The Sahara Forest Project

A proposal for ameliorating both the effects and causes of climate change

"No man, except in the first nine months before he draws his first breath, manages his affairs as well as a tree does" George Bernard Shaw.

1. Introduction

The world is running short of fresh water. With agriculture accounting for some 70% of all water used, the water shortage is closely linked to food production and economic development. The provision of clean water is a pre-condition to life, health and economic development and the lack of water in many parts of the world is the root cause of much suffering and poverty. Present methods of supplying water in arid regions include: over-abstraction from ground reserves, diverting water from other regions and energy-intensive desalination. None of these methods are sustainable in the long term and inequitable distribution leads to conflict. To make matters worse, global warming is tending to make dry areas drier and wet areas wetter. Since the 1980's, rainfall has increased in several large regions of the world, including eastern North and South America and northern Europe, while drying has been observed in the Sahel, the Mediterranean, southern Africa, Australia and parts of Asia.

The growth in demand for water and increasing shortages of supply are two of the most certain and predictable scenarios of the 21st century. Agriculture, with a high demand for water, is a major pressure point. A shortage of water will also affect the carbon cycle as shrinking forests will reduce the rate of carbon capture, and the regulating influence that trees and biomass have on our weather will be disrupted, exacerbating the situation further.

Fortunately, the world is not short of water, it is just in the wrong place. Converting seawater to fresh water in the right quantities and in the right places offers the potential to solve all the problems described above.

The world's surface may be conveniently divided into thirds. Two thirds are covered by the oceans, and if the planet was ground flat by a giant scraper, it would be covered by seawater, a mile deep. Thus while we are short of fresh water, we have an abundance of seawater. Of the land's surface, roughly one third is occupied by mankind in various states of development, one third is forest (and shrinking) and the remaining third is desert (and growing).

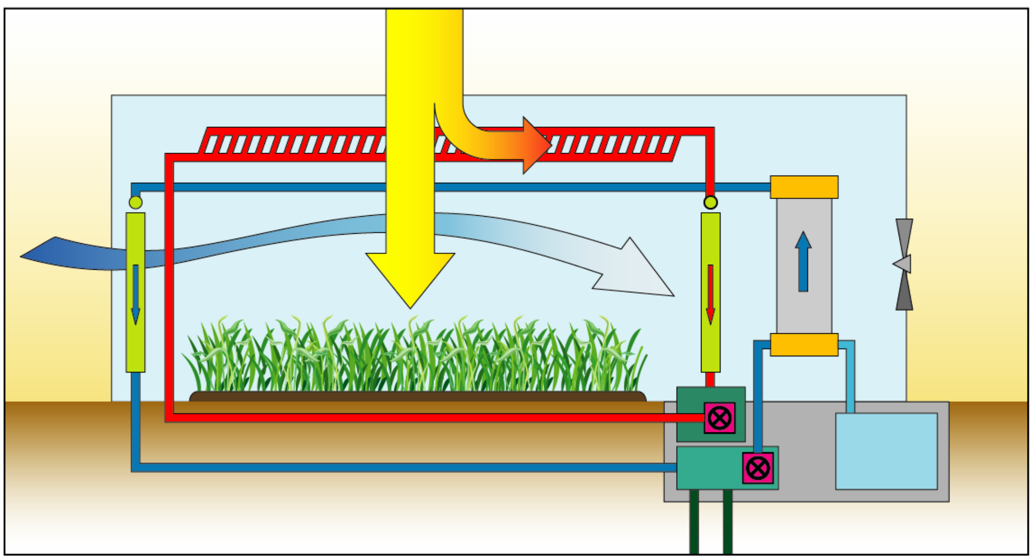
Many, if not all of the world's deserts formerly supported vegetation, and were it not for the lack of fresh water, they could do so now. We have demonstrated, albeit on a tiny scale, that it is relatively straightforward to convert seawater into fresh water, and thus enable crops and trees to grow in some of the most hot and arid places on earth. The following notes illustrate how this process could be scaled up and seeks to identify where it could be of greatest advantage.

