

Fog_Hive©

3D Fog Collection along the Coastal Atacama Desert

DR CRISTIAN SUAU¹

¹Welsh School of Architecture, Cardiff University, Cardiff, UK

ABSTRACT: The provision of drinking water turns out to be one of the great challenges for the future because central water supply systems cannot technically or logistically be implemented. FogHive©'s main aim is stopping desertification by repairing endangered fog oases ecosystems, and harvesting water for drinking and irrigation and fostering potential inhabitation in many arid coasts such as Chile, Peru and others latitudes. FogHive© is resilient to different climatic contexts and can dynamically response to the different and intermittent prevailing wind directions by keeping the screen ratio of 1:1 or 1:2. It is an adaptable and lightweight design with emphasis in optimal frame types, forms, structural and surface sizes, structural and constructional specifications made with aluminium, galvanised steel or timber. FogHive© employs hydrophobic meshes and a deployable space-frame to intersect atmospheric water and then harvest it for drinking and irrigation. FogHive© has been tested throughout climatic simulations in the fog oasis of Alto Patache, Atacama Desert (2010). It also performs like a shading/cooling device and a soil humidifier for greenery or crop. Being a transformable construction, it can easily be transported and installed. Its footprint is hexagonal (6m side) which is resistant against strong winds and 'aerodynamic' to the landscape. FogHive© consists of a water-repellent skin facing prevailing winds and a shading device facing the Equator. The water collector, filtering and irrigation network considers local structural materials and techniques. Regarding conventional two-dimensional fog collection, FogHive© upgrades the following aspects: 1. Increasing rate and yield of advection fog by taking into account harvesting rate and climatic parameters; 2. Structural reinforcement of fog collectors through lightweight and deployable space-frames; 3. Reducing installation and maintenance of fog collection; 4. Lowering physical impacts on surrounding.

Keywords: 3D fog collector, deployable space-frame, innovative water supply system for irrigation in arid lands, low-passive energy technologies

REESTABLISHING THE MISSING LINK

Even do the Earth is covered about 70% with water, unfortunately water is asymmetrically available. The supply of clean and potable water turns out to be one of the key challenges nowadays and for the future, mainly in arid regions. Currently, about one billion people have no access to fresh water, mainly in the developing countries. For instance, water supply systems very often cannot technically, economically and/or logistically be realized in coastal settlements along deserts due to the lack of transport network, remoteness or demographic shrinkage. A further large problem in the dry regions of the world e.g. at the Atacama coast is the high demand of drinking water consumption for agriculture. Almost 70% of the World's fresh water supply is used to irrigate 18% of the farmlands (*Wasserforum International*, 2011).

During thousands of years nature has managed the survival of plants and animals on its own by obtaining water from the humidity of the air. Many plants and trees like the *pinus canariensis* have grown to serve as natural fog collectors. They are able to obtain water from the atmosphere in the form of fog, dew or water vapour from

unsaturated air. This represents a topic of increasing interest during the last years and this phenomenon has not yet been fully examined.

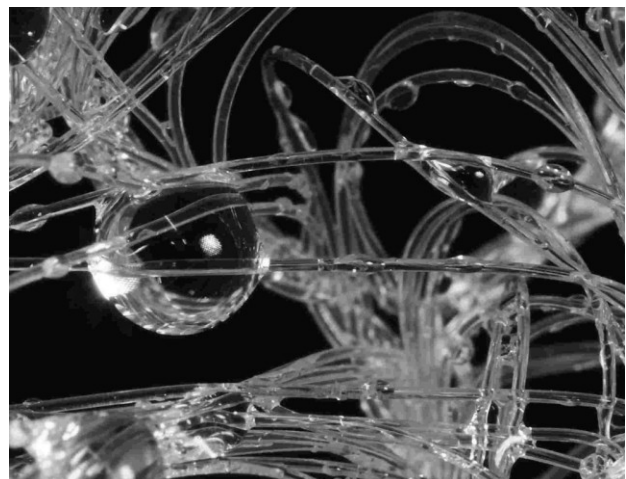


Figure 1: Development of innovative textile based systems to gain water from humidity of the air (fog/dew) without further energy supply. Based on competent biological studies of high

efficient mechanism in living nature which are able to collect already condensed water drops (fog) and/or humidity by capillary condensation as well as cool themselves by special coatings, has already been developed by the German Institutes for Textile and Fiber Research Denkendorf (DITF). Source: DITF

