





RESPONDING TO GLOBAL CHALLENGES USING NATURE'S OWN SOLUTIONS





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Seawater Greenhouse Ltd., Explorer Architecture, Max Fordham Consulting Engineers and The Bellona Foundation.

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For media inquiries, please contact:

The Bellona Foundation Tone Foss Aspevoll tone@bellona.no Tel: +47 91 72 02 67 P.O. box 2141, Grünerløkka 0505 Oslo, Norway

For technical inquiries, please contact

Seawater Greenhouse Charlie Paton charlie@seawatergreenhouse.com Tel: +44 [0]20 7249 3627 2a Greenwood Road London E8 1AB, United Kingdom

0r

The Bellona Foundation Joakim Hauge joakim@bellona.no Tel: +47 23 23 46 00 P.O. box 2141, Grünerløkka 0505 Oslo, Norway

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Foreword

Deserts are often used as symbols of infertility and lost hope. Many, if not all of the world's deserts, formerly supported vegetation. Were it not for the lack of freshwater, they could still do so.

The initiation of the Sahara Forest Project was based on the recognition that the world is not short of water. The water is just in the wrong place and it is too salty. The Sahara Forest Project Team has been developing a unique combination of technologies enabling sustainable production of freshwater, energy, crops and ecosystem-services from seawater, sunlight and nutrients. Until now, the partners behind the Sahara Forest Project consisted of Seawater Greenhouse, Exploration Architecture and Max Fordham Consulting Engineers. As of June 2009, The Bellona Foundation joins the Sahara Forest Project as a fourth partner.

We believe that the partnership will provide an exciting combination of knowledge, creativity and implementation skills. During the development of the project we will team up with solution-orientated politicians, companies, investors and scientists. Together we will bring the Sahara Forest Project to its full potential. Our first step will be to realize an Industrial Ecology Centre.

This folder outlines the backdrop, technologies and potential for the Sahara Forest Project. Now we embark on the path from concept towards realization.



Charlie Paton Seawater Greenhouse



Michael Pawlyn Exploration Architecture



Bill Watts Max Fordham



Frederic Hauge
The Bellona Foundation

Executive summary

The objective of the Sahara
Forest Project Team is to
develop and deploy an integrated, large-scale system
for production of freshwater,
energy, biomass and ecosystem
services on a significant scale.

The inputs are simple and abundant: Nutrients, sunlight and seawater.

The first stage of the project is to establish an Industrial Ecology Centre in order to provide a platform for international cooperation on innovation and development and pave the way for a large-scale roll-out.

The processes integrated into the Sahara Forest Project will work optimally under sunny and arid conditions. The unique benefit of the system arises synergistically from the integration of proven technologies, such as:

Seawater Greenhouses

Seawater greenhouses allow the production of freshwater from seawater, and provides a cool and humid micro-climate well-suited for food and biomass production. Seawater greenhouses have already been built in some of the hottest regions on earth.

Concentrated Solar Power

Concentrated solar power uses solar radiation to produce heat and power, and is the fastest growing technology for harvesting solar energy in the world.

