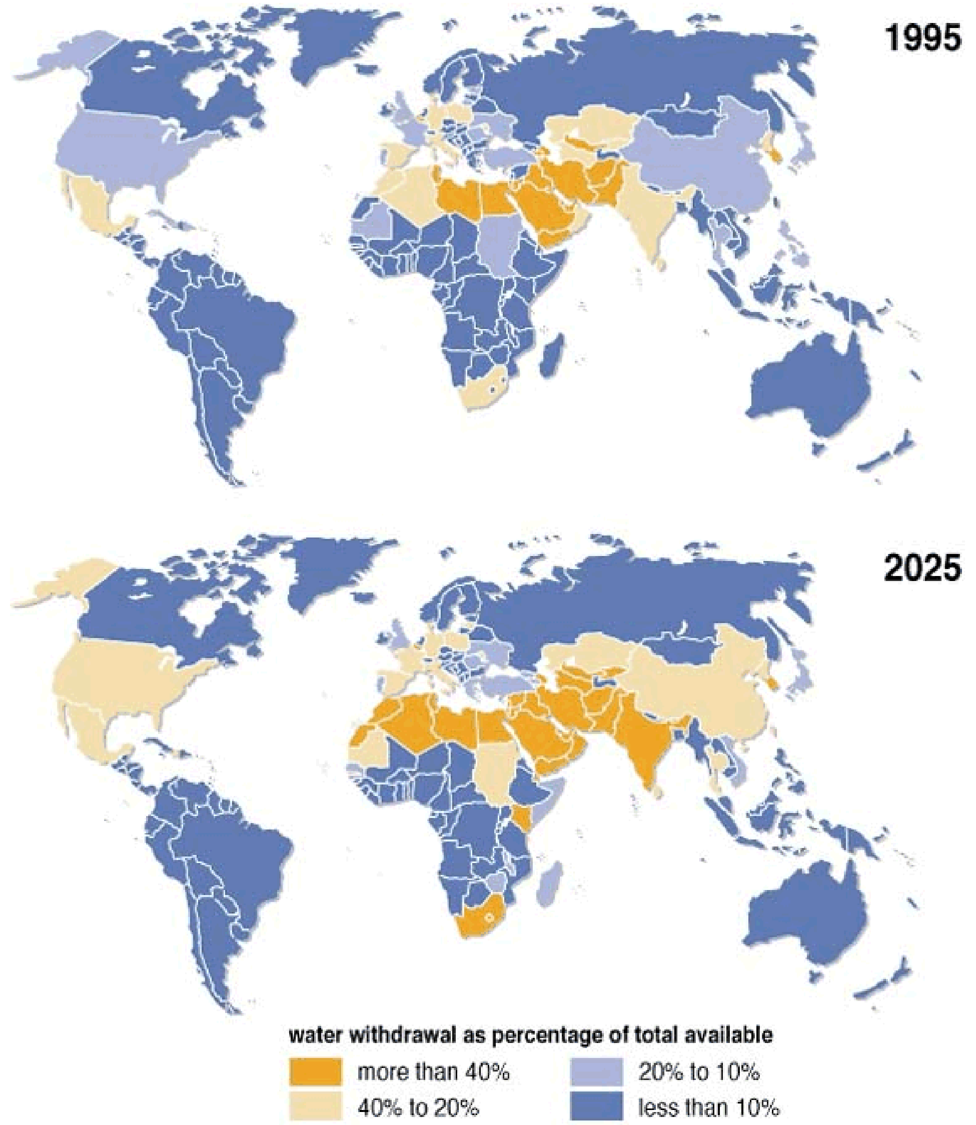
Water scarcity and desalination: who, where

97 percent of the earth's water mass lies in its oceans. Of the remaining 3 percent, 5/6 is brackish, leaving a mere 0,5 percent as fresh water. As a result, many people do not have access to adequate and inexpensive supplies of potable water. This leads to population concentration around existing water supplies, marginal health conditions, and a generally low standard of living **[1]**

Along with the deterioration of existing water supplies, the growing world population leads to the assumption that two thirds of the population will lack sufficient fresh water by the year 2025. The areas with the severest water shortages are the warm, arid countries in the northern Africa and southern Asia within the latitudes 15-35°N.
In view of these facts, desalination seems to be the only realistic hope for a new source for fresh water. Moreover, the regions in most need of additional fresh water are also the regions with the most intense solar radiation. For this reason thermal solar energy in desalination processes should be the most promising application of renewable energies to seawater desalination **[2]**

