

The Sahara Forest Project
From vision to reality



QATAR PILOT PLANT



A collaboration between Qafco, The Sahara Forest Project AS and Yara International ASA

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Introduction

The production of key resources, such as clean water, clean energy and a sustainable production of food represents some of our time's greatest challenges. The Sahara Forest Project is a new environmental solution to create re-vegetation and green jobs through profitable production of food, water, clean electricity and biomass in desert areas.

The Sahara Forest Project is designed to utilize what we have enough of to produce what we need more of, using deserts, saltwater and CO₂ to produce food, water and clean energy. This is done by combining already existing and proven environmental technologies, including saltwater-cooled greenhouses, concentrated solar power and technologies for desert revegetation around a saltwater infrastructure.

The Sahara Forest Project also offers a positive measure to combat climate change and desertification. Through the establishment of vegetation in arid areas, CO₂ from the atmosphere will be stored in the soil and new biomass. This represents a potential for a financial viable method to establish a "carbon negative" value-chain.

To develop the project on the ground, The Sahara Forest Project entered in 2011 into a cooperation with Yara ASA, the world's largest supplier of fertilizer and the Qatari company Qafco, the world's largest single site producer of urea and ammonia. In addition to core competence in crop nutrition, Yara and Qafco have long experience in building industry and bring their implementation capacity into the partnership.

After successfully completing a comprehensive feasibility study on Qatar, the partners signed in February 2012 an agreement to build the first fully operational Sahara Forest Project Pilot Plant in Qatar. With this ambitious step, Yara, Qafco and The Sahara Forest Project set out to contribute to Qatar's objective of increased food security through sustainable water and energy production.

The Sahara Forest Project Pilot Facility is now operational in Qatar. The work to enable restorative growth in desert areas has begun.



Signing ceremony in Oslo under the patronage of the Norwegian Prime Minister HE Jens Stoltenberg and Qatari Prime Minister HE Sheikh Hamad bin Jassim bin Jaber Al Thani

From left:

Khalifa A. Al Sowaidi, CEO Qafco,
Jørgen Ole Haslestad, CEO Yara International,
Joakim Hauge, CEO The Sahara Forest Project

From vision to reality

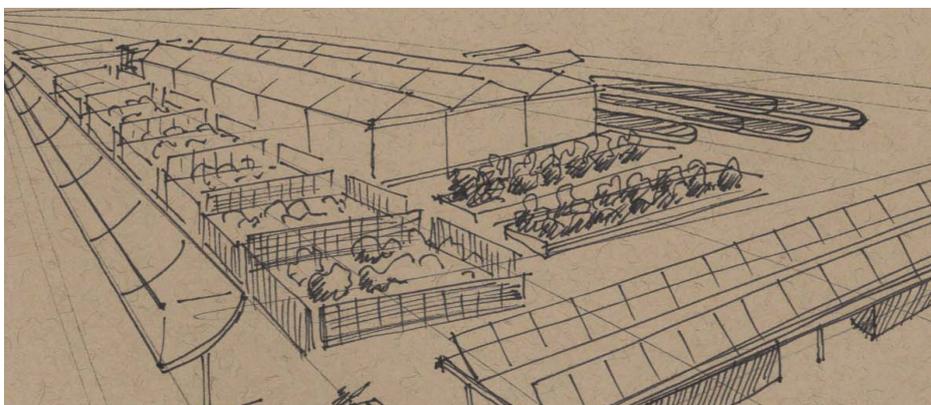


The Sahara Forest Project vision

In 2050 about 9.3 billion people will share our planet. Already today the world is facing intertwined challenges of food, water and energy security, coupled with climate change, desertification and shrinking forests. None of these challenges are without solutions. At the same time it is ever clearer that we cannot afford to pursue responses to one challenge that come at the expense of another. The greatest challenges of our time are closely interlinked and the same must be true for their answers.

The Sahara Forest Project proposes to establish groups of interconnected economic activities in different low lying desert areas around the world. The simple core of the concept is an infrastructure for bringing saltwater inland. 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.

