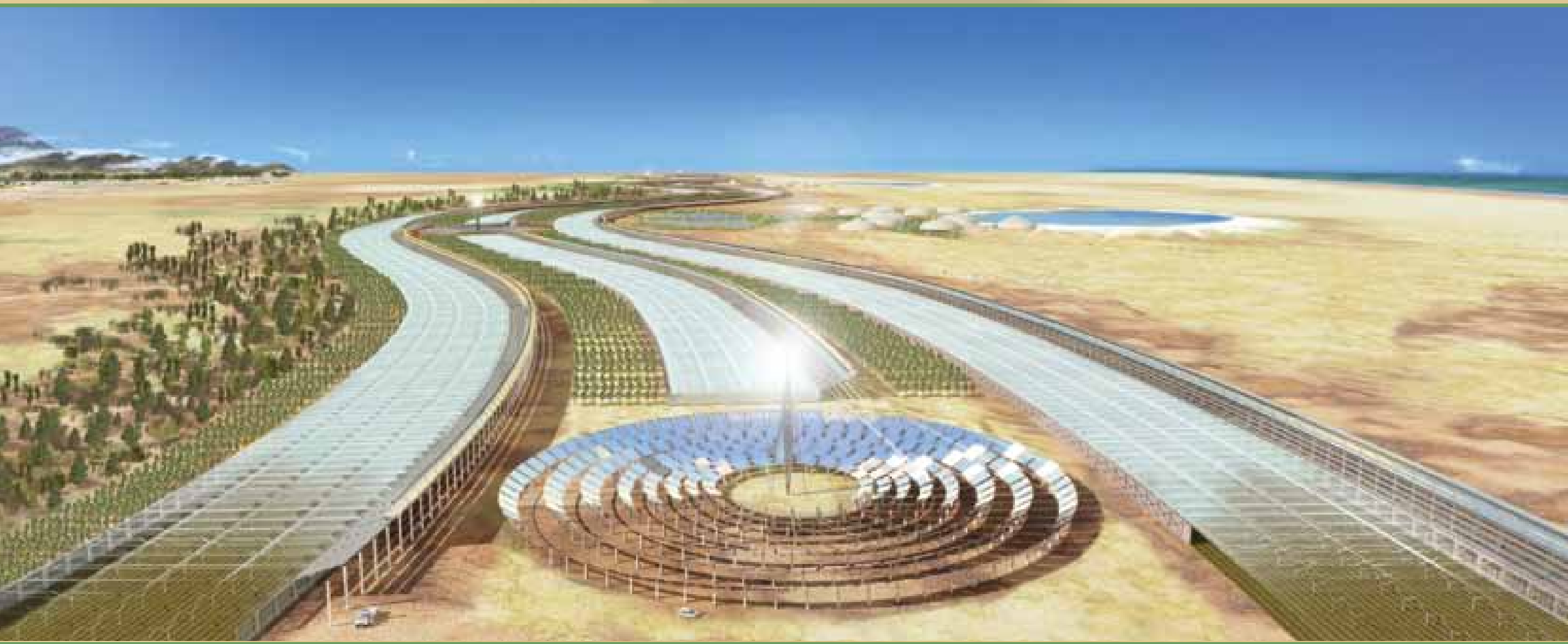


The Impact Potential of The Sahara Forest Project

– a scenario towards 2050

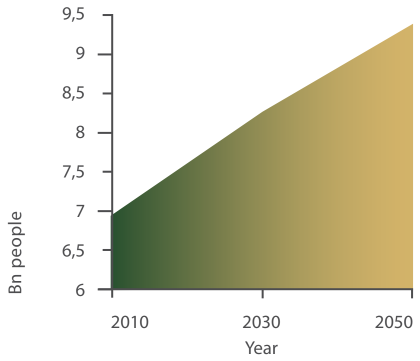
SAHARA
FOREST
PROJECT

The global challenges

In 2050 there will be about 9.3 billion people sharing the same planet[1]. Already today the world is facing intertwined challenges of food, water and energy security, as well climate change and desertification. Neither of these challenges is without solutions. At the same time it is clear that we cannot afford a response to one challenge that comes at the expense of another. The greatest challenges of our time are closely interlinked - the same must be true for the answers. To borrow the words of Albert Einstein: *"We can't solve problems by using the same kind of thinking we used when we created them."*