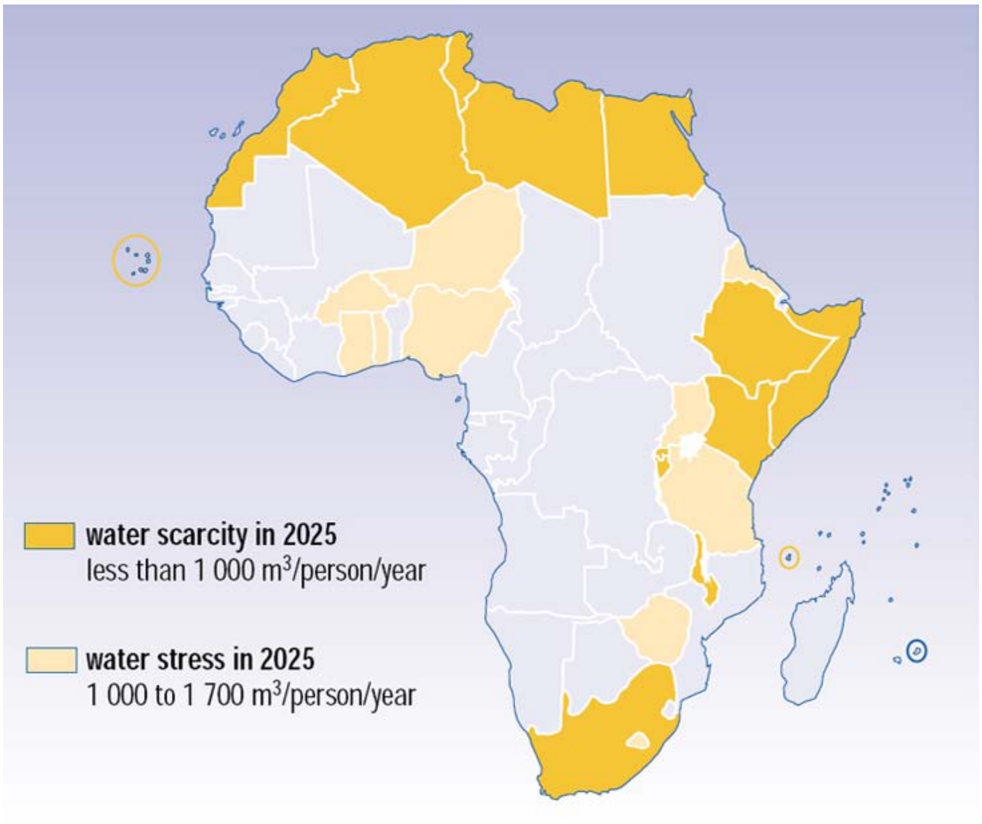
Some areas having the need and the possibility to use this technology are: South Mediterranean Countries, Middle east, Sub-Saharan Countries, Eastern African Countries, India, … **[3]**



[1] source: Horace McCracken and Joel Gordes, Understanding Solar Stills

[2] source: Jenny Lindblom, Solar Thermal Technologies for Seawater Desalination: state of the art

[3] source: United Nations Environment Programme http://www.unep.org



[4]

Desalination techniques

The main problems with the use of solar thermal energy in large scale desalination plants are the relatively low productivity rate, the low thermal efficiency and the considerable land area required. Since solar desalination plants are characterized by free energy and insignificant operation cost, this technology is, on the other hand, suitable for small-scale production, especially in remote arid areas and islands, where the supply of conventional energy is scarce. The use of solar energy for driving the desalination plant is also motivated in these areas by the fact that they imply a way for energy independence and water insurance. The low environmental impact as well as the easy operation and maintenance are also incitements for this technology.
A solar distillation plant may consist of separated or integrated systems for the solar collector and the distiller. Integrated systems are often referred to as “direct solar desalination”. Separated systems are known as “indirect solar desalination” **[5]**
Other water treatment techniques are the reverse osmosis, the ultra-, micro- and nanofiltration, But those techniques needs electricity and advanced technologies that are too expensive or not available in the developing Countries.