Realizing the Qatar Pilot Facility



Pilot sketch - November 2011



Pilot illustration - February 2012

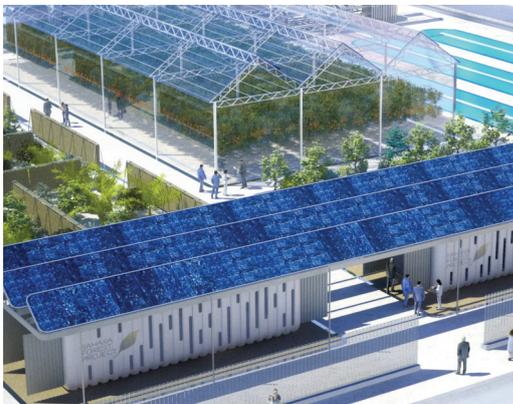
While conventional approaches to production of goods often involve simple, mono-functional systems that aim to maximize one goal (for instance energy production or food output), the Sahara Forest Project involves creating a complex, interconnected cluster of technologies that aims for an optimized overall system rather than a single maximized goal. The synergies arising from integrating the technologies into low-waste interconnected systems improve performance and economics compared to those of the individual components.

By establishing a saltwater value chain, the Sahara Forest Project will make electricity generation from concentrated solar power (CSP) more efficient, operate energy- and water-efficient saltwater-cooled greenhouses for growing high-value crops in the desert, produce freshwater for irrigation or drinking, safely manage brine and harvest useful compounds from the resulting salt, grow biomass for energy purposes without competing with food cultivation, and revegetate desert lands.

A Sahara Forest Project facility will be successful only when it is well integrated with the local communities. In addition to mitigating effects of climate change and contributing to conflict reduction in resource-scarce areas, the SFP facilities will provide employment for both high- and low-skilled workers. Programs and facilities for knowledge transfer and training will be established to ensure that long-term social and economic development opportunities are created.

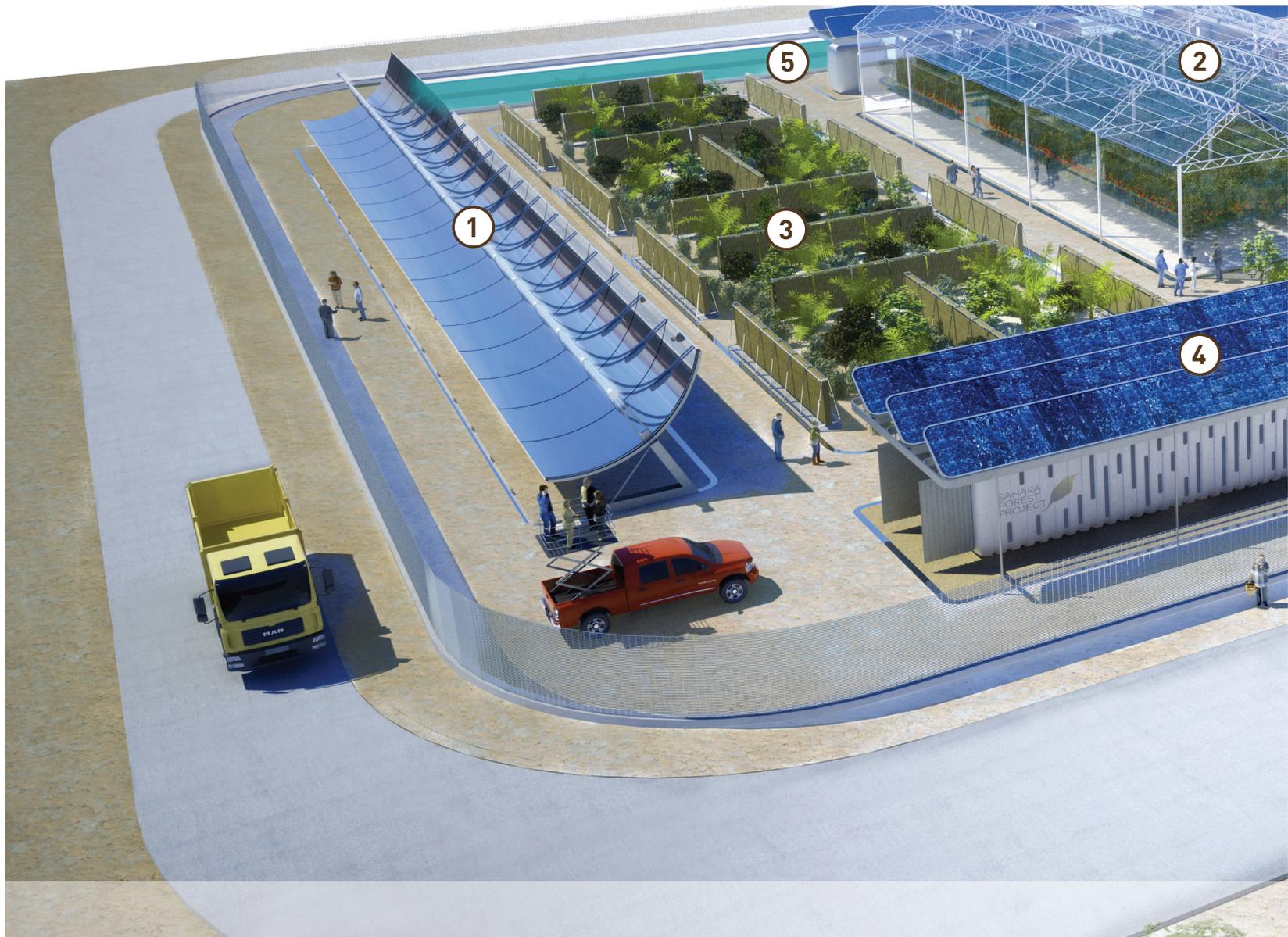
In this way the Sahara Forest Project commits to a true triple bottom line approach; it shall be good for the environment, good for people and good for business.

