Center of Excellence for Water

WEF Nexus School 2023

WEF Nexus Success Stories

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Exchange, Training, and Scholarships Pillar activities are implemented in cooperation with:

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sundrop

Center of Excellence for Water - Exchange, Training, and Scholarships

Sundrop

- https://youtu.be/bCW6OF_cmaU

Background about Sundrop

- Headquarters and Pilot Location
  - Port Augusta, South Australia
- A 20 hectare greenhouse is operational
  - Operations began with a 0.2 hectare pilot facility in 2009
  - The pilot paved the way for the development of the 20 hectare farm

Sundrop Philosophy

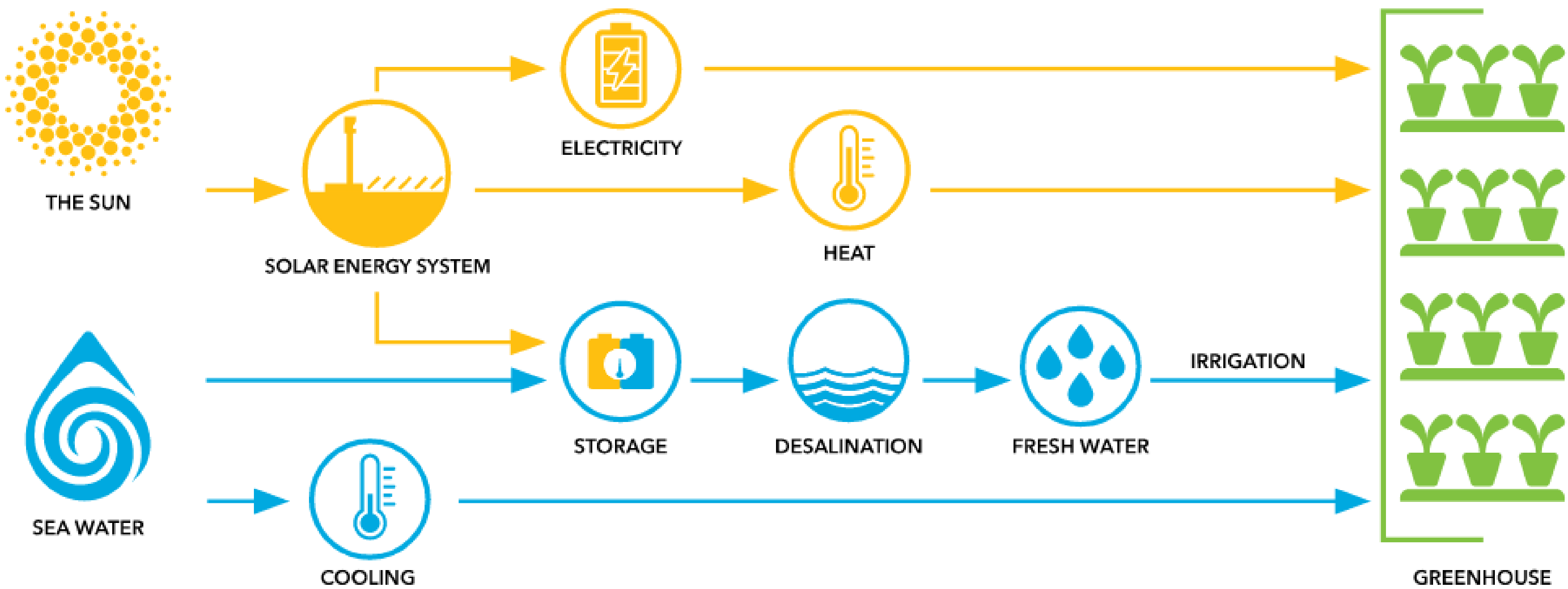
- Sundrop integrates
  - solar power
  - electricity generation
  - fresh water conservation and production
  - climate control
  - Hydroponics
- Enable year-round production of premium produce at high yields with consistent quality
- deliver a meaningful reduction in fossil fuel and water use through innovative use of renewable energy / low carbon technologies
- forms long term partnerships with its customers allowing the design of customized facilities to precisely meet the customers requirement