2. The Core Elements of the Proposal

2.1 The Seawater Greenhouse

The Seawater Greenhouse process uses seawater to cool and humidify greenhouses and to convert sufficient humidity back in to fresh water to irrigate the crops and a surplus for further agriculture or human consumption. It works well in that a simple and low cost solution enables crops to be grown throughout the year in some of the hottest countries on earth.

As the diagram below illustrates, the process is reasonably simple. The air going into the greenhouse is first cooled and humidified by the first evaporator. This provides good climate conditions for the crops in the growing area. As the air leaves the growing area, it passes through the second evaporator which has seawater flowing over it that has been heated by the sun in a network of black pipes above the growing area. Thus the air is made much hotter and more humid, such that fresh water will condense out of the air-stream when it is cooled.



In a sense, the simplicity of the process mimics the natural hydrological cycle where seawater heated by the sun, evaporates, forms clouds and returns to the earth as rain or dew.

Interestingly, the cooler and more humid conditions enable crops to grow with very little water, and as the crops are not stressed by excessive transpiration, the yield and quality is higher. It is interesting to note that part of the solution to the world's water shortage may not be to produce more water, but to use less water, yet grow better crops.

Irrigation requirements -Tenerife.

When compared with conventional greenhouses and conventional desalination, the Seawater Greenhouse uses very little electrical power, as the thermodynamic work of cooling and distillation is performed by energy from the sun and the wind. For example, 1kW of electrical energy used for pumping seawater can remove 800kW of heat through evaporation. The modest electrical demand enhances the potential for driving the entire process using photovoltaic power, yet without the need for batteries, inverters etc. Such a development would enable food and water self-sufficiency, especially in remote, arid regions.

However, it has two extra qualities that become significant when scaled up:

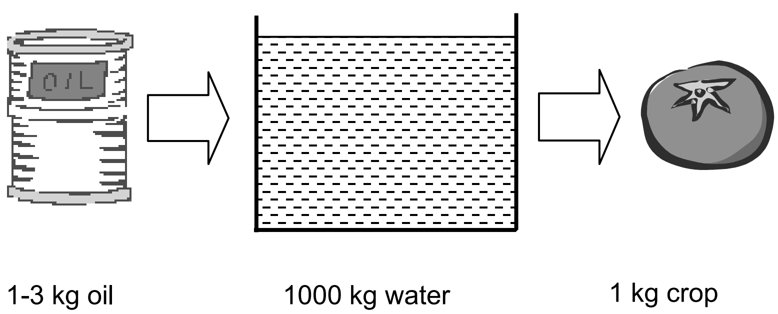
1 The evaporators are very effective air scrubbers, and in combination with the salt water, have a biocidal effect on any airborne contaminants, pests etc. Accordingly, we have never had to use pesticides inside the greenhouse.

2 It evaporates a great deal more water than it condenses back into fresh water. This humid air is 'lost' as we maintain high rates of ventilation to keep the plants cool and supplied with CO_2, but it maybe that this ‘free’ humidity becomes the most significant factor.

2.2 Large-scale application of the Seawater Greenhouse

The photograph below shows Almeria in the south of Spain, and is used here as a reference example of how to convert unsustainable greenhouses into a new and sustainable source of fresh water. The region comprises 20,000+ hectares of greenhouses in a desert. There are a further 20,000 hectares up the coast in Murcia. These greenhouses have caused a lot of environmental damage as they consume 5 times more water than they get in rainfall, and as they are poorly managed and have no climate control, they use excessive quantities of pesticides, which are becoming increasingly ineffective, especially against whitefly. The whole region is now suffering from severe environmental degradation and productivity is severely threatened.

If they were converted to use the Seawater Greenhouse process, the situation would be reversed, and rather than depleting the south of Spain of fresh water, they would make a positive contribution to it. However, in considering solutions to the problem, the authorities made a choice between diverting the Ebra river in the north of Spain, and building large scale, fossil fuel driven desalination plants on the coast. They have chosen to implement the latter.



Basic economy of conventional desalination for agricultural use

The energy intensive nature of conventional desalination makes this a questionable practice, as illustrated in the diagram above. The choice was driven by political and commercial motives, as the huge commercial success of the horticultural industry has taken the region from the bottom of the country's regional league table for wealth creation at number 80 to number 5.

