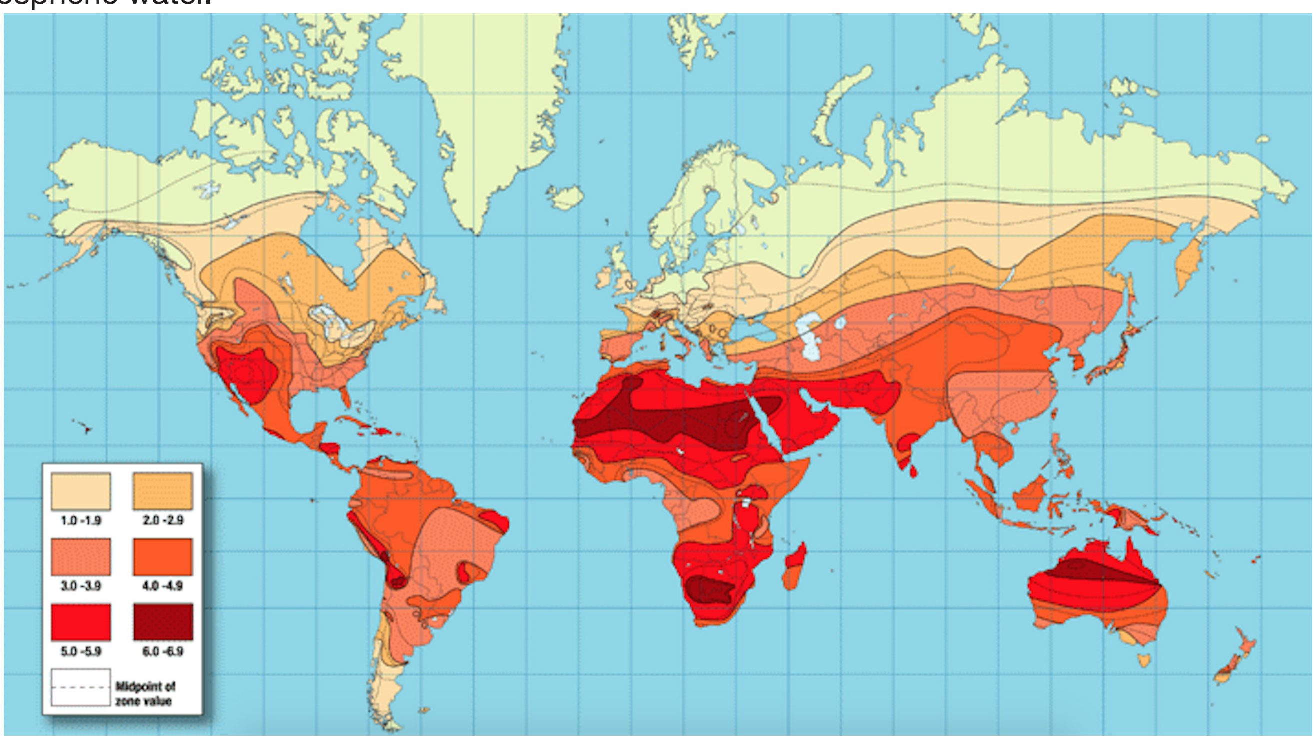


Figure 3

Ideal Zones

FOR AMBIENT WATER TECHNOLOGY

These areas happen to also be the best areas for generating atmospheric waters well for multiple reasons that will be discussed in detail in the Environment section. This map (figure 4) was developed by Aquaboy who are amongst the leading companies in the field of capturing atmospheric water.



These same areas also happen to be the best areas to harvest solar power from the sun according to Neville Williams (figure 5). The reason being mainly that the sun heats these areas making the water in the form of gas and also allowing the hot air to carry more water.

Case study

A good example of one of the places suffering lack of clean potable water yet fitting in the criteria of the environment where the device should work best is Egypt. At the time of the Ancient Egyptians if someone polluted the river Nile in any way they would be executed because it was considered the holy source of life, and it actually is the birth of civilization because it allowed irrigation and growing crops. Over the years the Nile was being renewed and the population around it was not big enough to affect it even if they polluted it. Yet in the last fifty years, the population in Egypt went from twenty million to ninety million people of which twenty million are living in greater Cairo. Now the Nile is actually green in color and it is definitely not as pure as it was . In the article by Walaa Hussein titled “Egypt faces drinking water shortage because of Nile pollution” she explains further how the water level is getting lower and how this makes the pollution even more dense. We can also clearly see in this picture (figure 6) how bad it is considering there is a carcass in the water and there is a person collecting some water right next to it because there is simply no other choice.

Figure 6

The local solutions that exist now in these places are usually water trucks, carrying the water for long distances (figure 7) or using a dwell, usually one would have to pay for. The dwells are usually serving the people perfectly fine until the population appears to be exceeding the accessibility to it, making some people use force to get it. Usually when force succeeds, other people then have to pay to get the water or they have to organize another militia and take over the dwell. Having to walk to the river or lake is the most common way of getting water in developing countries and it is also accompanied by many disadvantages. Aside from having to waste at least two or three hours a day to go to the source of water and back, along with having to carry tens of pounds on shoulders or heads, there is sometimes a bigger disappointment which is basically not being able to reach the water source for any reason.

The water trucks (figure 8 and 9) tend to be the most appreciated modern solution to the

Figure 7

problem since the truck tends to get that water close to where the person lives instead of forcing the person to walk and carry the water. The problem with that is that one has to pay for it and it usually passes by each area once a week. The bigger problem is when the water truck does not come to the area for any reason, there is at least a week that will be spent for a very small amount of water, and this happens frequently.

Figure 8

Figure 9

However, the worst problem that actually accompanies these three solutions is that usually this water is still not clean nor potable but when it is a matter of survival there is no option but to drink it (figure 10).

Figure 10

Biomimicry

Seeing this clearly in this matter and being fascinated by nature and biomimicry, I instantly started to search for solutions that could be found in nature, our biggest influencer. I wanted to look for a way to have a source of water almost inside the place people live at, while being very easy to use and being very cheap or almost for free. There were many examples of how creatures tend to harvest water including plants, microbiological organisms, insects and many other beings. The most interesting of them was the Namibian Desert beetle. This creature appears to be depending on a completely sustainable source of collecting water from the moisture in the air, which is the pattern on it's back. Having bumps that area superhydrophobic on their backs, those beetles can just walk until they feel a heavier weight on their backs and then simply lean forward for a few minutes to allow this water to flow down to their mouths. Manon Mollard explains the mechanism in details saying "As fog blows horizontally across the beetle's back, water droplets just 15-20 microns in diameter start to accumulate on the bump on its back. Bumps (water - attracting = super-hydrophilic) are surrounded by waxy water-repelling channels (water – repelling = superhydrophobic). When a bump collects enough water to form a big droplet, it rolls down a channel right into the beetle's mouth."

Here is a diagram (figure 11) that explains the simple mechanism of the beetle that allows it to collect the dew by the South China University, School of Life Science.

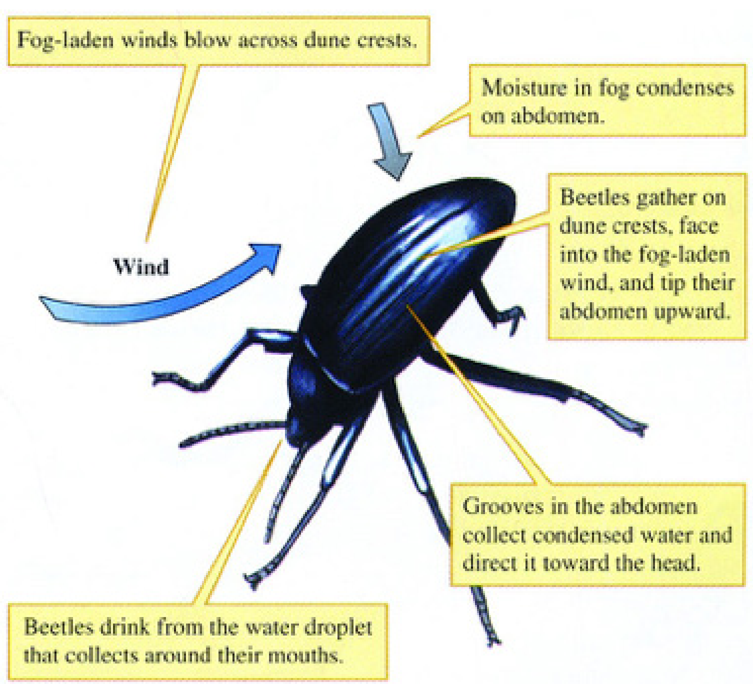


Figure 11

And so as we can see in this image (figure 12) from the article by Nørgaar author and Dacke, the Namibian Desert Beetle appears to be one of the few creatures on this planet that does not need to be looking for water at any point in its life, simply because water will come to it. This was a really inspiring point because the fact that we pause and realize there is actually water around us in the air with different amounts depending on the location appears to be of great importance. Then all we need to do is actually collect it.