Sundrop Beliefs

- Nature is a **partner**, not a supplier
- **People** are our most important asset
- Hire **exceptional** talent
- Delicious, natural food is **affordable**
- In **scarcity** there is opportunity for **abundance**
- Re-imagining agriculture requires **creativity** and a strong sense of **entrepreneurship**
- Maximizing **long-term and sustainable profits** helps spread our business model to new locations and helps our partners, the planet, and our people

The Sundrop System

Use **sun's energy** to produce **freshwater** for **irrigation** and turn produced energy into **electricity** to power **greenhouse** to **heat** and **cool** crops



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The Sundrop System

Sun

Sunlight is the beginning of everything we do, from harvesting its energy to run our solar energy systems to providing the light needed to produce our high quality produce.

Sea water

We draw seawater from the nearby Spencer Gulf to provide water for our evaporative cooling systems and to feed out desalination plan.

Solar energy systems

Our Concentrated Solar Power (CSP) system reduces our reliance on fossil fuels by producing heat, electricity and water for our greenhouse use.

Electricity

Steam generated from the CSP is fed into a steam turbine to provide electricity needed to power critical equipment in our greenhouses.

Desalination

Using heat from the CSP and seawater drawn from the Spencer Gulf, our Multi Effect Distillation system produces freshwater to irrigate our crops.

Fresh water

Freshwater produced on site and supplemented with town water is combined with nutrients to irrigate our crops.

Greenhouses

Our best in class greenhouses provide the ideal growing environment to produce high quality fruit and provide barriers to pests and disease more prevalent in open field farming.

Sundrop Benefits

Pure genius

Sundrop Farms desalination process produces freshwater that is pure and distilled, with no need for chemical treatment.

We use the sun for energy

At Sundrop Farms we use sunlight to cool, heat and run our growing environments, so we're not adding to the world's output of C02.

Keeping costs consistently low

We don't use either volatile water and energy in our production processes. Instead we turn to abundant, renewable inputs like sea water and heat from the sun.

