Deepening

Team Member

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Introduction

My deepening is about desalination methods. It will consist of a description of the different methods of desalination, a comparison between the methods, explains how the principles of the methods work, and do a benchmarking analysis to learn from the processes and smart ideas that already assist. Furthermore, my deepening will describe the way we thought about our design choices, and show the red line of the story from ideas to reality.

My deepening will consist of an explanation, comparison and benchmarking analysis in written form, then there will be design and prototype visualisation. This way of showing the different parts of my deepening ensures that I document the way of arriving at a prototype technology in the right order, through the right methods. Therefore my deepening will start from scratch defining the methods and processes to explain my reasoning for the design choices made in the design exploration phase of the semester project, after that, I will dive more in-depth into the methods, what are the pros and cons, the physical restrictions, and the differences between the two.

After that, I will go even more in-depth into one of the methods, depending on the method is most appropriate. A benchmarking analysis of the limited amount of product that exists will indicate what design ideas make the products in the field successful. Combining, adding and optimising these design ideas is our guide for designing our solution.

When most of the technical details are all clear, and I know the details of the factors that influence the design of the product I will explore the design and form of the product to put all of that knowledge into one product. Making sure our prototype technology is appropriate.

Intended Learning Outcomes

I want to learn how to do a benchmarking analysis, make design sketches involving cut-outs to show the inside workings of a project, and learn to quickly use a solid works model for design checking, in 3 dimensions. Furthermore, I want to learn how to decrease ambiguity by having visuals accompany the text, and just more practice for soft skills, like researching, writing and structuring a document.

- Learn how to sketch functional cut out design drawings.
- Learn how to do a proper benchmarking analysis.
- Learn to make Solidworks models for design exploration and sketch checking

The above-mentioned goals are my final intended learning outcomes.

Relevance

In the middle of my ikigai, there is a dream to become an inventor or creator. Product design and understanding the mechanical processes is one of the most important things for an inventor. It is a process that is essential if you want to solve problems by inventing physical products. The ability to understand the situation to be able to make things happen is a really important step in the process of making something. Understanding the process on a small mechanical level helps develop a general understanding of the product design. Designing through functionality is my style of designing, that is why is chose desalination processes as my deepening. The design part of problem-solving is the direction that I want to head into later in my career and in atlas. That is why I have a design visualisation component into my deepening. First getting a better understanding of the process of what you are designing for, then designing the product makes for a more thoughtful design.

I want to be an inventor; somebody who comes up with concepts and can design products to solve complex problems. Solving a problem (even though it is stated as a challenge) by designing a physical product (invention) is what this challenge is about. Only now the teams are pushed in the direction of problems related to COVID-19, the problem is just more specific. The general methods of design still apply. I will grow in experience by taking that part of the design challenge upon myself. Practice makes perfect.

The desalination process

The urgent problem

The problem is that refugees have to stand in line to get drink water, or water to use for washing their hands. These queues are high risks for the transmission of COVID-19. It is clear that a lack of drinking water is the direct cause of the queues. When investigating the stakeholder's geological surroundings it becomes apparent that a specific natural resource is available, however not in the appropriate form; the refugee camp is close to the sea, there is an abundance of seawater. That is where our prototype technology comes in. By increasing water autonomy by providing personal (or per tent) seawater filtration or distillation systems we can lower the transmission rate in the refugee camp, by reducing the need for queuing.

What is desalination

Desalination is defined as the process of removing salt and other contaminants from water for human consumption (Mallinson, 2016). Contaminated saltwater is desalinated to produce water that is suitable for human consumption and washing hands. During desalinating water, the desired clean water is separated from the concentrate of the contaminated saltwater. This highly concentrated by-product is called brine. The process of desalination is one of the only sources of water product that is not dependent on rainfall (Fischetti, 2007; Mallinson, 2016). Making this method of producing water particularly effective and reliable in areas with warm and dry climates with access to seawater.

One of the issues associated with water desalination is the energy to cost ratio (Mallinson, 2016). This issue is remarkably explained by Professor Lienhard from MIT, an expert in the field of desalination, in the following example:

> *“For example, a well designed thermodynamic power cycle might run at a 60% exergetic efficiency, while a well designed desalination system typical reaches 20-30% exergetic efficiency at best, and often much less. But many of the potential solutions for improving energy efficiency, such as enlarging a surface area for heat exchange, also increase the total cost of the system. Suddenly you’ve got an energy-efficient device that’s not at all cost effective. The issues of cost are particularly challenging in impoverished areas such as parts of India, where the need is dire but the ability to pay is low.”* (Mallinson, 2016)

Getting the optimum desalination system is a hard process that involves a great deal of research, refining and fine-tuning. Understanding the exact mechanical process is a mandatory piece of research to be taken into account when optimizing a desalination system. The following section will cover the overview of the processes involved.

The different methods of desalination

When it comes to desalination, the overall quality of the water is determined by the total dissolved solids (Oram, 2020). However, the TDS is not a good indicator for water quality, what is effectively measured is the amount of minerals dissolved in the fluid, not the water quality or if the water is within the regulations of safe consumption. A TDS reader measures the conductivity of the water, thus the number of dissolved metals in the ionized form (team, 2020).

For distillation, the total dissolved solids in the liquid do not matter *(as long as the dissolved solids do not have the sameor a lower boiling temperature)*, for membrane filtrations however this is different. The more TDS the more energy in the form of pressure is needed to separate the permeate(the clean water) from the brine. When choosing the appropriate desalination method this needs to be taken into account.

One of the dissolved solids in seawater that limits the use of types of membranes is salt. When salt is dissolved in water it is broken apart in a positive and negative ion, these very small charged particles are difficult to filter out. The amount of total dissolved solids and charged particles in the water therefore are the requirements for the desalination method. The only method of membrane filtration, which filters out dissolved salt particles is reverse osmosis filtration.

There are numerous methods of desalination. These methods are grouped into two groups: distillation and membrane filtration. There are numerous sub-methods of these umbrella methods. In this deepening, I will be discussing the ones most appropriate to the situation of our stakeholder.

Distillation

The process of distillation is a way of separating a liquid of the solids and liquids dissolved in it. A heating source separates the two components through a difference in boiling point. The desired liquid substance will evaporate and is then cooled down and caught in a liquid state, the residue of all the dissolved solids and liquid remains. For the method of distillation, this is the brine.

The method of distillation requires a liquid to be vaporised, utilizing an external heat source or a high-pressure vacuum chamber. This method demands a great deal of energy. As an inspiration for desalination methods the natural processes of evaporation and cloud forming could be utilized, it becomes apparent that there is an abundance of natural energy waiting to be harnessed. The sun is a free, reliable and powerful source of energy. There is one method of distillation which uses the heat of the sun, namely solar thermal powered desalination.

Solar thermal-desalination methods make use of solar radiation primarily in the infrared (IR) range to power the desalination of saltwater to freshwater. (Reif & Alhalabi, 2015). The specific method within solar thermal-desalination I will be focussing on uses the thermal energy of the sun to evaporate water, then the pure water is cooled down on a cold surface, and stored in a container for later usage.