The Sahara Forest Project is not too good to be true. It is an integrated system designed to harvest technological synergies while minimizing waste. The design is founded on the premise that we must find a more holistic approach to successfully tackle challenges related to energy, food, and water security.



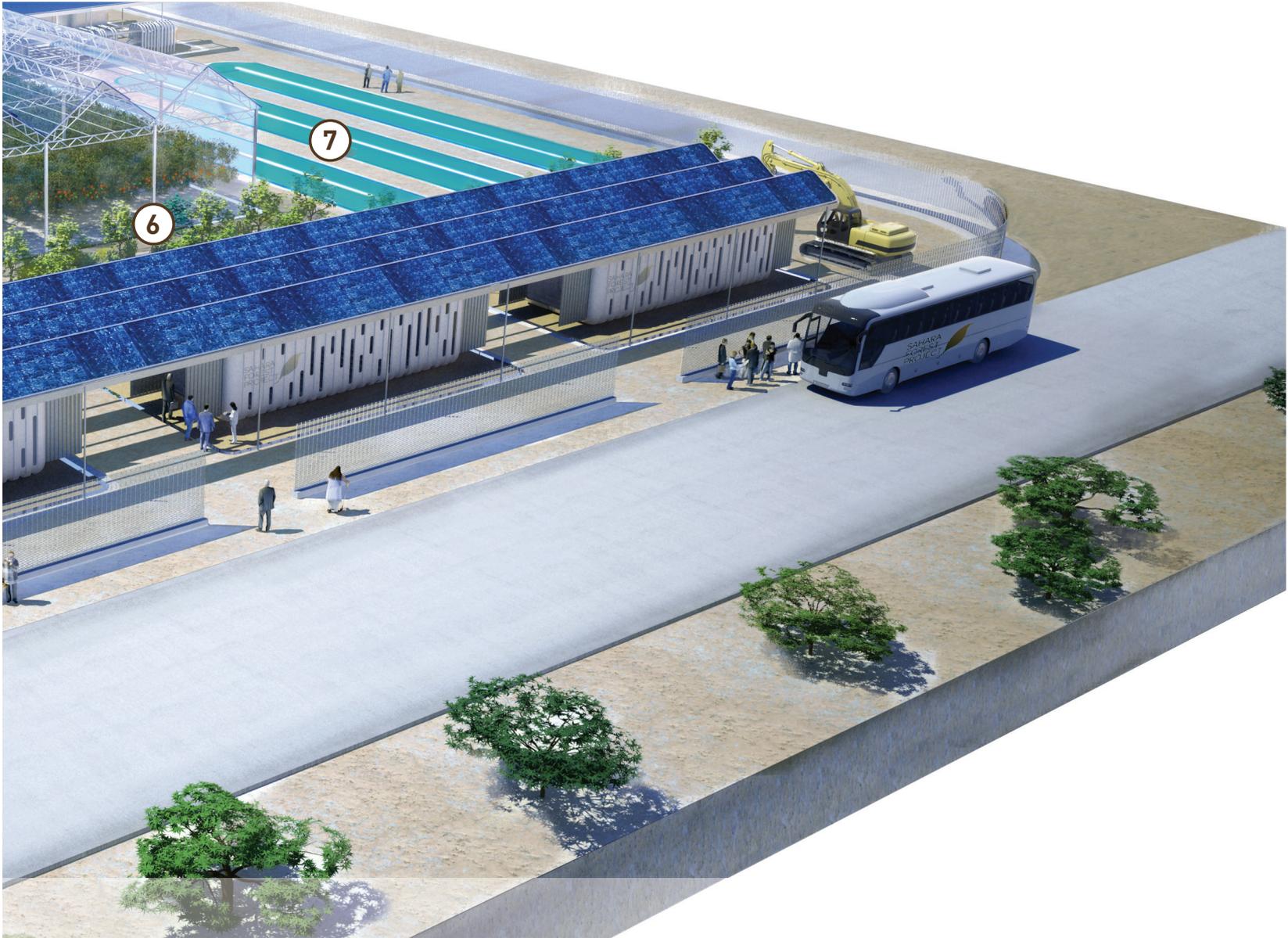
Pilot construction - November 2012

Overview of the Qatar Pilot Plant



1. Concentrated Solar Power
2. Saltwater-cooled greenhouses
3. Outside vegetation and evaporative hedges
4. Photovoltaic Solar Power
5. Salt production
6. Halophytes
7. Algae production

The Sahara Forest Project pilot facility in Qatar provides a unique research platform to demonstrate and optimize environmental technologies that will enable restorative growth in desert areas around the world.