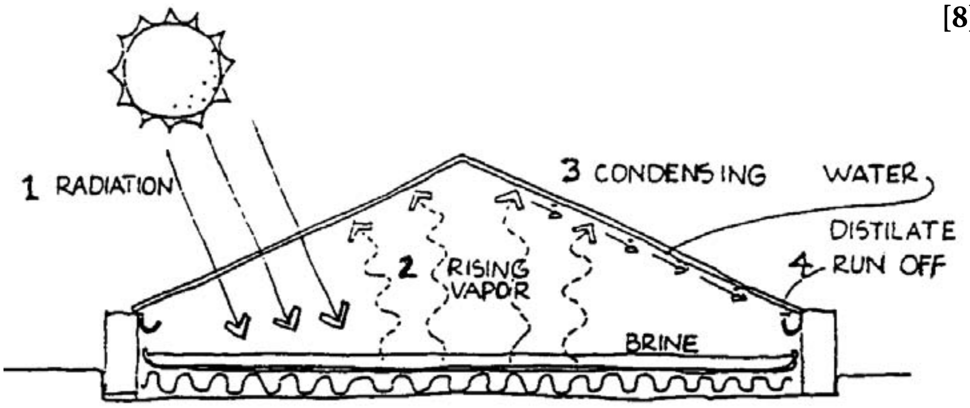
[4] source: United Nations Environment Programme

[5] source: Jenny Lindblom, Solar Thermal Technologies for Seawater Desalination: state of the art

The direct solar still (basin still)

The original solar still can be described as a basin with a transparent cover of e.g. glass. The interior of the still contains seawater and air. When the seawater is heated by solar radiation, it starts to evaporate and the formed vapor is mixed with the air above the water surface. On meeting the inside of the glass ceiling of the still the moisture is re-cooled and some of the vapor condenses on the glass and runs down into a collection trough, leaving behind the salts, minerals, and most other impurities, including germs **[6]**
One of the main setbacks for this type of desalination plant is the low thermal efficiency and productivity. This low production rate is mainly explained by the low operating temperature and pressure of the steam [7]
Furthermore, the basin still needs a constant maintenance because it has to be always very clean: as the salt remains on the bottom, the black bottom becomes white, thus reducing the efficiency of the system.

[8]



Health related issues

According to the World Health Organization (WHO), the desalination process can ensure the safety of drinking water because it is able to kill microbes, germs, and to eliminate any kind of dangerous salts, like the magnesium and arsenic salts.
The desalination process can be applied to different source waters like waste water, brackish and seawater. **[9]**

Virtually any kind of water can be used in a solar still, except a water highly polluted by chemicals (for instance the water coming out from industrial fields, or city dumps). But in the rural areas a solar still is always safe, the water comes out with a good flavor, completely clear.
The only one thing that would be better to do, is to add a teaspoon of salt every 10 liters of water, because to drink always distilled water is not healthy.

[6] source: Horace McCracken and Joel Gordes, Understanding Solar Stills

[7] source: Jenny Lindblom, Solar Thermal Technologies for Seawater Desalination: state of the art

[8] source: Daniel C. Dunham, Fresh Water from the Sun, p.16

[9] source: "Guidelines for Drinking Water Quality" (GDWQ) published by the WHO, 2004

Innovation

Most of the development work about desalination for poor countries has been directed toward reducing the construction cost of solar basin distillation equipment through use of cheaper materials, simpler design, and other measures. Less effort has been devoted to technical improvements which might increase distiller efficiency and reduce the necessary size of a unit for a certain water production capacity **[10]**

This is exactly what I did with my project:
to create a new kind of solar still, completely different from the "classic" basin still, being able to increase the efficiency, reduce the size, transform a big equipment in a compact household, that is very easy to use and to understand.

This came out from a radically new approach to the project of a cheap still, that involved ideas and details that are present sometimes just in the big, industrial-like desalination plants.

The following aspects are the main innovations of my project:

>The idea to keep the evaporator completely separated from the condenser, and above all to keep the second one under the shade of the first one (thus increasing the temperature Delta between the two, thanks to the shade. This increases the efficiency of the system)

>The idea to let the pressure grow into the evaporator: this pressure force the steam down in the pipe to the condenser. As the steam expands in the condenser, it cools down faster (due to a simple physical reason), then increasing the efficiency of the system

>The construction of the Eliodomestico allows to use a metal (steel, aluminum, ...) as a building material for the condenser. This increases the efficiency very much compared to the classical basin still, were the condenser is the glass (that is a bad heat conductor)

In short, Eliodomestico may be patented/protected, because it is a new invention.

