SUSTAINABLE WATER DESALINATION FROM THE SOLAR ENERGY

Angel Bosch I Bosch [1*], **Ignacio** J. Moncho Esteve [1], **Eva** López Fornieles[1]

[1] AQUA.abib water solutions s.l.
Esteve Terradas, 1 #113ª PMT- UPC, Castelldefels 08860, Barcelona- Spain
angel.bosch@aqua-abib.com, www.aqua-abib.com, (+34) 934 137 536

Abstract:

Seawater desalination is the main source of water in areas where it is scarce. Reverse osmosis is among the technologies used for that purpose. It implies high energy consumption costs and, accordingly, a significant carbon footprint, as well as the depletion of limited natural resources and pollution from brine generated.

AQUA.abib has developed a technology that provides fresh water as well as salt, two products from the same process, derived from seawater with few requirements from conventional energy. The thermal energy required is provided by the Sun.

A pyramidal shaped energy collector is comprised of two layers: a transparent outer film and a black inner surface which heats the air between the two. It concentrates heated air at its apex where seawater is sprayed, to fully separate water from salt. The salt is collected and processed for marketing and steam-laden air is driven through a column down to an underground gallery to fully condense and collect distilled water. Latent condensation heat is recovered. No brine is produced, so no pollution is associated with the process.

Economic returns come from fresh water, salt, and a multifunctional inner area enclosed in the pyramid. The structure provides a climatic conditioned space suitable for: green housing, animal farming, work and leisure activities, housing or storage.

In geographical areas (or during seasons) in which water is scarce, the Sun is an excellent energy source due to its high level of irradiation. Hence, the supply of fresh water fits the demand like a key fits its lock.

This technology has been tested and evaluated in different scenarios and has received a grant from the EASME programme of the European Commission. The construction of the first commercial size prototype plant is foreseen to take place at Ciutadella (Menorca, Spain) by Spring, 2018.

Keywords: Sustainable, Desalination, Sun driven energy, Salt recovery

1. Introduction

Water is at the core of life and development; any industrial or agricultural activity needs it (Wu, 2008). Where water is unavailable, life is jeopardized and development is impaired. More than 40% of habitable emerged land is unproductive due to water shortage.

Water availability can be determined by the evapotranspiration (ET) versus rainfall (RF) balance for every part of the Earth (Thompson et al., 1981). When ET surpasses RF, deserts arise. When the opposite balance occurs, green areas develop with water that comes from elsewhere with high ET values and a negative balance (Burman & Pochop, 1994). The Sahara's desert and Northern Europe are classic examples of these two cases, respectively.

Therefore, water that is evaporated in tropical and subtropical areas is transported by the atmosphere to high latitude areas where it falls as rain or snow (Perrier, 1982). This unbalance works in favour or against certain geographical areas in creating green regions and deserts (Garratt, 1992).

2. Approach: Deserts and water shortage

Considering ET capacity and rainfall as a base line, the capture of the vapour that is produced in desert areas due to the Sun's high radiation and the confining of this vapour-laden air, can equal the balance between ET and rainfall. Thus, desertification can be overcome.

Imperial Valley is an extension of Death Valley down south in California. Today, this desert area is the most productive land on Earth thanks to the water from the Colorado river. Desert irrigation is a key element for expanding human settlement.

2.1 Design

We have devised a system that does these tasks: evaporation of seawater, confinement of the vapour, and condensation and salt separation from water, all in an enclosed piece of atmosphere by using its own rules.

A pyramidal shaped structure formed by an outer transparent film with a parallel black layer underneath captures the Sun's energy by heating the air between them. Loss of density by the rise in temperature moves the warm air towards the apex of the pyramid reaching more than 100°C.

In a small area near the apex of the pyramid seawater is sprayed, and by exposing the droplets to extremely dry, hot air, instant evaporation occurs, leaving aside small crystals of NaCl, which fall to the bottom of a collecting sleeve.

A central condensation column absorbs vapour-laden air. A heat interchange process allows the latent condensation calories of the process to be used, warming, in turn, the water that feeds the nebulizers. Mechanical vapour compression technology is used for better administration of the caloric resources, following the works of Palandre & Denis (2003). This process allows the use of every calorie more than four times. Along the column, the temperature lowers as the distillation process proceeds to the underground gallery.