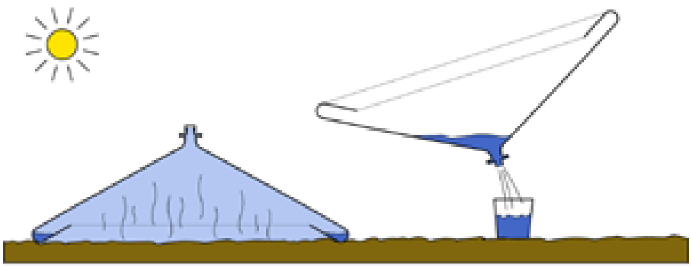


Fig 1: An example is the water cone. as depicted in the figure above. (NAIB, 2007)

Membrane filtrations

Membrane filtration is a separating method, this method is characterized by the ability to separate molecules of different sizes and characteristics. Membrane filtrations use a semi-permeable membrane that lets through molecules of certain sizes while it blocks others. The water stream on one side of the membrane is passed through the membrane and through that the water is separated into the permeate and retentate. The separating force is created by having a pressure difference. Membrane technology is relatively cheap, in energy usage and production costs, however, this is highly dependent on the solids dissolved in the water. (Laval, 2020)

The semi-permeable membrane consists of a thin barrier. The pores of such membrane are extremely small and pressure is required to force the liquid through them. In some of the specific membrane filtrations, like reverse osmosis and ultra-filtration, the pores in the membranes used for nanofiltration and reverse osmosis are so small that they cannot be seen even with a scanning electron microscope. (Laval, 2020)

There is only one membrane filtration that can filter dissolved salts out of seawater; reverse osmosis. Therefore I will mainly look at reverse osmosis, as a membrane filtration method.

Reverse osmosis

The principles of osmosis make this filtration system work. Osmosis is a way of diffusion. If there is a membrane or barrier where fluid can move through, but the dissolved solids in that liquid cant. The liquid will move through the membrane and make the concentration of the dissolved solids the same on both sides. (water, 2020)

For example, if the liquid would be water and the dissolved solid would be salt, and on the right side of the membrane, there would be normal drinking water, left there would be salty water. Then the following would happen: the water at the drinking water side would pass through the semi-permeable membrane and move to the saltwater side until the salt concentration of the liquid on both sides of the membrane is the same. This means that the water level of the saltwater side will rise, so there will be more (less salty) water and less fresh drinking water.

The idea of reverse osmosis is to not let this equilibrium balance out. By adding a lot of pressure to the saltwater the side the opposite of osmosis is going to happen. The concentration difference will get bigger and bigger. In the case of the water and salt example, by providing pressure the saltwater will be more concentrated creating fresh drinking water. (water, 2020)

This is the process of operation of a reverse osmosis filter.

Comparison of methods

Now there are multiple options for desalination of seawater, but which solution is the best one in camp Moria? The optimum desalination proses are impacted by multiple factors. The stakeholder and the environmental situation shape the need for certain features.

Taking into account the environment and stakeholder situation five priorities come up. The water production rate, production cost, maintenance, usability and mobility (transport) are these factors in order of priority.

If we look at the water production rate, figures depend greatly on the technique used and on the setup. Certain methods are more scalable than others. In this case, the methods are both efficient, and potent enough for a good working solution

In production cost, we see a world of difference. The reverse osmosis filter is very high tech, especially considering the size of the device. The hight tech and high water production rate come at the cost of difficult manufacturing, and higher production costs.

On the idea of maintenance more high-tech methods are more likely to break, and the repair is most of the time more difficult if not impossible. A lower-tech solution has fewer parts that can be missing, and less can go wrong if it does someone with a very deficient knowledge on the product might still be able to fix it.

Usability is one of the areas where there is a lot of difference between the methods. The options of Reverse osmosis we have looked at are active processes compared to thermal powered distillation, which is a passive process. For Reverse osmosis you need to be there, to power the pressure chamber, it means you need to put in a lot of physical work to get your work, but it's very reliable. Thermal solar-powered desalination, however, does the work on its own, you leave the desalination device in the sun, fill it with water and then you wait. The ease of use of this method is what makes it appealing from a usability standpoint. It does have some drawback since it is weather dependent and the distilled water has a lack of heavy metals and natural salts and can cause a mineral deficit long term.

The last factor is mobility or transport. In this case, it depends on the device made, both methods could be made highly mobile. Since easy transport is one of our requirements we will make sure that this factor will be satisfied, without compromising on the other 4 factors.

In conclusion, the reverse osmosis is more reliable but more expensive, harder to maintain, and harder to use than a thermal solar-powered desalination device. Because of this, our solution is going to be based on thermal solar-powered distillation. Even though there are drawbacks, like, weather dependence, the lack of minerals in the distilled water, and the requirement of high enough temperatures.

Since our product is to be an additional water source and not a replacement for bottled water, the solution is not meant to be solely dependent on, so a bad weather day will mean more queuing for water and not an immediate water shortage for the entire camp. Therefore the difference in reliability insignificant for our solution design phase.

Benchmarking analysis

For this benchmarking analysis, I am going to be looking at a (semi-)portable seawater purifier, that is cheap, durable and sustainable. It needs to be an as low tech as possible for it to be cheap, and be able to be made out of biodegradable materials.

The key performance metrics:

The key problem in the refugee camp has been identified as the clean water shortage, there are 8000 refugees in camp Moria, who have to queue to get access to clean water. The people in the refugee camp come from multiple different countries and backgrounds, that means the product should be easy to use and the user must be intuitive, because of the language barrier.

The key performance metrics identified with these problems and requirements are:

- The product should desalinate a minimum of 2.5 litres per day.
- The product needs to use 100 % free energy in the process of desalination every day.

Benchmarking areas

Some areas have used specialised, water purification gear in the past. The military and the outdoor trekking field both have some examples of portable water purifiers. However, there are only a handful of products that do water desalination. This form of purification is more severe since more and smaller dissolved particles need to be separated from the water.

ROWPU

In the military field, the American forces have been using water purification and desalination technology for decades.

To make sure water is available during missions, the military has adopted reverse osmosis (RO) technology in the form of “Reverse Osmosis Water Purification Units,” or ROWPUs. These devices create potable water from oceans, lakes or any other source of water that’s available. Without ROWPUs, it would be impossible for any amphibious unit or tank division to operate for an extended time in many areas of the world. Each ROWPU has a detachment of people to operate and maintain it. Each ROWPU unit can also supply fresh water for as long as the supply of raw water remains. Depending on the quality of the supply, ROWPUs can produce from 600 to 3,000 gallons of water per hour. The more dissolved solids are in the water the lower amount of water can be produced from it. (Nicoll, 2020)

A ROWPU is a complete, self-contained water treatment system surrounded by a rigid, metal frame. Typically, units like this are 8×10 feet, and 8 feet high. A unit this size generally weighs around 7,500 pounds. As with most water purification plants of any size, there are a series of pretreatment technologies for the water before it reaches the RO elements. RO technology treats water down to the molecular level. Larger particulates are more efficiently removed with media other than the RO membrane. With the suspended impurities removed, RO can more efficiently remove dissolved impurities. Portability is also a factor. (Nicoll, 2020)

The modular nature of RO technology makes it ideal for the battlefield. If a membrane module is damaged or plugged, it can easily be replaced with a new one. (Nicoll, 2020)

The military ROWPU is not small or lightweight. It needs an enormous amount of energy, that would normally be generated through gasoline generators or excess energy from a motorised vehicle.

QuenchSea

The only portable desalination device out in the outdoor trekking field is still in its prototyping phase. The product is called QuenchSea, the technology is based on a very small reverse osmosis and ultra-filtration membrane (Indiegogo, 2020).