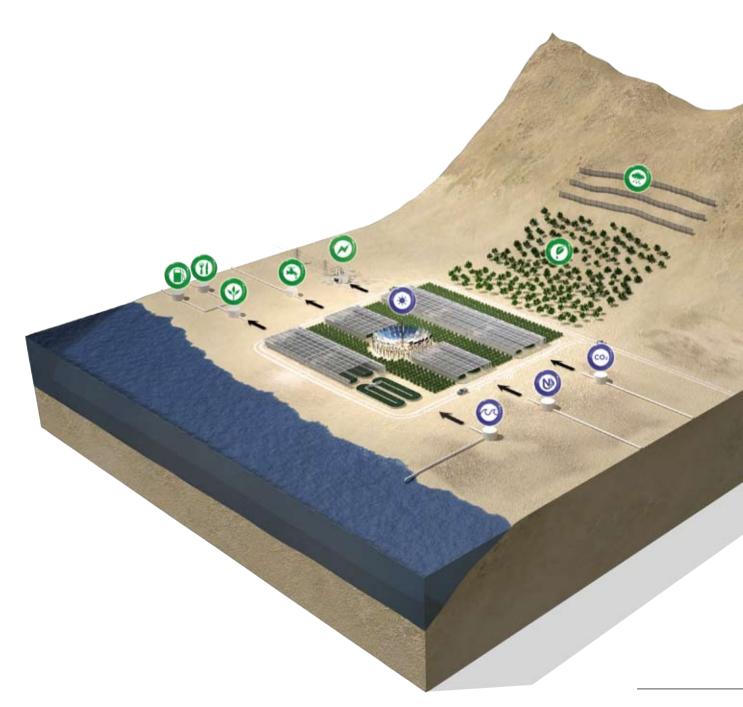
New promising crops, such as algae

Algae can be grown in freshwater, wastewater and seawater. They have unparalleled growth speeds and can be used for the production of fuel, food, fodder and fertilizer.

The team behind The Sahara Forest Project comprises award-winning experts from Exploration Architecture, Seawater Greenhouse, Max Fordham Consulting Engineers and The Bellona Foundation.

The Sahara Forest Project - Stage 1





Key challenges

A cluster of intertwined problems today poses a historic threat towards the stability of our ecosystems and human development.

We have only started to comprehend the gravity of this threat towards our future. However, we know more than enough to realize that failure to respond is simply not an option.

The challenge will be to properly identify the risks we are facing and use this knowledge to rethink how to supply resources for tomorrow's population.

Global warming poses a serious threat to human welfare, as well as to the stability of vital ecosystems. Emissions from energy generation make a large contribution to the total anthropogenic GHG-emissions¹. There is a clear need for substantial cuts. Additionally, the global population is expected to increase from 6.5 to 9.5 billion people by 2050. Without a doubt, this will lead to an additional demand for energy. To meet this tremendous challenge we will need a broad spectrum of nonfossil sources of energy.

A number of recent reports identify increased use of biomass for energy purposes as one important solution. However, the additional 3 billion people will not only need energy. They will also need food. Adding to the complexity of the equation are significant predicted increases in water shortage and land degradation, combined with highly uncertain effects of global warming on future biomass production.

To sum it up: How shall we produce food for 9.5 billion people, while at the same time vastly increasing the use of biomass for energy, in a world characterized by dwindling water resources, increased land degradation and threats from global warming?

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Rising greenhouse gas emissions

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References:

1) IEA (2008): World Energy Outlook. International Energy Agency.

Rising greenhouse gas emissions

Global warming is caused by emissions of CO₂ and other greenhouse gases. In 2009 the atmospheric concentrations of CO₂ reached 389 ppm¹. This is higher than the natural range over the last 650,000 years².

If no measures are taken, the global greenhouse gas emissions are expected to nearly double by 2050. This will lead to dangerous global warming^{3,4}.

Achievement of necessary cuts in anthropogenic greenhouse gas emissions represents an unprecedented global challenge.

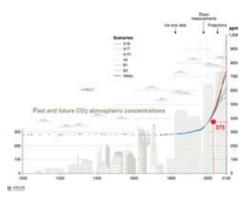
The fourth assessment report from the IPCC states that long-term unmitigated global warming is "likely to exceed the capacity of natural, managed and human systems to adapt"². A global warming of the climate system is described as "unequivocal". Most of the increase in temperature is classified as "very likely due to the observed increase in anthropogenic GHG-concentrations". Emissions of the most important GHG, CO₂, grew by approximately 80 percent between 1970 and 2004.

The consequences of global warming will be many, and they will be intricate. Despite regional differences, it is stated with confidence that the negative impacts of climate change on freshwater systems outweigh the benefits². Higher water temperatures and changes in weather extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution⁵.

Rising sea-levels are projected to extend areas of salinization of groundwater and estuaries. The result will be a decrease of freshwater availability in coastal areas. By 2050, it is predicted that the areas experiencing negative effects on water supplies will be twice as large as the areas positively affected².