The Seawater Greenhouse in Oman, illustrated above, evaporates around 5 tons of seawater a day from a 1000m2 greenhouse. That equates to 50 tons a day per hectare. Thus if we converted an area of greenhouses equivalent to that of Almeria to the SG process, it would take 1,000,000 tons of water out of the sea every day and evaporate it. Assuming that what goes up must come down, the water vapour would fall back as rain or dew - but where? If the greenhouses were located upwind of some significantly higher terrain then the rain would fall on land as rain or dew and would bring many benefits to arid regions.

If it fell in the Mediterranean, it would not be much use, but if it fell on land, and without flowing back to the sea, it would bring many benefits to arid regions.

The total area of greenhouses around the Mediterranean is 200,000 hectares, and this area has been growing at more than 10% a year - ie the size of Almeria every year, so such a scheme could be both profitable and self financing, as the additional water vapour is produced as an essentially free by-product of growing crops. Greenhouse horticulture in Europe is dwarfed by that in China, where there are some 2.1 million hectares of greenhouses, as well as a fast growing problem of desertification.

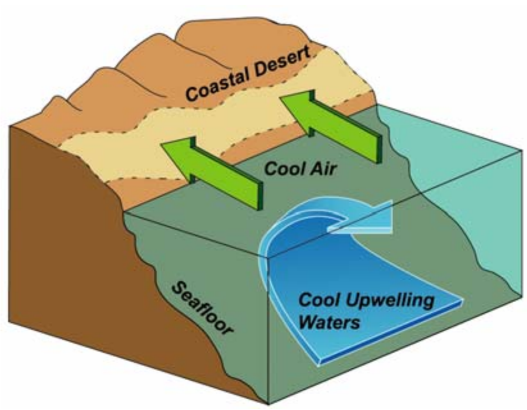
So, if this growth were concentrated where it could do most good, in say North Africa, it could increase rainfall in the Sahara and help restore the vegetation that used to be there. Other locations such as the Arabian Peninsular may offer similar potential. The geographical areas identified as promising would need to be studied in greater depth, including climate modeling in order to assess their suitability and potential.

2.3 Further opportunities from the Seawater Greenhouse

The SG process works highly effectively in a wide range of climate conditions. Two examples are suggested here that describe the extremes.

2.3.1 Arid coastal deserts

Arid coastal deserts are often caused by the presence of cold ocean currents or the upwelling of cold water, Examples are found in Namibia, Chile, Peru, California and Morocco.



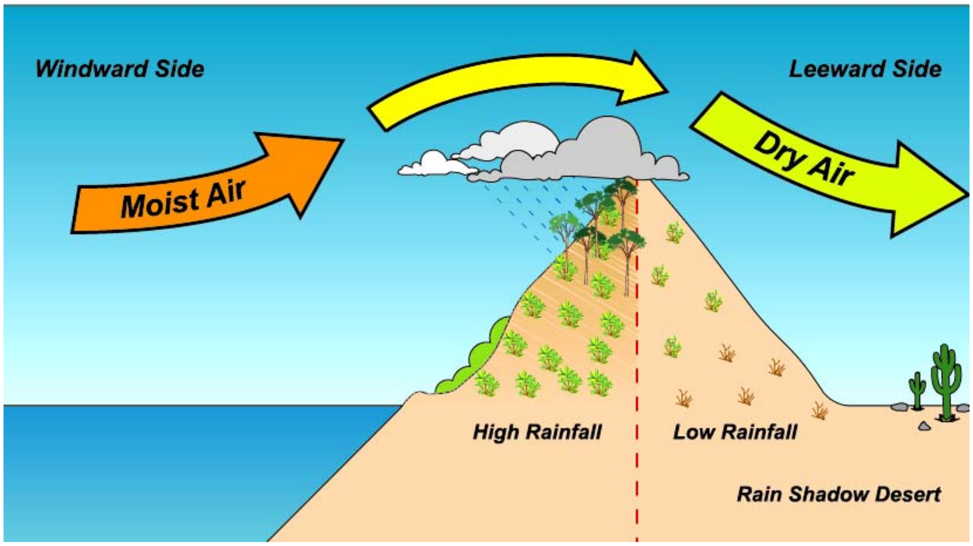
Even though these regions enjoy abundant sunshine, the air blowing off the sea is cooled by the chilly seawater, reducing its capacity to hold water vapour. It frequently comes ashore as fog, which is rapidly driven off by the heat of the land. Such regions often have a flat coastal plain with a mountain range further inland, e.g. the Atlas in Morocco or the Andes in Peru and Chile. As air blows up the mountain, it cools, typically by 1ºC every 100 metres. The effect is illustrated above.