For instance, further systematic investigation with respect to the constitution of certain surface structures (i.e.: plant hairs or trichomes) and their interactions between atmospheric water and plant surface is expected to show results, which are of substantial interest for textile-based technical applications in fog collectors [1].

Apart from these innovative surfaces survey, the shape and size (1:1 or 2:1 ratios) are also key aspects to be investigating, mainly when the water catching/harvesting periods and wind factors are intermittent both daily and seasonally.

FOG FORMATIONS IN THE ATACAMA COAST

The phenomenon of desertification is caused by both climate change and the actions of man (United Nations Environment Programme). In the case of Chile, the land degradation of arid, semi-arid and dry sub-humid areas is the result of two main variables: El Niño's climatic performance and massive mining activities along the Andes Range, which require large amounts of surface and subterranean water resources for extracting, processing and transporting minerals.

Stretching 1000 kilometres from Peru's Southern border into northern Chile, the Atacama Desert rises from a thin coastal shelf to the 'pampas'. There are sterile, intimidating stretches where rain has never been measured. Without moisture, nothing rots. Everything turns into perpetual vastness. Human settlements are established along the coast, mining camps or fishing communities. In the Atacama's coastline, a dense fog known as 'Camanchaca' is abundant. Despite its aridity, the Atacama Desert hosts an impressive variety of plant life. The fog feeds flora called 'lomas', isolated islands of vegetation that can contain a wide variety of species, from cactuses to ferns.

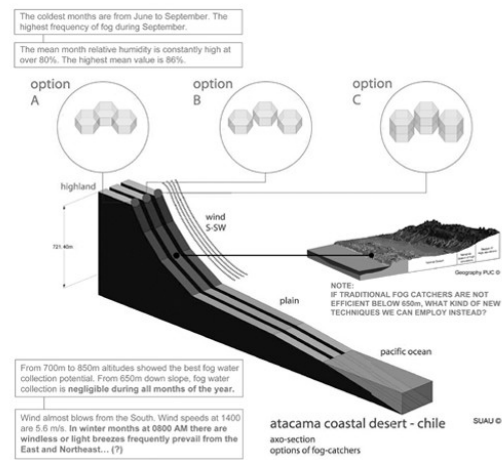


Figure 2. Atacama Desert and its 'Camanchaca' phenomenon: Section and views of the cliff facing S-SW winds in the fog oasis of Alto Patache (Chile). Source: Suau archive, www.ecofab.org

According to environmentalist and activist groups, about 1/3 of the Atacama's total land surface is been affected by this dehydration process. With no rainfall, the depletion and pollution of freshwater sources, and the existing pressures of urban population densities in the port cities, the current administration seems in weak in the attempt to mitigate and trim down the precious water exploitation caused by the mining sector.

Demographic data shows how rural settlements are shrinking, or simply depopulating and immigrating to port cities such as Antofagasta or Iquique. It is urgent to develop a map that shows how this territory is at risk by exposing current water resources and the shrinkage of rural settlements and degradation of fertile hectares used for agriculture. Water scarcity intrudes just as harmfully on communities less accustomed to managing with freshwater shortages, from the high valleys of the mountains to coastal hillside of slums. As a result, this fragile ecological linkage is experiencing the loss of regional biodiversity.

METHOD: RESEARCH BY DESIGN

We have to find new methods to tackle climate into sustainable living by providing an effective and holistic water management, particularly led by science-based innovations in the landscape and urban environments.