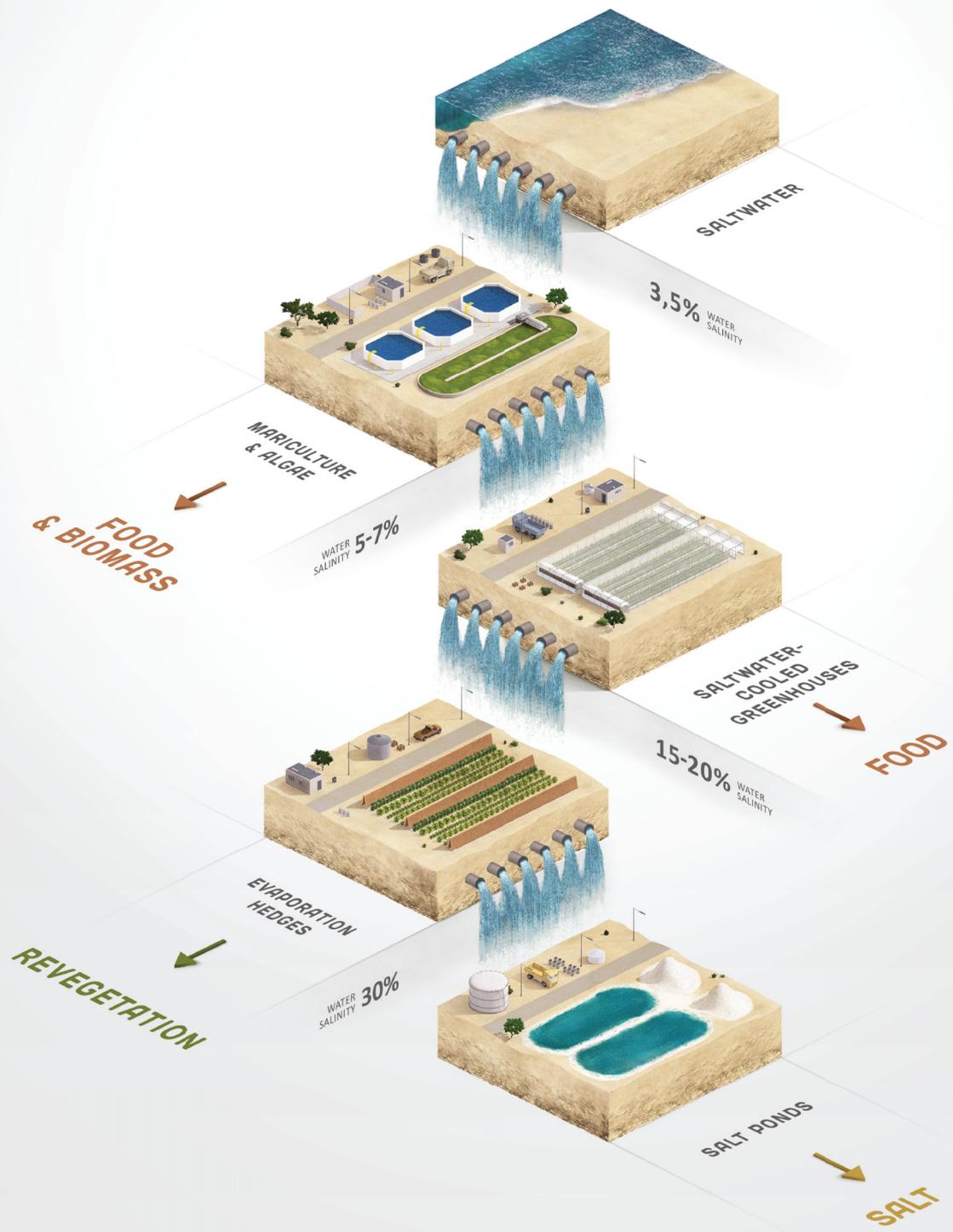


The Sahara Forest Project concept optimizes synergies between existing and proven environmental technologies to make restorative growth economically and environmentally profitable.

The Qatar pilot facility will provide the first demonstration of those synergies at scale, and provide a unique research platform to develop and prove new strategies for providing food, freshwater, and clean energy in desert environments.

The work done at the Sahara Forest Project Qatar pilot by Yara, Qafco, the Sahara Forest Project research staff and members of a large international network of scientific collaborators, will lay sound scientific foundations for bringing restorative growth to Qatar and to deserts around the world.

The Saltwater Infrastructure



Qatar Pilot Plant Technologies



1. Concentrated Solar Power

A strikingly simple interface replaces the water-thirsty cooling towers of a typical CSP plant with a saltwater cooling system that dissipate the heat from the CSP process. At the Pilot Facility, SFP demonstrates an innovative greenhouse-CSP cooling system, which enables the low-cost use of saltwater to achieve wet-cooling efficiencies without utilizing precious freshwater resources.

The heat from the CSP mirrors is used to drive a multistage evaporative desalination system for production of distilled water for the plants in the greenhouse and outside. Heat is also used to warm the greenhouses in the winter and to regenerate the desiccant used for dehumidifying the air.

The SFP Pilot Facility is home to the first fully operational CSP unit in Qatar. It is used to measure the performance of CSP collectors in Qatari conditions, providing vital information for future larger scale solar power facilities. So too is the Pilot providing the first testing ground to examine the impacts of co-locating CSP collectors with revegetated areas, in which plants and humidifying hedges can reduce the dust levels in the air. This can in turn increase the performance of solar energy systems, and partially protect the valuable CSP mirrors from harsh desert winds.

2. Saltwater-cooled greenhouses