“QuenchSea can produce 3 litres of water per hour with the resulting liquid said to meet World Health Organization standards. It was primarily developed to make an impact by providing access to clean fresh water globally. At its core is a special type of filtration known as ‘Reverse Osmosis’, which uses a semi-permeable, thin membrane with pores small enough to pass pure water through while rejecting larger molecules such as dissolved salts and other impurities like bacteria.” (Marches, 2020)

The quench sea technology uses a lever connected to a hydraulic system creating the 60 bars of pressure that are needed for the reverse osmosis process. The lever arm is collapsible and a foot paddle can be used to make use of the torque of the long lever. QuenchSea is cheap and very portable and works on “free” energy. (Marches, 2020)

QuenchSea is light, cheap, and uses human work as a power source. This product, however, is too complex and high tech to be used in a refugee camp and is not within our scope of products to improve.

Watercone

Other innovations like the Watercone come from an innovation standpoint, there to help people that need the support of having clean water.

The Watercone is a very simple and ingenious product. It turns saltwater into freshwater using only the power of the sun. Watercone is easy to use, very simple and doesn’t use any fossil fuel. On average in good conditions, one Watercone can produce 1 litre of water every day. Watercone user perspectives, it can be used to catch rainwater, and float on water. At about 20 Euros it would pay for itself in a couple of months and provide potable water a lifetime of 4 to 5 years. Watercone is made out of recyclable plastic. (NAIB, 2007)

Eliodomestico

Eliodomestico is such also an innovation to help people in developing countries get rid of water shortage.

Eliodomestico is a solar-powered water distillation device. It is designed by Gabriele Diamante to provide drinking water for families in developing countries. At the start of each day, seawater is poured into the black boiler on top of the solar still. As the day begins the black boiler heats up and eventually gets hot enough to boil the water, creating steam. The steam gets forced into the expansion nozzle at the top and then condenses against the condenser lid, where it then drips down into the catch basin below. At the end of the day, assuming it was hot enough outside, there will be 5 litres of fresh drinking water available in the basin. (Meinhold, 2020)

The efficiency of the Eliodomestico is mainly coming from the idea of separating the boiler and the condenser units. When these two units have separated the heat of the boiler can be kept at a higher temperature since the steam does not have to condense at the same place it is being produced.

Eliodomestico works without fuel, electricity, filters, and it requires no maintenance, except for cleaning the residue out of the boiler. The idea is that the solar still can be built anywhere from readily available, local materials. Any craftsman who can throw a pot can handcraft the main elements necessary for the water filter. The designer estimates that normal solar still costs around 100 dollars and only produces about 3 litres a day, while his Eliodomestico could be made for $50 and produce 5 litres. The design is available as an open-source project for anyone who wants to make one and is licensed under a CC Attribution-NonCommercial-ShareAlike 2.0 Generic License. (Meinhold, 2020)

Design opportunities

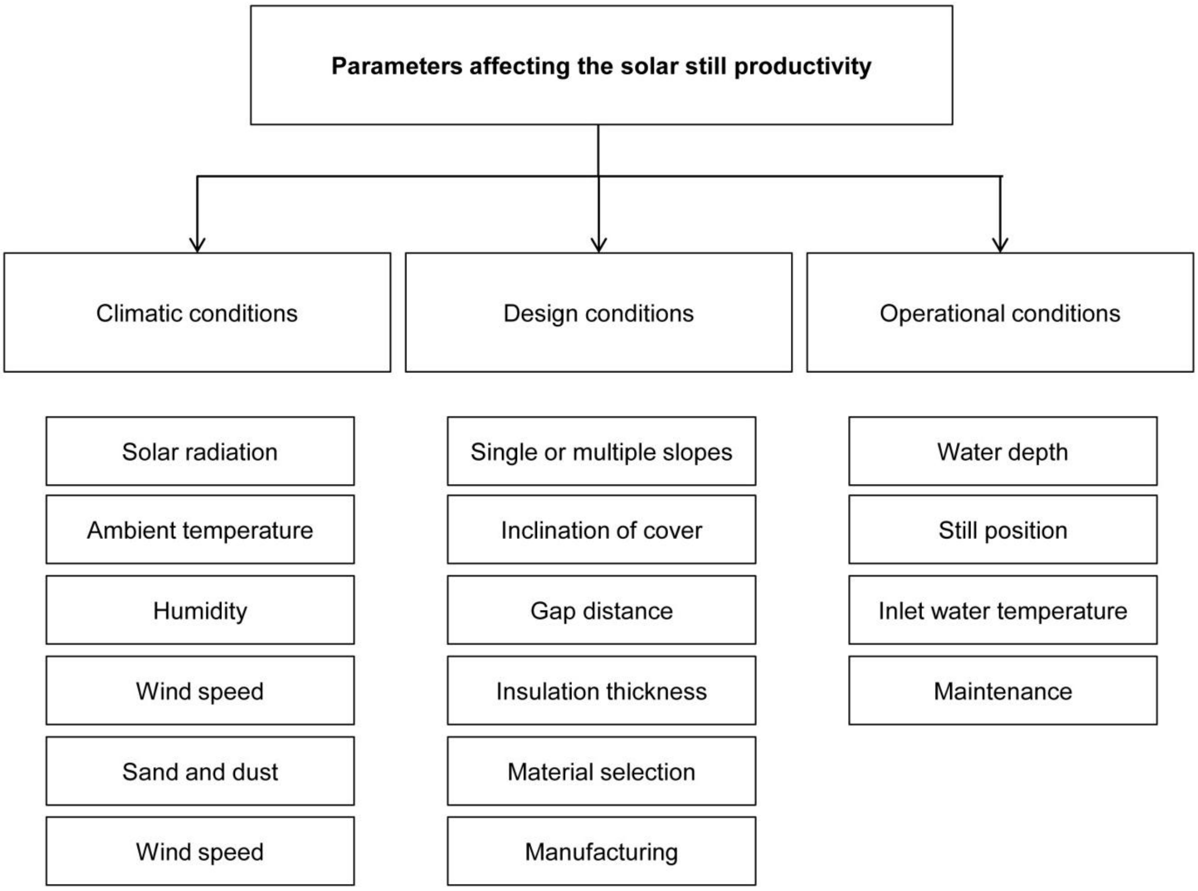
Design features that can be taken from the products in the different fields are:

- Making use of sustainable free energy, like solar power or human work.
- Increasing efficiency through a higher pressure build-up in reverse osmosis filter or separate the boiler and condenser units for a thermally powered distillation.
- Using plastic is lightweight, and can be made biodegradable. Because of its lightweight, the solution can be easily transported.
- Plastic can be injected-moulded, is relatively cheap.
- A system can be made cheap when the amount of parts necessary is as low as possible.

Through combining all these parts we can arrive at an efficient, sustainable and appropriate solution to the urgent water shortage problem.

Practical details Solar distillation

The following parameters affect the productivity rate of desalination for solar stills.



(Kopperdal, 2015)

From this list of parameters of solar stills, a few of these factors would greatly influence the productivity and efficiency rates of a solar still, while others only apply to specific forms of solar stills.

The wind speed, sand and dust manufacturing parameters are some of the most important regarding our environmental situation. Wind speed and sand and dust, can lower the production rate and are a threat to the proper functioning of the device.