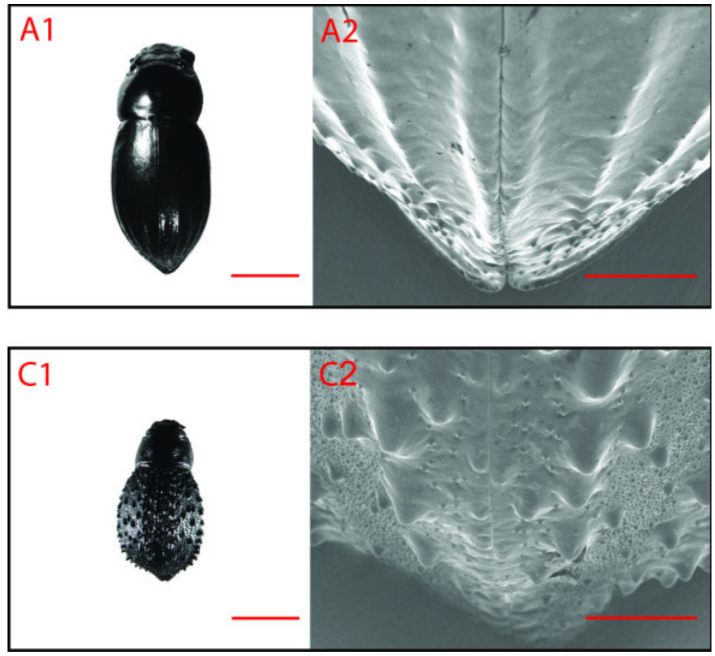


Figure 12

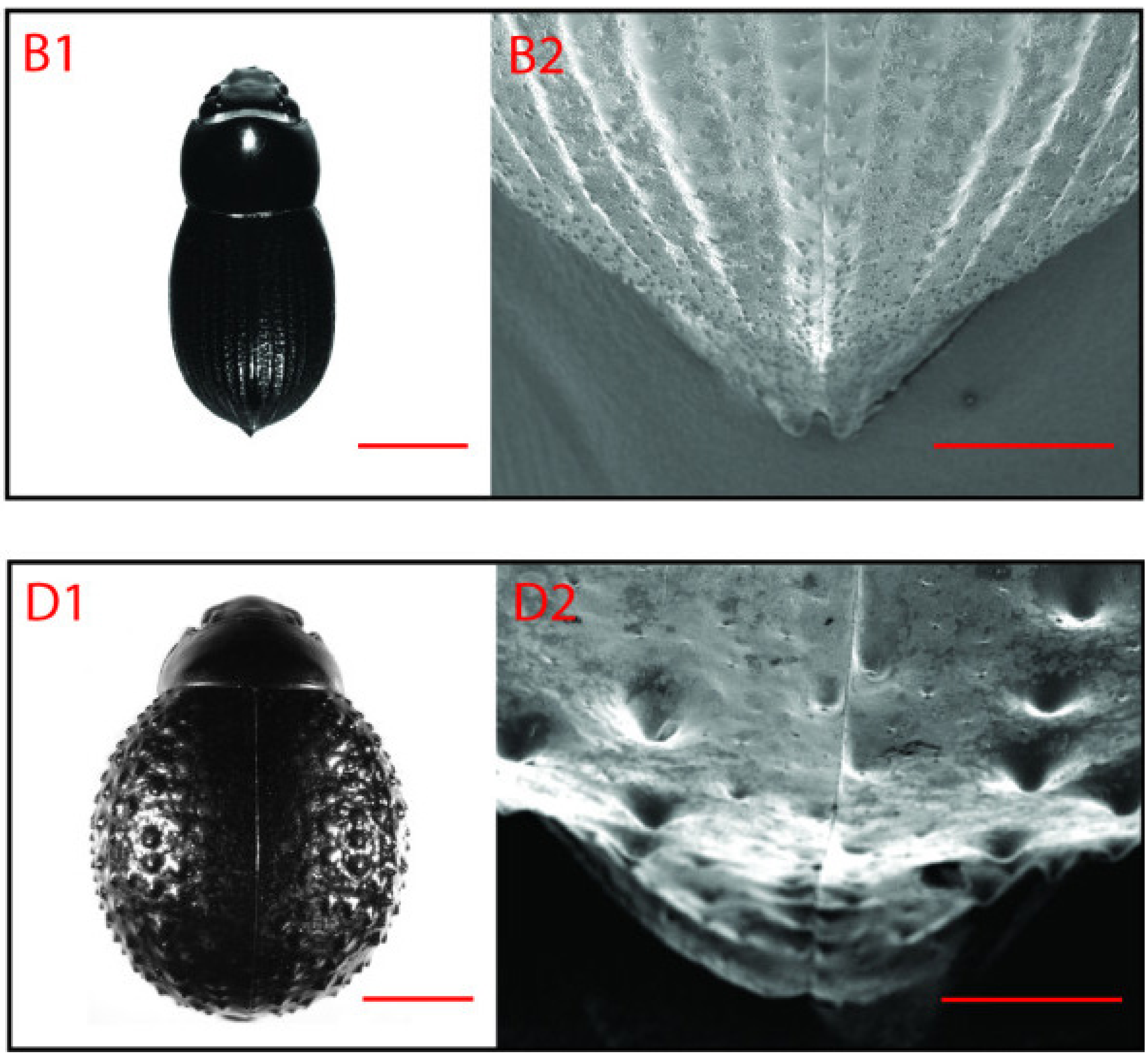


Figure 12 cont.

Early prototyping

Figure 13

I started to experiment with plastic 3d prints and making steel cones in an attempt to imitate the mechanism used by the beetle but more research was required in this area. The idea was if the beetle had a semi-sphered back because it is limited by the functions it needs to do in nature, we could do it in the shape of the cone to make the surface area much larger. Knowing the beetle had bumps that are superhydrophobic, I started to experiment with sprays that do a similar function along with using tinfoil and other rapid prototyping material to try to understand how it works.

I later went to Egypt in an attempt to test this prototype and see how much water it can collect. So in this case I had cones that did not have any of the pattern, cooling, protection, solar panel or even a proper container (figure 13). The whole idea was to test the shape and how it would work.

Figure 14

The cone alone without any cooling did not work almost at all (figure 14), especially since the material was steel (non-galvanized) which turns sticky when there is a very small amount of water on it.

So the second attempt with this model was to have two of the cones next to each other while having one of them being put in the fridge for a while beforehand in an attempt to see how much of a difference there will would be between both models. In this experiment, the cone that was put in the fridge had some dew on it for the first 2 minutes then its temperature went back to be equivalent to the surrounding environment because it is a very thin sheet of metal (26 gauge). And so it gave some hope that the experiment might work but it needs to be cooled for a longer time.

The third attempt was having the same exact variables, yet the only different variable was instead of putting the cone in the fridge I actually put ice inside it. This time it was similar to the cone next to it for the first minute, and then it started to collect dew with small quantities (figure 15).

Figure 15

The most important point was that the atmospheric water generators have always been trying to do it without any added factors except for playing around with the shapes and sizes of the tool collecting the water. The perfect time to collect dew is at sunrise. The reason for that is because the surfaces are cooled down throughout the night but the air is also cold, yet when the sun rises the air starts to get hotter while the surfaces are still cold. After half an hour or an hour most of the temperatures of surfaces get higher from the sun affecting it hence leaving only a small window for collecting the most amount of dew. And so I was trying to figure out a way to make the surface cold at every point in the day, which will allow for a good amount of collection for the night but also the sixteen hours of sunlight if it is in the summer.

After extensive research and a lot of failing trials for a tool that could cool the surface and consume the least amount of energy there appeared to be a very good candidate, which is the Peltier plate. According to TE Technology INC “Peltier plates are ceramic thermoelectric coolers that use the Peltier effect to create a heat flux between the junction of two different types of materials”. They are sealed and hence waterproof, they run on 9 volts and they are less than 3 dollars in price. They are also very small in size and are very light so they are almost unnoticed in the device. This device will be further discussed in the methodology chapter.

Precedents

The community of practice for doing similar devices is one that stretches back to thousands of years. Ever since the times of the Romans people were attempting to build an efficient atmospheric water generator. There were Air wells but they were later concluded as being inefficient due to them not collecting enough water. And now there are some radiative condensers that appear to be successful models in certain locations, but they have to be built on a very large scale like most of the attempts to build devices with the same purpose.

Figure 16

This is a picture of the outside of a Roman Condenser (figure 16), a device that was obviously promising considering the size of it and the time it must have taken to build it.

Note the pattern that is on the inside of the walls (figure 17) which serves the same purpose as the Namibian desert beetle in terms of collecting water in a more efficient manner. The whole idea behind it is to basically have the water condense and guide the water in the right direction instead of having it be scattered on the surface.

Figure 17

This is a picture of a Radiative condenser in India (figure 18). This appears to be one of the most successful models built for the purpose of atmospheric water generation. This project in specific is supplying water to a village in India and is completely sustainable. It is best in the area it is at because of the high temperature and very high relative humidity levels.

Figure 18

One of the organizations that has been working extensively on this topic is The International Organization for Dew Utilization in Paris (OPUR). This organization has developed many models and techniques that allowed the advancement of the fields of atmospheric water generation. They have helped me a lot and gave me feedback about how to proceed further with the device and if there are any alterations that I need to do at the beginning of the prototyping phase.

Another very helpful source of information that I have been in contact with is Thomas Row. He was the one who designed the Atmospheric Water Collector Bottle (figure 19 & 20). It uses the same technique of the beetle but in a different way. He also has very helpful diagrams that help understand the breakdown of his project. His project was a very good idea but it was never successful in getting the amount of water needed. Thomas along with Daniel from OPUR were the ones who told me it is best to test the device in an artificial environment so it could be easy to change any of the variables and test the difference it makes.

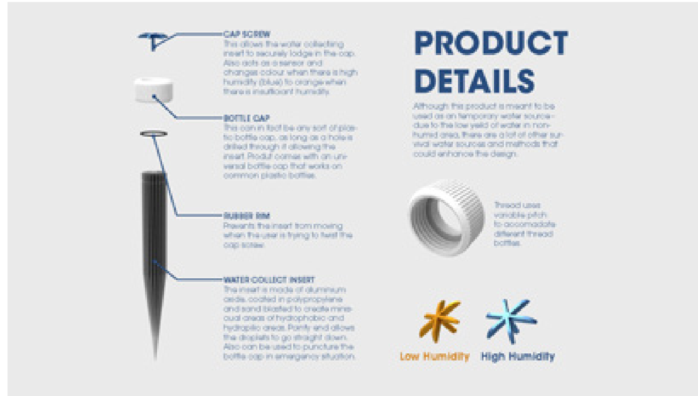


Figure 19

Figure 20

The Hippo Roller (figure 21) is a very smart and simple idea that solves the problem of having to carry the water for long distances. It is basically turning the barrel on its side and attaching a handle to it to allow it to roll instead of being carried. This is a very good solution in terms of making it less exhausting to transfer water from one place to another with the minimum effort possible. The only disadvantage of it is having to waste a lot of time doing it.


Figure 21

The Life-straw (figure 22) is also a very smart and simple idea which is basically an instant filtration system that allows people do place the bottom of the straw in unclean water and drinking from it while having it filter the water instantly. This is a very practical solution if one happens to have a river or a lake next to where they live but still requiring the person to be at the physical place of the water at every time hey want to drink, or\

Figure 22

carrying water and then drinking it at home with the straw, still requiring time and effort.