Saltwater-cooled greenhouses provide suitable growing conditions that enable year-round cultivation of high-value vegetable crops in the harsh Qatari desert. The greenhouse-structure consists of 3 bays to allow for comparisons of performances between ETFE and polythene roof coverings on the horticultural yield. The cooling system is an evaporative cooler at one end of the greenhouse. The cool air is supplied under the plants via polythene ducts to ensure that the cool air is distributed evenly along the greenhouse and at low level. As the air heats up it rises and is expelled via high level openings in the end wall.

The middle bay has a twin skin ETFE membrane roof that forms a void over the greenhouse. This is linked to an evaporator pad and fan that can use the waste heat from the CSP to evaporate seawater or regenerate the desiccant and produce hot moist air. When the air is passed through the void at night it cools and the moisture in the air condense out to give fresh water that can be used for irrigation of the plants.

By using saltwater to provide evaporative cooling and humidification, the crops' water requirements are minimized and yields maximized with a minimal carbon footprint.

Qatar Pilot Plant Technologies



3. Outside vegetation and evaporative hedges

The water coming from the greenhouse is at a concentration of about 15 % salinity. To reduce the water content further, the brine is passed over external vertical evaporators set out in an array to create sheltered and humid environments. These areas are planted to take advantage of the beneficial growing conditions for food and fodder crops and for a wide range of desert species. New candidate species for use as harvested and grazing fodder for livestock, and as bioenergy feedstock, is identified and characterized from among native desert plants. The carbon sequestration benefits of various planting and cropping approaches are measured and compared.



4. Photovoltaic Solar Power

The Pilot Plant is supported by state of the art PV-technology. Dust arresting from the surrounding vegetation and water for cleaning the PV-panels ensure an efficient electricity generation.



5. Salt production

As the water is evaporated from saltwater the salinity increases to the point that the salts pre-cipitate out from the brine. The last stage of this process is taking place in conventional evaporation ponds. The brine has about 30 % salinity when entering the evaporation ponds. This in contrast to traditional evaporation ponds for commercial salt production, that typically start at ordinary seawater concentration levels of 3,5 % salinity. This both means efficient use of the fresh water, and also that we can keep the evaporation ponds smaller than otherwise required.