Manufacturing plays an important role because the product needs to be cheap and accessible. Making that possible starts with an optimization of the manufacturing process through efficient design where manufacturing is taken into account. This indirectly means that the device should be an as low tech as possible while having the greatest productivity to material cost ratio.

Physical design requirements

What are the boundaries of a sun-powered distillation unit?

A large surface area for the sun to heat up is required, furthermore, it needs to be cheap, moveable and consist of the least amount of parts possible. It also needs to retain its productivity rate for a longer period of time (for example some clear plastics will slowly become more opaque and block sunlight).

The device should still work in colder time periods, and when it is cloudy, or windy. (an example of a solution could be a water storage tank, for periods of time when the filter does not (fully) work)

What are the boundaries of the system?

For a working reverse osmosis filter, the pressure needs to be in the range of 55 to 75 bar as a minimum (Schrotter, Rapenne, Leparc, Remize, & Casas, 2010). The higher the pressure the higher the permeate to brine volume ratio will be and the more concentrated brine solution will be produced.

For distillation, there needs to be enough pressure and heat built up in the distillation tank. Efficiency optimisation needs to ensure this condition.

There is a need for a power source, to produce heat and, or pressure (depending on the desalination method. This source should be cheap, green, and there should be plenty available, human muscles are also such a power source.

How to get the water container portable?

The device needs to be small enough to be carried/ transported by 1 to 2 adult peoples (for example QuenchSea(Indiegogo, 2020)), other military solutions are made to fit on humpies and in helicopters, and then a small generator is the power source. In the refugee camp, there is a lack of resources, so a generator is not suitable, but human power or solar power is free sustainable and quite reliable.

Filter size

The filter can be made small, it needs to be a combination of multiple filters, like ultra-filtration, activated carbon, sediment, and reverse osmosis. Sometimes a UV lamp is included to sterilize the drinking water by destroying the bacteria and viruses. (a combination of the above-mentioned filters needs to be fit in one system unless the desalination device uses the method of distilling). (Berkey, 2020)

The mechanism

The solar still works by the heating of the black boiler. The water will start to evaporate as the temperature and pressure in the boiler rise. Because of the increase in temperature and pressure the water will boil faster and faster. The created steam will go through a connection pipe to the condenser, in this case, the water storage tank. The transport of the steam happens as a result of the pressure that is built up in the system. There is higher pressure in the boiler than in the connection pipe and condenser.

In short, the seawater is evaporated and then caught in the storage tank The residue of impurities and salt will stay behind in the boiler. This is the technical process of the Solar Still.

The efficiency of this system is based on the separation between the boiler and the condenser units. This principle is from the opensource project of Eliodomestico opensource project by designer Gabriele Diamante. To honour this our product is open source and can be used by anyone, as long as it is kept opensource.

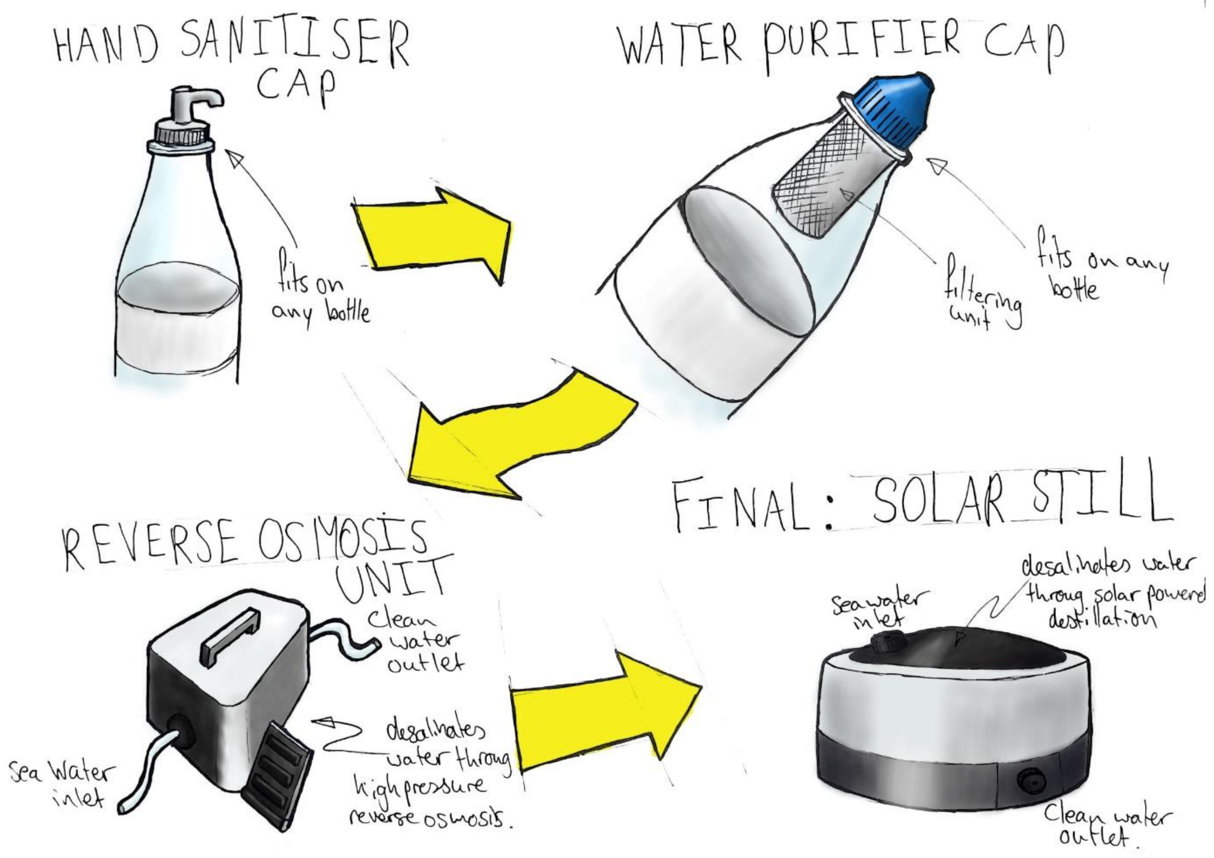
Our solution

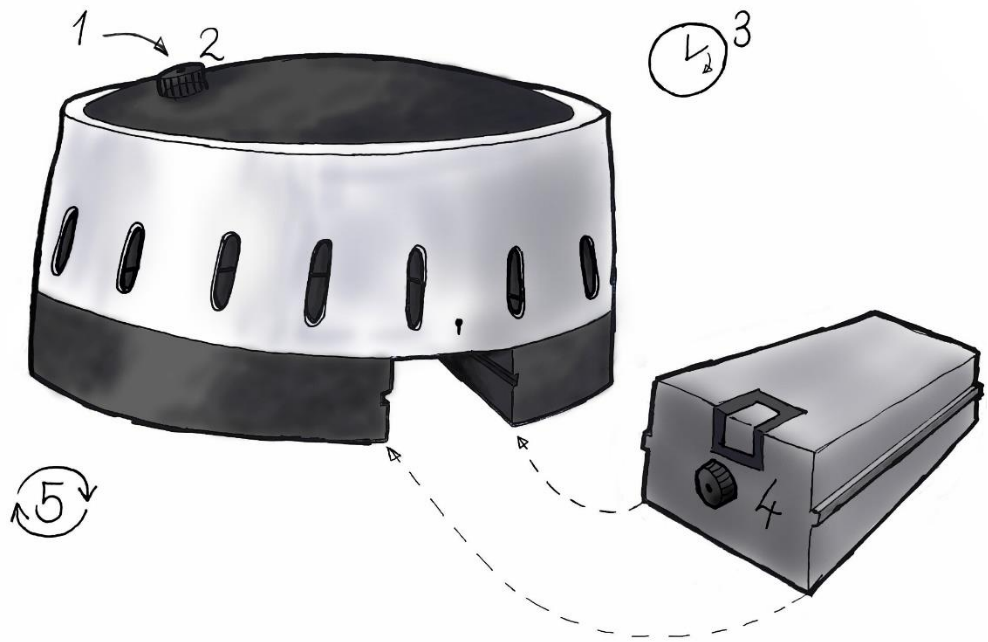
Through taking into account the restrictors and environmental parameters, we slowly arrive at a concept. A prototype technology that produces safe drinking water, uses clean and free energy, is easy to use and is 95% biodegradable. Furthermore, the solution is cheap and low tech, mass-producible, optimised for a shipment while increasing the efficiency of the normal square solar still.