Past and future CO₂ concentrations⁶:



References:

- 1) Earth Systems Research Laboratory (ESRL) / National Oceanic and Atmospheric Administration (NOAA): http://co2now.org/
- 2) Intergovernmental Panel on Climate Change (2007): *Climate Change 2007*. Synthesis report.
- 3) International Energy Agency (2006): Energy Technology Perspectives 2006. International Energy Agency report.
- 4) Intergovernmental Panel on Climate Change (2000): IPPC Special Report Emission Scenarios.
- 5) Intergovernmental Panel on Climate Change (2008): Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. B. C. Bates, Z.W. Kundzewicz, S. Wu and J.P. Palutikof.
- 6) Past and future CO₂ concentrations. (2005). In UNEP/GRID-Arendal Maps and Graphics Library. Retrieved 01:20, June 3, 2009 from http://maps.grida.no/go/graphic/past_and_future_co2_concentrations.

Freshwater shortage

Today, 1.2 billion people live in areas with physical water scarcity¹.

An increasing world population will require more water. By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be approaching water scarcity¹.

The challenge will be to sustainably produce enough freshwater for production of future food and biomass.

Freshwater is much too often obtained through over-abstraction from ground reserves. Such practices are diverting water from other regions and increasing the use of energy-intensive desalination.

Shortage of water will affect the carbon cycle as shrinking forests will reduce the natural rate of carbon capture, and the regulating influence that trees and biomass have on our climate will be disrupted, exacerbating the situation further.

Agriculture accounts for more than 70 percent of the world's current total water use¹. According to UNEP it will be necessary to double water use by crops by 2050 in order to meet the Millennium Development Goal on hunger². Improvements can be made in irrigation efficiency, but this will not be sufficient.



Conventional desalination:



References:

- 1) UN Water (2007): Coping with water scarcity challenge of the twenty first century.
- 2) United Nations Environment Program (2007): Global Environment Outlook 4 environment for development.
- 3) WWF (2007): Making water Desalination, Option or Distraction for a thirsty world?

Transition from fossil-based energy

Sixty-one percent of global GHG emissions are from energy-related ${\rm CO_2}^1$.

The US Department of Energy predicts that world market energy consumption will grow by 50 percent from 2005 to 2030, given no changes in current laws and policies².

In a summary of the findings from Energy Technology Perspectives 2008 the challenge was outlined: "The rate of change needed is unprecedented. The analogy is not that we need an Apollo project or other grand undertaking, but more like we need an energy revolution"3.

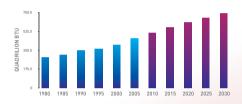
The International Energy Agency (IEA) has concluded that "the era of cheap oil is over"². The agency has called for an energy revolution, stating: "Current global trends in energy supply and consumption are patently unsustainable - environmentally, economically and socially".

The United Nations Framework Convention on Climate Change concludes that current levels of funding will be insufficient to address the future financial flows estimated to be needed for adaptation and mitigation under a strengthened future climate change deal post 2012⁴. UNFCCC further states that particularly in the energy sector, huge investment flows are needed.

It is clear that changes in current laws and policies, as well as increases in global investments, will be necessary to bring down the energy-related GHG emissions. Existing and emerging sustainable energy solutions must be utilized should we have any hope of reaching even the most modest targets for anthropogenic GHG emissions. Rising GHG emissions come at a high cost for our society. Putting a price on GHG emissions, reflecting on some of these costs, will be necessary to ensure investments and utilization of renewable sources of energy and CCS.



World Marketed Energy Consumption 1980 - 2030⁵



References:

- 1) International Energy Agency (2008): World Energy Outlook.
- 2) Energy Information Agency (2008): *International Energy Outlook 2008*, US Department of Energy.
- 3) Dolf Gielen, et al. (2008): *Energy Technology Perspectives 2008*. International Energy Workshop. Paris, IEA/OECD.
- 4) UFCCC (2008) Fact sheet: Financing climate change action.
- 5) Sources: History: Energy Information Administration (EIA) (2007): International Energy Annual 2005. Projections: EIA (2008): World Energy Projections Plus.

Non-sustainable production of food

In 2009 as many as 800 million people suffer from hunger. Thus far, attempts to solve this situation have failed.

It is predicted that we have to double our food production over the next 25 to 30 years to be able to feed a global population of more than 9 billion people in 20501.

The challenge is that our present system of food production will face difficulties in supporting such an increase in a sustainable manner.

As arable land faces threats from land degradation, deficits in freshwater supply and climate changes, our potential food output will increasingly be put under pressure. At best it is uncertain whether increases in crop yield can match those of the past. At the same time, limited amounts of new land will be available for sustainable agriculture.