Qatar Pilot Plant Technologies



6. Halophytes

Beyond traditional horticulture and agriculture, halophytes – salt-loving plant species – are cultivated in saltwater. These hardy plants, often already well adapted to desert conditions, are highly promising sources of fodder and bioenergy feedstocks that can thrive in highly saline environments. However, irrigating with saltwater directly into the soil can cause significant environmental harm. The Qatar Pilot Facility is implementing and testing a variety of novel cultivation techniques to allow low-cost halophyte cultivation while ensuring no saltwater enters surrounding soil or groundwater aquifers.

7. Algae production

The state-of-the-art 50 m³ algae test facility – the only of its kind in Qatar and the larger region – enables commercial-scale research on the cultivation of marine algae species native to the Gulf and Red Sea for use as nutraceuticals, biofuels, and as animal and fish fodder. New synergies with the SFP saltwater-cooled greenhouse infrastructure, mariculture operations, and soil remediation methods are optimized, while cutting-edge research in cultivation and harvesting methods is carried by SFP staff and its team of international collaborators.



The first cucumber harvest at the Qatar Pilot Plant - November 2012

Going large scale

The Sahara Forest Project concept and technologies can be implemented in many of the world's hot deserts. A large-scale rollout will create a sustainable increase of food, water and energy security and provide a powerful tool to combat climate change.

Let's explore a scenario of a truly large-scale Sahara Forest Project reaching out over 4 000 hectares situated in the northern part of Africa. This hypothetical mega-facility could as an example provide:

- Concentrated Solar Power (CSP) powering all the Oasis' needs and exporting 325 GWh/year
- Self-sustained thermal desalination of freshwater for all irrigation needs
- 300 hectares of saltwater greenhouses, yielding 190 000 annual tons of tomatoes and melons

- 2 000 hectares of new outdoor revegetation and crops, yielding 30 000 tons/year of fodder crops
- 150 hectares of algae cultivation, capable of yielding 7 500 tons/year of biofuel-ready algae oils

While the above is but one example of many possible scenarios, it illustrates how a major Sahara Forest Project scheme can yield substantial amounts of energy, food, fuel and fodder crops. This particular example could employ up to 20 000 people directly – and support five times as many.

What is truly unique is that it is all achieved in a closed-loop system which revegetates arid land and provides carbon sequestration in the magnitude of 50 000 tons per year.

Jobs:



20 000 people directly employed

Food:



190 000 tons of tomatoes and melons

Electricity:



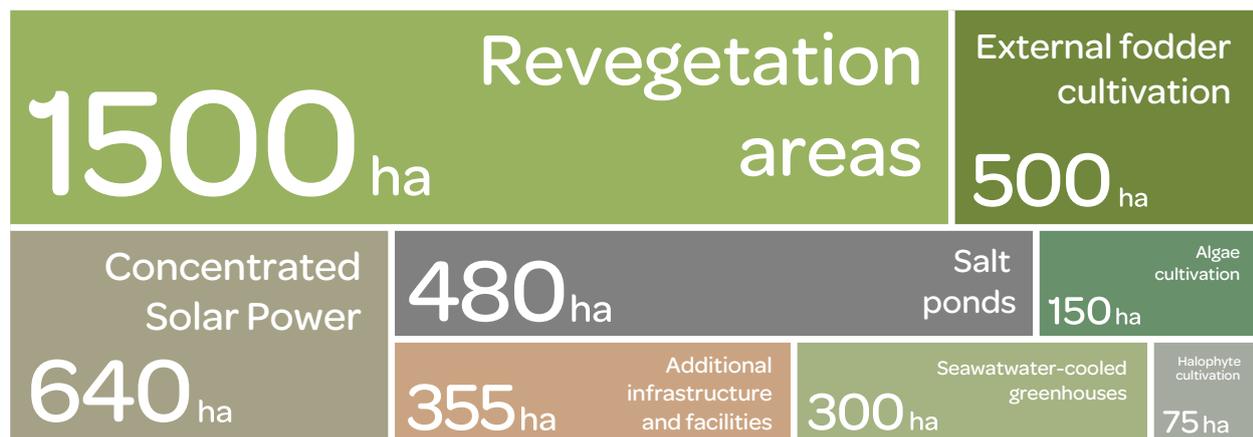
325 GWh/year

CO₂ storage:



50 000 tons/year

Land distribution of a 4000 ha facility:



The Sahara Forest Project AS



The Sahara Forest Project AS is a Norwegian private limited liability company. The purpose of the company is to create profitable innovation and environmental solutions within the food, water and energy sector. This is achieved by bringing The Sahara Forest Project technology to the market in relevant countries.