Some designs that are not yet implemented but are worthy of mentioning are the Water Collecting Tent by Abeer Seikaly and Warkawater by Arturu Vitorri. These designs, along with many others, although they might be fictional to some extent, they will probably take place in the future at some point when the material and tools are possible for building them.

Also an great design that works in a very similar manner is Fontus by Kristof Retezar (figure 23). This is also a very good example of having an almost identical technique of condensation but for a slightly different purpose. It is basically for allowing the air to flow into the container when people are riding bicycles, which makes it like an infinite supply of water for a biker who is on the move. The device is also cooled through Peltier plates and was also inspired from the beetle. This is a very smart idea but it is not finished and into the markets yet.

After many failing prototypes, I started to get disappointed and rather confused about whether it is doable or not. Maybe this is why everyone has not taken it further since the times of the Romans? Maybe it will never get the amount of water needed? I knew it worked theoretically and I had it in my mind and in my research, but I had not seen it work with the amount of water required. However, four months after my initial prototyping, Kristof Retezar did not stop at the

Figure 23

Figure 24

concept design of the bike bottle, he later was able to design AIRO (figure 24) along with a larger group. AIRO is basically the same technology used by Fontus and by my device as well, along with being solar powered. AIRO seems for me to be the perfect solution for camping and outdoor activities, but it is still not serving the population that would dehydrate if they do not have it. It is still not released in the market yet but it is estimated to be around $250 plus $70 of shipping since it will be manufactured in the United States. This is a cheap price for someone who goes camping for fun in a developed country considering that it is a one-time investment, but this price could be a major obstacle for people in the developing world.

The weather trick

Although one always thought the hotter a place is the drier it gets, there appears to be a small trick in this equation that took me some time to grasp. So it is true that the desert is drier than most of the other places on the planet and Antarctica for example has more water (in a frozen form) than anywhere else on the planet as well. Yet the trick comes not when the water is solid or liquid, but when it is in a gas form. So everything in the world has different densities even the air in one place has a different density than another place. And as science tells us, the colder the temperature is at a certain place the higher the density will be of the air around it. And the higher the density of air, the lower there is space between the molecules to carry water. This is a very crucial point in this research because it basically indicates that the hotter a place is, the more water the air can carry in it.

The factor that was also somehow confusing was the percentage of humidity. It is a common misconception that the percentage of humidity is simply how much percent of the air is formed of H2O molecules. But that means that if the percentage of humidity is 100% then we would be walking in a block of water. The reality is every point in temperature has a different capacity of carrying H2O in it as explained above. So the percentage of humidity is basically an indicator to how much water the air is carrying compared to its capacity to carry it. Hence if the humidity levels in a hot and a cold place are both 50%, this would still mean the amount of water in the air in the cold area is much lower than that in the hot area. This point was a very important point because it means the device will actually work best for the people who really need it, making it work less the colder it gets. Yet the colder it gets, the less the density of the air becomes and so it can carry less water making it start raining. This means that most of the areas in which the device will not work very efficiently it will be raining anyway, eliminating the need for this device. On the other hand, if the temperature gets hotter at some place, the water will evaporate making it easy to be captured by the device with efficient quantities.

Yet another question that rises is based on what will the H2O turn into liquid? and could be captured? The answer to this question lies in the dew point. The dew point is simply the point in temperature at which water turns from gas to liquid. So any surface that will be at the dew point in any circumstance should be able to turn any H2O in the form of gas that passes by it into liquid. There is an equation to enable solving for the dew point temperature where “T” is temperature, “f” is relative humidity and “TD” is the dew point temperature:

$$T_D = \left(\frac{f}{100}\right)^{1/8}(112+0.9T)+0.1T-112$$

Figure 25

Yet with the technological advancement and user-friendly interfaces there are now websites that gives the results and allows people to play around and test every number in the simplest manner.

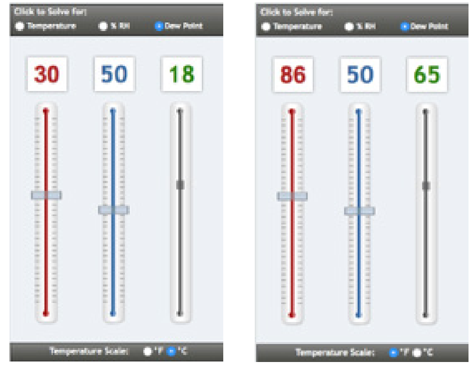


Figure 26

In this example (figure 26) we can see that if the average is 50% humidity with a temperature of 30°, the dew point will be 18°. This is a percentage below average in the target area for the project.

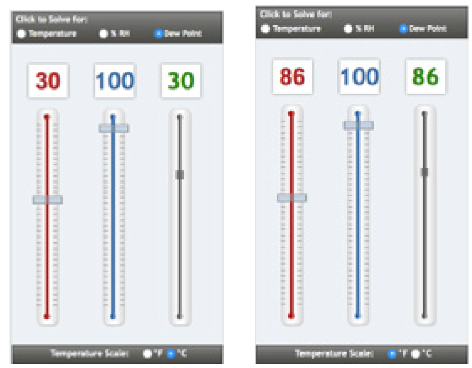


Figure 27

This example (figure 27) is one at which the percentage of humidity is 100%, which does not really happen much but it is a good example in terms of explaining the idea. As we can see, at that point any surface with the temperature of the surrounding environment will turn any water in the air into dew. This is why we can almost never see it because as soon as humidity reaches 100% it starts turning into liquid and by that reducing the amount of humidity in the air incidentally.

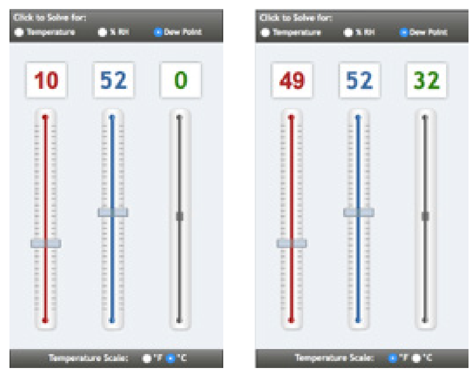


Figure 28

In this example (figure 28), we can see that if the weather is colder than the average and the humidity is average then the dew point will be at the freezing point. In that case there will be no water collection because as soon as the water turns into liquid, it will turn into ice in a very small time period.

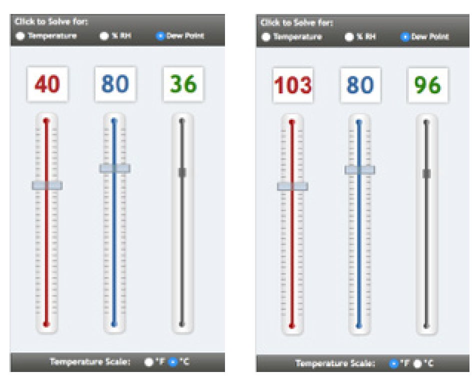


Figure 29

Methodology

Cooling

Most solid surfaces collect water when they reach a temperature below the dew point. As soon as the dew point is reached, the molecules in the air appear to be residing on the surface and turning into liquid. The small droplets then start to get closer to each other and connect to form bigger and bigger droplets until it is too heavy to be held on the surface and is pulled down by gravity, making a new space for new droplets to condense. If the droplets were not heavy enough or the surface was not smooth enough, they will then remain in their same location on the surface until they dry out. There are various reasons that prevent the droplets from connecting, growing bigger and then being pulled by gravity to flow in a certain random or designated direction.

The reasons that could restrain the water from expanding and connecting with new droplets include many factors namely the air temperature, surface temperature, percentage of humidity, pressure, gravity and smoothness of the surface. The reasons why these factors affect the condensation are proven to work and could be found as general knowledge in many sources, yet utilizing and manipulating them to get different results could enable us to control the outcomes afforded to us by nature.

The temperature of the air and percentage of humidity in it will probably be something that we do not want to control but rather to benefit from. The areas targeted range in temperature between 15° celsius (60 Fahrenheit) and 40° celsius (104 Fahrenheit), while ranging in percentage of humidity between 20 to 95 percent. However, most time of the year (for 9-10 months) they appear to be having a temperature range of 25° celsius (77 Fahrenheit) to 40° (104 Fahrenheit) and a percentage humidity ranging from 50 to 95 percent. Considering these numbers and the calculations done for the dew point, the minimum temperature needed by the surface to be reached is 14° celsius (56 Fahrenheit). The reason simply being that at the driest and hottest 9 to 10 months of the year, the dew point will be more than 14°. In that case, getting the surface to reach and stay at this point of temperature will guarantee the condensation to be happening. The question is then how to cool down a surface to this temperature?

The answer to this question was one that always included the consumption of lots of power and big machinery, resulting in the device being the size of an average fridge. Yet with the Peltier junction technology, we are now able to get a cooling plate that is smaller than 1.5” x 1.5” that is ideal for small surface cooling. The Peltier plate (figure 30) is one that when supplied with electricity it would have one of its sides being cold and the other producing heat. The good part is that the cooling produced by the cold side could make the surface reach 14° in the matter of seconds if attached to it properly. The bad side is that the hot side gets much hotter and more powerful after about a minute and at some point actually starting to heat the cold side as well. After two minutes both sides become extremely hot and they could melt if they were not turned off. This was also another obstacle that played an essential role in the size and shape of the whole device as the hot side had to b cooled down or else the Peltier plate will not cool the device. The best feasible solution for this problem would be using heatsinks that are commonly used to cool down computer CPUs. The CPU is usually around 1.5” x 1.5”, while there is a Peltier plate with the size of 1.575” by 1.575” making them a perfect match to each other. So attaching the heatsinks with thermal compounds to the Peltier plates and then attaching them both from the Plate’s side to the source that needs cooling appears to be a perfect solution.