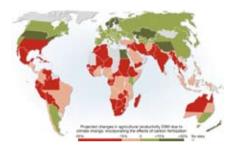
A portion of the required increase in food production can be achieved through better distribution, stricter policies and improved agricultural practices, but clearly not all.

A transformation of our agricultural system is needed. This transformation has to be based on sustainable principles.

Sustainability was defined by the Brundtland Commission as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"². This criterion must be at the core of any evaluation of the options we have for securing the future food supply.



Projected losses in food production due to climate change by 2080:



This projection is based on a consensus estimate of 6 climate models and two crop modeling methods³.

References

- 1) IFPRI (2001): Sustainable Food Security for All by 2020 Proceedings of an International Conference
- 2) World Commission on Environment and Development. (1987): *Our Common Future*
- 3) Projected losses in food production due to climate change by 2080. (2009, Edited by Joel Benoit). In UNEP/GRID-Arendal Maps and Graphics Library. Retrieved 16:46, May 31, 2009 from http://maps.grida.no/go/graphic/projected-losses-in-food-production-due-to-climate-change-by-2080.

Biomass shortage

Biomass in the form of plant material and animal waste has historically been one of the most important sources of energy in the world, and will play a significant role in a global society based on renewable energy.

It is predicted that world demand for biomass will increase substantially over the next years.

The challenge is that there is limited land available for large-scale biomass production.

Biomass for energy purposes is a carbon neutral process. This is due to the fact that the $\rm CO_2$ emitted during combustion is balanced by the uptake of $\rm CO_2$ through photosynthesis during biomass growth.

In the scenario "How to combat global Warming" The Bellona Foundation concluded that biomass had an important role to play in reducing CO₂ emissions¹. A number of other studies also identify biomass for production of energy as a key element in future non-fossil energy production. However, there are huge variations when concluding on the size of the contribution from biomass². A main reason for this variance is differences in predictions of land availability and future yield levels for crop production. Production of biomass normally requires arable land, a requirement that is becoming increasingly difficult to fulfill.

A large-scale sustainable production of biomass in areas that are now non-arable, could significantly add to the potential of bioenergy as a part of future energy solutions.



References

- 1) The Bellona Foundation: 135 (2008): How to Combat Global Warming An ambitious but necessary approach to reduce greenhouse gas emission
- 2) Berndes, G., M. Hoogwijk, et al. (2003) *The contribution of biomass in the future global energy supply: a review of 17 studies.* Biomass & Bioenergy 25: 1-28

Key technologies

During the last 3.7 billion years, numerous species has flourished and vanished. Species which wasted energy, water or food and species that could not find their niche in the ecosystem have lost to those more efficient and adaptive. The selective forces of nature have ruthlessly favoured efficient and flexible principles and designs. This process presents us with an unparalleled amount of time-tested designs.

The Sahara Forest Project aims to make available a new source of fresh water, food and renewable energy in hot, arid regions. This is achieved by the creation of a highly synergetic system with some of the most promising environmental technologies available.

The Sahara Forest Project have the potential to provide a restorative effect of returning areas of desert to forested land and sequestering substantial quantities of atmospheric carbon in new plant growth and reactivated soils. The project incorporates Concentrated Solar Power, Seawater Greenhouses, and facilities for growth of crops such as algae and other valuable crops.

Principles and designs from nature have been incorporated into the architecture, the engineering and the creation of a synergetic technological system. Simplicity has been favoured over complexity, while at the same time pursuing efficiency and flexibility.

The Sahara Forest Project is meant to be continuously evolving and adapting, incorporating new technologies and knowledge.

Read more about:



Concentrated solar power

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Concentrated solar power

According to the legend
Archimedes once used polished
shields to concentrate sunlight
on the invading Roman fleet
and repel them from Syracuse.
Today this principle of Concentrated solar power (CSP)
is applied in the largest solar
power plants in the world. In
fact, many see CSP as one of the
most promising technologies
for the production of cheap,
renewable energy.

Traditional photovoltaic solar panels convert sunlight directly into electricity. CSP utilizes mirrors to focus light on water pipes or boilers, generating superheated steam to operate conventional steam turbines.

