El oro Azul

A desalinating solution

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Frederique Baas,
Fons Mentink ,
Michiel Roelofs

Biography

We, Frederique, Fons and Michiel, are three students of the Strabrecht College in Geldrop. At the moment we attend a school of pre-university education. This year we will finish our fifth year of education. We all follow beta classes. Frederique and Fons both follow Sience, Physics and Mathematics and Biology. Michiel attends the same classes as Frederique and Fons and extra Physics, Extra Sience and extra Mathematics. We all study Economy and Fons and Michiel both attend Management & Organisation Classes.

After this education Michiel (16) will study mechanical engineer at Technical University in Delft, Fons (17) will attend technical business administration at the Technical University in Eindhoven and Frederique wants to study English abroad before she goes to the Technical University.

It is hard to tell what we want to do after finishing our education. Michiel and Fons will both attend for an MBA graduate. Of course we are not able of choosing our jobs by now, but we expect to work in the energy, food and water or innovative techniques –sector.

Acronyms

Saturated

Point where the evaporation rate and the condense rate are equal and optimized.

Equilibrium

A dynamic balance.

Graham water-cooler

A cooler based on the countercurrent principle. It maximizes the contact surface between the two substances by a spiral.

Toricelli's law

A law describing the influence of height at the flow rate in an open system. Based on Bernoulli's law.

Salvage Value

The net cash inflow you will gain for an asset after its depreciation. It is the net value of an asset at the end of its life.

Reversed Osmosis

A desalinating technique that uses the phenomenon of osmosis in a industrialised way.

Summary

This project belongs to a generation of projects that use new and innovative techniques for developing aid. Our project is capable of helping farmers on several locations around the world. By using the advanced technology of electrospraying, we are able to successfully desalinate large amounts of seawater in a relatively cheap way.

Peru is one of the many countries suffering from the food and water crisis. We chose Peru for this project, since it has more advantages than other third world countries. Peru has a relatively stable economy, a stable government and it is decreasing its poverty. In the long run, project has to be able to help other countries too, yet, the first project has to take place under perfect circumstances.

Our machine is based on a continuous process. In this way we will not lose valuable time. After basic information gained from the Technical University of Delft, we were able to develop the machine to its current state. In a meeting with Centre for Concepts in Mechatronics (CCM) we showed our first designs and set-ups. Enthusiastic reactions from the employees motivated us to improve our designs and exceed our previous ideas.

Together with its businessplan, this project is able to grow to a solution for problems that occur all around the world. If the desalinated water is handled with care, we can achieve a high efficiency rate as long as we use low-pressure irrigation systems.

El oro Azul

A desalinating solution

Sources

- The Dutch Ministry of Agriculture

- Technical University Delft

- University of Wageningen

- Wetsus

- Harbour of Rotterdam

- Airport Schiphol

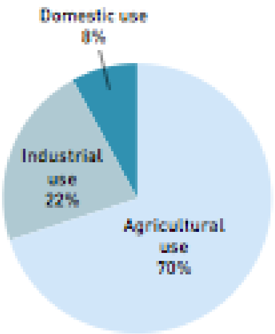
- Koninklijk Instituut voor de Tropen

- The United Nations (Book of references ‘World Water Development Report’)

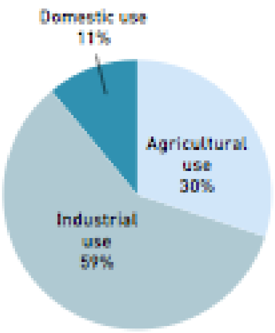
Paper

Chapter 1 – Water case

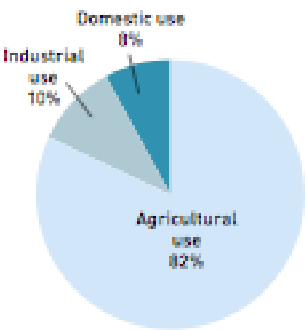
We all share the same world. We all share its content. In a perfect situation we all would have had the amount of water we wished for. But at this moment, that situation seems to be far from reality. Decades filled with war, ignorance and poverty caused this mess to arise. In those years the rich western countries ignored the steadily rising food and water shortage in this world. A lack of investments and a bad water management were the main causes for the present food and water crisis.



Competing water uses (world)



Competing water uses (high-income countries)



Competing water uses (low- and middle-income countries)

The food crisis has struck 777 million people in third world countries. 777 million malnourished people suffer from this crisis day after day. It requires a tremendous amount of food to solve this shortage. Due to the growing world population the request for food has increased. The growing demand for food from Asia, usage of crops for bio diesel and ethanol and the loss of agriculture due to the global warming, major investments are required to increase the production of agriculture on a global scale.