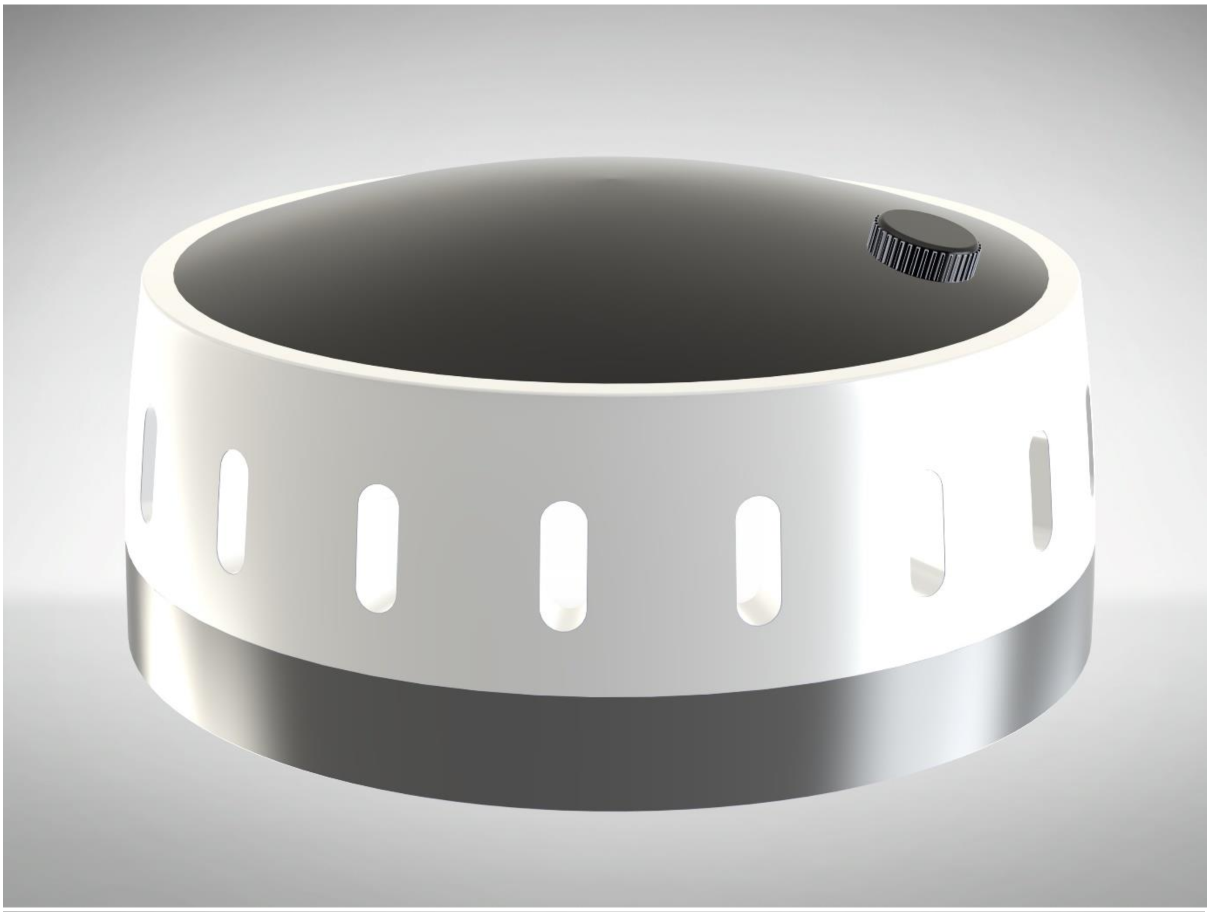
Our solution is a seawater distillation device, a solar still, that through evaporation of water filters water with only the power of the sun. The device is 3 times more efficient than normal solar still in the same conditions and it can produce an estimate of 5,1 litres of clean water a day. That is 10 litres per day per square meter.

the solar still is easy to use. In the morning the seawater storage tank on the top is filled with seawater. Then the watertight cap is screwed on, and the solar still is ready. At the end of the day, the water can be collected from the storage container, which is locked by a unique key. Then this cycle repeats itself daily.