The most common types are the parabolic trough collector, the solar tower and the parabolic dish. The parabolic trough collector utilizes a trough which rotates in a single plane in order to follow the sun. The solar tower and the parabolic disk both use two axis reflectors to track the sun and focus the energy on a single point. The efficiency of CSP in converting heat to electricity is typically between 20 and 30 percent, and the amount of energy generated depends on the solar intensity of the location.





Solar towers like this is the is at the core of CSP installations. In May 2009 the world's largest solar power tower plant made up of more than 1200 mirrored heliostats surrounding a huge 54 story high tower went on line near Seville in Spain, Developed by Spanish engineering company Abengoa, the PS20 plant generates 20 megawatts [MW] of electricity, enough to supply 10,000 homes.

The Seawater Greenhouse

The Seawater Greenhouse represents a simple and low cost solution that enables crops to be grown throughout the year in some of the hottest countries on earth. Many years of modeling and testing has resulted in an integration of technologies, mimicking natural processes, and producing the highest maximum yield.

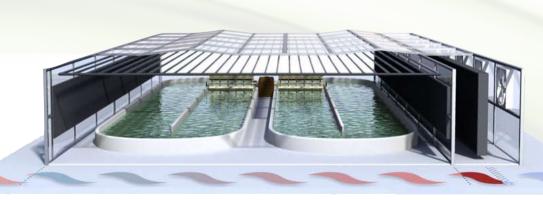
With Seawater Greenhouse it is possible to grow crops without any supply of freshwater. Seawater is evaporated from grilles at the front of the greenhouse to create cool humid conditions inside. A proportion of the evaporated seawater is then condensed as freshwater that can be used to irrigate the crops.

The diagram illustrates the basics of the process. The air going into the greenhouse is first cooled and humidified by seawater, which trickles over the first evaporator. This provides good climate conditions for the crops. As the air leaves the growing area, it passes through the second evaporator over which seawater is flowing. This seawater 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. It then meets a series of vertical polytene

tubes through which cool seawater that has come from the bottom of the first evaporator grilles is passed. When the hot humid air meets these cool surfaces, freshwater will condense as droplets that run down to the base where they can be collected.

The cool and humid conditions in the greenhouse enable crops to grow with very little water. When crops are not stressed by excessive transpiration, both the yield and the quality will be higher.

The simplicity of the process mimics the natural hydrological cycle where seawater heated by the sun evaporates, cools down to form clouds, and returns to the earth as rain, fog or dew.



Schematic of The Seawater Greenhouse with algae ponds



A 1000 m² Seawater Greenhouse has been erected in Oman, evaporating around 5 m³ of seawater a day. That equates to 50 m³ of water a day per hectare of land.

In comparison with conventional greenhouses and conventional desalination facilities, 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, 1 kW of electrical energy used for pumping seawater can remove 800 kW of heat through evaporation.

The modest demand for electricity enhances the potential for driving the entire process using solar power, yet without the need for batteries, inverters etc., as power is only needed during the hours of daylight. Stand-alone operation will enable food and water self-sufficiency, especially in remote, off-grid regions.

The Seawater Greenhouse evaporates a great deal more water than it condenses back into freshwater. This humid air is `lost' due to high rates of ventilation to keep the crops cool and supplied with CO₂. The humidity delivered to the outside environment allows for cultivation of crops, or revegetation of the environment downwind of the greenhouse.





Seawater Greenhouse in Oman





Seawater Greenhouse in Abu Dhabi

Cultivation of algae

It will become increasingly difficult to cover our need for biomass by traditional utilization of agricultural land. However, the oceans and lakes of the world also produce an enormous amount of biomass from algae.

Much of our fossil energy reserves are the remainders of ancient algae. The algae have been a part of the answer to old energy demands and given rise to the environmental problems of today. Could the algae also be a part of future energy- and environmental solutions?

The biomass from algae can be used for food, fodder, fuel or as fertilizer.

All algae utilize the sunlight through photosynthesis. In addition to water, algae also need CO₂ and nutrients, such as nitrogen and phosphor, for growth. The algae are global mega producers of oxygen and global mega consumers of CO₂.

The diverse group of organisms we refer to as algae include the seaweeds, (macro-algae) and a vast number of microscopic species (micro-algae).