https://www.youtube.com/watch?v=Abzzlavlr9M

Sundrop Benefits

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Agriculture Transformation

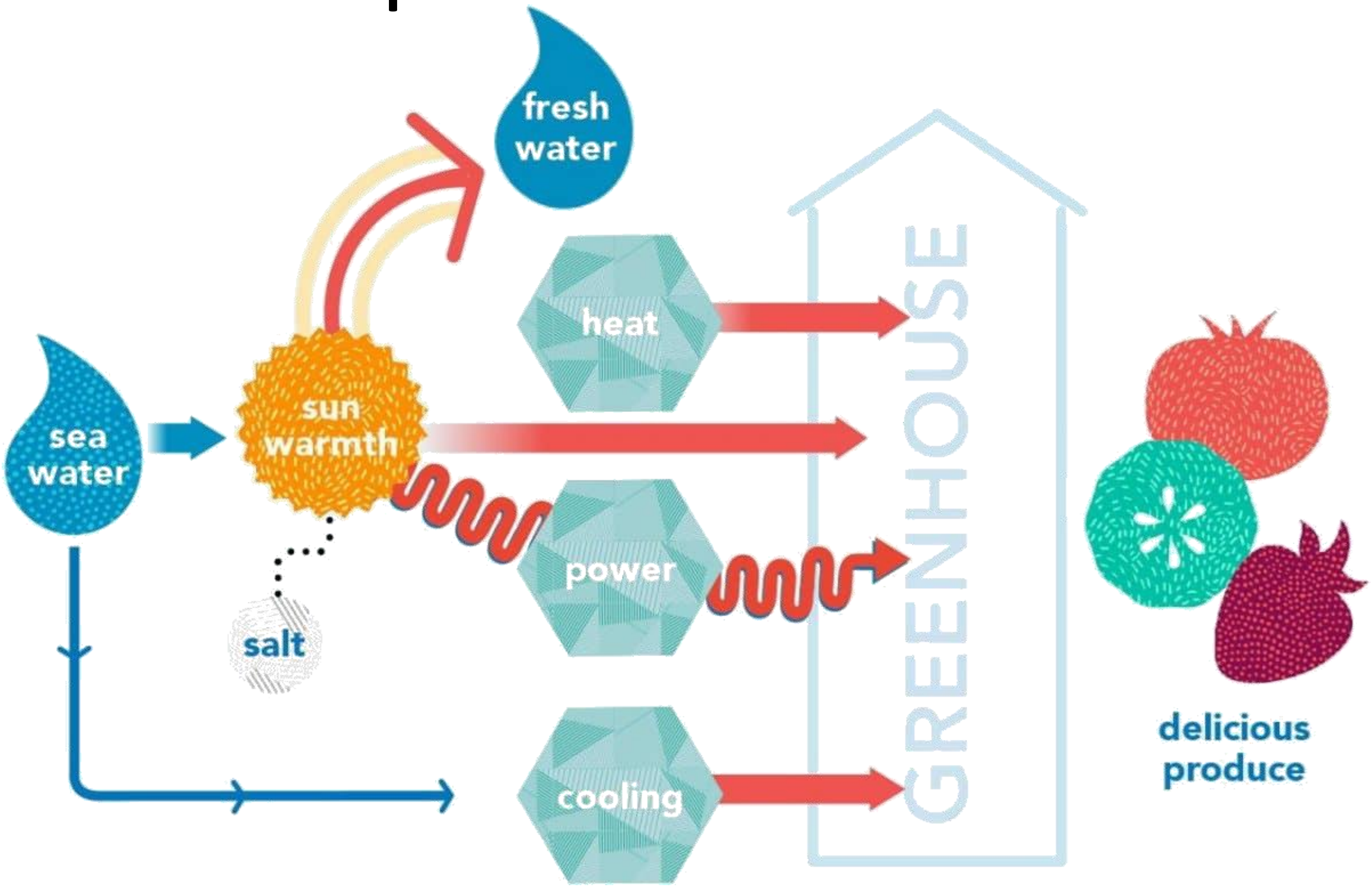
We are showing the world that you can grow delicious, mouthwatering produce without needing fossil fuels, vast amounts of fresh water and thousands of acres of cultivated farmland.

In other words, we are breaking farming's dependence on finite resources.

Sundrop Process

1. Seawater is used to cool and warm the greenhouses
2. The sun's energy is used to produce fresh water for irrigation
3. Solar energy is used to heat the water to produce electricity
4. Electricity heats and cools crops in greenhouses
5. Water is re-cycled
6. The final product: a Sundrop tomato

Sundrop Process Schematic



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Sundrop Produce

- what **doesn't go into** the fruit that makes the difference
- selecting naturally bred seeds from delicious varieties of fruit that are suitable for Australian tastes and growing conditions
- tech greenhouses provide **natural barriers** to pest and disease
- Desalinated water is recycled to maximize the use of the nutrients within the water and minimize waste

Sundrop Produce

- high quality truss tomatoes that are distributed across Australia through Coles
- deliver only the highest quality fruit that provides a great taste that is great for Australian conditions
- continually monitor global trends to provide varieties that are the best-in-class, to provide a better customer experience

Where does the water used come from?