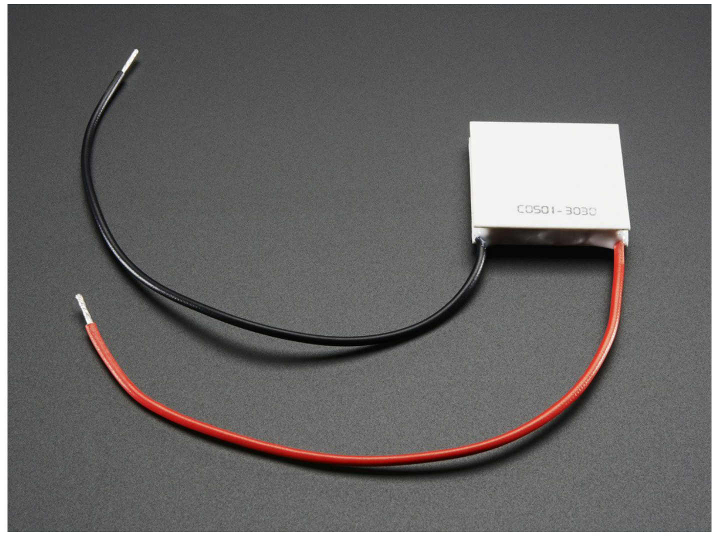


Figure 30

The pattern (crocodile eyes)

Up until this point, everything appears to be working and the water would be condensed on the sides through cooling the surface, but would it stay there and just reside on the surface simply taking the space and not allowing new water to be condensed? If the surface is flat, especially if it is hydrophilic, then the answer is definitely yes. This was one of the reasons that took this research so long as it was not very clear at which point the water would start moving downwards, giving space to new droplets and by that action actually collecting water in a container beneath the surface. The natural ideas that come to mind would be making the surface as flat and smooth as possible, while having something push the water droplets downwards. The first one was easy to have, yet having something that pushed the water droplets downwards was the tricky point. Going back to the Namibian Desert beetle, we would see that the bumps actually tend to help a lot in condensing more water than a flat surface and it helps push it downwards to flow with gravity.

By observing this behavior, it was natural to conclude that when the water droplets start forming, and while growing on a surface that is not completely flat, allows them to be bigger in size. The droplets tend to run out of space and they merge together, forming heavier droplets that are forced to flow downwards by gravity. I then started to work on different 3d models of the shapes of bumps and how what they should be like in terms of form and function. I then came to the conclusion, based on theoretical evidence, that what I called “the crocodile eyes” (shown in figures 31, 32 and 33) tend to be the best simulation for this natural phenomenon. The bumps get this name by having a curvature on the top of the bump in which the water should start collecting.

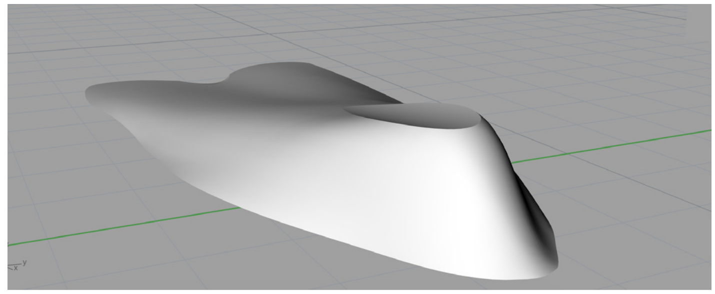


Figure 31

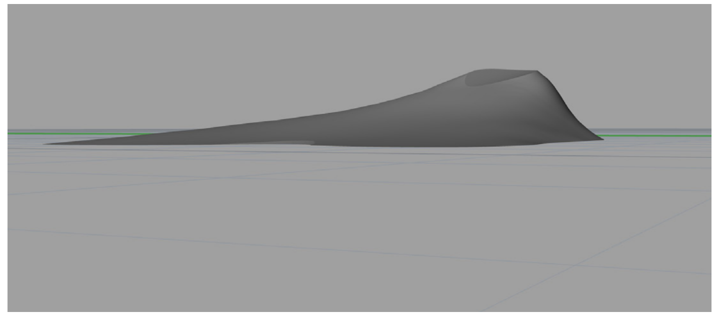


Figure 32

I was posing everything as a theory and in sketches while not really believing that it would work well, until I read the article by William Herkewitz published on February 24, 2016 that showed the amazing discovery by mechanical engineer Kyoo-Chul Park and his team. This pattern (figure 34) is a combination between the bumps on the back of the Namibian Desert beetle, combined with spikes from a cactus along with the slippery surface coating of carnivorous Pitcher plant. Having these three biomimic inspirations, the team was able to show footage of how the droplet starts forming and how it will make it 10 times more efficient in turning vapor into water than any other surface.

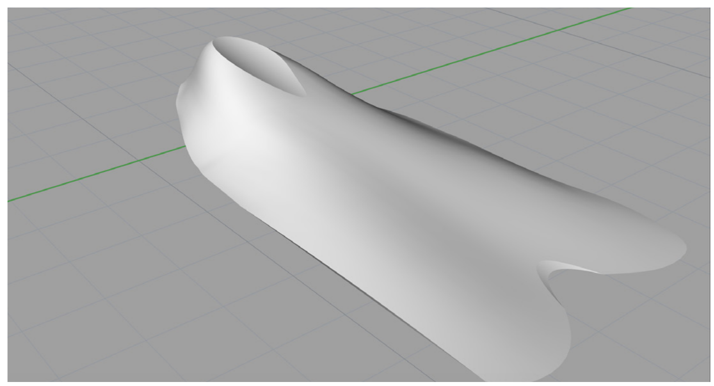
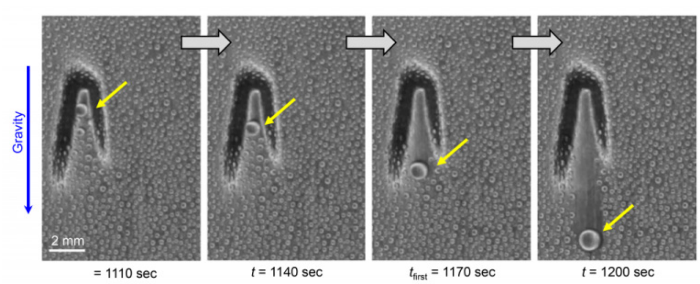


Figure 33



Copper 3d printing

After seeing the shape discovered by Mechanical engineer Kyoo-Chul Park and his team I felt that I was on the right track and it was not a theory in my mind anymore. I then finalized the 3d model that I wanted to test and 3d printed it in Copper and got it shipped from Belgium. The plate (figure 35) is a testing prototype out of which no one will be drinking so having it in copper seemed to be a good idea since it is around 20% of the price of stainless steel if printed with the DMLS 3d printer, which gives the smoothest and most precise surfaces. The results were astonishing when I came to test them as this piece (1.5” x 3” in total size) was able to gather 10ml in 15 minutes. First I did not see it as a good number but then when I did the math and realized it is actually 960ml per day (almost 1/3 of a gallon) I started to understand how useful this device might be. I was aiming for having the whole device collect 2 liters per day (almost 1/2 gallon) since this is the minimum human consumption, but now after realizing how small this piece is I believe the whole device could deliver more than a gallon per day.

In the video documenting the condensation happening on this copper plate in a controlled environment can be viewed on this link “https://vimeo.com/163973057”. It explains also how the idea of the droplets sliding down the surface hence freeing more space to allow for more water to be condensed.

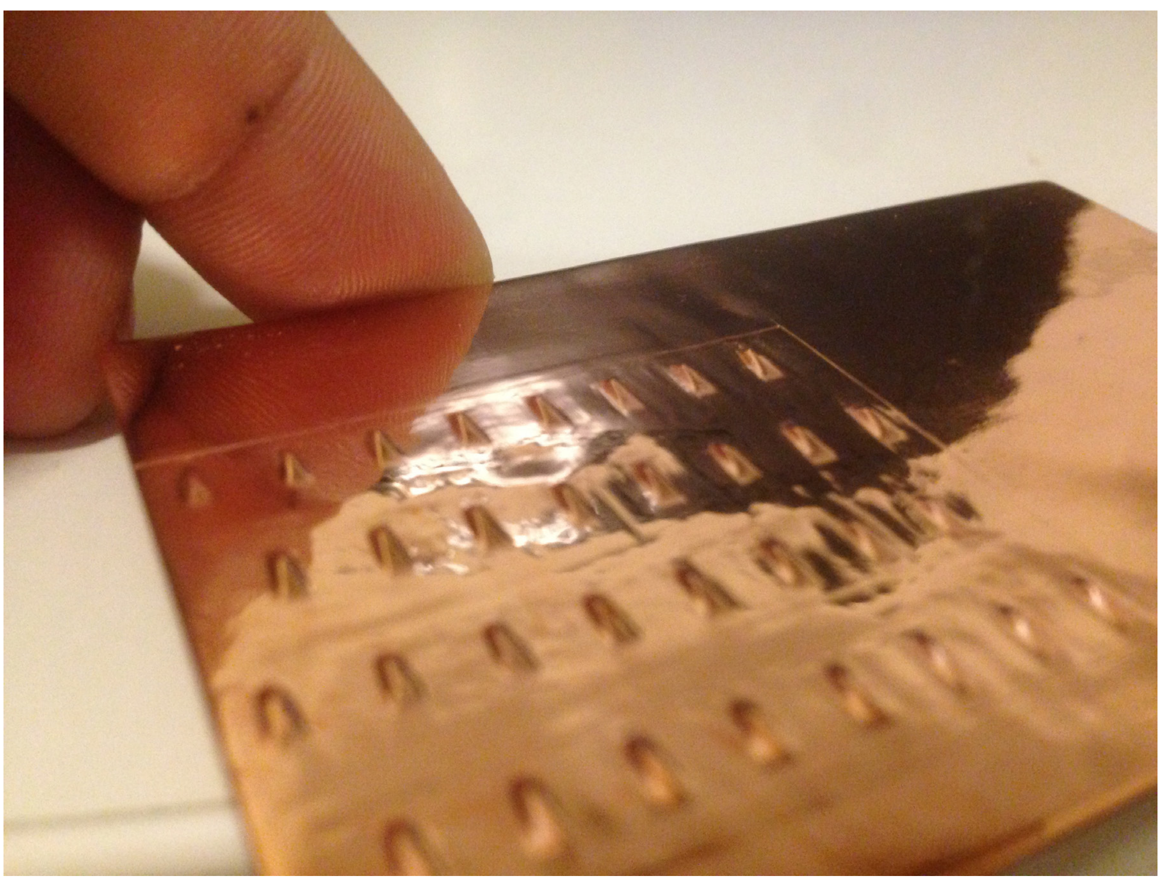


Figure 35

I later wanted to experiment with the idea of having the patterns attached to pillars instead of a flat surface to allow for better air and water flow. So I printed another piece (figure 36) also in copper and was able to test it out in an artificial environment as well.