However, I didn't do it. And I don't want to register any patent about this project for a simple reason: the Eliodomestico is made for poor people, and is specifically designed to be produced by craftsmen all over the world in small series, using poor materials and traditional craft techniques.
This in my opinion cannot be a business of any interest for any company.
So it doesn't make much sense to me to register a patent if there is no economical interest.
I decided to give my project for free to anyone who wants to produce it. The only protection I gave to Eliodomestico is the Creative Commons: like in the open source software, there are 3 commitments:

>attribution (people has to say that the original project is mine)
>non-commercial (they cannot make business with my project, as I didn't)
>share-alike (they are free to modify or improve the Eliodomestico, but if so they have to release the project for free to the people under the same rule)

[10] source: Fundamental Problems in Solar Distillation, by George 0.g. Lof

Experiments

When I invented the Eliodomestico, I made some test in order to prove my insights. So I made a small-scale prototype with scrap materials.

Here I write a little report of 2 experiments that were made with a slight different version of the same concept (there was still a glass on the top), but they are enough to prove that the Eliodomestico works well, and they allowed me to estimate an average production of freshwater.

Please note that my experiments are empirical, not scientific in the real meaning of this word. A scientific documentation would need an investiment in a laboratory research with precision instruments and lamps.

The model was tested with a 300W halogen lamp, placed at 10 cm from the surface, to simulate the sun. Please note that this system, although not very accurate due to the different spectrum compared to the solar radiation, is very useful in order to simulate the average power of the solar radiation during a day at the temperature of 20°C, that is also the condition normally considered to be the annual average in places like sub-Saharan Countries **[11]**
If I wanted to test a condition of maximum solar radiation during a hot summer day, I had to use a 550W halogen lamp, at the same distance from the surface **[11]**

[11] source: solar cookers international, http://solarcookers.org

Experiment A

Situation:
the output pipe of the model is inserted in a bottle full of water

Goal:
to check if the pressure in the evaporator is able to push down the steam, and in which quantity and intensity

Observation:

>After 15 minutes there are bubbles in the evaporator. Nothing in the bottle

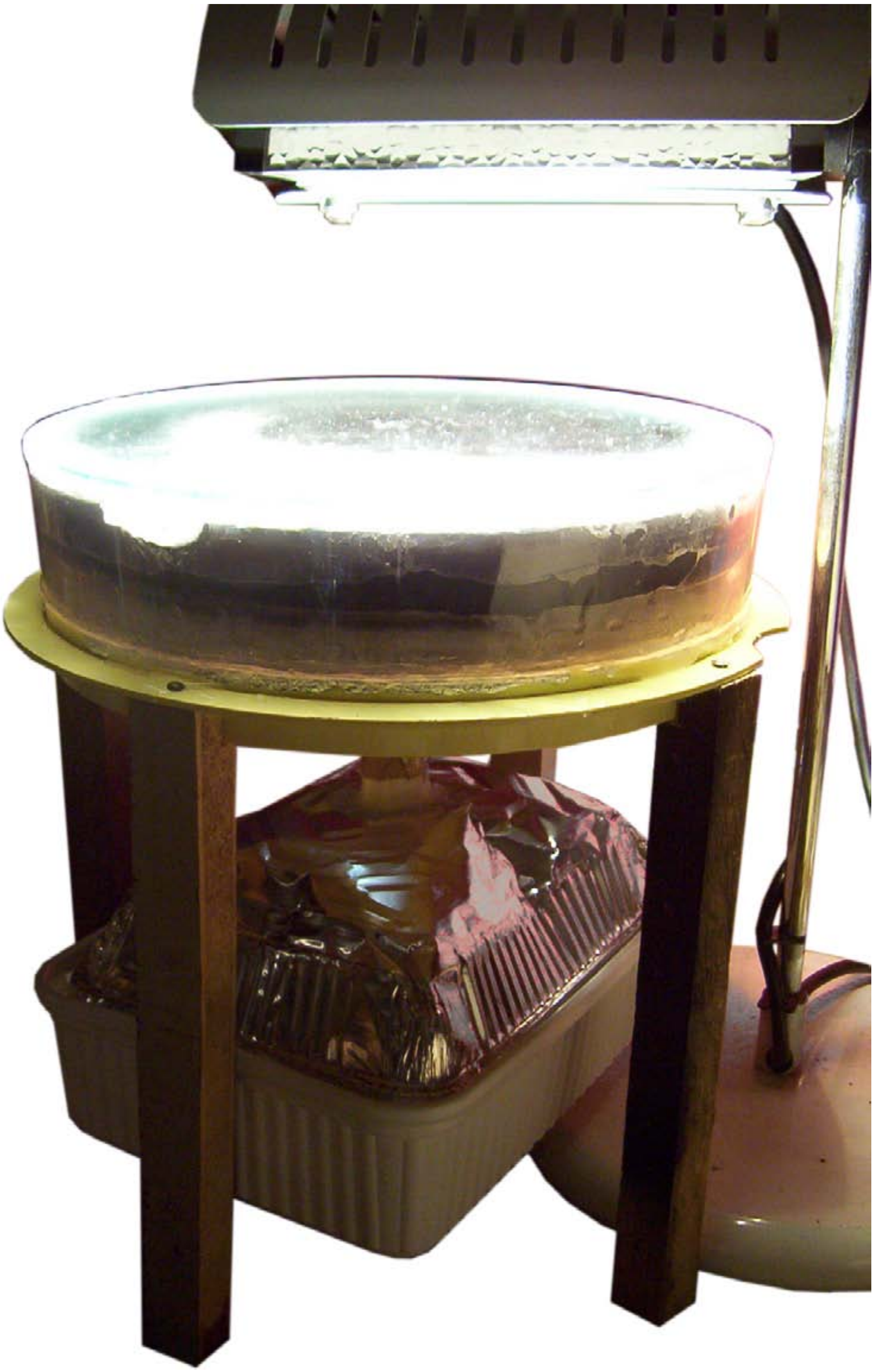
>After 30 minutes the bubbles in the evaporator are increased in number and dimension. Nothing in the bottle