- Utilize seawater from the **Spencer Gulf** for various purposes
- Use the **saltwater** in both our **irrigation** and **cooling** systems
- Desalinate the seawater to supplement irrigation needs
- **Thermal desalination** system is powered by solar tower

Sundrop Greenhouses

- Four **5 ha high-tech greenhouses**
- From planting to harvest takes 10-12 weeks
- crops harvested **weekly by hand** after which the process becomes automated
- **Robotic carts** take the fruit away and feed it through a state-of-the-art packing facility
- In the middle of summer, in peak production, around **75 tons** are shipped out every day
- Goal is to produce about **15,000 tons** of tomatoes a year, accounting for about **13% of the Australian crop**
- Cost of production is **lower than the average** greenhouse business **but capital investment is higher**

Sundrop Greenhouses

- Process **eliminates the need for 14,000 lit of diesel a week** to heat the greenhouses
- The **climate and irrigation** inside the greenhouses are **controlled** to ensure the tomatoes receive the right levels of nutrients, light, water, temperature and carbon dioxide
- The tomatoes are grown **hydroponically** on a tray, trained up on a string, and fed nutrients and water via an irrigation dripper.
- Any plant-eating bugs that withstand the seawater-based conditions are controlled by **natural pests, eliminating the need for toxic sprays**

Greenhouses

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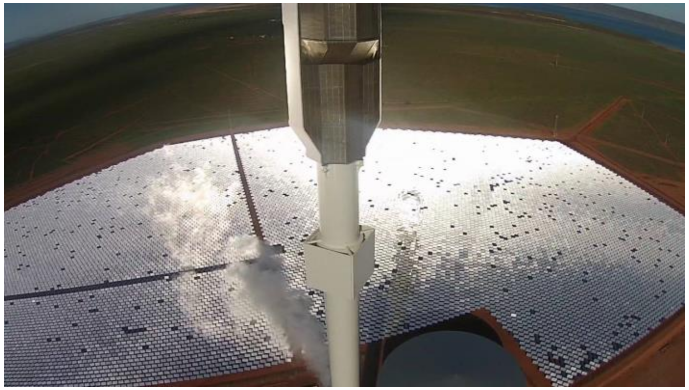
Greenhouses

Greenhouses

Energy Generation

- Uses multiple energy streams for heating, fresh water and electricity
- **23,788 mirrors** (each 2 m^2), automatically tune in and tune out their focus, depending on demand, towards the **37 GW boiler tower (127 m high)** that acts as a collection point for that concentrated heat



Energy Generation

- The water is kept in **storage tanks** before being delivered via a pipe system throughout the greenhouses
- Water **recycled** and heads to the solar tower, where it is heated and used for desalination

Glass Mirrors

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Sundrop

Sundrop

Long video coverage:
https://www.youtube.com/watch?v=IaTS00Df5jY&t=3s

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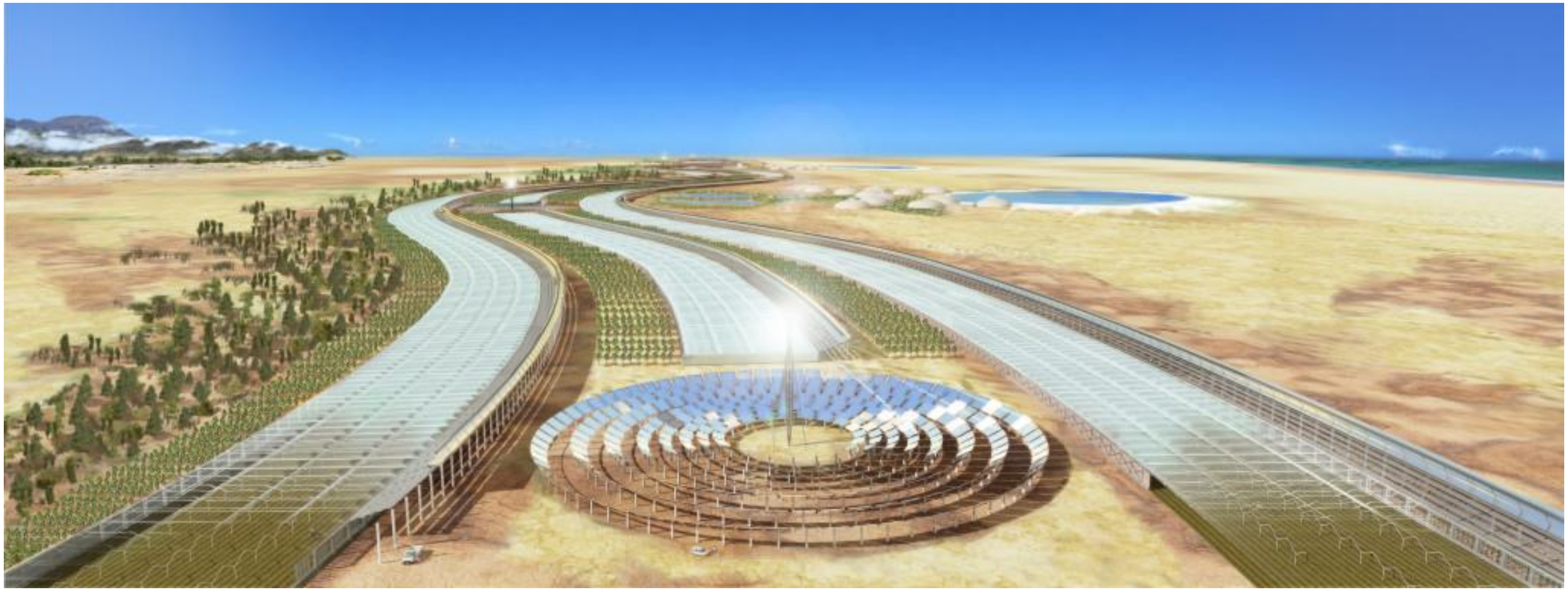
SAHARA FOREST PROJECT