Many species of algae can contain a considerable amount of lipids (oils). The exact percentage will vary with species and environmental conditions, but a content of up to 40 percent is achievable for a number of species, while others go even higher. The fact that microalgae can be cultivated in saltwater or wastewater makes them even more suitable for future biomass solutions. Only a small fraction of the algal species are scientifically named and classified.

Many companies cultivate algae for a number of purposes such as food additives and biochemicals. A lot of the commercial interests are linked to potential production of biodiesel and aviation fuel from micro-algae. The residual biomass can be used as fodder, or fertilizer. Technological progress and cost reductions will be necessary before realization of large-scale production for energy-purposes. However, over the last years the increasing investments, scientific efforts and technological progress has been very promising.



Flue gases from the Niederaussem power station in Germany are fed into an algae production plant to convert the CO2 from the flue gas into algae biomass. (Source of picture: RWE Power).



Arrangement of photobioreactors in a traditional greenhouse. (Source of picture: RWE Power)



Cultivation of micro-algae can be done in open systems, or in photo-bioreactors. The open systems can for instance be open, shallow dams/canals where a paddle wheel provides circulation and mixing. These open systems have many advantages, such as low cost, but can be vulnerable to contamination from other species, as well as evaporation.

Photobioreactors are closed systems which provide high productivity and enhanced possibilities for more control of environmental parameters. A numbers of different designs exist. Photobioreactors will often have higher investment and operation costs than open systems, and it has proven difficult to realize large-scale facilities.

Even though there are considerable variations, most algae have very high growth rates, especially if supplied with CO_2 . In fact, cultivation of algae represents a potential for binding CO_2 into biomass at an unparalleled rate. This speed is in part due to the fact that algae do not develop complicated structures, or tissues.

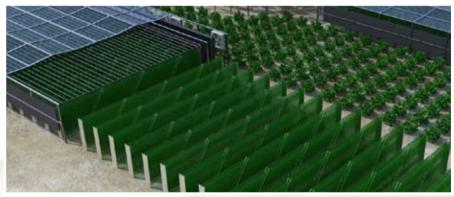
Many comparisons of growth speed exist between various traditional crops and algae. According to the US National Renewable Energy Laboratory algae can generate 30 times more oil per acre than plants used for biodiesel and other biofuels, offering the possibility to significantly reduce our use of fossil fuels.



1) Yusuf Chisti (2007): *Biodiesel from micro-algae Biotechnology Advances* 25, 294 – 306



Photobioreactor with ponds



Photobioreactor with tubes



Photobioreactor with bags

Stage 1: Realization of an Industrial Ecology Centre

The Sahara Forest Project represents a unique possibility for production of biomass from seawater, with the additional benefits of freshwater production, power production and ecosystem services.

It provides an opportunity that should not be missed.

An Industrial Ecology Centre is envisioned in order to provide a cutting-edge environment for testing new and promising technologies for energy and biomass production.

This will represent a major effort towards realizing the Sahara Forest Project's full potential.

We will team up with scientists and companies interested in environmental technologies and the cultivation of crops from seawater.

Our main measure of success will be the ability to facilitate and accelerate the development of new and promising environmental solutions.

The partners of The Sahara
Forest Project have entered into the
process of securing funding, and are
conducting an initial analysis. Our
enthusiasm for this amazing project
is only equaled by our desire to
meet our challenges with a
thoroughly scientific approach.

During the coming months we will further develop our plans into feasibility studies and models. We will look for synergetic technologies, as well as scientific and commercial partners that share our visions for the future.





The Industrial Ecology Centre will provide a cutting-edge environment for testing new and promising technologies for energy and biomass production.

Synergies: The Sahara Forest Project

The Sahara Forest Project is a vision of how the Seawater Greenhouse, Concentrated solar power (CSP) and cultivation of new promising crops can be integrated on a large scale to revegetate arid areas and create substantial amounts of freshwater, electricity and biomass.

The following is a presentation of the most important synergies arising from this unique combination of technologies:

The greenhouse evaporators make very efficient dust traps, (as do plants that are growing outside) which benefits the CSP since the mirrors stay cleaner and therefore operate more efficiently. Along the windward edge of the greenhouses an elevated CSP parabolic trough collector would provide added benefits to the Seawater Greenhouses by acting as wind catchers.