>After 45 minutes the water in the evaporator is almost boiling. In the bottle, at the end of the pipe, I can see big bubbles growing slowly and float up to the surface at a frequency of 2 bubbles per minute

>After 60 minutes the water in the evaporator is boiling. In the bottle, from the end of the pipe, 2 bubbles per second are going out towards the surface

Result:
success!
The pressure is high enough to push down quite a lot of steam...

Experiment B



Situation:
An aluminum bowl is inserted on the output of the pipe, reproducing the final scheme of the condenser lid of the Eliodomestico. At the bottom there is a plastic bowl to collect the water.

Goal:
to verify if the steam condenses in the aluminum lid, and in which quantity in a given period of time.

Observation:

>After 30 minutes the water in the evaporator is almost boiling. The aluminum condenser is very hot: it means that the heat exchange happens in this area

>After 60 minutes I stop the experiment to check the result

Result:
success!
The condensation happens in the lid, as supposed in accordance with the theory (the condensation happens always in the freshest part of a given system. In the hottest part it doesn't)

I measured the water production: in 1 hour it was 55ml of H_2O.

Calculations and conclusions

According to observational data in literature, a typical basin still produces an annual average of 3 liters of freshwater per day per square meter of surface **[12]** A typical production day is calculated in 10 hours of irradiation per day (annual average, including rainy days).

As told before (see **[11]**), the conditions replicated in the experiment are similar to the annual average.

The model used in the experiment has a diameter of 26 cm.
The irradiation area is then:
$A = \pi r^2 = 531\ cm^2 = 0{,}053\ m^2$

According to the practical test, this area produces 55 ml of freshwater per hour.

Compared to a surface of 1 m^2, the model produces:
$(1/0{,}053) \times 55ml = 1037\ ml \approx 1$ liter/hour per square meter of irradiation surface.

That means a production of 10 liters per day per square meter of surface... approximately 3 times the production of the basin still in the same condition and dimensions.
This is a very good result that allows to build a smaller solar still, having the same daily production in liters.

In a small-scale distribution and production, where the product is made using traditional craft techniques, it is always possible to vary the dimensions adapting the production rate to the needs.

It is very simple to argue the daily production rate (dPR) of an Eliodomestico, just resolving this proportion (after measuring the diameter of the evaporator):
$A : 1m^2 = dPR : 10l$
$dPR = (A \times 10l) / 1m^2$
$dPR = \pi r^2 \times 10l / 1m^2$

$dPR = 10 \pi r^2$
(the result is in liters, if the radius is expressed in meters)

For example:
- if the diameter is 100cm → dPR = 31,4 x 0,25 ≈ 7,8 l/day
- if the diameter is 80cm → dPR ≈ 5 l/day
- if the diameter is 60cm → dPR ≈ 2,8 l/day

The present prototype has a diameter of 60 cm, and an irradiation area of 0,28 m^2. **Therefore at the moment it produces 2,8 l/day** (note that during the summer the value is almost the double).
This is an excellent result, because it's the same production of a 1m^2 solar basin still, but it costs the half, and it takes up 1/3 of the room as the other one.
Of course it is possible to scale the dimensions and to build devices with a 80cm diameter, producing 5 liters per day.