In a world without organised agriculture, 500 million people can live. 6 Billion people worldwide ensure the need of organised agriculture. In the present, the worldwide efficiency of irrigation water is only 38%. Even though it is expected to rise to 42% in the year 2030, this has to change. As you can see in the figure to the left, the efficiency in third world countries is even lower.

Since it is hard to increase the efficiency, we have to find ways of creating fresh water. In the past decades creating fresh water from salt water had never been a solution to this problem. The main reason was the fact that it was too expensive.

With the technique used in this project, we are able to pass this threshold. We are able to desalinate water from seawater in a cheap and sustainable way. The technique that can be the solution is called electrospraying.

Chapter 2 – Peru

The West coast of Peru has a very dry climate. The average daily temperature is 22 °C and there hardly falls any rain (1mm a month), so it is a very barren place with little growth and wide desert areas. The numerous little mountain rivers (with a similar temperature as the seawater, which is on average 15 °C) are overloaded by the agriculture. Because the only water source are these rivers, the agriculture is concentrated on its banks. The combination of the very small amount of water, wrong irrigation methods and a high evaporation rate causes nothing but a salt, dry unfertile piece of land to remain.

The agriculture is a sector with a lot of potential, but under these circumstances it can not exploit its potential in an optimal way. There are many cooperation’s between the local farmers, which are resulting in big farming companies with a lot of agricultural knowledge.

We can use the knowledge, farmland, and the expertise of the local farmers to start a join venture. Together with the students of the university of lima we can provide the technical knowledge required for desalinating water. In this way we can give the local farmers the opportunity to exploit the optimal capacity of agriculture. The dry piece of land can be useful again and the local farmers are available to focus on the grow of maize and wheat. With the growth of these products we can solve the problem of underdeveloped agriculture, we give the local farmers food and income.

Peru is just one example. Drought is a worldwide problem. On many places in the world causes the drought an underdeveloped agriculture.
Our technique can solve this problem and can improve the agriculture service world-wide. This is a picture on our exact location taken by a Peru specialist.

Chapter 3 – Technique

Electrospraying is phenomenon that is based on taking a liquid and use an electric field to divide it into very fine droplets. Depending on your flow rate, the level of voltage applied and the surface tension you can produce different charged droplets of variable sizes. This technique is used for various applications such as medicine specified for lung patients, spraying pesticide and applying a coating. In this project we will focus on the use of electrospraying to desalinate salt water.

Electrospraying

To spray the seawater we use nozzles with a diameter of half a millimeter. We pump the seawater trough these nozzles with a very low flow rate (1 mililitre/hour). Then we charge the nozzle positive and as a result of that the salt water will also become positive. We create an electric field by placing a metal ring underneath which is charged negative. At this point the salt water encounters three kind of forces.

-Gravity

-Electric forces

-The saltwater particles repel each other because they are all charged positive

These three forces change the shape of the droplet at the end of the nozzle into a conus. At the end of this conus a tiny jet will emerge and because of the mutual electric forces this jet will split up into a lot of small droplets. The size of this droplets varies from a few micrometer to a few nanometer depending on how much charge you use in the electric field. These droplets are still charged.

Desalination

The fine mist of droplets that is produced by the electrospray has a lot of surface. Ehen you use the optimal settings for an electrospray you can increase the surface a 100.000 times per litre. Because of this large surface the water will start to evaporate a lot faster than in a normal situation. The majority of the salt water will evaporate and in this way we have a mixture of charged salt water particles and vapor. We separate them using a second electric field. We charge a plate negative and the positive charged salt water droplets are attracted to that plate while the vapor will condense at another plate because of it has a lower temperature since we cool it using the cold incoming seawater. *This is all shown in figure 2.*