The evaporators of the Seawater Greenhouse are also very effective air scrubbers. This is a greatly advantageous feature, reducing the problems of biological contamination in the algae ponds.

The combination of cooling and a lot of sunlight provides excellent growing conditions for algae and other crops, allowing for maximized growth rates. High growth rates also mean high rates of $\rm CO_2$ absorption. Part of the algae biomass could in addition be used as fertilizer for the cultivation of the outside environment.

In addition to traditional crops and micro-algae, we wish to explore the possibilities that may arise from cultivation of halophytes in such a system. Halophytes are plants tolerant of salty conditions. Some species can grow in an environment with as much as 60 grams of salt per litre of water. Many halophytes are both fast-growing and rich in energy. This makes halophytes promising candidates for future energy crops.

Both the Seawater Greenhouse, and the cultivation of algae and saltwater crops, will need a supply of salt water as well as power. CSP will be an ideal candidate for generating electricity and creating beneficial synergies with the Seawater Greenhouse. CSP systems need water for cleaning the mirrors, and for the generation of steam to drive the turbines. This will be provided by the Seawater greenhouse. With CSP, only about 25 percent of the collected solar energy is converted into electricity. In combination with sea water, another 50 percent of the collected energy, normally released as heat, can be used for desalination.

The Seawater Greenhouse evaporates large volumes of seawater. When cultivating saltwater microalgae inside the greenhouse, additional freshwater will be available for outside use, since the algae will not need freshwater for growth. The `lost' humidity from evaporation will provide a micro-climate of cooler and more humid air downwind of the greenhouse, reducing the water demand and enhancing the growing conditions for vegetation. In addition, the `lost' humidity will increase the potential for precipitation through dew formation or rainfall.

An area covered with greenhouses has a similar effect on the climate as an area covered by forest. The combinations of technologies in the Sahara Forest Project could be located some distance from the coast in a desert region. At a significant scale very large quantities of seawater can be evaporated. The greenhouses can be arranged as a long `hedge' to provide a windbreak and shelter to outdoor planting, and to maximize the area of evaporation. At intervals along the `hedge' of greenhouses CSP arrays would be installed.

At locations at or below sea level. pumping costs are minimized or avoided altogether. If the facility 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. This precipitation could fall as rain, or be collected using fog-nets thus allowing additional areas of desert to be revegetated. The new plant growth and the soils would sequester significant quantities of carbon from the atmosphere. A forest could grow in the dessert.



Vision: Going carbon negative

Carbon capture and storage (CCS) involves capturing CO₂ from power plants and industrial plants and safely storing it deep in geological formations. This makes it possible to use coal, oil and natural gas almost without emissions of CO₂.

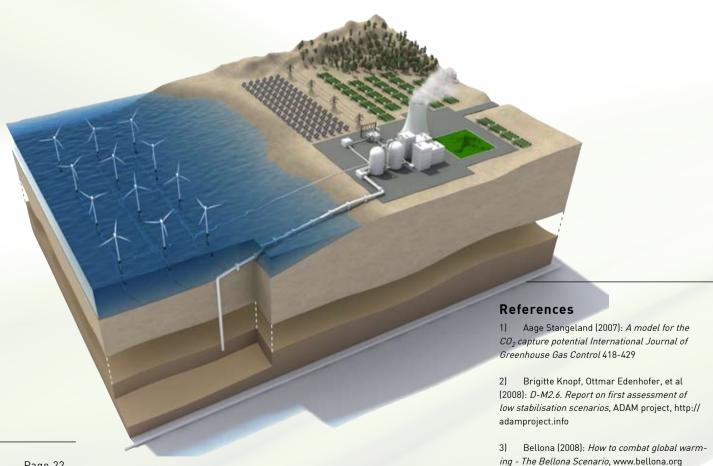
If all large factories and coal and gas power plants were equipped with CCS, about onethird of global manmade CO₂ emissions could be eliminated by 20501

Another important solution to global warming is to replace fossil fuels with biomass, for example in power stations, cars and planes. Burning biomass still emits CO₂, however, the difference is that the carbon is fresh. Since biomass binds carbon as it grows, this makes bioenergy carbon neutral.