Each of the three pillars in this piece have a different curvature and a different pattern shape. I wanted to test them out as well to know if there is a difference in the pattern being effective or if I was misguided. In this video “https://vimeo.com/166155367 “ it was evident that the difference in the pattern and curvature definitely makes a difference in the amount of water being collected and how it flows.

This version was not as successful as I wanted it to be since it got almost the same amount of water by the flat surface. The biggest factor that affected this was that the outer surface of these pillars was not as smooth as the plate because it is simply harder to treat. This problem is just for the 3d printing and prototyping but if it is a mold then it will definitely be as smooth as any other part.

The core of the device, also the part that actually does the condensation, should be a solid hexagonal prism in which there will be pillars with the pattern on them. This hexagonal prism (figure 37) and everything inside it is to be done in marine grade stainless - 316 stainless. One reason for that of course being is that it is highly conductive, but the other also evident reason is because it is safe to drink from if the condensation happens on it.

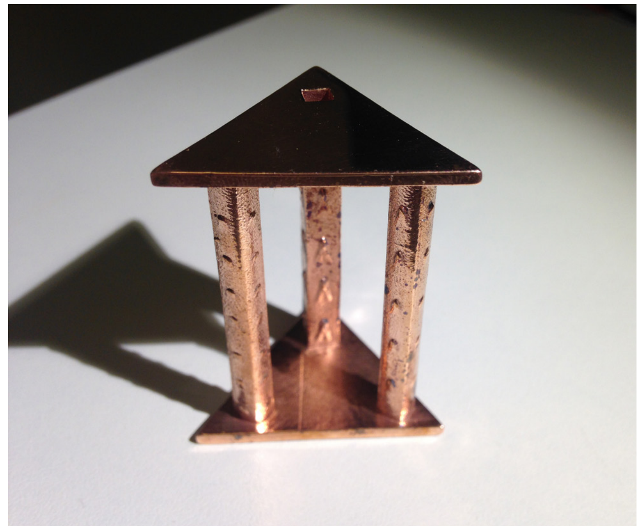


Figure 36

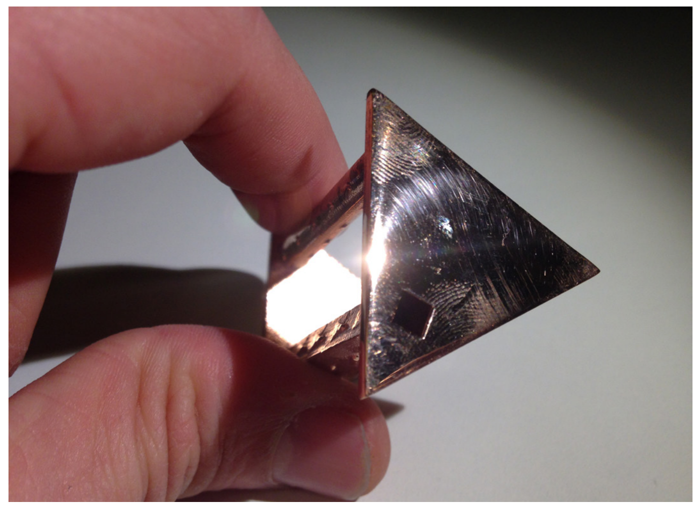


Figure 37

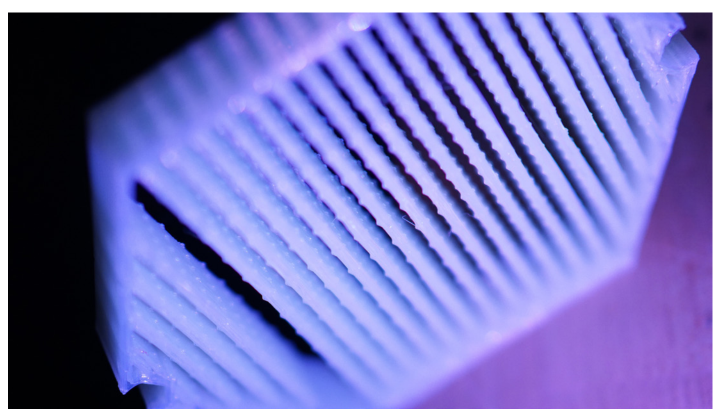


Figure 38

Each one of these pillars (shown in figure 39) will have 80 small crocodile eyes. The surface area of each of the pillars should be around 5000mm (196.8504”). Multiplying this number by the number of pillars, 50 pillars, we would get a surface area of 250,000mm in total, allowing a lot of room for condensation to take place.

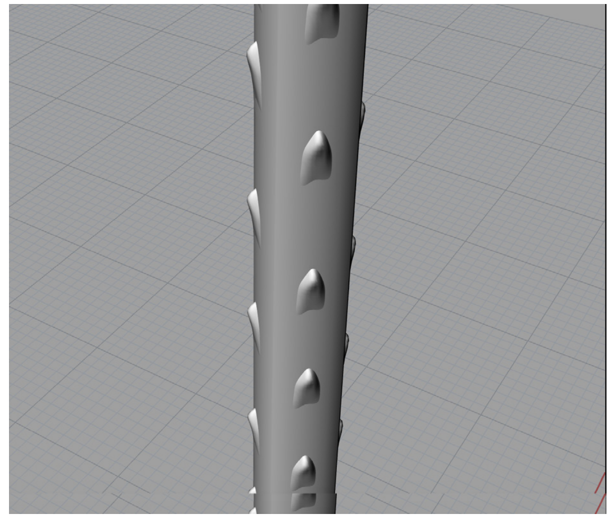


Figure 39

The core of the device needs two very important factors: all as one solid unit to allow for the best thermal conductivity, along with it being manufactured in a very precise scale since the precision of the curves is less than 1mm in precision (0.001”) in order to get the desired curvature.

Usability

This device is meant to be for people who are having a hard time finding clean water to drink and it should be spread in various countries all over the are around the tropics of capricorn and cancer. This would certainly require it to be very easy to use and universal in the way it is deal with. Knowing that many of the target audience speaks different languages is not that much of a challenge, yet knowing that most of them are illiterate is something that should be figured out. The solution for that appears to be having a manual that depends completely on visuals and does not include any writing.

Collecting the water should also be very easy and not time consuming. The device will have a threaded hole which will be the same size of a plastic bottle cap. This will enable the user to insert it, twist it and leave it to collect more water (figures 40 and 41).

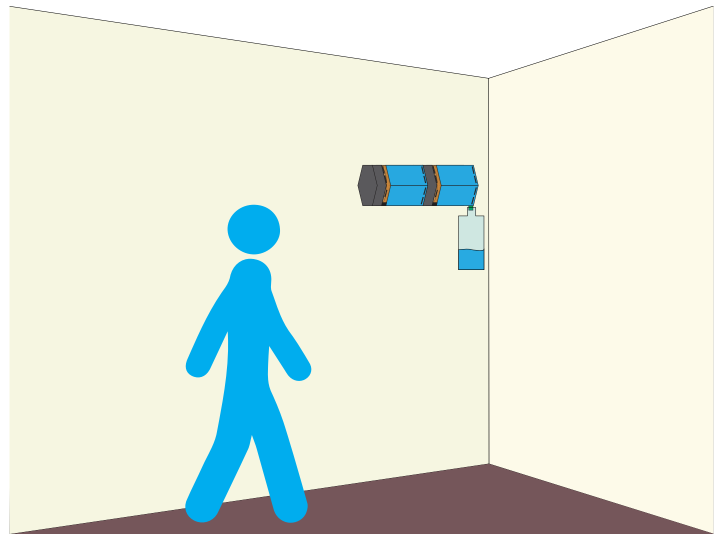


Figure 40

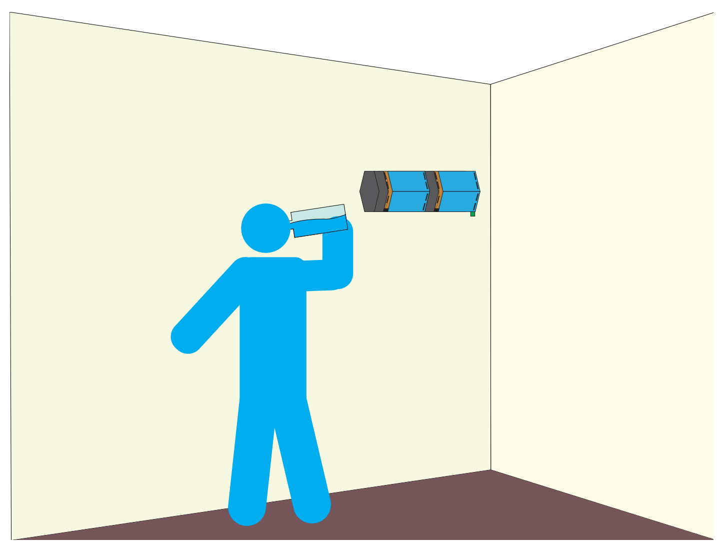


Figure 41

The device is also very easy to assemble and do maintenance if needed since it is not composed of many pieces and every piece fits the place it should be at. The device will be composed of 5 parts and their connectors. These five parts should be easy to connect by just attaching the heatsinks to the core, placing this group in the cover shell and tying the two rods to connect them with their hands. The cover assembly is more evident in the steps in figures 42, 42.1, 42.2, 42.3, 42.4, 42.5, 42.6 having the cover which was 3d printed in plastic.