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Sahara Forest Project

- The Sahara Forest Project (SFP) uses **deserts, saltwater, sunlight and CO_2** to produce **food, water and clean energy**
- SFP is a combination of environmental technologies to enable **restorative growth** and creation of green jobs through profitable production of **food, freshwater, biofuels and electricity**
- 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**

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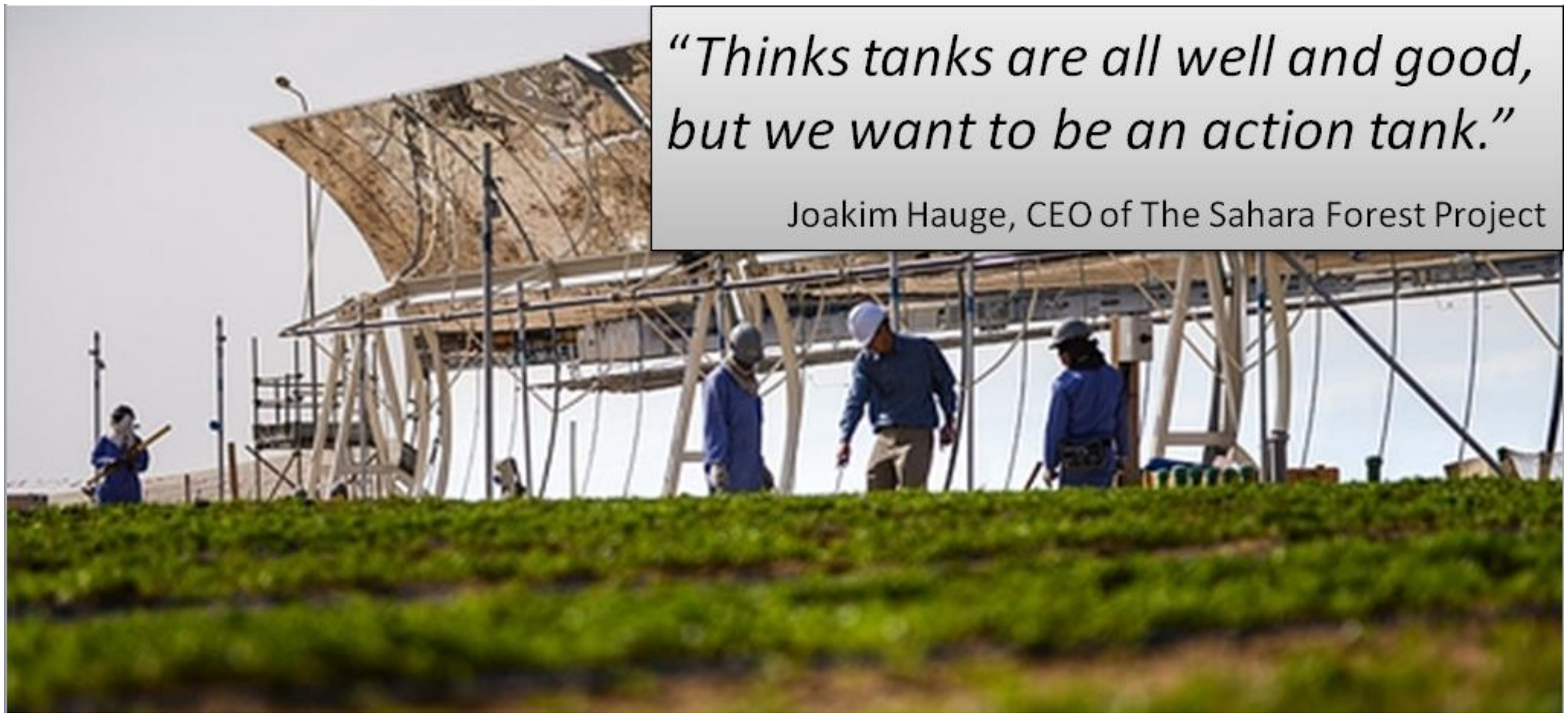
Background about SFP