Graph 1:

Global population growth towards 2050

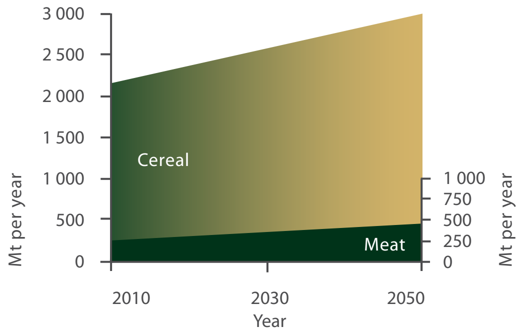


Food scarcity

Today, more than 800 million people are "food insecure", meaning that they either starve or do not know where their next meal will come from[2]. This situation brings with it large social and economic consequences. Experts agree that it is possible to achieve the increases in food production necessary to feed a population of 9.3 billion in 2050, but only if sufficient and timely investments are undertaken and policies to increase agricultural production are put in place.

Graph 2:

Demand for meat and cereal

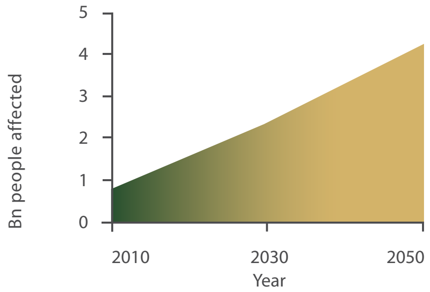


Water scarcity

Water scarcity already affects a large portion of the global population. And the situation is not expected to improve any time soon: according to UNEP water use for crop irrigation must double by 2050 to meet the Millennium Development Goal on hunger[3]. Imbalances between availability and demand, degradation of ground- and surface water quality, as well as escalating regional and international competition for water resources are among the key issues that must be addressed.

Graph 3:

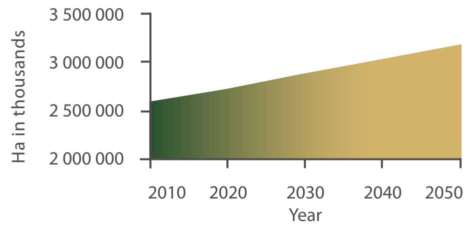
Bn people living with water scarcity



Desertification

The livelihoods of more than one billion people in some 100 countries are threatened by desertification. It is estimated that desertification and land degradation represent an income loss of US$42 billion per year. Further, the barren lands lost annually could have provided 20 million tons of grain[4]. Even though desertification is most often directly triggered by localized drought, human activities are almost always a key underlying cause. It is therefore of major importance to introduce sustainable cultivation and irrigation practices, and to implement programs to prevent over-grazing and unsustainable outtake of biomass.

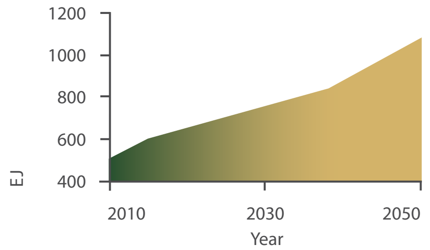
Graph 4:
Growth in arid and hyper-arid areas



Energy consumption

The IEA's Energy Technology Perspectives 2010 presents a baseline scenario assuming no new energy and climate policies. The scenario predicts that primary energy use will rise by 84% – and energy-related CO_2 emissions roughly double – by 2050[5]. In the face of climate science, such numbers leave little room for doubt that a low carbon/ renewable energy revolution is necessary. This revolution has the potential to bring about substantial benefits not just for the climate, but also in enhanced energy security and accelerated economic development.

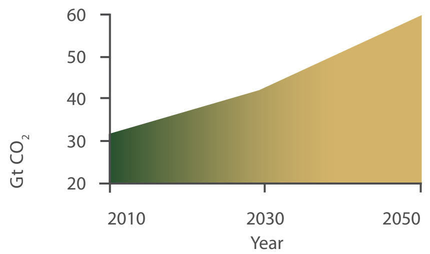
Graph 5:
Energy consumption in a no-change scenario



Climate change

The atmospheric concentration of CO_2 passed 391,5ppm in 2011[6]. This is higher than it has ever been in the last 650,000 years[7]. The IPCC had earlier advised that it would be necessary to achieve at least a 50 % reduction in global CO_2 emissions by 2050, compared to 2000 levels. Leading experts are now warning that even this target may prove inadequate to prevent serious consequences of global warming[5].