The Sahara Forest Project AS is actively engaged in R&D, consultancy, development of technical products and project developments and implementation. A key pillar for The Sahara Forest Project is that the company's activities shall be good for the environment, good for social development and provide long term economic benefits to the investors. This is the company's triple bottom line approach. As such, The Sahara Forest Project AS bases its work on close cooperation with businesses, academia and civil society in the countries where it operates.

The Sahara Forest Project AS operates under the Ethical Guidelines for commercial initiatives set out by The Sahara Forest Foundation.

The Sahara Forest Project Foundation



The Sahara Forest Project Foundation sets out to facilitate and promote research, knowledge and the use of technologies, which enable revegetation and the creation of new jobs through the profitable production of food, water, biomass and electricity. This concept of "Restorative Growth" has already gained significant support as an innovative way of thinking about resource use, and is recognized by high-level support from decision makers, business and media alike.

The Sahara Forest Project Foundation acts as an incubator for new initiatives that bring the concept of Restorative Growth and The Sahara Forest Project technologies out to the markets. Additionally the foundation aims to raise awareness and knowledge about the potential for restorative growth and green innovation for sustainably increasing food, water and energy security.

The SFP Foundation has established a set of Ethical Guidelines applicable to all commercial Sahara Forest Project Initiatives. The work of The Sahara Forest Project Foundation is funded by philanthropic donations, such as from The Grieg Foundation and Sundt AS.

Yara International ASA



Who we are

Yara delivers solutions for sustainable agriculture and the environment. Our fertilizers and crop nutrition programs help produce the food required for the growing world population. Our industrial products and solutions reduce emissions, improve air quality and support safe and efficient operations. Founded in Norway in 1905, Yara has a worldwide presence with sales to 150 countries. Safety is always our top priority.

What we do

Upstream is the backbone of Yara's manufacturing system. It includes mass production of ammonia, urea, nitrates and other nitrogen based products as well as phosphoric acid.

Downstream offers a complete fertilizer portfolio to growers worldwide. It provides knowledge and tools to secure the right nutrients and optimize application and yield with minimal environmental impact.

Industrial is a reliable partner in chemical products. It enables innovative solutions based on ammonia production and knowledge, and helps customers reach compliance with environmental legislation.

What we offer

Agricultural products: We offer a complete portfolio of fertilizers covering all necessary nutrients for any crop.

Industrial products: We offer a wide range of nitrogen and specialty chemicals in addition to CO₂, dry ice and civil explosives solutions.

Environmental solutions: We offer complete solutions for NO_x abatement, odor control, wastewater treatment and corrosion prevention.

Our performance

Yara has consistently delivered financial performance in line with our ambitions, with a CROGI level in 2011 of 20.9% and revenues of USD 14.4 billion.

Our Vision is to be an industry shaper, setting standards through performance and growth.

Delivering on our ambitions, we reduced our total emissions of greenhouse gases by more than 45% from 2004 to 2011.

Qafco



Qafco is the world's largest single-site producer of both ammonia and urea and exports ammonia and urea to more than 35 nations across the globe. QAFCO was founded in 1969. After successfully implementing several expansion projects the Company has evolved into a world-class fertiliser producer. Qafco is now owned 75% by Industries Qatar (IQ) and 25% by Yara Netherland and is located in Mesaieed Industrial City, 40 Km south of Doha, on the east coast of Qatar peninsula.

Qafco's primary markets are the countries of South East Asia, North America, Australasia and Southern Africa. To cater to the world markets, which are showing increasing fertilizer consumption patterns, the Company currently seeks to maximize its production of granular urea as opposed to urea prills. Granular fertilizers are considered better suited to the more technology-dependent cultivation. In addition, Qafco is planning to produce Sulphur-Coated Urea (SCU), a product that will increase the nutrient recovery and improve crops yield and also reduce the negative environmental impacts of urea.

Qafco has long ago recognized the importance of protecting the environment while conducting its business. Qafco believes that caring for the environment is not only an ethical and legal obligation but also a mechanism for success. Qafco has always taken the lead to collaborate study/research initiatives with local universities and provide facilities that will benefit all industries in Qatar, such as providing De-NOx technology to a broad range of industries in Qatar.