Stored water at the gallery provides the lowest temperature in the whole process so that the minimum absolute humidity remains in the cooled air. This air reaches the base of the pyramid providing natural, geothermal air conditioning. Air enters the interlayer space and closes the circuit. Other technologies have used some of the elements here exposed, but the open circuit of the air leads to a significant reduction of yield and a lower water production (Seawatergreenhouse, Davies & Paton, 2005).

Different optimization processes allow the best administration of the energy provided by the Sun. A 70% energy capturing capacity has been determined by analytical processes. Altogether, a production of more than 16.000 m^3/annum can be obtained at a latitude 40°N for the irradiation conditions of Ciutadella (Menorca, Spain). Much better values can be expected in higher irradiation areas such are the deserts of Abu Dhabi, Nevada, Western Australia or Namibia, just to mention some of the highest irradiation areas around the world (see below).

The complete setting of the mentioned infrastructure is being developed at present time after the support from the European Commission through the EASME programme. Under these conditions, we expect to set up a commercial size plant in Menorca to learn from it, show it and fully certify the technology developed, by spring of 2018.

2.2 Process Engineering

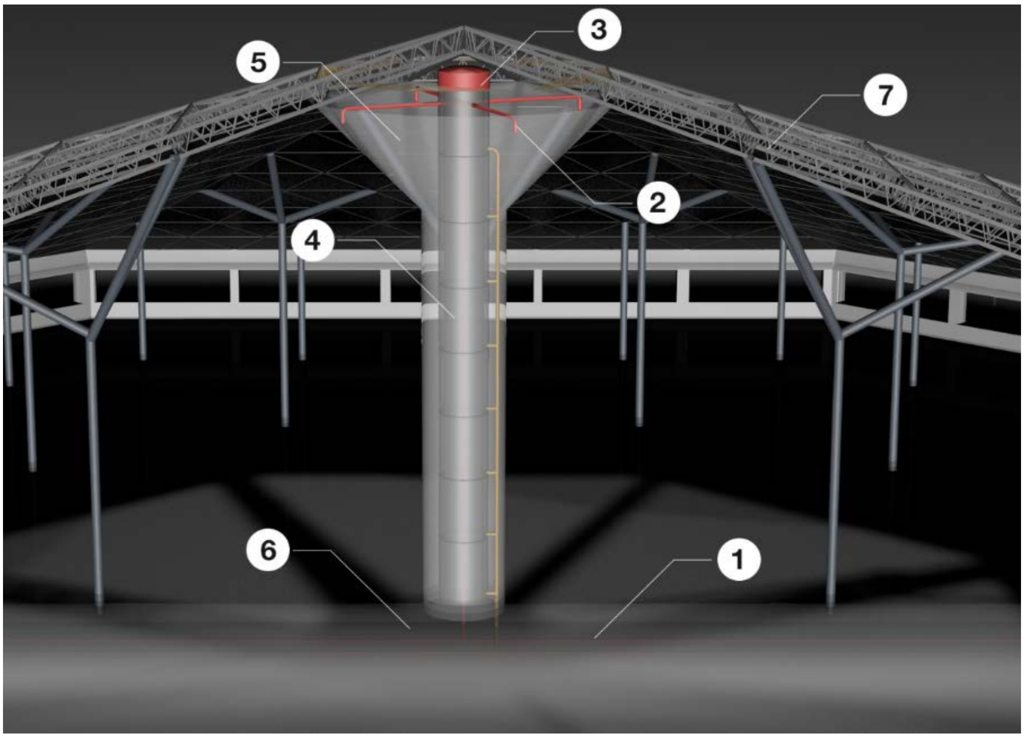

Figure 1. Design elements

The whole desalination system comprises:

1. *Seawater intake pipe:* Main collector of water from the sea, which includes also the pre-treatment equipment (filtering & dosing).
2. *Nebulisers* – 4 racks including 3 nebulisers each, working at pressures from 1.5 to 6 bar.
3. *Compressor* **–** Compressor with variable speed and pressure (from 0.1 to 1.3 bar) placed on the top of the condensation column.
4. *Condensation Column* **-** Supporting column located at the axis of the pyramid, which allocates condensed water flowing from the top within 8 vertical chambers called “stages” (decreasing in pressure & temperature), as well as a main inlet seawater pipeline passing through the stages from the ground. Heat transfer occurs in such a process and reaches the underground gallery of fresh distilled water.