Graph 6:
Energy related CO_2-emissions in a no-change scenario



Key assumptions for the scenario

The Sahara Forest Project (SFP) is a new environmental technology that makes possible the development of profitable saltwater infrastructures in low-lying desert areas. An SFP-facility can be tailor-made to meet specific production needs. Primary production opportunities include food (in greenhouses and outside), electrical energy from Concentrated Solar Power (CSP), biofuels (in greenhouses and outside), salt and freshwater. In addition SFP-facilities offer the potential to remove significant quantities of CO_2 from the atmosphere by vegetating desert areas.

Globally, the quantity of land under greenhouse cultivation is increasing steadily. Between 1995 and 2009 the global area of greenhouses grew on average by nearly 57,000 ha each year, not counting low-tunnel systems [8,9,10].

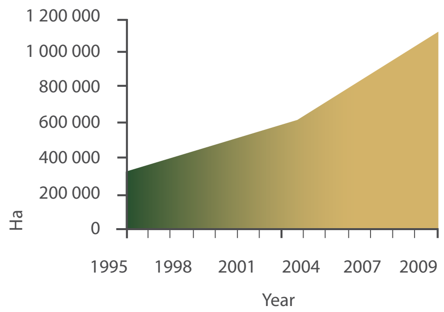
Assumption 1

Taking into account the rapid population growth expected towards 2050, and the increases in global demand for food and feed that will accompany it, we assume that the global area under greenhouse cultivation will grow at least as rapidly as it did in the 1995-2009 period, with a linear growth rate of nearly 57,000 ha per year towards 2050.

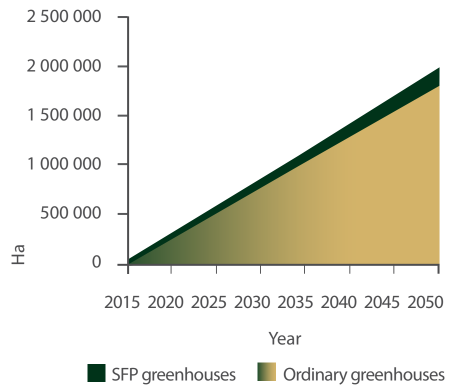
Assumption 2

For this scenario we assume that 10% of all greenhouses built between 2015 and 2050 will be part of desert-based SFP-facilities, utilizing saltwater for production of freshwater. This amounts tonearly 5700 ha of new SFP-greenhouses each year.

Graph 7:
Ha greenhouses 1995-2009



Graph 8:
Ha new greenhouses from 2015 (10% SFP)



Assuming a market share of 10% of all greenhouses built between 2015 and 2050, this scenario explores opportunities from SFP facilities including the following basic units:

- 1 ha saltwater based greenhouse
- 0.75 ha CSP to make electricity for operations and export
- 0.25 ha CSP to power a Reverse Osmosis desalination facility
- 7.5 ha of Eucalyptus plantation

At latitudes similar to those of the Sahara desert, Eucalyptus plantations with 1000 trees/ha are found to have a total net primary productivity of 0.5 to 1 x 10^7gC/ha/yr[11]. This is achieved with about 1000 mm/yr precipitation. However, high-efficiency irrigation can be at least twice as efficient as rainfall in delivering water to trees[12]. Therefore, with an amount of freshwater equivalent to around 500 mm annual rainfall, plantations can be established to store large amounts of carbon in what are now deserts.

Assumption 3

For simplicity the calculations are based on the assumption that the SFP greenhouses will be used either 100% for the production of tomatoes, or 100% for the cultivation of microalgae to produce biodiesel. In actual SFP facilities, a more diverse production mix is anticipated.

Assumption 4

Through the integration of a Reverse Osmosis (RO) desalination facility powered by CSP, the SFP facility will produce enough water to irrigate 7.5 ha of *Eucalyptus grandis* for each ha of SFP greenhouse and CSP. The higher salinity wastewater released as brine from the RO process will be fed into the saltwater greenhouses for evaporative cooling.