The main aim is stopping desertification by repairing endangered fog oases ecosystems, and harvesting water for drinking and irrigation along arid coasts. Decades of pioneer applied research developed by *University del Norte* (Chile, 1957) and continued by the *Centro del*

Desierto de Atacama (Chile) have demonstrated that the technical deployments to resolve scarcities have been implemented at the level of fog oasis, farming fields, local villages and impoverished neighbourhoods

The design methods mainly consisted of a literature review; fieldwork; a comparative analysis of existing fog collection's techniques, and climatic design simulations. This research stage has critically revised the studies made by the hydrologist Christiaan Gischler and the three-dimensional fogtraps so called 'macro-diamonds' developed by Carlos Espinosa and Ricardo Zuleta at the Camanchaca laboratory. Based on these precedents, this survey updated and collected climatic and geographic data provided by CDA combining meeting with experts and fieldwork in the fog oasis of Alto Patache. The current research stage is to elaborate standard design codes for 3D fog catchers: shape, frame and components. In doing so, I take into account three climatic factors: wind (direction and speed), humidity and temperature. Parametric design is employed to test optimal solutions of fog collectors.

FOGHIVE©: POLYHEDRAL FOG COLLECTORS

The conventional fog collectors implemented along the Atacama coast through vertical tensile mesh require urgently to be upgraded, mainly through new shapes, fabrics and structural frames by following the design principles of lightness, transformability and portability.

These alternatives are variables under our control; however, there are outer variables affecting the deposition rate over which we have no control. These include wind speed, air temperature, and humidity. There are several routes to understanding the relationship between the variables. One is based on experience from tradition, which might be able to affirm which materials work well in which specific locations. Another one is through experiments that researchers have done which have yielded empirical relationships, such as wind speed, fog density, and deposition rates.

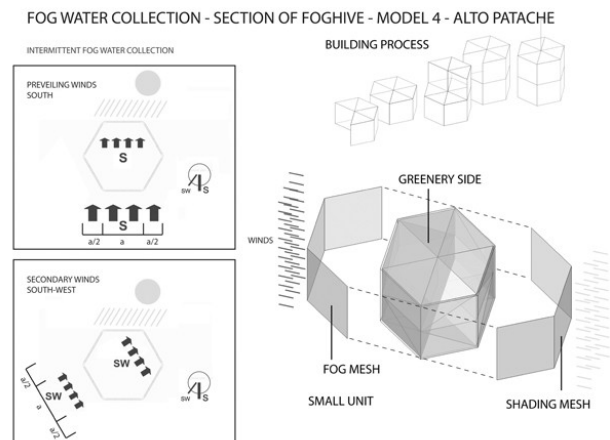


Figure 3. Plans and axonometric models of FogHive© - model 4. The hexagonal footprint seems the most efficient way to response climatically to shading and fog water capture aspects. It secures the best length/height ratio for 3D fog collectors, which is 1:1 or 1:2 (proportional dimensions). Source: Suau archive (2011), www.ecofab.org

This design phase has climatically analysed and chosen as significant natural scenario the fog oasis of Alto Patache located along the coast of Atacama (Northern Chile). By collecting climatic data, I simulated several 3D fog collectors and calculated which one was able to increase the yield and therefore harvesting of fog water. Then design recommendations (inclusive structural and constructional details) were diagrammatically developed to generate the final form of FogHive©.

Regarding conventional two-dimensional fog collection, FogHive© upgrades the following aspects: A. Increasing rate and yield of advection fog by taking into account harvesting rate and climatic parameters; B. Structural reinforcement of fog collectors through lightweight and deployable space-frames; C. Reducing installation and maintenance of fog collection; D. Lowering physical impacts on surrounding.

FogHive© framework consists of a 'mecanoo' structure made with aluminium, galvanised steel or timber pieces. The screening (or membrane) is based on hydrophobic 3D textile fabrics developed by the Institute of Textile Technology and Process Engineering Denkendorf. The structural and constructional components of FogHive© are well defined. The space-frame has a hexagonal footprint (6m size), which is both resistant against strong winds, yield a better efficiency, and add an appropriate 'aerodynamic' feature to the abrupt coastal contours by allowing various configurations and groupings.