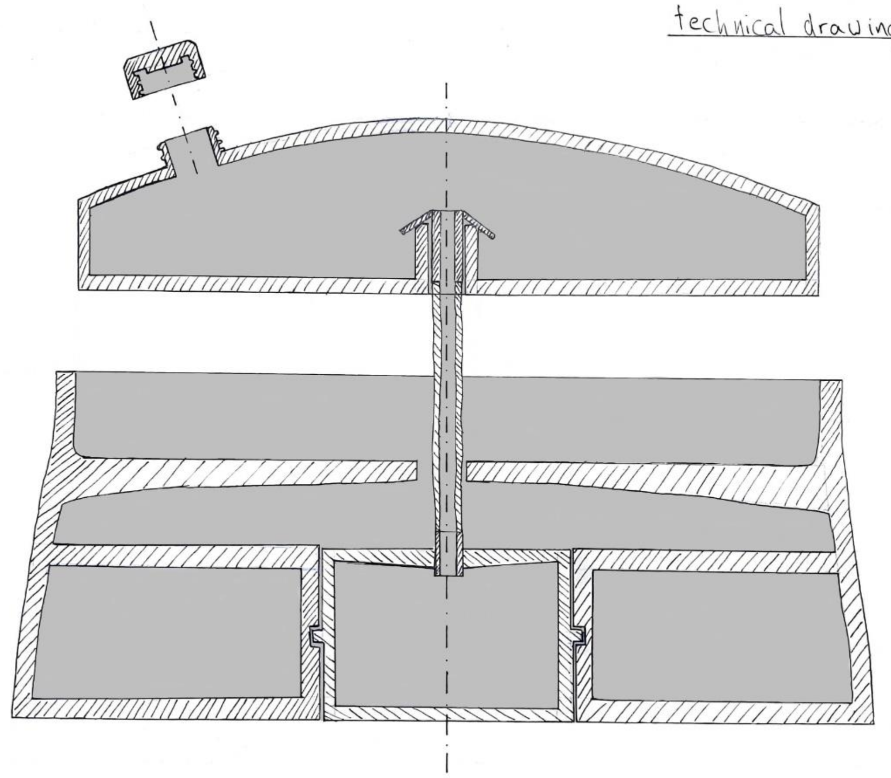
Design sketches

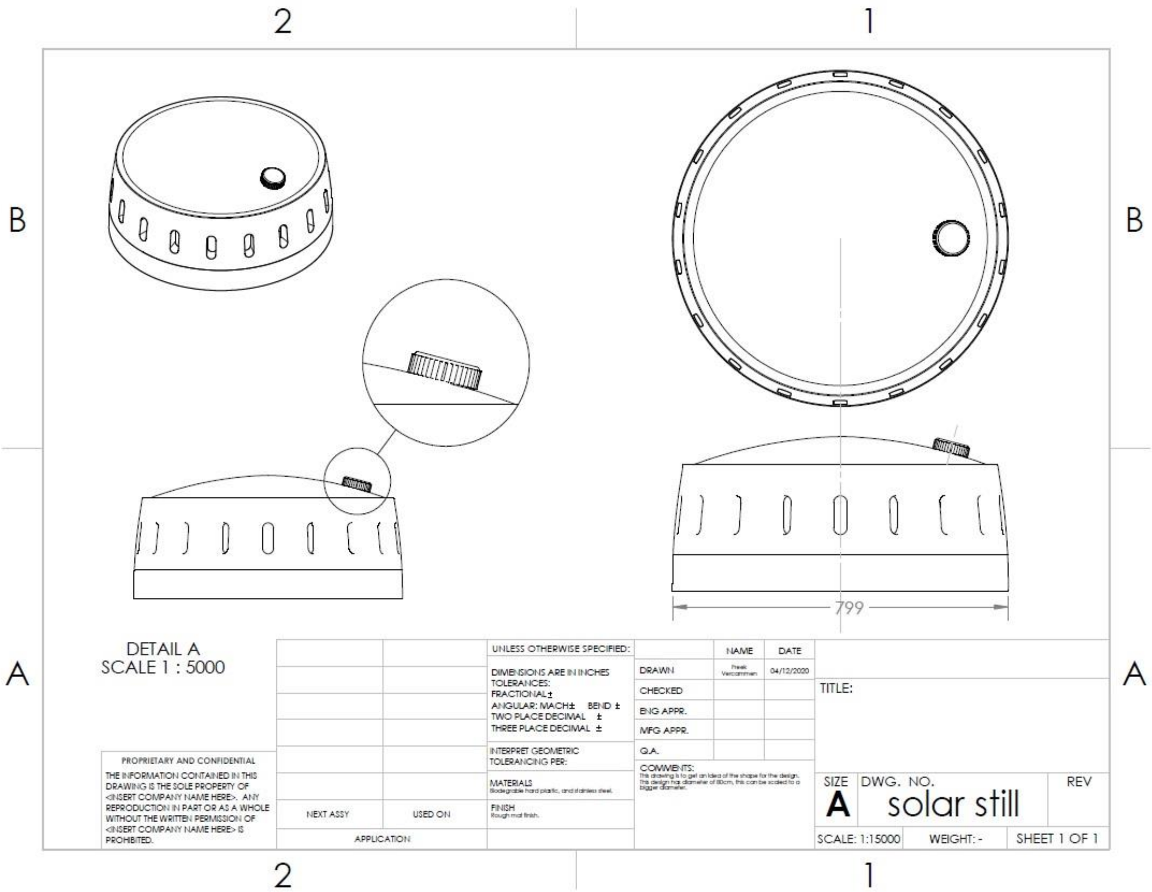


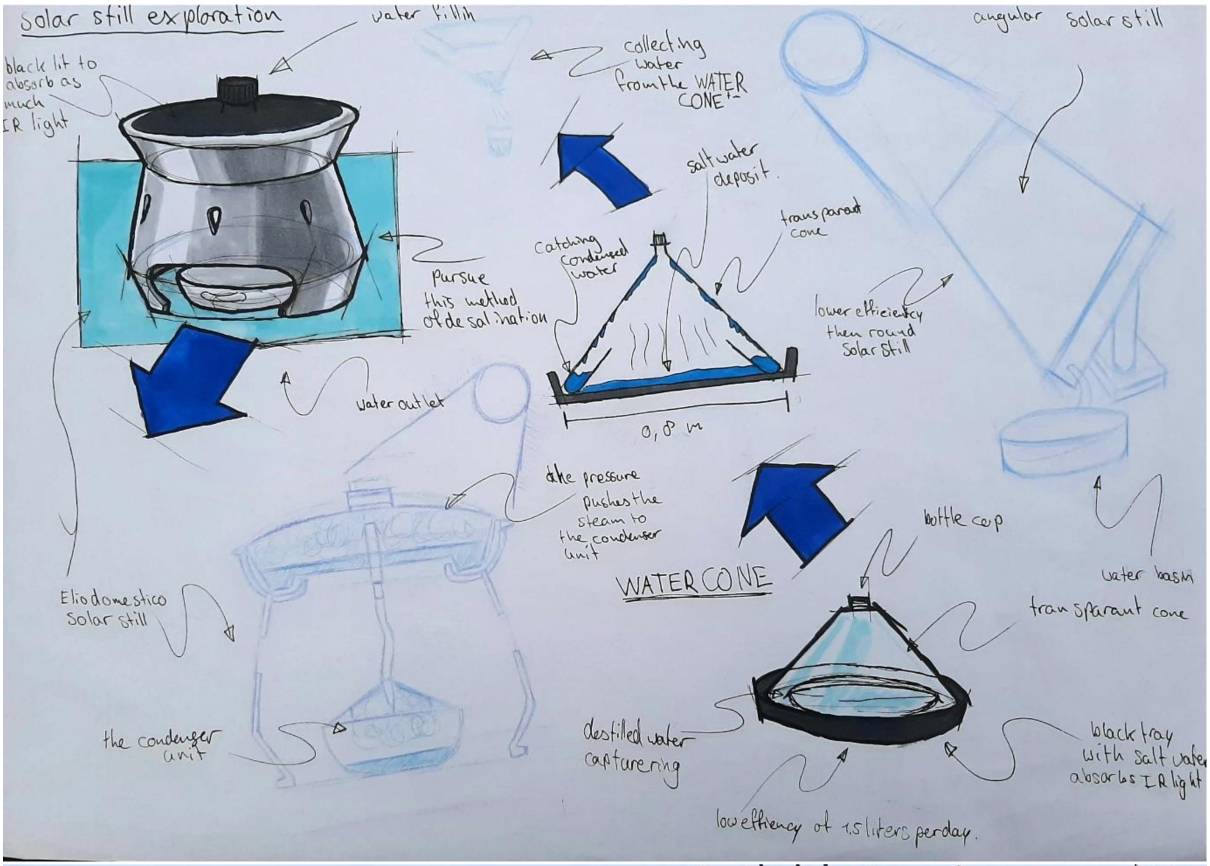





technical drawing






solar still exploration
water fillin
black lit to absorb as much IR light
collecting water from the WATER CONE
angular solar still
salt water deposit
transparant cone
catching condensed water
pursue this method of desalination