In such locations, an array of SG's on the coastal plain would increase the volume of water vapour in the air and increase the likelihood of precipitation on the mountain slope. It often happens that dew or mist will not condense on bare rock as it is too hot, while grass or trees, being cooler, will encourage condensation. The redwood forests in California for example, get most of their water from intercepting the mist that rolls in from the sea.

Enormous volumes of water are contained in the fog present in coastal and mountainous regions. The water droplets in these fogs can be collected by vegetation, as in tropical or temperate cloud forests, or deposited onto grass covered hills. In desert regions, or where tree cover has been removed, deposition is minimal and the fogs ultimately evaporate. However, these regions offer the possibility to capture fog droplets in large artificial fog collectors. This is an inexpensive, low-technology source of water for domestic, agricultural and forestry uses. If the water collected by fog nets is used to irrigate tree saplings, the trees will take over the role of the fog nets once they are established.

2.3.2 Hot Inland deserts

Many of the world's deserts are located in subtropical latitudes and are characterised by dry air masses descending. Low relative humidities are produced as the air is heated due to compression as it descends into a region of higher pressure. The Sahara and the Arabian Peninsula are typical examples. While they have an abundance of space, the main objection to locating greenhouses in these deserts is the cost associated with laying pipes, pumping and the disposal of the salt. This issue is addressed in the next section.