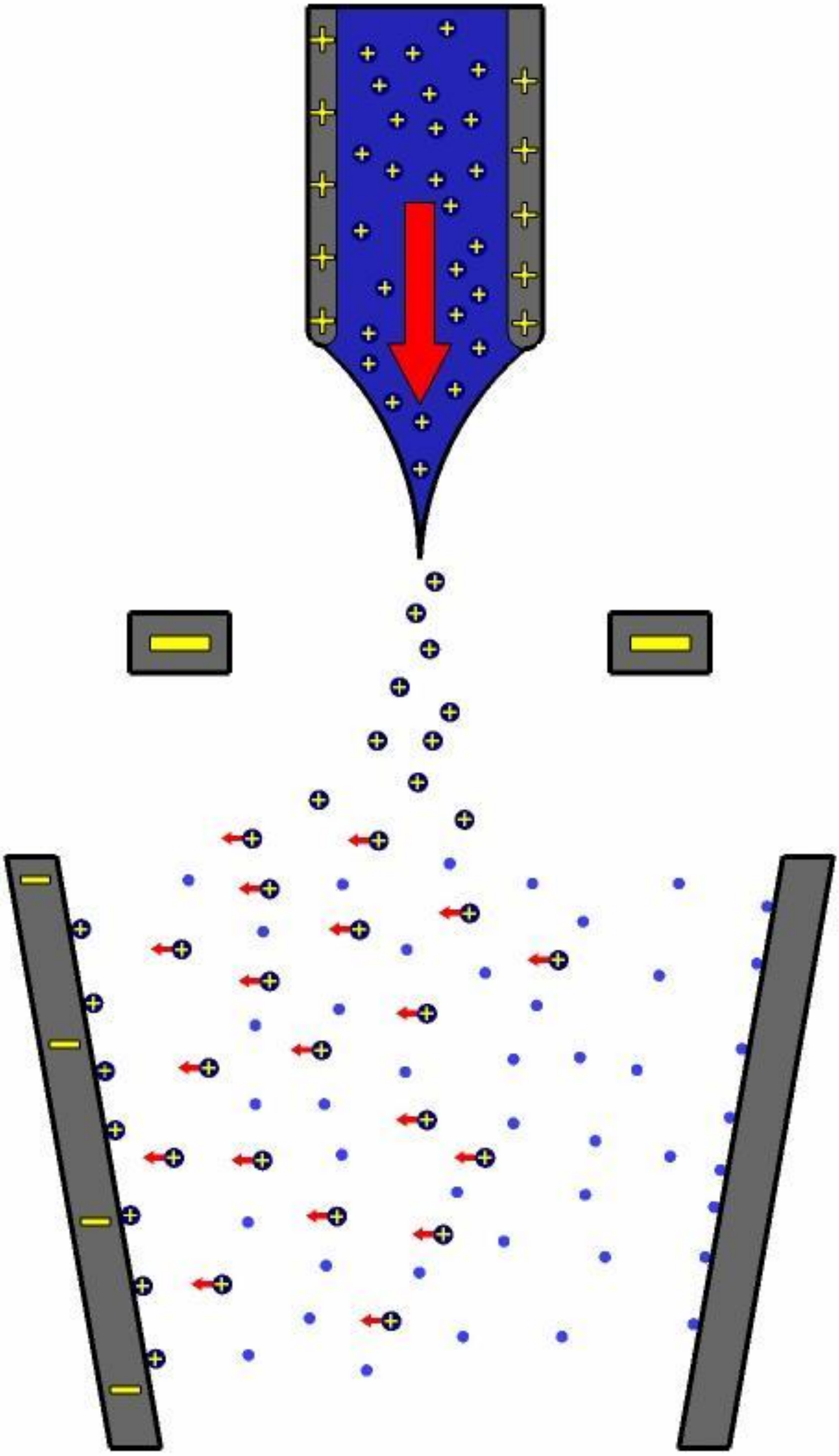


Figure 2.

Chapter 4 – Process

There are a lot of techniques to desalinate water and the majority is based on distillation. There are two problems that occur when you use them on a larger scale.

- low evaporation rate
- high input of energy

Evaporation rate

This is the keyword in desalination techniques. The higher the evaporation rate the faster and more efficient you process will be. There are three parameters that determine the evaporation rate:

-Temperature

-Air humitidy

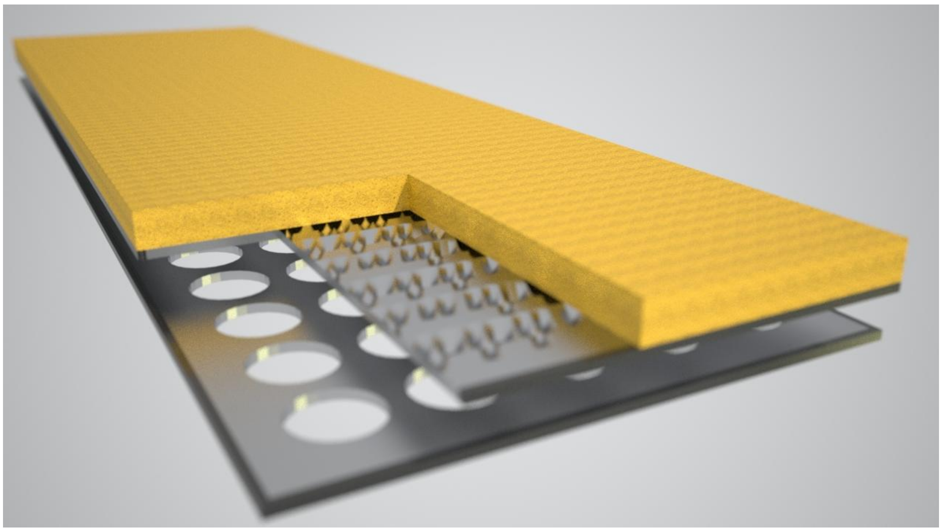
-Evaporation surface

This was our starting point, we had to develop a continuous process that combined all these factors and that can be used on a large scale.

Evaporation surface

One electrospray has the capacity of 1 millilitre/hour. So when you want to use electrospraying on a larger scale you have to increase the number of nozzles. Instead of using nozzles we use lasered iron plates with 250.000 holes per square meter. These holes will act as nozzles and we can increase the capacity of the process to 250 littres per hour per machine.

One big problem when you are working with holes that are so small is surface tension. We use a porous sponge-like material to break the surface tension and divide the water equally over the nozzles. *This is shown in the figure below.*



Air humidity

Water always tend to evaporate, and the speed of this process depends on the circumstances. Vapor however also tends to condense in any condition. At a certain point the speed of these processes is the same. The air is then saturated and the number of water particles that evaporate and condenses is the same. This is called a dynamic balance. In this equilibrium the concentration or air humidity together with the temperature determine the evaporation rate. So when our goal is a very high evaporation rate we need a constant stream of dry air.

We apply this in our project by pumping fresh air into the evaporation chambers. The constant stream of air with a low air humidity constantly affects the dynamic balance in favor of the evaporation rate. The air is pumped trough the air chambers and salt plates into the evaporation chambers and is then transported by air to the thermic exchange where it will condense. We will pump the air trough the fresh water reservoir so that a bigger percentage of the vapor condenses and it will also assure that our system is closed. *This is shown in figure 4.*

Temperature

The temperature in the evaporation chambers and the temperature of the water is vital. Because a lower temperature slows down the evaporation rate. Important in this process is the energy management. The energy that is required to evaporate one litre of water is 2260KJ. We have two systems to deliver the energy needed.

Air temperature

The temperature in our evaporation chambers is about 30 degrees. We do so because in this way we can use the thermic energy of the air from Peru. Because of it has a warm climate the temperature of the air is around 25° Celsius and that is perfect for our process. In this way a lot of energy is imported into the system. We can have our process at such a low temperature because our evaporation rate is very high. This comes mainly from our huge evaporation surface.

Thermic exchange

The energy that is needed to evaporate the water is released when the water condenses. We exchange this energy in the thermic exchange. The cold seawater is used to condense the vapor and when we apply a countercurrent Graham cooler change we can achieve a very high efficiency and the seawater has a high temperature when it enters the evaporation chambers. Because the majority of the energy circulates In the system and you constantly add thermic energy by air you have enough energy to run this process.

Salt deposit

In our system the salt is extracted to the plates at the side. Because salt in salt water has a mass percentage of 3,5% , 8,75 kilograms of salt is stored on the salt plates per hour. Because of this layer of salt the electric field will not be as strong as in a normal situation. Manually switching the plates might work on small scale but it is now option when you work with al lot more capacity. One requirement of this technique is that it should work continuously. Therefore we integrated a flushing system. The small holes above the salt plates will pump in seawater that will flush away the salt. Since water can dissolve more salt than 3,5%.This flushing will go in cycles, one side of the chamber at the time so that the process is not disturbed. This also explains the distinctive shape of the air holes. The shape extends so that now water will run into the air chambers.

Flow rate

The electrospraying process is very delicate. One little shift in the flow rate can cause the conus to be unstable. In stead of using very expensive accurate water pumps we use the water pressure. The Graham cooler will fill itself till the edge. Because we have an overflow the water level of that vessel will be constant. Then we connect it to a second vessel called the pressure vessel. We calculate the exact distance of the water level in the pressure vessel using Toricelli’s law. Because the water surface is at an constant height the water pressure is also constant and perfect for regulating our flow rate. First we need to calculate the speed of the water. We calculate the flow rate of one group of 10 machines witch are coupled in our plant that is explained in the financial prognosis.