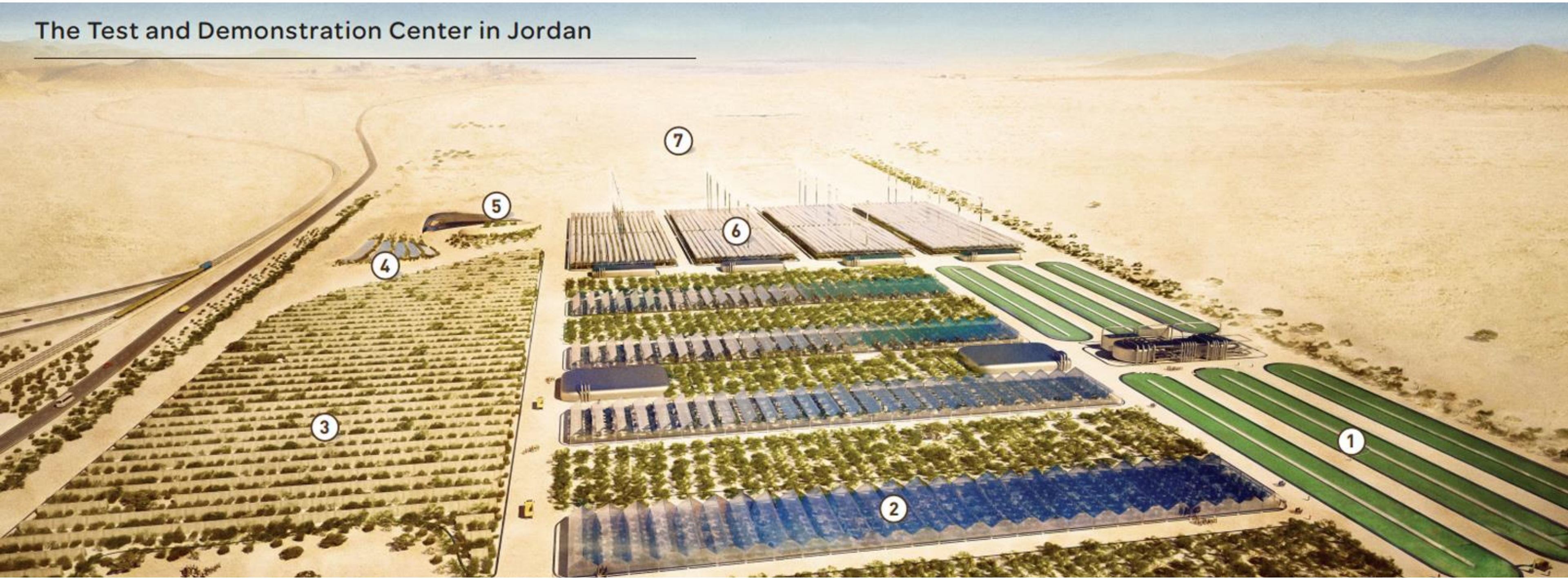
- Headquarters
  - Oslo, Norway
- Office
  - Aqaba, Jordan
- Pilot Locations
  - Qatar (2012)
  - Jordan (2017)
- In Tunisia and Australia, SFP is engaged in carrying out Feasibility Studies to map out opportunities for near-term establishment of new facilities