Qafco is a partner of The Sahara Forest Project Pilot Facility in Qatar.

"QAFCO and Yara are sponsoring this Environmental Project to be executed by The Sahara Forest Project in a pilot scale to demonstrate the potential of the Green Technology in arid region like Qatar, using seawater and solar energy for future larger scale research and commercial platform in the area of horticulture, freshwater generation, energy production, algae Production. This project is expected pave way for commercialization of this green technology for large scale implementation with a vision to produce energy, food and fresh water not only for Qatar but for tomorrow's world population in a sustainable way," said Khalifa Abdulla Al-Sowaldi, Vice-Chairman and CEO of Qafco.

"This pilot Project could show how we can grow vegetables with less water or brackish water. I think this will not be important only to Qatar, but to the whole region and elsewhere where they have the same climate as Qatar. So, I have a lot of hope." - **Sheikh Hamad bin Jassim bin Jaber Al Thani**, Prime Minister of Qatar. "This is an example of the need for new and environmental friendly technologies to contribute to both increase the global production of food, but at the same time reduce the global emissions of greenhouse gasses." - **Jens Stoltenberg**, Prime Minister of Norway. "This is a gold standard in a day and age where we have a hot and crowded planet, and we need to move towards a low-carbon future fast." - **Olav Kjørven**, Assistant Secretary-General of the United Nations Development Program. "The Sahara Forest Project appears to be a very interesting example of the more integrated and holistic kind of thinking that we will need a lot more of in the future to make our energy, water and industrial systems more sustainable." - EU Energy Commissioner **Andris Piebalgs**. "It deserves follow-up and attention from private investors, but certainly also partly a public funding system that makes it possible to move ahead." - **Dr. Gro Harlem Brundtland**, Special Envoy on Climate Change, former Prime Minister of Norway, former chair of the World Commission on Environment and Development and Director General of the WHO. "A novel combination of technologies that has the potential to turn large areas of desert green, producing commercial quantities of food and energy crops, fresh water, and electricity" - **Science** "That Sahara Forest-thing just blows my mind!" (...) "Fantastic! This draws upon synergies from a range of different of technologies" - **Lord John Prescott**, UK Former Deputy Prime Minister. "SFP is a pioneering project that reflects the kind of holistic vision and solution that we need to explore so that we can address the interconnected challenges of food, water and energy security. It is about optimizing the whole system rather than maximizing one goal." - **Dr. Dan Kammen**, Chief Technical Specialist for Renewable Energy and Energy Efficiency, The World Bank. "A renewable-energy "oasis" (...) may serve as a proving ground for new technologies designed to bring green living to the desert." - **National Geographic** "A very spectacular and potentially important project on renewable energy, where we try to pool our experience in some adventurous and entrepreneurial approaches to exploring the potential of this country and the solar potential of the Middle Eastern region. Starting in Jordan is really a promising starting point." - **Jonas Gahr Støre**, Norwegian Minister of Foreign Affairs. "It may sound like an environmentalist's pipe dream, but giant greenhouses could soon be popping up in some of the world's deserts, producing fresh drinking water, food and fuel." - **New Scientist** "Individually, the various technologies are commercially proved, but excitement stems from using them together for the first time." - **Financial Times** "A project at the forefront of cutting-edge technology." - **José María Figueres** Former President of Costa Rica, Initiator and president of The Global Observatory and Member of the Club of Madrid. "Arnold Schwarzenegger stole the show for a while as a star speaker at COP15 (and confirmed that California is the best state in the world), but the Sahara Forest Project remains by far the most original initiative to combat climate change." - **Gulf News**. "Sahara Forest Project is an ambitious attempt to use concentrated solar power and seawater-cooled greenhouses to produce renewable energy, crops and water. Its success thus far has inspired new feasibility studies in Jordan and Qatar." - **The Economist**. "The Sahara Forest Project proposes building CSP plants below sea level (the Sahara has several such depressions) so that seawater can flow into them and be condensed into distilled water for powering turbines and washing dust off the mirrors." - **TIME Magazine**. "The idea sounds too good to be true: vast greenhouses-cum-power-plants that sit in the desert, producing food, energy and fresh water. Yet that is the proposed design for the Sahara Forest Project." - **Telegraph**. "Seawater greenhouses to bring life to the desert. The planned project would use solar power to evaporate salt water, generating cool air and pure water thereby allowing food to be grown." - **Guardian**