Calculation

Toricelli's Law: $V = \sqrt{(2 \times 9{,}81 \times H)}$ → The surface of the pipe is $3{,}14 \times 10^{-4}\ m^2$

$2{,}5M^3$ /hour $= 7 \times 10^{-4}\ m^3/s$. $V = (7 \times 10^{-4}\ m^3/s) / (3{,}14 \times 10^{-4}\ m^2) = 2{,}2 m/s = V$

→ $2{,}2 = \sqrt{(2 \times 9{,}81 \times H)}$

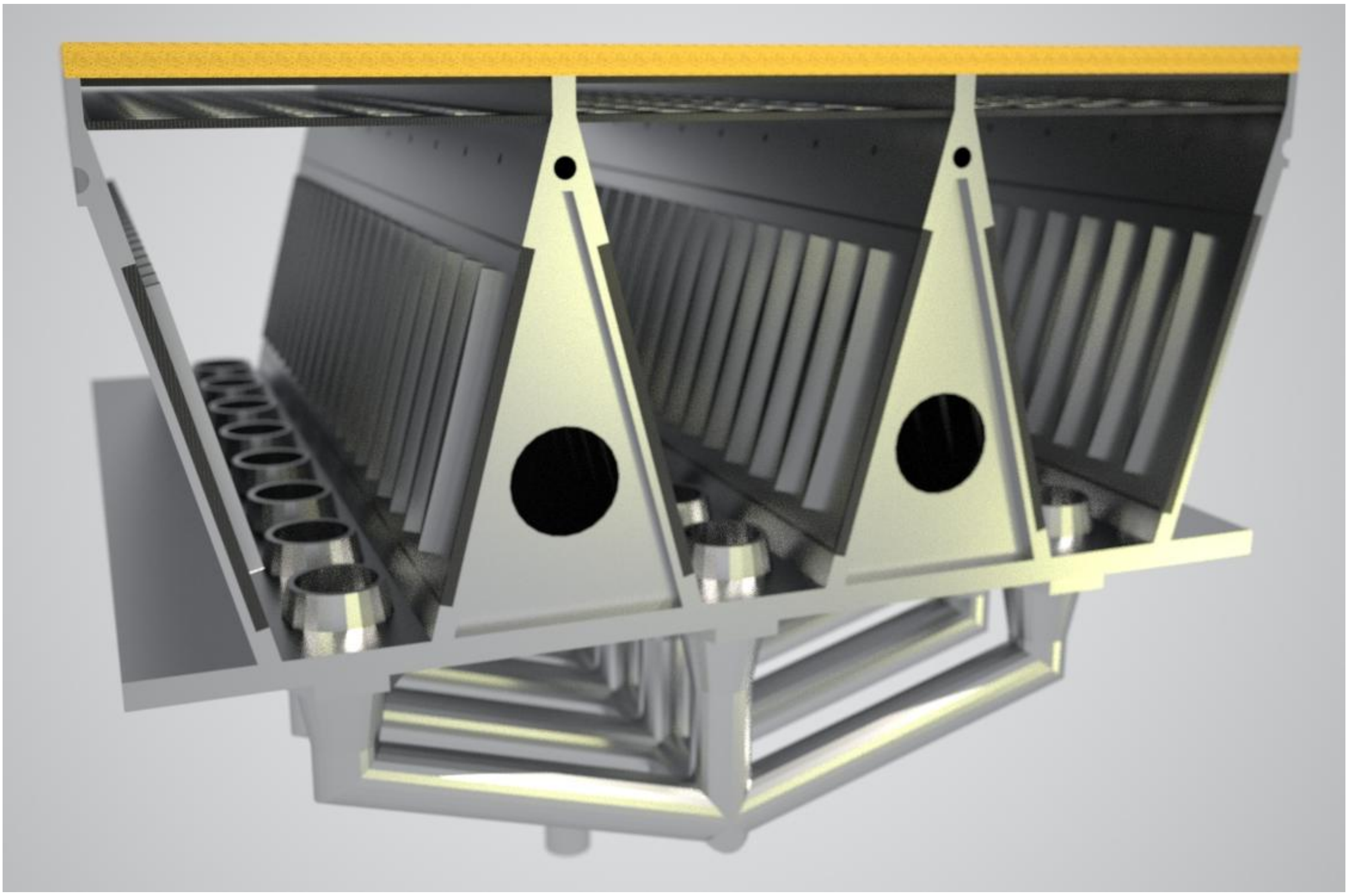
H = 25 CM

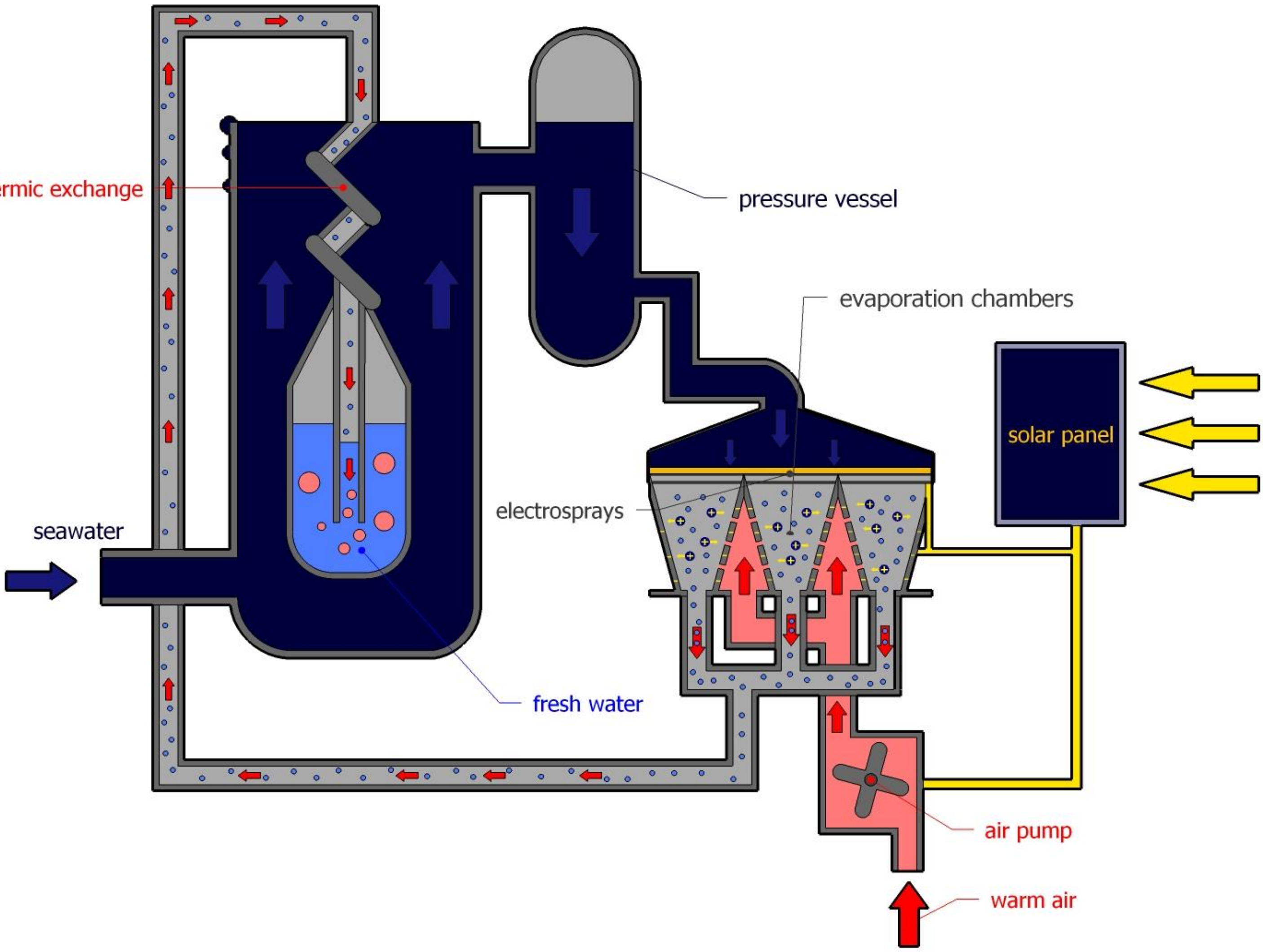
Electricity

We use an electric potential of 4,8 KV, this relatively high but the actual usage of power is determined by the current. And because the only transportation of charge is by the salt water droplets, electrospraying consumes not a lot of power. We will use solar panels to provide this power and the power that is required by the pumps.

For safety we isolate all the plates from the main body of the machine. We ground the body so that in case of malfunction of the isolation the charge is transported out of the system.

We made a 2d and a 3d impression of our process and our evaporation chambers.




thermic exchange
pressure vessel
evaporation chambers
solar panel
electrosprays
seawater
fresh water
air pump
warm air

Chapter 5 - Finance

In order to compete with other desalinating techniques we have to be able to achieve a very low price per litre, so we made a financial prognosis.