Sahara Forest Project

- https://vimeo.com/70325635



Sahara Forest Project



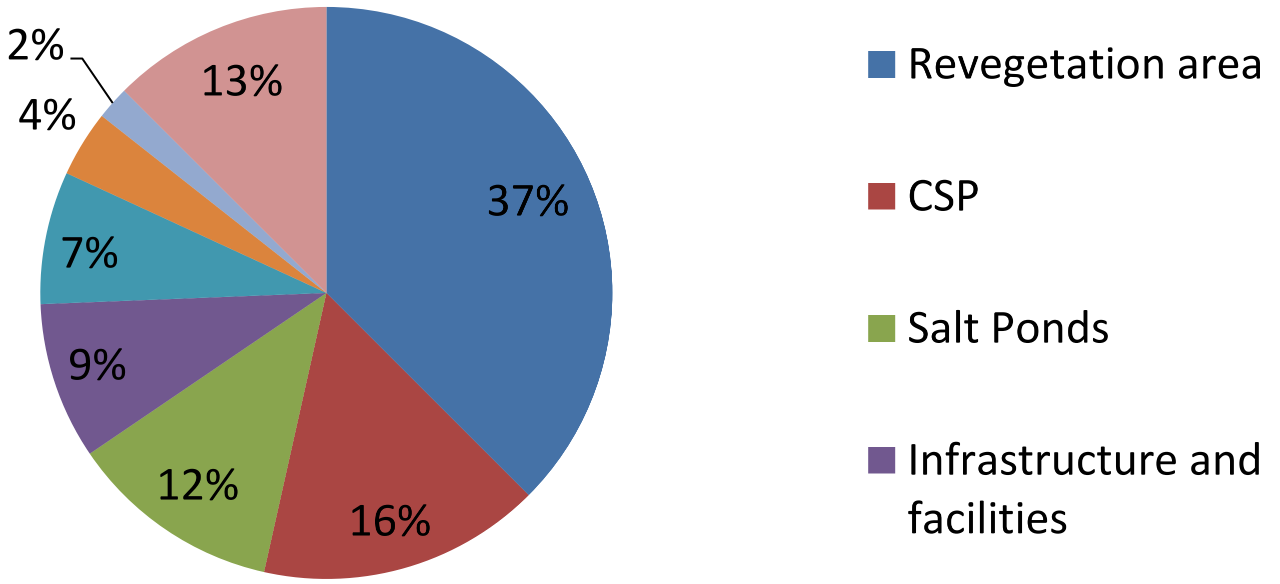
1. Algae-facility; 2. Saltwater based Greenhouses; 3. External vegetation and evaporative hedges; 4. Designed stepped protection for flash floods; 5. Facilities for research and accommodation; 6. Concentrated Solar Power facilities; 7. Evaporative ponds

Sahara Forest Project

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

Typical Land Distribution



https://prezi.com/v8h8l1v43ssg/sahara-forest-project/

SFP Technologies

SFP Technologies

Core Technologies

- Sea-water Cooled Greenhouses
- Solar Power
- Revegetation

Technology Extension

- Salt Extraction
- Traditional Desalination
- Bio-Energy
- Integrating waste CO2
- Algae
- Mariculture
- Livestock Farming
- Halophytes