When CCS is used in combination with biomass, CO₂ is effectively removed from the atmosphere. This makes it possible to create a carbon negative energy system. Regardless of whether you were driving your electric car, vacuuming the house, or running your internet server, you would be removing CO₂ from the atmosphere.

The latest research on how to combat global warming shows that large-scale generation of carbon negative energy is crucial in order to enable deep cuts in global greenhouse gas emissions 2,3 .

The critical question is how to sustainably supply a sufficiently large amount of biomass without negative effects on freshwater supply and food production. The ambition of The Sahara Forest Project is to answer this question, and in so doing, create a system which removes CO₂ from the atmosphere, generates freshwater from salt water, and at the same time provides energy and food for sustainable growth.



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The participants

Seawater Greenhouse Ltd. is whollyowned by its founder Charlie Paton. Mr. Paton has a highly regarded track record in innovation, research and development. His broad understanding of a range of technologies and the intricate mechanism of photosynthesis led to the concept of the



Seawater Greenhouse

Seawater Greenhouse. He has since been actively engaged in the development of this concept. Charlie Paton has received a number of awards for his work. Recently this includes the `IET´ Institute of Engineering + Technology 2006 Sustainability Award, `Tech Award´ Technology for the benefit

of Mankind, Tech Museum of San Jose CA (2006), The St. Andrews Prize for the Environment (2007) and Courvoisier / Observer - The Future 500 Science and Innovation winner (2008).

Exploration Architecture was established by Michael Pawlyn in 2007 to focus exclusively on environmentally sustainable projects that take their inspiration from nature. From 1997 to 2007 Pawlyn worked with Grimshaw Architects and was instrumental in the design development of the Eden Project. He



was responsible for leading the design of the Biomes and proposals for a third major climatic enclosure.

Michael Pawlyn has lectured widely on the subject of sustainable design in the UK and abroad. In 2006, he was appointed to

represent Grimshaw as a Founder Member of the UK Green Building Council and in 2007 was elected as a committee member of `The Edge', a think-tank dedicated to addressing important political, social and professional issues.

maxfordham

Max Fordham Consulting Engineers are award-winning designers of energy-efficient systems for building services and the wider environment. For over forty years, the success and approach of this British company has brought many awards, including The Queen's Award for Enterprise in Sustainable Development. Bill Watts joined Max Fordham

LLP in 1980 and became a Senior Partner and team leader in 1988. He has worked on the design of a large number of buildings in the housing, office, sport, theatre, museum, health and education sectors. Bill Watts has written on a wide range of subjects including chapters in the "Sustainable Design", "Photovoltaics in Architecture" and the "Pool

Water Treatment Advisory Group" guide book. He is a regular speaker on low energy buildings at the Carbon Trust in Northern Ireland. He sits on the RIBA Sustainable Futures Group and the British Property Federation Sustainability Group.

BELLONA

The Bellona Foundation was founded in 1986 as a direct-action protest group, and has become recognized as a technologically- and solutions- oriented environmental organization. Bellona has offices in Oslo, Murmansk, St. Petersburg, Brussels and Washington D.C. Today, Bellona has over 70 highly skilled employees that work on a wide spectrum of environmental issues. Bellona seeks to find sustainable solutions to the world's most pressing environmental problems. Climate change is an enormous challenge, one that requires predictable framework conditions for industry and consumers. Bellona works

to build bridges between politicians and the business community by working closely with the latter to help them respond to environmental challenges in their fields, with particular emphasis on the development and commercialization of new, more environmentally friendly technologies

Frederic Hauge is the founder and President of The Bellona Foundation. In addition, Frederic Hauge has served as Vice-Chairman of the EU Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) for several years and in 2009 was appointed

Member of the Board of the EU Biofuels Technology Platform. In both the government and business sectors, he is actively engaged in promoting development of new climate mitigation technologies like biomass production with CCS. For his relentless efforts for the benefit of the environment, Frederic Hauge has received a number of awards including TIME Magazines `Hero of the Environment' Award in 2007.

The Sahara Forest Project is a vision of how the Seawater Greenhouse, Concentrated solar power and cultivation of new promising crops can be integrated on a large scale to revegetate arid areas and create substantial amounts of freshwater, electricity and biomass.