lower efficiency then round solar still
water outlet
0,8 m
the pressure pushes the steam to the condenser unit
bottle cap
WATERCONE
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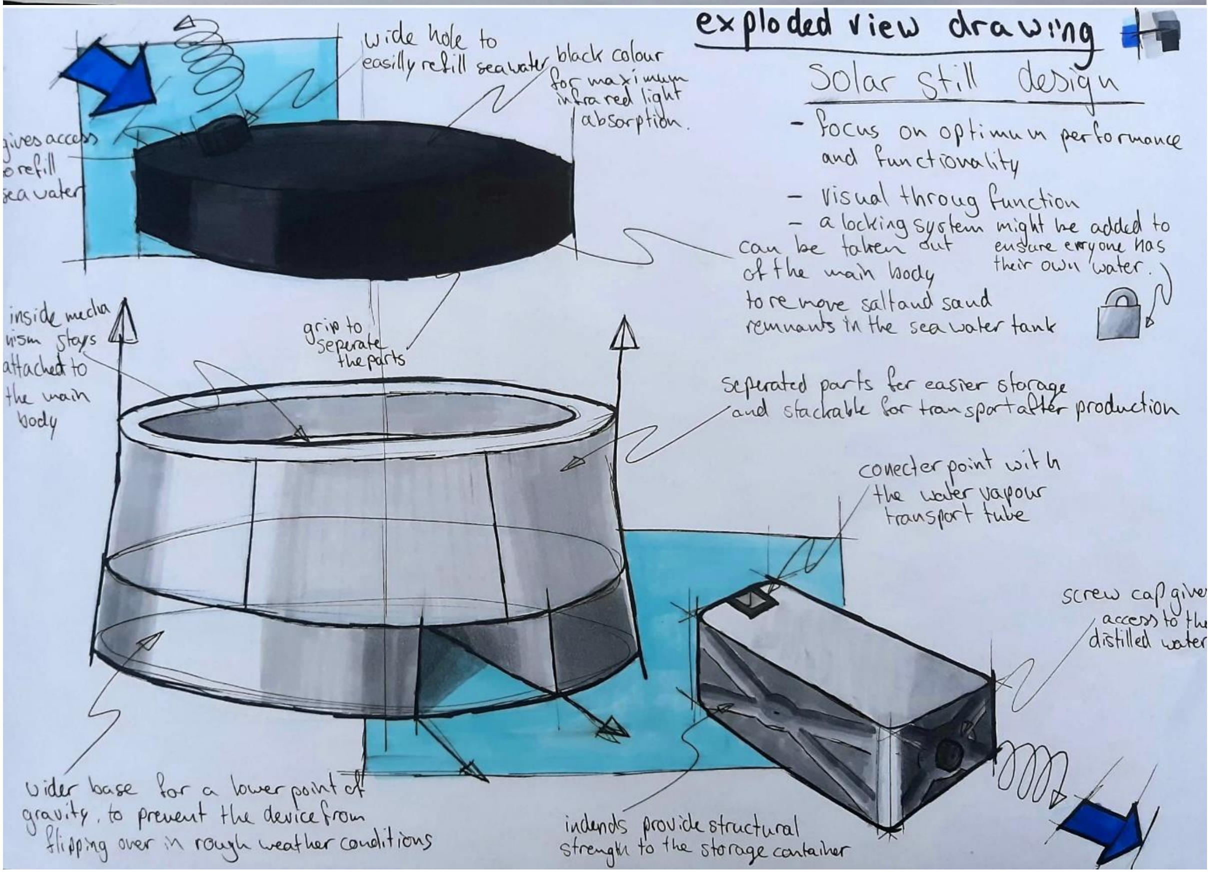
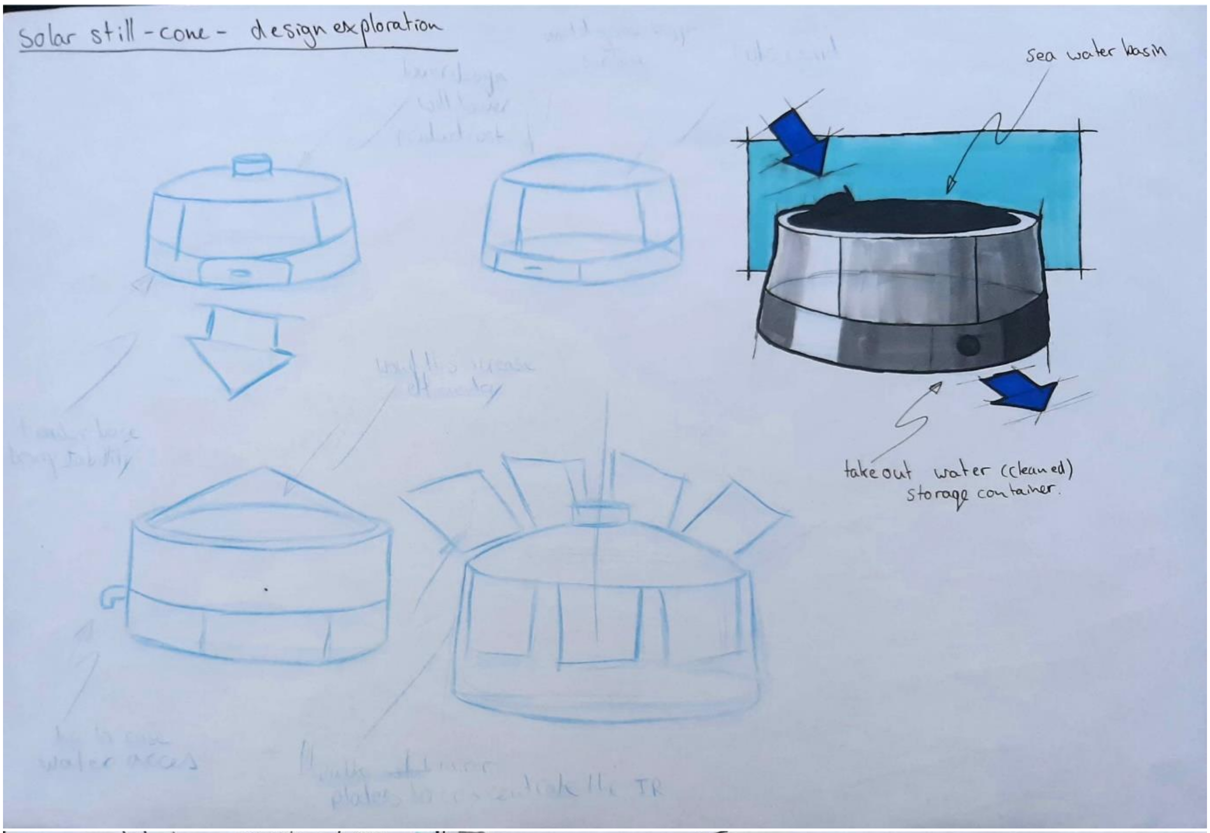
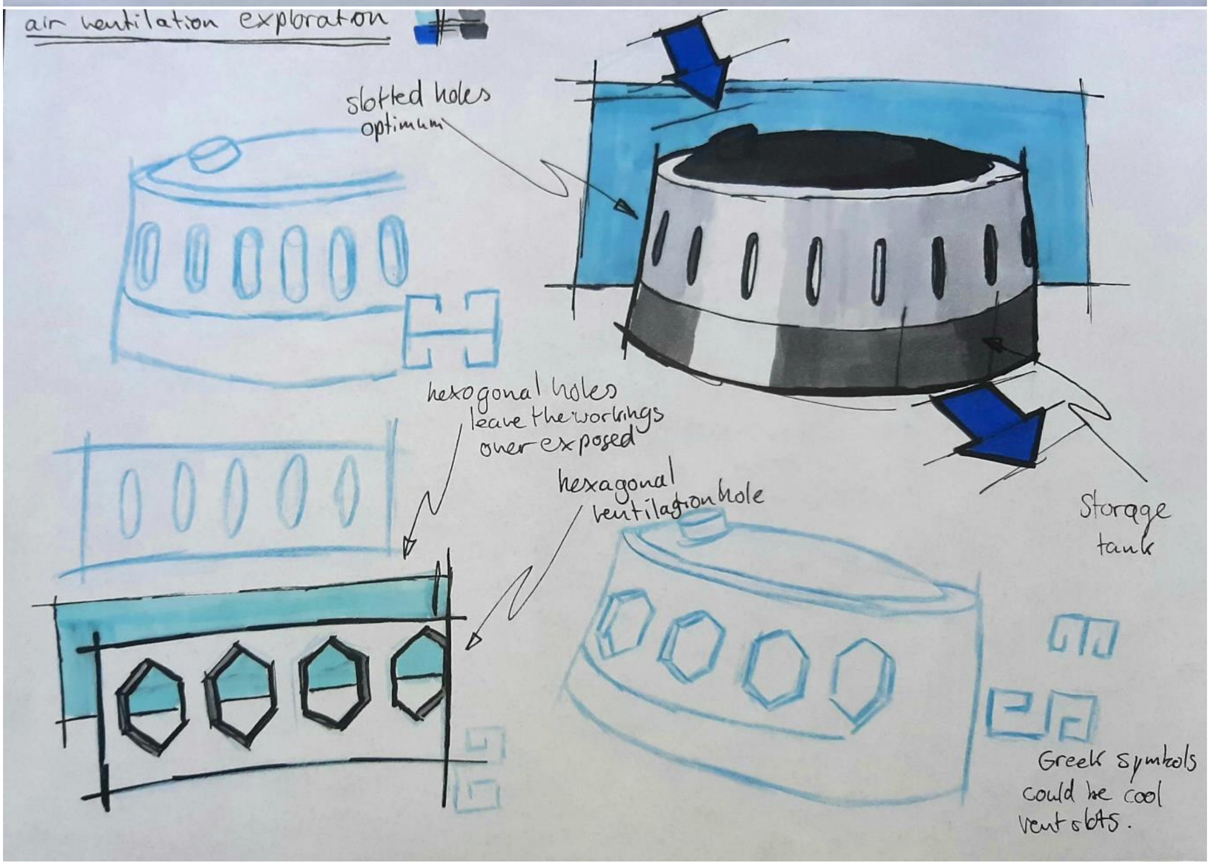
the condenser unit
destilled water captarering
black tray with salt water absorbs IR light
low effiency of 1,5 liters perday.