The precise rate of carbon sequestration depends on a number of factors, including soil fertility and harvesting practices. However, the data clearly show that the establishment of Eucalyptus forests in deserts would store between 22 and 44 tons of CO_2 per hectare per year, making them asignificant Carbon Negative solution.

Before establishing forests in desert areas, thorough ecological impact assessments will be required. In suitable areas the use of locally adapted species and alternatives to monocultures would be preferred.

Assumption 5

We adopt the mean of the annual CO_2 storage rates observed in experimental data, such that 1 ha of Eucalyptus forest is taken to store 33 tons of CO_2 per hectare per year.

Impact potential

Food-focus

Product	2025	2035	2050	Unit	Notes
Greenhouses	56 686	113 365	198 383	Ha	Assuming 10% of greenhouses built after 2015
CSP	56 686	113 365	198 383	Ha	1 ha greenhouse: 1 ha CSP
Vegetation outside greenhouses	425 148	850 240	1 487 879	Ha	Assuming growth of *Eucalyptus grandis* with freshwater requirement of 500 mm rainfall per year[13,14,15]
Total electricity produced	113 372	226 730	396 767	GWh/yr	Assuming 200 kwh/m^2/yr, based on annual solar irradiance of 2000 kwh/m^2/yr, and solar efficiency of 10% over the full solar field[16].
Liquid freshwater produced and used	2 539	5 078	8 887	Mt/yr	Assuming greenhouses produce 2l/m^2/year[17], enough for their own irrigation, with RO providing equivalent of 500mm annual rainfall for outside vegetation
Freshwater vapour	3 454	6 907	120 87	Mt/yr	From greenhouses and evaporative hedges, 90% saltwater evaporated
Tomatoes	26	52	91	Mt/yr	Assuming 46kg/m^2/yr[18]
Electricity for export	73 692	147375	257 899	GWh/yr	Assuming 10% of electricity is used for saltwater infrastructure, and 25% for RO
Greenhouse jobs	566 864	1 133 654	1 983 839	ee	Assuming 10 employees per ha greenhouse
Salt	22	44	78	Mt/yr	Assuming saltwater density of 1000 Kg/m^3 and a salinity of 3.5%.
CO_2 stored outside greenhouses	14	28	49	Mt/yr	Assuming outdoor growth of 7.5 ha of *Eucalyptus grandisper* ha greenhouse, with each ha storing 33 t CO_2 per year.

Biofuel-focus

Product	2025	2035	2050	Unit	Notes
Greenhouses	56 686	113 365	198 383	Ha	Assuming 10% of greenhouses built after 2015
CSP	56 686	113 365	198 383	Ha	1 ha greenhouse: 1 ha CSP
Vegetation outside greenhouses	425 148	850 240	1 487 879	Ha	Assuming growth of *Eucalyptus grandis* with freshwater requirement of 500 mm rainfall per year
Total electricity produced	113 372	226 730	396 767	GWh/yr	Assuming 200 kwh/m^2/yr, based on annual solar irradiance of 2000 kwh/m^2/yr, and solar efficiency of 10% over the full solar field[22].
Liquid freshwater produced and used	2 125	4 251	7 439,4	Mt/yr	All freshwater used for irrigation of outside vegetation. Assuming greenhouses produce 2l/m^2 /year[23], and RO provides the rest, to together supply equivalent of 500mm annual rainfall.
Freshwater vapour	2 709	5 417	9 480	Mt/yr	From greenhouses and evaporative hedges, 90% saltwater evaporated
Biodiesel	2 834	5 668	9 919	Million L/yr	Assuming production of 50000l/ha[24]
Electricity for export	79 209	158 409	277 208	GWh/yr	Assuming 10% of electricity is used for saltwater infrastructure, and 25% for RO
Greenhouse jobs	566 864	1 133 654	1 983 839	ee	Assuming 10 employees per ha greenhouse
Salt	18	35	62	Mt/yr	Assuming saltwater density of 1000 Kg/m^3 and a salinity of 3.5%.
CO_2 stored outside greenhouses	14	28	49	Mt/yr	Assuming outdoor growth of 7.5 ha of *Eucalyptus grandisper* ha greenhouse, with each ha storing 33 t CO_2 per year.