Figure 42

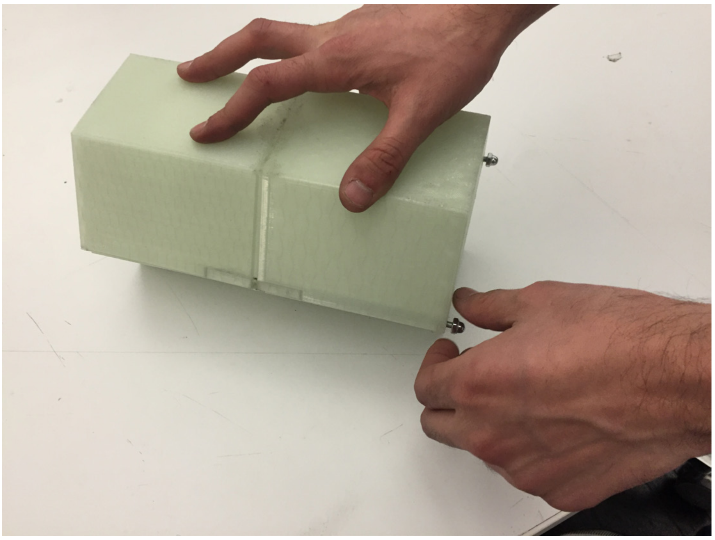


Figure 42.1

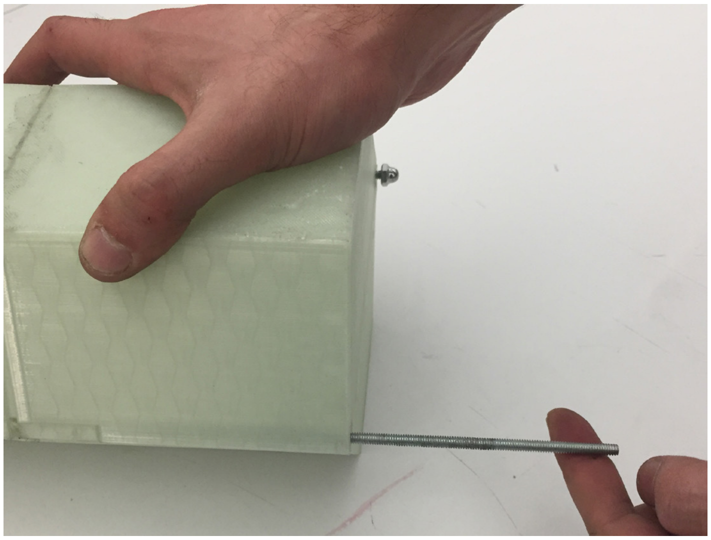


Figure 42.2

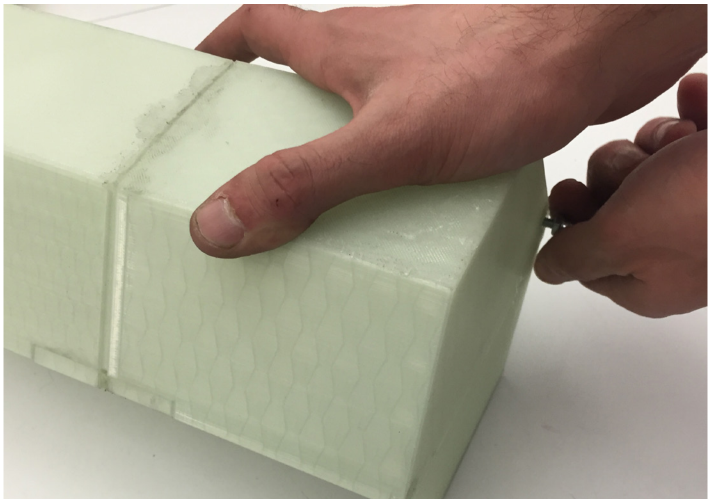


Figure 42.3

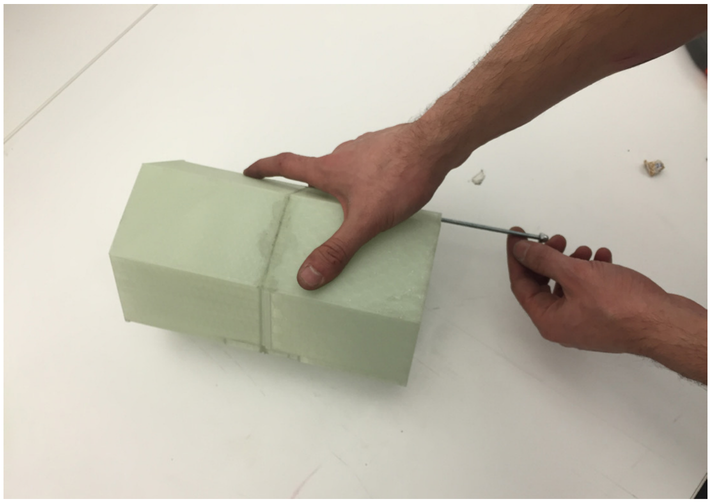


Figure 42.4

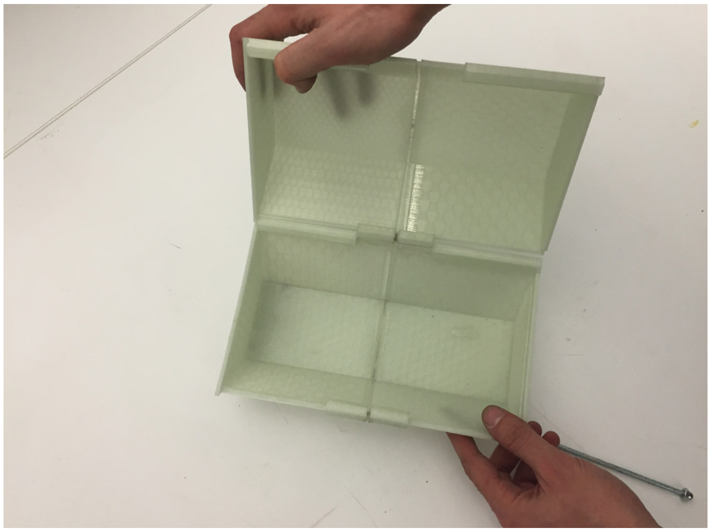


Figure 4.5

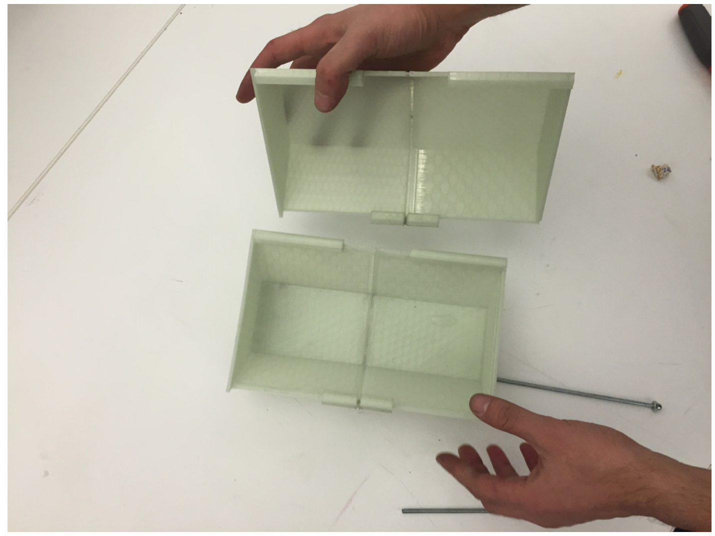


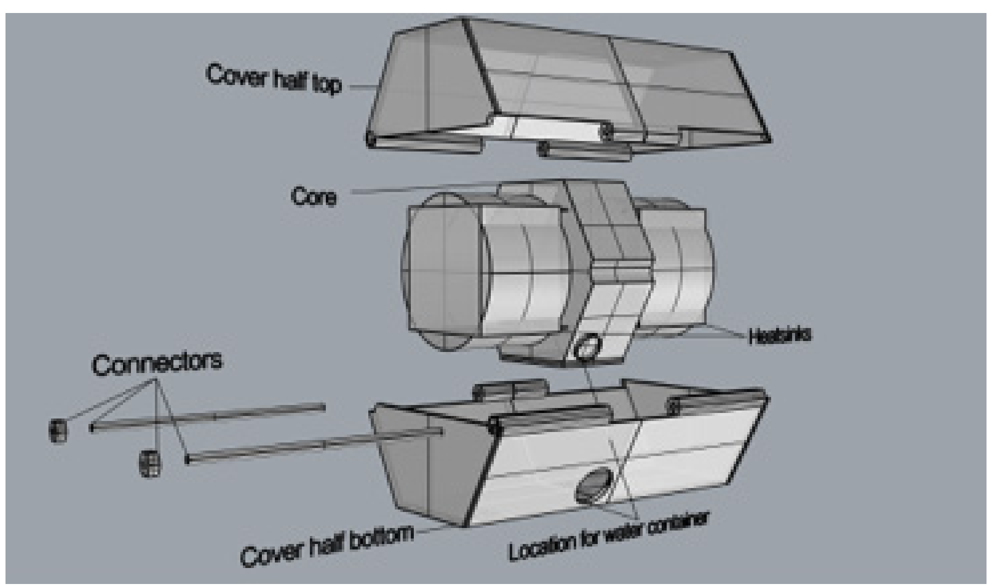
Figure 42.6

The device should have an adjustable filter and here is a prototype of it (figure 43) in wich the plastic bottle gets attached to the device and it is used whenever it is full.

The components of the device are explained better in the 3d model (figure 44) in which these five parts should be easy to connect by just attaching the heatsinks to the core, placing this group in the cover shell and tying the two rods to connect them with their hands as shown in the previous example.

Figure 43

Figure 44



Evaluation

And so after a lot of research and trying to test what the best form of each single unit is, it became evident that it needed to be concave to simply allow the every droplet to be heavier in comparison to the case of straight or convex in relation to the area it is taking. When the surface is convex (figure 43) the droplets tend to be spread out and flat making them very light and less likely to connect or be pulled by gravity. When the surface is concave (figure 45) the droplets tend to get closer to each other more easily and therefore increasing the probability of them connecting.
Another advantage of the convex shape is that every droplet tends to be heavier than those in the flat or convex surfaces. If we say the surface is 4mm then the droplet it can carry for example could weigh 1gram. If the surface was flat then the same 4mm would probably carry 3/4 grams and if it was convex it would carry 1/2 grams. Having every droplet heavier allows it to overcome the resistance of the surface and move easier.