Initial Costs

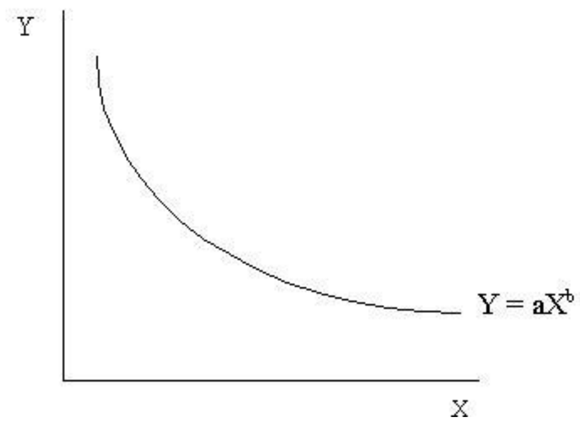
The machine which we designed in Chapter Technology, can be produced by CCM (Centre for Concepts in Mechatronics). The metal case and components for the machine will cost an estimated 2800,00$. The first plate, which has holes with a diameter of 0.5 mm, will cost an estimated 2900,00$. The second plate, with holes of 1,5 mm in diameter, will cost 500.00$. The total price per 3 components is 6200,00$.

Learning curve

This technique is still in a developing stage, which means that the current price, as calculated above, will decrease. This is called the learning curve. This means that in this developing stage the price will decrease at a higher rate than proportional. This is caused by several reasons, such as experience, research, industrialization and the economy of scale.

Wright's Cumulative Average Model

This is a simplified mathematical model for a cost learning curve. With this model we can make a prognosis over the price of a machine throughout the years.



X = Duration of the research.

Y = The cumulative average or cost per unit.

A = Cost required to produce the first unit.

B = Defines the slope of the curve

Estimating price per product

We estimated that we need about 3,5 years of research before we can use the technique in our scale. At that time the production line for the components is industrialized and the evaporation chambers are build optimal. We use a 75% learning curve with a period of a halve year. The main reason for this steep price development is that the present price of the machine is based on a non-industrial way of producing and the price contains lots of development costs. This technique still requires a lot of research but the price per machine will drop when the production line is industrialized. For example outsourcing the production of the plates that contain the nozzles is very expensive.

B= $^{10}\log 0,75/^{10}\log 2 = -0,4150$

$(6200,00\$)\times 7^{-0,4150} = 2764,88\$$

So conform our calculations the price per machine after 3,5 years is about 2750,00$.

Each production process has two kinds of costs:

Variable Costs

The size of the variable costs depends on the quantity of products produced.

Fixed costs

Fixed costs are costs that have no relation to the quantity, such as irrigation systems, the storage of fresh water and management.. Another important fixed cost in our case is research costs. These costs are fixed costs, since the amount of research is a fixed cost.

Economy of scale

Economy of scale is based on increasing your capacity to lower your average cost. Since we use a very large capacity, the fixed costs remain virtually the same. The variable costs will remain the same per litre, but spreading the fixed costs over more litres, will cause the fixed price per litre to drop. Thus decreasing the total price per litre.

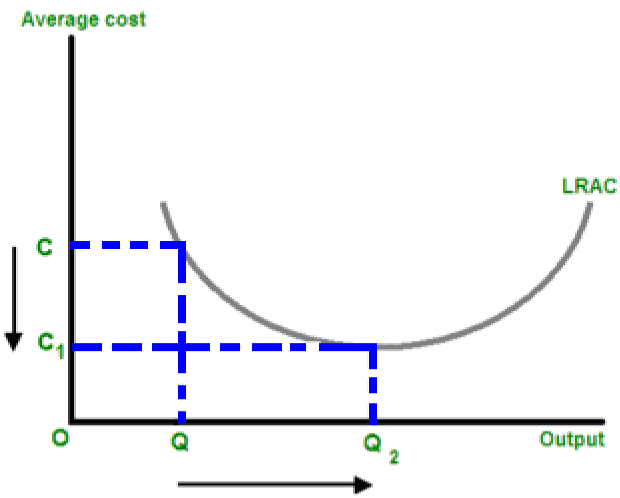


Figure 7

Chapter 6 – Financial Prognosis

Since our project has to be profitable in the long run, we have to be in control of the costs and income. Costs will occur as variable and fixed costs. Profit can be made from the harvest on the irrigated acres.

For this project we will work on a certain scale. This scale is chosen to give a clear view of this project' capabilities. The scale can vary, depending on the size of the project. We chose to work with 500 machines, which means that we have 1500 components. We will have these components to work together in groups of 30. Our total capacity will be (250 Litre/hour per 3 components) 125.000 Litres per hour. Which are 10.680.000.000 litres per year. With this amount of water, we can successfully irrigate an area of 50 acres. This project will use one facility that contains the machines and three distribution facilities that are connected to irrigation systems on different acres. On these acres we will cultivate wheat. The prices have been rising steadily and are highly likely to continue to. One hectare grows about 12.000 kilo's of wheat. This means that we can produce 600.000 kilo's of wheat per year. The price of wheat is 440$ per metric ton (prices march 2008 IMF). This means that we have a profit of 264.000$ per year. This is a prognosis based on the current wheat prizes. But the prize of wheat will rise inevitable. This means that on the long run our profit will only grow.