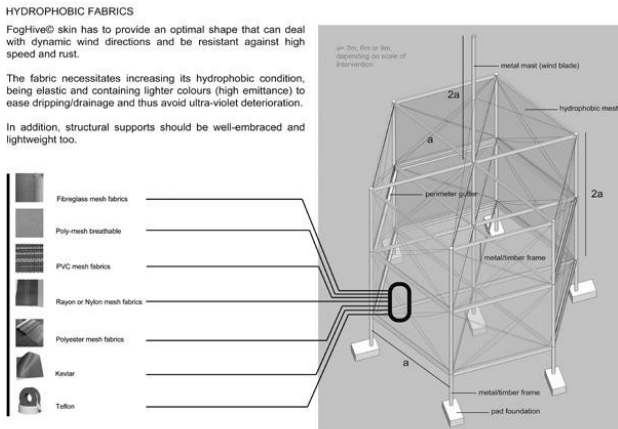


Figure 4. Palette of hydrophobic skins applied in FogHive©. Source: Suau archive (2011), www.ecofab.org

Each side is 6 meters and it is elevated at least 1.5 meters from the ground level, facilitating the inflows of fog and therefore the intersection of droplets in the rear surfaces as well. The other advantage of this form is that performs as a shade-space: it shades the inner space and the surfaces behind the ones that are facing the equator.



Figure 5. FogHive© is intersecting the 'camanchaca' in the fog oasis of Alto Patache (Chile) at dusk. Source: Suau archive (2011), www.ecofab.org

From, size and ratio matter! As result, the prototype FogHive© is a deployable and modular space-frame which adapts to different geographic and climatic contexts. It was invented by Dr. Cristian Suau.

Due to his hexagonal footprint, it dynamically responds to the intermittent wind directions by establishing a screen ratio of 1:1 or 1:2. This design always allows intersecting fog from any direction. FogHive© is a modular device adjustable to any optimal form, frame and surface size. For instance, one of the key

design premises affirms that 'there is a relationship between temperature, wind and fog collecting: the cooler the mesh surface, the more water is collected.' Colour matters! It is clear that any conventional dark mesh exposes to direct sunlight is high-absorbance surfaces and does not enable the grouping of droplets during daytime.

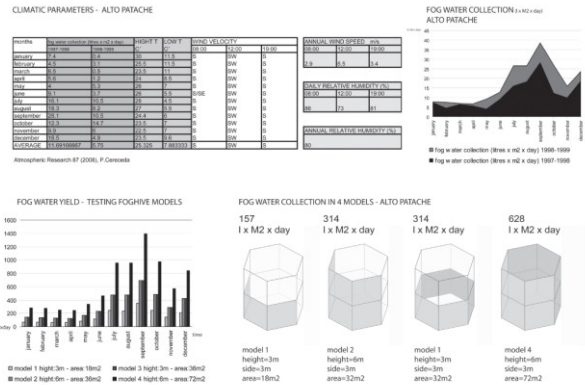


Figure 6. Climatic parameters, fog water collection and yield applied in 4 models of FogHive© (size=6m). Source: Suau archive (2011), www.ecofab.org

This issue lowers the current fog water efficiency of the two dimensional fogtraps whilst opens room for improvement. Instead of applying conventional double-layer black 'Raschel knit' mesh, FogHive© employs light coloured hydrophobic membrane that response better to the water collection. If the surface deploy tri-dimensionally, then it can intersect fog in any direction of the wind flows.

Both frames and skins have to provide an optimal shape that can deal with dynamic wind directions and be resistant against high speed and rust.

The fabric used necessitates increasing its hydrophobic condition, being elastic and containing lighter colours (high emittance) to ease dripping/drainage and thus avoid ultra-violet deterioration. In addition, structural supports are well braced and lightweight.