The surface that will be collecting the water of the pattern will then be concave almost like a spoon. It should have the strongest curvature at the top of it since this is the part needed to push the water downwards in order to allow for more water to condense on the whole surface. The single unit (figure 46) will be very narrow and should have smooth edges at the bottom


Figure 43


Figure 44


Figure 45

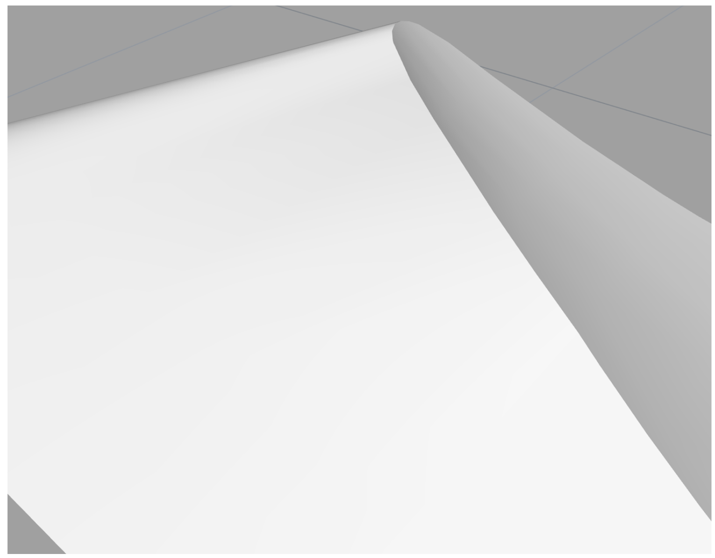


Figure 46

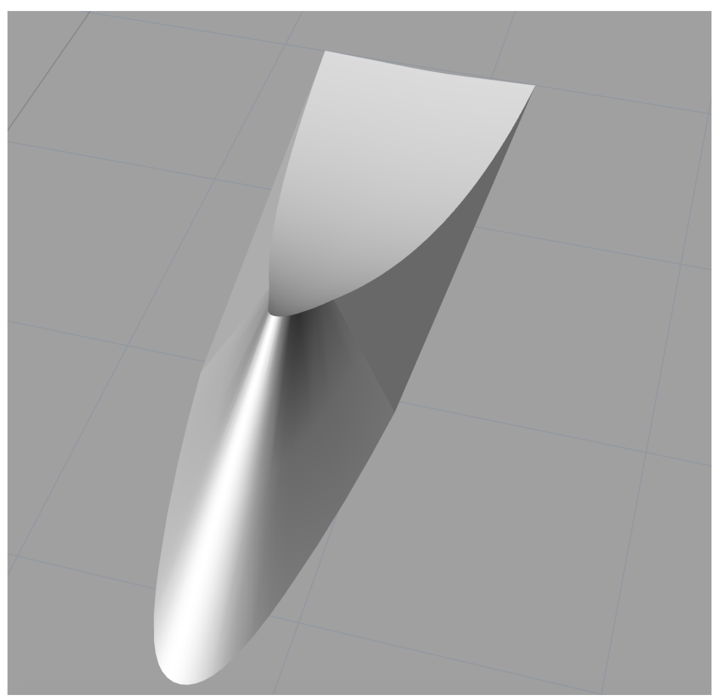


Figure 47

but sharper edges on top (figure 47). The reason for that being the ones on the top needing to be sharper in order to prevent the water from going in any other direction other than downwards, while the bottom parts need to be smooth since the water should flow by then and not get trapped at any point.

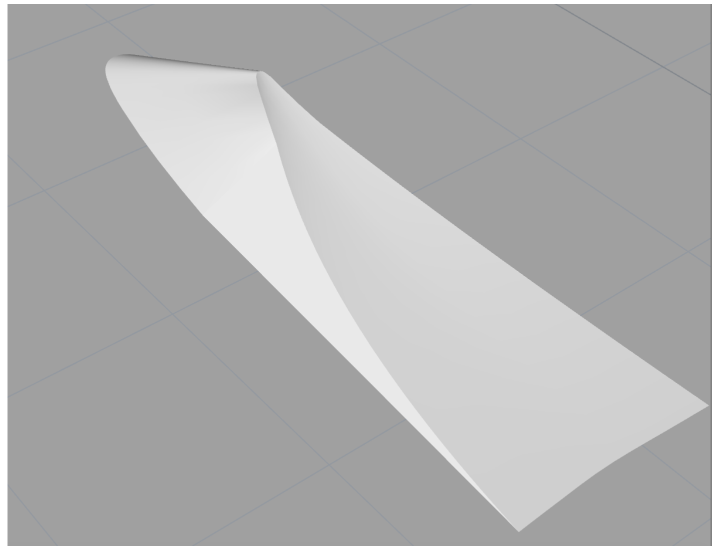


Figure 49

Having this narrow pattern will allow it to increase the numbers of patterns on each surface, allowing for more and more water to be collected. Having it concave should also increase the speed by which the droplets fall with making space even faster and by that adding more water. The results should be compared to the same a 3d print of the same size, which collected more than 0.5 gallons per day. This represents the possibility of producing an artifact that can be deployed as strategy for tackling the issue of drinkable water in multiple areas of need, wherever they may be.

Next steps

Having worked with NGOs when I was in Egypt and also while I was studying Sociology, I came to understand that there are a lot of complications that happen when middlemen are included. The incidents varied but the reason usually revolved around corruption, lack of control or even huge fights. In most of the cases the product needed to reach these people never did, and it was either destroyed or went to someone who did not need it as much but happened to just have more control. And by middlemen I mean the people who are armed and tend to have a say in everyone's lives not people working at grocery stores.

Not having middlemen eliminates two possibilities namely making it for free or having it being expensive but subsidized and sold through the subsidizing organization. The best option then appears to be selling it at a very low and affordable price since this will eliminate the need for middlemen. It will allow it to be sold on every shelf and it will be a matter of supply and demand rather than being a certain number of subsidized products for example and the competition is to get these particular ones.

Another major advantage of having it at a low price is that it would be easier and more guaranteed to invest in since the cheaper and the smaller a product is, while being efficient of course, the easier it is to spread around the world. And of course having it cheaper will also make it less vulnerable to being stolen or treated as an expensive item one needs to worry about.

And so the device should ideally range between $10-$20 which is considered also expensive for someone living below the poverty line, but if it was perceived as an investment it would be more convincing. It should also keep decreasing in price as much as possible as this will allow it to reach much larger audiences. This will be easier when everything is bought and shipped in quantities. The Peltier plates are available on Amazon for less than $2 while the CPU heatsinks are available on Amazon also for less than $5. The stainless steel in would cost less than $10 and the plastic will cost less than $3. So having 2 heatsinks, 2 Peltier plates, 1/2 kg of stainless steel along with the plastic will cost $27 using Amazon. This price will be cut down to its fifth if it was bought, produced and sold in quantities.

There is competition in the areas where this project should be but they are not very similar to this device. The closest competitor to it in terms of size and price is Lifestraw but the disadvantage of it is that one would have to be at the place where the water is in order to drink. AIRO is the device using the most similar technology and it has a small size but it will cost $320, which is also not very close to competing. The four-quadrant illustration (figure 50) shows what products are competing with device in a clearer manner.

Competition

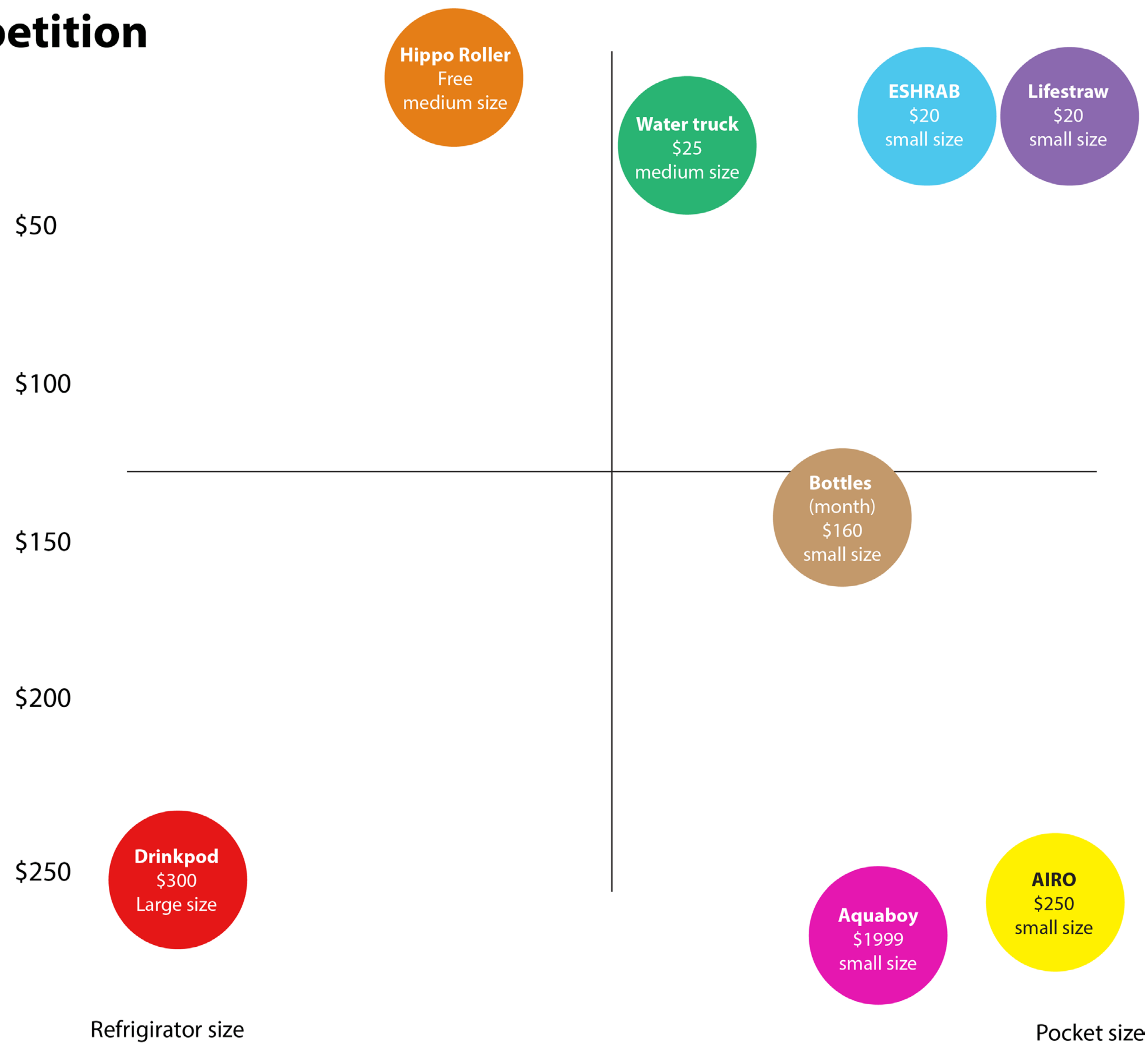


Figure 50

Assuming the device will cost $12 to manufacture and $20 to sell, here is a graph (figure 51) that shows the financials for the next five years.