Income:	**264.000$**
Harvest of 50 acres	264.000$
Costs:	**162.916$**
Depreciation costs	107.916$
Machine (Salvage Value is 0$) ((2750$ ·500)/15(lifetime in years))	*91.666$*
Extra Material (Salvage Value is 0$) (100.000$/10)	*10.000$*
Facility (Salvage Value is 50.000$) (300.000$/40)	*6.250$*
Estimated repair costs	55.000$
Annual Profit:	**101.084$**

Chapter 7 – Business case

El Oro Azul is a perfect example of new, innovative technologies applied in third-world countries. Despite the fact that more research is required to optimize its process, those projects are already helping people around the world.

Our project uses the new advanced technology of electrospraying. With this technique we can help governments in their search to solve the food crisis.

In order to apply this technique in one of these projects, we had to design a machine that was capable of producing large enough quantities in a relatively cheap way. The machine was designed in cooperation with Centre for Concepts in Mechatronics (CCM) and the Technical University of Delft. The machine is based on components, which can work together or on their own.

Because we have split the machines into components, investors are able to chose almost any amount of desalinated water per hour. This enables them to construct facilities that are perfectly designed for their duty. This will help them to decrease their price per litre. The price of the final product is vital to this project. It has to be able to compete with projects that use reversed osmosis and other desalinating techniques.

According to our calculations this project is able to do so:

Starting Costs

Product/Service	**Price**
Machines (500) with a price of 2750$.	(500×2750$) 1.375.000$
Total facility costs (Water pumps, Air pumps, building)	(Estimated) 350.000$
Transport costs, packing 24 machines in one container.	(25×1351,5$) 33.787$
Distribution costs (water hoses, distribution points)	50.000$
Total	**1.958.787$**

These costs are prognoses, but based on reliable figures. The machine costs are calculated above, the facility costs are calculated by standards, the transports costs are calculated by the port of Rotterdam and the distribution costs are estimated in consult together with a specialist in developing aid.

Water price

We must be able to compete with the local price. In Peru this price is 0,41$ per 1000 Litres. In this example we will calculate the final water price.

Operational costs *162.916$*

In one year we will be able to produce 1.095.000.000 litres per year.

$$\frac{162.916\$}{1.095.000.000 \text{ litre}} = 0{,}15\$ \text{ per 1000 litre}$$

This is 56% below the current price of water in Peru.

Investments

In this way this project is a interesting option for investors especially when you take the price prognosis of wheat in the coming years in account. Our project requires an investment of 1.960.000$ with an annual profit of 101.084$. This is a profit of 5,2% per year if the wheat prizes remain the same. But the demand for wheat is growing.

- Increased demand from Asia.
- Use of crops to produce ethanol and bio diesel.
- Climate change will make more land unfertile for agriculture.

Since the wheat prices are likely to rise further, our project will probably generate more profit in a couple of years. The high annual profit can attract investors to start their own business in water and food aid.

Market

The fact that we can generate such an amount of fresh water in this way is a great achievement. We were not only focussed on our project. We had to be sure that we were able to get the project to be carried out. In a meeting with P. Kuijt, we were told that ex-minister Robles of Peru is very interested and has the financial resources to start this project.

Chapter 8 – Conclusion

This project is a great opportunity for scientists to show that research does deliver practical solutions for worldwide problems. By supporting this project, this project can help people all over the world.

The Netherlands always had a leading and important role in water projects. About 40% of the Netherlands is located below sea level. In 1953 The Netherlands were hit by a great flood. This encouraged the Dutch to invent the Deltaworks. This project is an example of technology used in a Dutch project. This system defends the Netherlands from the high tides and floods in the future.

The Dutch Crown-Prince, Z.K.H. Prince Willem Alexander, is the Patron for some water institutions. He represents the Global Water Partnership and the Royal Dutch Watersports Bond of the Netherlands. And he is the Preseident of the Dutch Advice Commision for Water and since 2006 he is the President of the independent Advice Committee Water for the United Nations. This shows that the Netherlands are connected with water.

If the Netherlands want to keep this position in the world the keyword is innovation. If we invest in small research projects we will benefit from it on the long term.