FogHive© combines the agile structural principles of Tensegrity and Geodesic principles widely developed by the American engineer Buckminster Fuller –geodesic domes (1948-49)- and the German structural engineer Frei Otto, with his lightweight, tensile and membrane structures developed in the late 1950's.

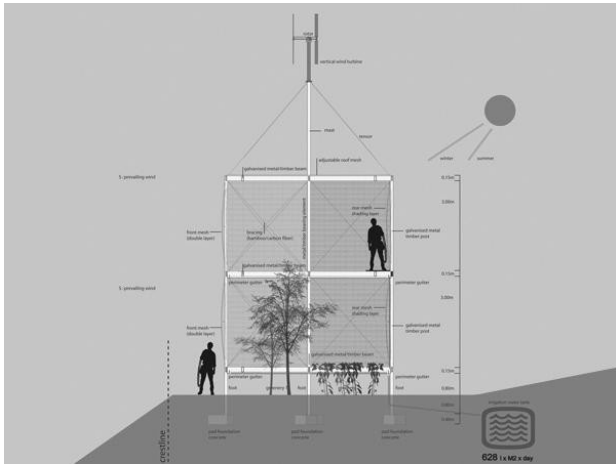


Figure 7. FogHive© harvests 672 l x M2 per day. It means it can irrigate almost 27 times its hexagonal surface average. The cultivating surface varies according to the type of greenery established. Source: Suau archive (2011), www.ecofab.org

FogHive© is a lightweight, polyvalent and modular space-frame, fully wrapped with a light hydrophobic mesh, which can collect water fog. It is also a shading/cooling device and a soil humidifier for greenery and potential inhabitation. Being a transformable construction, it can easily be installed on flatten or uneven grounds. Its footprint is hexagonal.

CONCLUSION

Despite the fact that the technology currently meets the requirement for small volumes of water, future development work should be directed toward increasing the yield from the harvesters for small, intermediate and large applications. In particular, if this goal is to be achieved, studies need to be aimed at design principles that might increase the flows of fog towards the collection area.

A rigorous study of updated meteorological parameters must precede any further proposed application of polyhedral systems, not only to determine if the correct combination of geographic and climatic conditions exists, but also to contribute to the understanding the complexity of these factors so that their occurrence may be predicted properly. In terms of climatic issues, we still need to know in depth about the timing and nature of the fog events. Unfortunately there is no a climatic station in our chosen site and the existing data is primarily average, either aggregates of several events or averaged over a long period. The suggestion of a time lapse film, ideally attached with accurate atmospheric measurement might help as well. This study still has to establish the efficiency of the capture; i.e.: total latent water in the air, and how much can be extracted. That would give us an

idea of how far the FogHive© concept could be pushed. One way to establish this is to measure the total water content of the air during any fog episode. One simple method to do this is from a measure of visibility: the denser the fog, the greater the water.

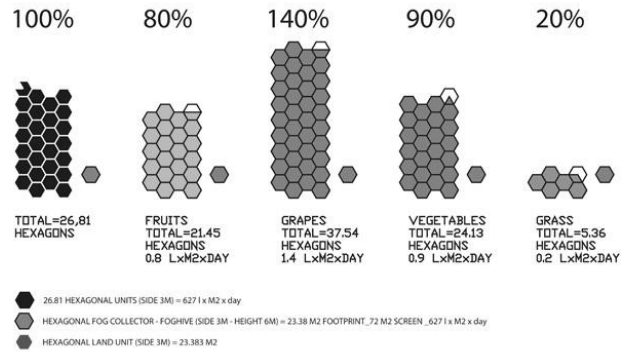


Figure 8. FogHive© harvests 672 l x M2 per day. It means it can irrigate almost 27 times its hexagonal surface average. The cultivating surface varies according to the type of greenery established. Source: Suau archive (2011), www.ecofab.org

Based on the initial research of hydrophobic fabrics, we still have to research the size (or range of sizes) of the droplets. It could be useful in deciding on the mechanisms for fog capture, and so inform on the size of net filaments, levels of porosity, etc. The polyhedral meshes do not just respond to fog catching collection but also allow the potential repairing for endangered local flora and fauna or the establishing of mini-agriculture due to their performance as 'shading spaces'. The modules could also allow the possibility for temporary or transient accommodation at the collection sites; for instance, maintenance workers, water harvesters, farmers or even eco-tourists.