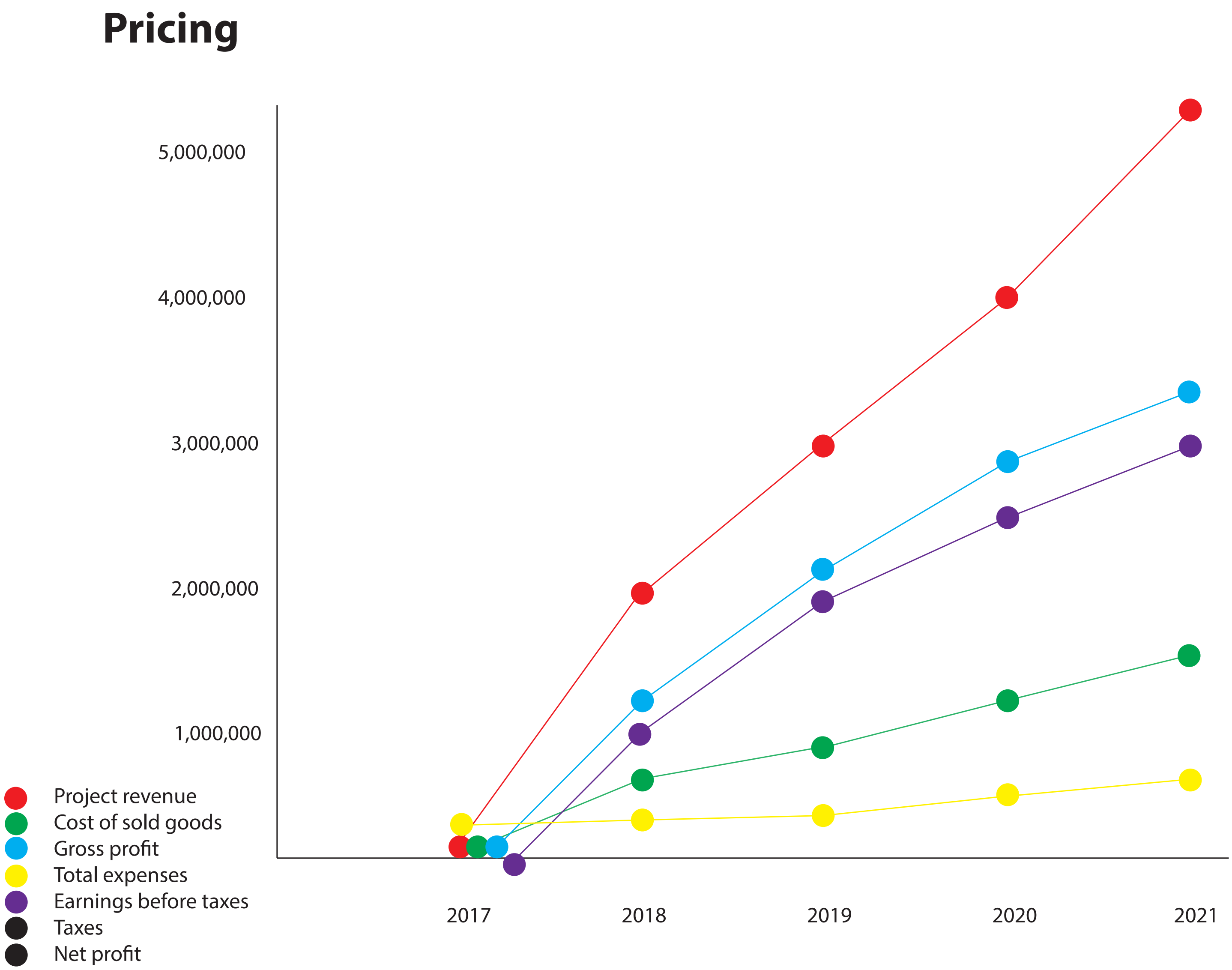


Figure 51

This project would ideally get into a Kickstarter or Indiegogo campaign that would attract funding and use it to finish the prototyping. As soon as there is a product ready to be sold it should start selling immediately in order to get the data from the whole year and planet faster. Then it would be ideal if investors got interested after seeing the product's success on the campaigns and in the actual market. Here is an overview of the timeline (figure 52) that also explains the next steps in a clearer manner.

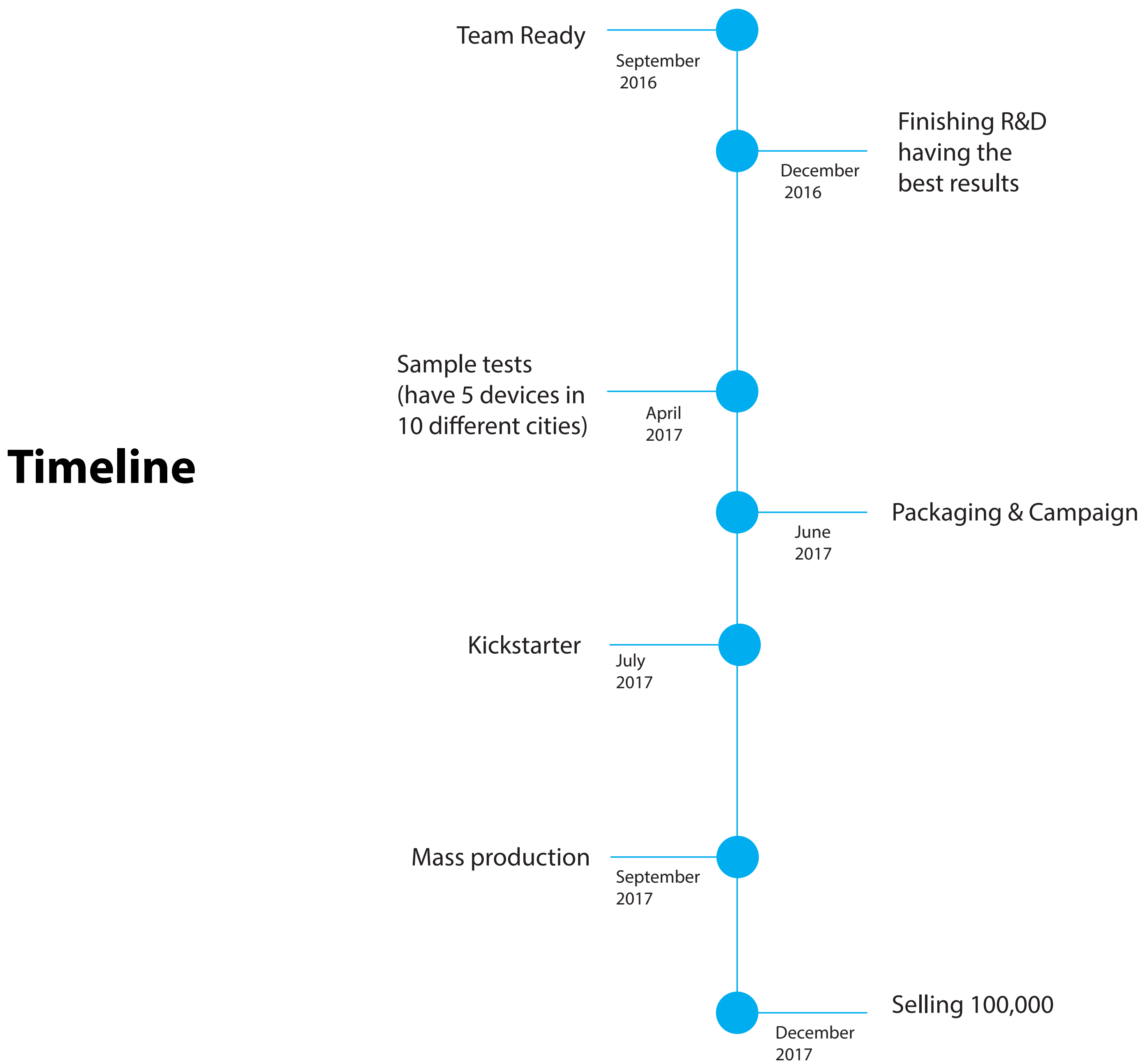


Figure 52

Conclusion

Being able to collect more than 2 liters per day and by that satisfying the minimum human survival needs is a great thing of course and is something that could save many lives. Yet being able to actually penetrate the cycle of poverty and eliminating the fears of getting diseases, consuming a lot of time, spending a lot of money, risking your life is something that might make many people sleep at night in peace knowing they have at least one problem off their minds. It does not have to be something very expensive and it should actually not be in order to succeed. One does not need to renovate their whole building in order to be living sustainably, but rather by replacing smaller elements one by one it could be easier to get closer to this goal. And when one loops with nature and is able to get into its cycle then the success is much greater than trying to resist it and ending up spending too much money, time and effort. It is amazing how many solutions are there and how biomimicry tends to make our life much easier in much more sustainable approaches as well. We need to learn how to benefit from nature without destroying it, and who would be better at teaching us how to be part of the cycle of nature other than nature itself.

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