[12] source: solar cookers international, http://solarcookers.org

Further experiments and tests

Eliodomestico is in a prototype stage.
However it has been tested indoor and outdoor, trying to simulate different conditions.
Further tests with the real scale prototype confirmed the previous calculations.

Known drawbacks of the design:
1. The indoor tests that were made with halogen lamps demonstrated a high efficiency in very hot climates. But according to the last outdoor test carried out during August 2012 in the Mediterranean area, the device suffers from efficiency loss when the climate is windy and humid. I already have the solution (which was designed since the beginning), but I still have to build it. So I'm working at the second improved version of the prototype that should solve the problem completely. It will be very similar, just the black boiler will be slightly different, having a transparent plastic cover on it.
2. As any other existing water distiller, Eliodomestico delivers distilled water, hence small quantities of salt should be added to the freshwater for enhanced health benefits. It is possible to use the same salt that was in the saltwater before the distillation process.

It is possible to view a live demonstration of Eliodomestico for the italian TV, at the following link (italian language, but clear images):
http://www.rai.tv/dl/RaiTV/programmi/media/ContentItem-9b334c24-833a-4ecc-b29a-b944528c0d45.html

Usability

I put a big effort into designing a really usable object.
After a wide research on the African cultures, I discovered that the form and the materials are really important for such a project:
In literature there is plenty of examples of failures in the attempts to introduce new objects/concept in the rural and poor areas of the world. The failures were always caused by objects too far from the people's collective imagination (see the parabolic solar oven in Somalia as an example **[13]**), mostly causing a refusal of the innovation, or in some case a misunderstanding of the object's purpose.

A new object, especially an household like the Eliodomestico, has to be simple to understand. It's shape has to remind traditional archetypes, it has not to be alien, and the materials involved in the production have to belong to the local traditions.
Best of all, the object might be produced by locals, because making is the best way to understand.

Moreover, this is also the reason why the freshwater container is designed to support the common habit of the woman to transport things over the head.

I didn't design an extra cover for it, because the Eliodomestico is conceived to work close to the home, in the villages, like any household does. Therefore the distance to walk transporting the water is quite short. Moreover the women are so skilled in this, that a cover would be unuseful. There is also no need to keep the water container at home as a water reserve, because people at home are used to have a big water container to perform this task, so the water container of the Eliodomestico will be returned right back to its place, in order to catch the water for the next day **[14]**

Compared to a basin still, the Eliodomestico is simpler to use and the maintenance is also very simple, because:

- >there is no glass to keep clean (in a basin still if the glass is dirty, there are efficiency losses)
- >the salt stays only in the evaporator. In the pipe it runs just pure steam and drops of water (pure H_2O)
- >nothing in the system can be clogged up, because when the water evaporates, the salt cannot go up with the moisture, but it stays on the

[13] source: solar cookers int.

[14] see the image as an example of home water container in Senegal. Source: The Food and Agriculture Organization of the United Nations (FAO) archive. http://www.fao.org

bottom
>the only maintenance to do (like once in a month) is to unscrew the pipe, bring the evaporator away and wash it with any kind of water. The purpose of this operation is just to bring away the salty sediment from the bottom of the evaporator... because after a very long time the sediment can fill up the evaporator. But the big advantage of my project is that the sediment (even if present in huge quantity) doesn't affect the performance, while in the normal basin still it does (the white sediment reflects the solar radiation trough the glass).
So, if the maintenance is not really constant, it doesn't matter that much.

There is no other tasks to do, except charging the evaporator with salty water every 3-6 days (depending on the season). Compared to the basin still this is another advantage in the usability: the evaporator contains more or less 10 liters, which is enough for the woman to forget about the still, just like it happens with every household while it's working.
On the contrary, a standard basin still needs more attention, and a frequent refill of the water.

Credits:
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Freelance industrial designer, graduated BA and MA in Industrial Design at Milan Polytechnic, Italy.
Studied at Milan Polytechnic and Berlin University of Arts (UdK), Germany

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