There is a regional concern over the issue of collecting and concentrating atmospheric pollutants into the soil when untreated water is used for irrigation. There might also be concern over the impact of different net types and its durability due to birds' intrusion searching for water. One of the contributions of 3D fogtraps in rural or natural contexts is mainly to repairing endangered ecosystems (existing fog oases); establish new flora and thus stopping coastal erosion or desertification along the coast in different latitudes. FogHive© offers the possibility of obtaining water without energy input (as opposed to traditional, energy-intensive membrane technology for treating salt water), so that the long-term shortage of primary energy sources and the current climate change due to the increase of CO₂ emissions can

be counteracted. Finally, this study set up the foundation to fabricate a mock-up model which can test 'in situ' both structural supports for the fabrics and connectors/appliances for water collection, filtering (purification), storage and irrigation systems. It will be tested in small-scale trials and, after developing commercially viable production and potential new regions for their deployment will be mapped.



Figure 9. Fog oasis: accidents along the Atacama coast in Northern Chile. Source: Suau archive (2011), www.ecofab.org

ACKNOWLEDGEMENTS

Special gratitude is given towards the team of *Centro del Desierto de Atacama* (CDA) led by Pilar Cereceda in Chile. They provide the updated climatic and geographic data of my research; and co-ordinating my fieldwork in the fog oases of Alto Patache and Cerro Guanaco, Iquique. Finally, this research was possible due to the support of two exceptional researchers: Dr. Pablo Osses and Dr. Horacio Larrain, who make possible my on-site design tests and climatic verifications. Finally, I cannot forget the brainstorming sessions, discussion and presentations carried out at the Welsh School of Architecture where Dr. Mike Fedeski and Dr. Don Alexander gave me their expertise guidance in the fields of Physics and Sustainable Environments.

REFERENCES

1. Due to an almost infinite number of combinations in terms of fibres, surface and volume structures, advanced textiles offer a huge potential for the separation and harvesting of water from the atmosphere in the form of fog and dew. (Sarsour et al., Sept. 2010).
2. Pietro Laureano, *Atlas del Agua* (Barcelona, UNESCO, LAIA editors: 2001)

'Water: Our Thirsty World', *National Geographic Magazine (special issue)*, Volume 210, No. 4, 2010

3. C. Gischler, *The Missing Link in a Production Chain* (Montevideo, UNESCO/ROSTLAC, 1991)

4. P. Cereceda, 'The Climate of the Coast and Fog Zone in the Atacama Desert of Tarapacá Region, Chile' in *Atmospheric Research*, N° 3-4, Volume 67 (2008) pp 301-311

5. P. Cereceda, H. Larrain, P. Osses, M. Fariás, and I. Egaña, 'The Spatial and Temporal Variability of Fog and Its Relation to Fog Oases in the Atacama Desert, Chile', *Atmospheric Research* (2007)

6. P. Cereceda, P. Osses, H. Larrain, P. Lázaro, R. Pinto, and R.S. Schemenauer, 'Advective, Orographic and Radiation Fog in the Tarapacá Region, Chile' *Atmospheric Research*, Elsevier Science, Volume 64 (2002) pp 261-271

7. H. Larrain; P. Cereceda.; R.S. Schemenauer; P. Osses.; P. Lázaro and A. Ugarte 'Human Occupation and Resources in a Fog-covered Site in Alto Patache (South of Iquique, Northern Chile)' in *Proceedings of the First International Conference on Fog and Fog Collection*, (Vancouver, Canada, 1998) pp 217-220

8. C. Gischler, *Camanchaca as a Potential Renewable Water Resource for Vegetation and Coastal Springs along the Pacific in South America* (Cairo, Egypt, UNESCO/ROSTAS, 1970)