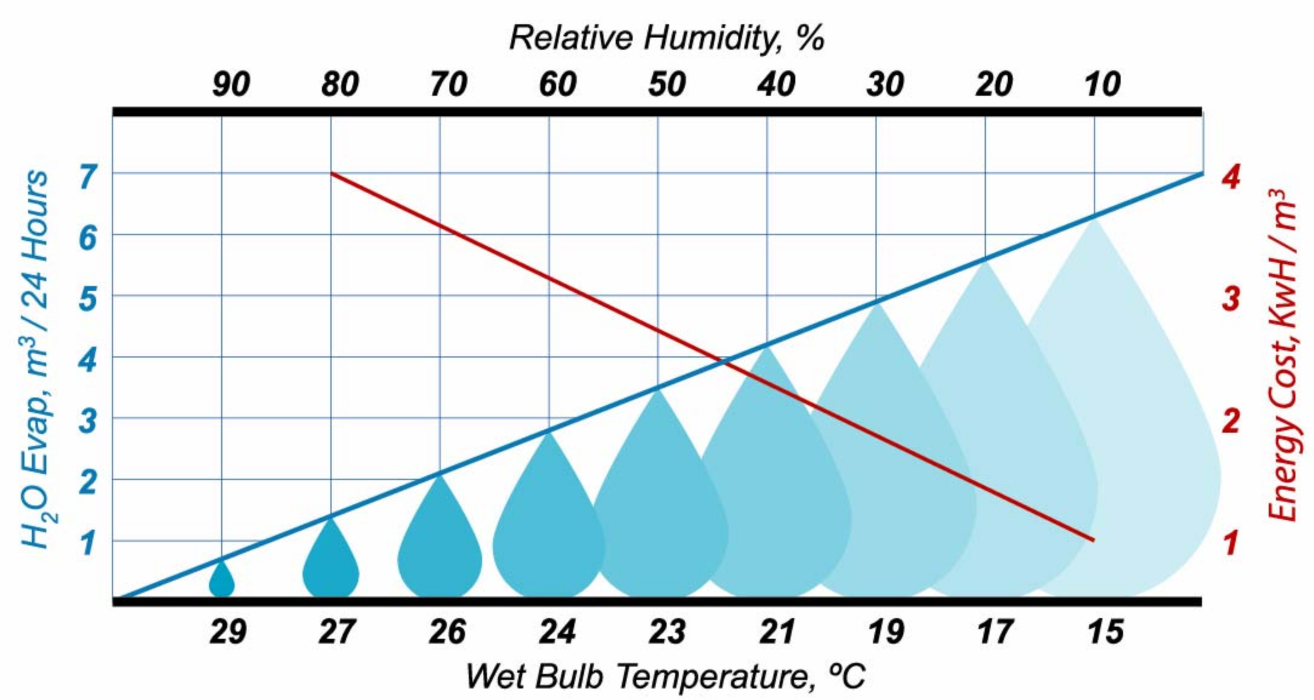


2.4 Potential to exploit land locations below sea level

There are a number of depressions in the Sahara in Morocco, Tunisia, Libya, Egypt and Eritrea. If these were used, there would be no pumping costs. The Qattara depression in Egypt is 133m below sea level, and could thus be further exploited for hydro-electric power[12]. There are depressions in the USA and Australia, and there is the Dead Sea, the lowest point on earth at some 400m below sea level. A major benefit of implementing the Seawater Greenhouse process inland is that the Relative Humidity (RH) tends to be lower further from the coast. Typically, the daytime prevailing wind blows off the sea on to the coast, and the RH in coastal regions is usually around 60-70%. This falls with increasing distance from the coast as water vapour is lighter than air and thus rises. In the middle of the Arabian Peninsular or the Sahara for example, the midday RH is typically 20% or less. At 20% RH the Seawater Greenhouse would evaporate almost three times as much water than it does at 70%RH. This would also achieve lower temperatures and increase fresh water production.

[1] http://www.unu.edu/unupress/unupbooks/80858e/80858E0a.htm#2.11%20Mediterranean-Qattara%20solar-hydro%20and%20pwnped-sto

[2] http://www.unu.edu/unupress/unupbooks/80858e/80858E1J.GIF



The chart illustrates the cooling effect and potential for evaporation for air at a constant temperature of 30ºC with reducing humidity. The values are based on a nominal 1000 m^2 Seawater Greenhouse.

As relative humidity falls, so too does the temperature of air that has passed over a wetted surface (the wet bulb temperature). At the same time, both the volume of seawater evaporated increases and the amount of fresh water that can be produced also increases. This is achieved without incurring any additional cost penalty, other than that of delivering the seawater to the site. Thus the volume of water produced, and its associated cost is very specific to the location and its environmental conditions.

The red line, right hand axis, illustrates how the nominal energy cost of producing 1m3 of water falls with reducing humidity. This value does not include the energy cost of pumping seawater to the site, or for cooling the greenhouse itself as this is dependent on location, with height above sea level being the most significant factor.

2.5 Concentrated Solar Power

Many of the locations that are well-suited to the Seawater Greenhouse are also ideal for Concentrated Solar Power (CSP), and there are a number of potential synergies with the Seawater Greenhouse process. Concentrated solar power is increasingly seen as one of the most promising forms of renewable energy, producing electricity from sunlight at a fraction of the cost of photovoltaics.

The principle of CSP involves using reflectors to focus the sun's energy to heat a reservoir of oil which in turn is used to turn water into steam to drive a turbine. The most common types are the parabolic trough collector, the solar tower and the parabolic dish. The first of these involves a trough which rotates in a single plane in order to follow the altitude angle of the sun. The second and third types involve heliotropic reflectors that follow the position of the sun. The efficiency of CSP is typically between 20% and 24% and amount of energy generated is dependent on the solar intensity of the location. Much of the Sahara receives over $800W/m^2$ and a $150,000km^2$ installation of CSP could provide the world's current demand for energy of all kinds.