Sources

Text:

[1] U.S. Census Bureau, International Data Base (06.2011)

[2] IFPRI (2001). Sustainable Food Security for All by 2020 - Proceedings of an International Conference

[3] UNEP (2007). Global Environment Outlook 4 - environment for development, United Nations Environment Programme

[4] United Nations Decade for Deserts and the Fight against Desertification – Fact Sheet: http://unddd.unccd.int/docs/factsheet.pdf

[5] International Energy Agency: Energy Technology Perspectives 2010

[6] The US National Oceanic and Atmospheric Administration. Thom as Conway and Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/)

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[14] See note 11

[15] Stape, J. L., Binkley, D., & Ryan, M. G. (2004). Testing the utility of the 3-PG model for growth of Eucalyptus grandis x urophylla with natural and manipulated supplies of water and nutrients. Forest Ecology and Management. 193: 219.

[16] German Aerospace Center (2007). Aqua-CSP: Concentrating Solar Power for Seawater Desalination.

[17] Based on thermodynamic modeling of relevant conditions.

[18] Cuesta Roble Greenhouse Consultants 2011

[19] See note 13

[20] See note 11

[21] See note 15

[22] German Aerospace Center (2007). Aqua-CSP: Concentrating Solar Power for Seawater Desalination.

[23] See note 17

[24] Martha J. Groom, Elizabeth M. Gray and Patricia A. Townsend, Biofuels and Biodiversity: "Principles for Creating Better Policies for Biofuel Production", Conservation Biology, 2008, Volume 22, No 3, 602-609

Graphs:

Graph 1: U.S. Census Bureau, International Data Base (06.2011)

Graph 2: FAO (2009) How to Feed the World in 2050

Graph 3: UN Water for Life Decade 2010, http://www.un.org/waterforlifedecade/scarcity.html ; IPCC Fourth Assessment Report: Climate Change 2007, http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch3s3-5-1.html#table-3-2

Graph 4: United Nations Decade for Deserts and the Fight against Desertification (2010-2020), http://unddd.unccd.int/docs/factsheet.pdf

Graph 5: IPCC Special Report on Emissions Scenarios (SRES), Nakienovi et al (2000); International Energy Outlook 2010 - Highlights from EIA, http://www.eia.gov/oiaf/ieo/highlights.html

Graph 6: IEA: Energy Technology Perspectives 2010

Graph 7: Wittwer, S., Castilla, N. 1995. Protected cultivation of horticultural crops, worldwide.HortTechnology 5:6–23
Solomon H Katz; William Woys Weaver.2003. Encyclopedia of food and culture. Greenhouse Horticulture. New York: Scribner
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Graph 8: Based on data from graph 8, assuming 10% for SFP

The Sahara Forest Project in short

- The Sahara Forest Project (SFP) is a new combination of environmental technologies that enables restorative growth, defined as revegetation and creation of green jobs through profitable production of food, freshwater, biofuels and electricity.

- While society still struggles to recognize that sustainable solutions must replace the traditional extractive use of resources, the Sahara Forest Project demonstrates the potential for restorative practices.

- SFP is designed to utilize what we have enough of to produce what we need more of, using deserts, saltwater and CO_2 to produce food, water and energy.

- The Sahara Forest Projects is not too good to be true and is not rocket science, but an innovative solution founded on the premise that we need a more holistic approach to successfully tackle challenges related to energy, food and water security.

- The Sahara Forest Project is a unique combination of existing environmental solutions based on tested principles that are combined to create highly desirable synergies.

- Sahara Forest Project combines solar thermal technologies with technologies for saltwater evaporation, condensation of freshwater and modern production of food and biomass without displacing existing agriculture or native vegetation.

- The best physical locations for a SFP-facility are low-lying, arid and sunny areas that normally have little agricultural activity or native vegetation.

- By establishing a commercially viable way to bring saltwater into the desert, The Sahara Forest Project works as an enabling technology, creating opportunities for a wide variety of businesses to develop alongside it.

- SFP makes it possible to go green by black numbers at the bottom-line, profitably creating valuable resources while providing ecosystem services.

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