5. *Salt gathering sleeve* **-** Made of Teflon to prevent adhesion of the salt or brackish water projected by the droplets.
6. *Underground Gallery* **–** located at the lowest level of the pyramid. It encloses fresh water storage (175 m^3) and it also serves as low temperature reservoir to attain the lowest temperature in the whole process.
7. *Structure* **–** Metallic supporting profiles that build-up the octagonal-based pyramid.

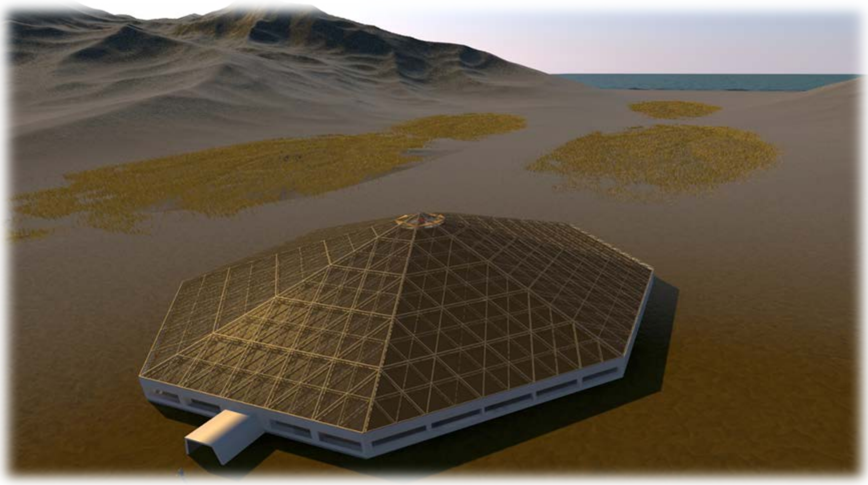

Figure 2. General layout.

2.3 Intellectual property

Patents (Table1) have been filled in the main markets around the world. Other than the European Patent for UE countries (and other associated countries such as Turkey, Montenegro, etc.) the technology is defended in 14 countries, including the Gulf Cooperation Council countries (approved), Mexico (approved), USA (approved), Australia (approved) and Namibia, South Africa, Israel, Jordan and India (patent pending).

▪ European Patent - EP2690069 A1	▪ Namibia NA 2013/0023
▪ International - WO2012127081 A1	▪ UA Emirates 2012/20850
▪ USA - US20140054159 A1	▪ Arabia Saudi 2012/20850
▪ Australia - AU2012230190	▪ Kuwait 2012/20850
▪ South Africa - ZA 2014/02729	▪ Oman 2012/20850
▪ Qatar 2012/20850	▪ India 8303/DELNP/2013
▪ Bahrein 2012/20850	▪ Mexico -MX/a/2013/010787
▪ Israel IL 228547	▪ Jordan - JO 279/2013

Table 1: List of patents

Location	*kW h m^{-2} day^{-1}*	*m^3 of fresh water*	*MT of salt*
Minorca (Spain)	4.44	16000	560
Abu Dhabi (UAE)	5.46	19676	689
Nevada desert (USA)	7.50	27027	946
Windhoek (Namibia)	6.12	22054	772
Perth (Australia)	5.75	20721	725
Gulf of Aqabah (Jordan)	6.55	23604	826

Table 2: Estimates of irradiation and fresh water and salt production in different locations.

3. Conclusions

A device set up to capture the energy from the Sun allows us to manage physical/thermal variables in a way that optimizes performance in fresh water produced from seawater at a minimum cost. Other than the current uses of solar energy we pursue a distinctive goal which includes salt production, and thus, the absence of brine pollution.

Salt value doesn't need to be emphasized as a prime resource for many industrial and domestic purposes (Maldon, 2017). It helps to reduce the cost allotted to fresh water production.

Through development of this ground-breaking technology, a new method to solve the water shortage problem of many areas around the globe is possible. A third output arises from this unique approach: a multifunctional covered space.

All of this can result in fresh water production at a very low cost. We can expand the opportunities for this solution to be adopted anywhere around the Earth, where and when needed.

4. Acknowledgements

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