exploded view drawing
wide hole to easilly refill seawater
black colour for maximum infrareed light absorption.
gives access to refill sea water
Solar still design
- focus on optimum performance and functionality
- visual throug function
- a locking system might be added to ensure eryone has their own water.
can be taken out of the main body to remove salt and sand remnants in the sea water tank
inside mechanism stays attached to the main body
grip to seperate the parts
seperated parts for easier storage and stackable for transport after production
conecter point with the water vapour transport tube
screw cap gives access to the distilled water
wider base for a lower point of gravity, to prevent the device from flipping over in rough weather conditions
indends provide structural strength to the storage container


Solar still - cone - design exploration
Sea water basin
take out water (cleaned)
storage container.


air ventilation exploration
slotted holes
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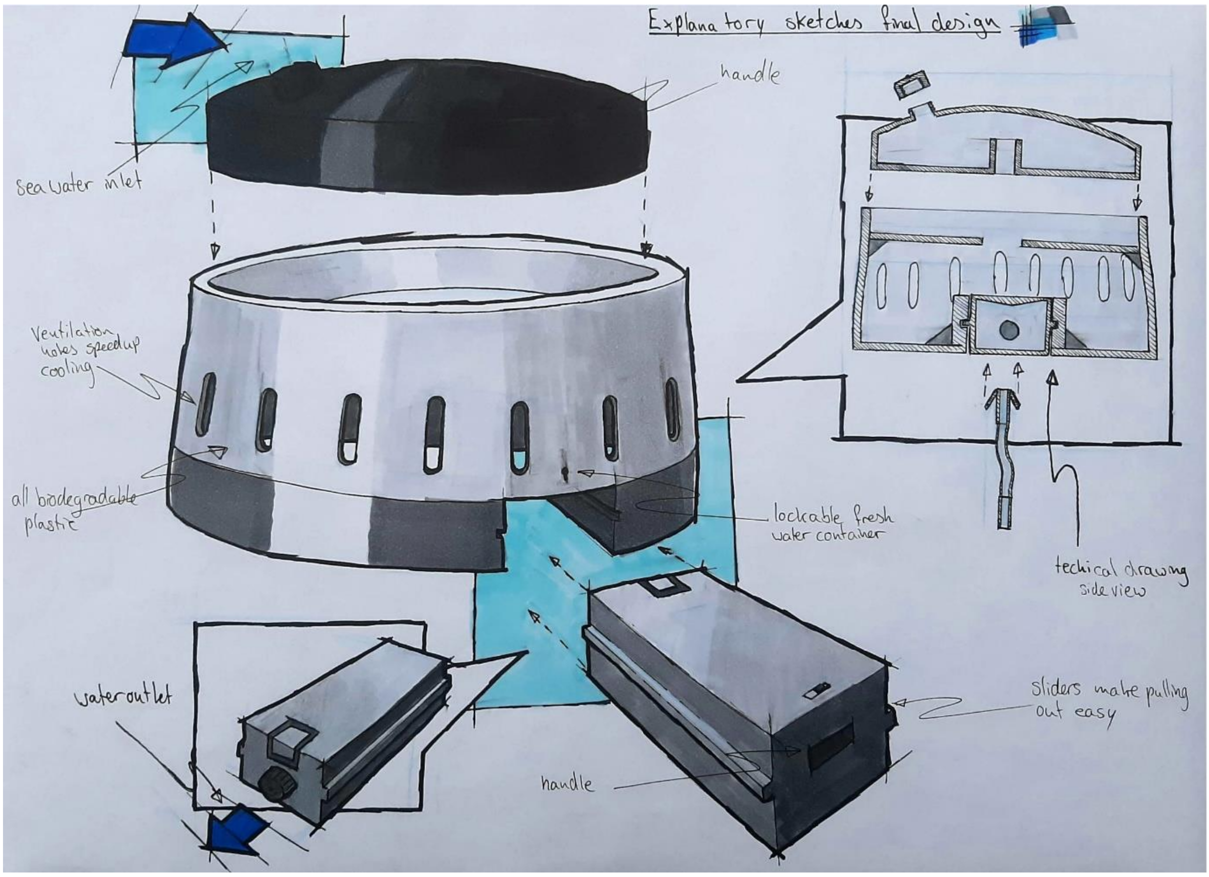
hexagonal
ventilation hole
Storage
tank
Greek symbols
could be cool
vent slots.



Explanatory sketches final design
handle
sea water inlet
ventilation holes speedup cooling
all biodegradable plastic
lockable fresh water container
techical drawing side view
water outlet
sliders make pulling out easy
handle

Reference list:

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