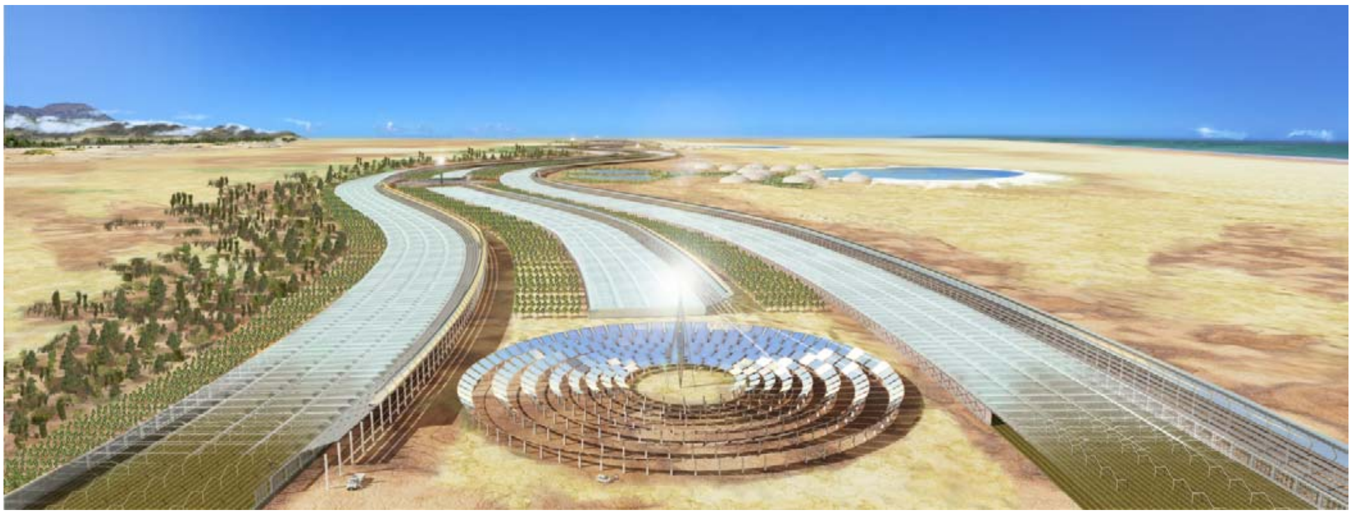
Nevada Solar 1, Las Vegas a 64 Megawatt parabolic trough system.

Solar Tower, Barstow, California

Parabolic Dish System, New Mexico

3. The Concept

The illustration below envisages a combined CSP / Seawater Greenhouse operation, located some distance from the coast in a desert region. The scheme is proposed at a significant scale such that very large quantities of seawater can be evaporated. The greenhouses are arranged as a long ‘hedge’ to provide a windbreak and shelter to the outdoor planting scheme, and to maximize the area of evaporation. If the location is at or below sea level, pumping costs are minimized or avoided altogether.



In most desert regions, humidity falls with increasing distance from the coast. Lower humidity translates to cooler growing conditions, enhanced fresh water production and enhanced rates of evaporation. These conditions will in turn increase the rate of night time dew formation, particularly where low night time conditions are experienced. A 10,000 hectare area of Seawater Greenhouses will evaporate over a million tonnes of seawater per day. If the scheme were located upwind of higher terrain then the air carrying this ‘lost’ humidity would rise and cool, contributing to the occurrence of cloud and dew.

Orchards are planted in the vicinity of the greenhouses which provide water for their irrigation, and a micro climate of humid air. Further downwind, the planting of native species and drought tolerant energy crops such as Jatropha is envisaged as a source of biofuel and to enhance soil fertility.

CSP systems need water for cleaning the mirrors and for the generation of steam to drive the turbines. The Greenhouse evaporators make very efficient dust traps, as do plants that are growing outside. In solar thermal power plants, only about 35% of the collected solar energy is converted into electricity. If combined with sea water another 50% of the collected energy, normally released as heat, can be used for thermal desalination. This way up to 85% of the collected solar energy can be used, and with each TWh of power, 40 million m^3 water can be desalinated in cogeneration. (http://www.desertec.org)

By combining these technologies, the processes both enhance each other, and there is a huge commercial potential to create a sustainable source of energy, food and water. As the only waste product of the process is biomass and humid air, the scheme enhances the restorative effect of reversing desertification and returning areas of desert to forested land.