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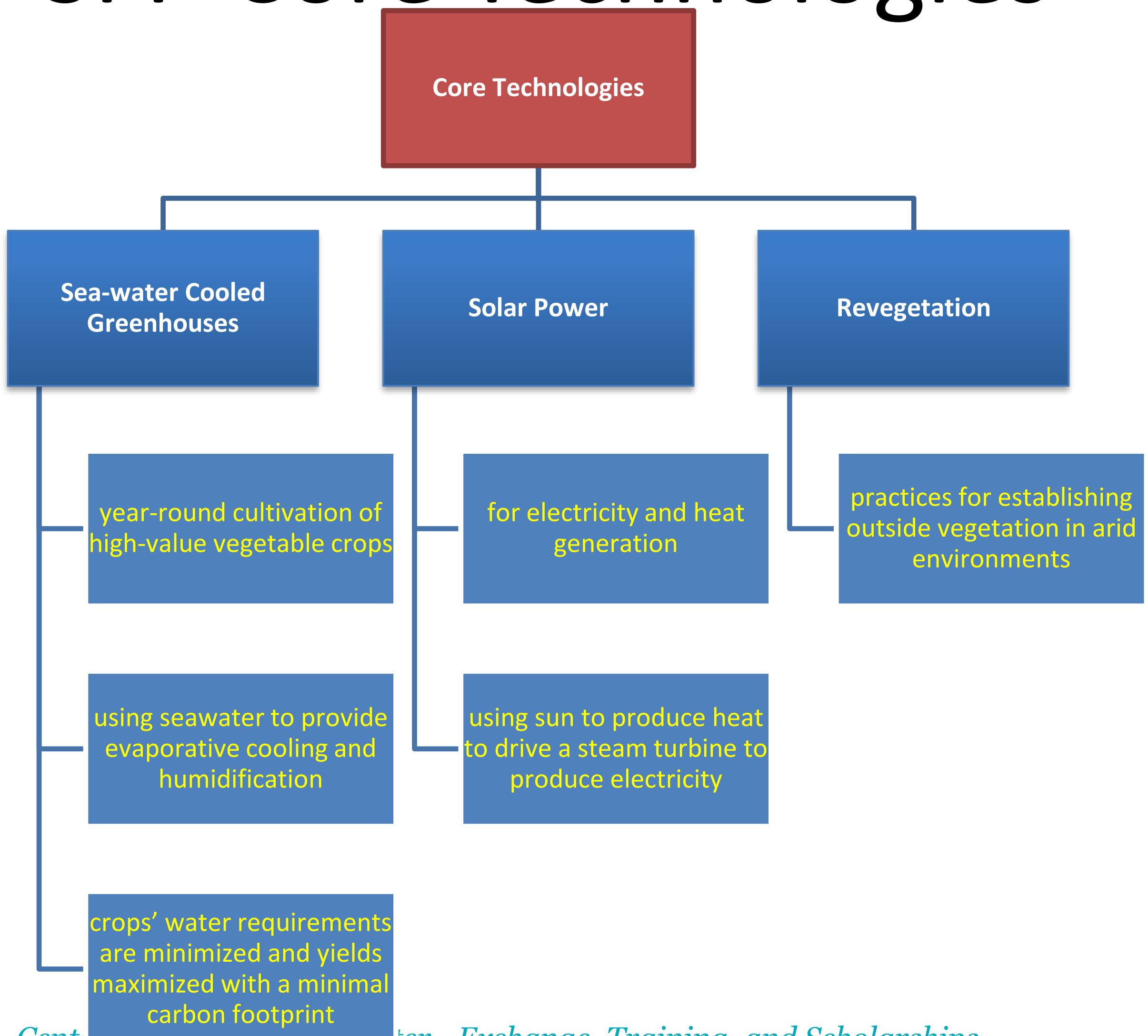
SFP Core Technologies



1. Seawater-Cooled Greenhouses

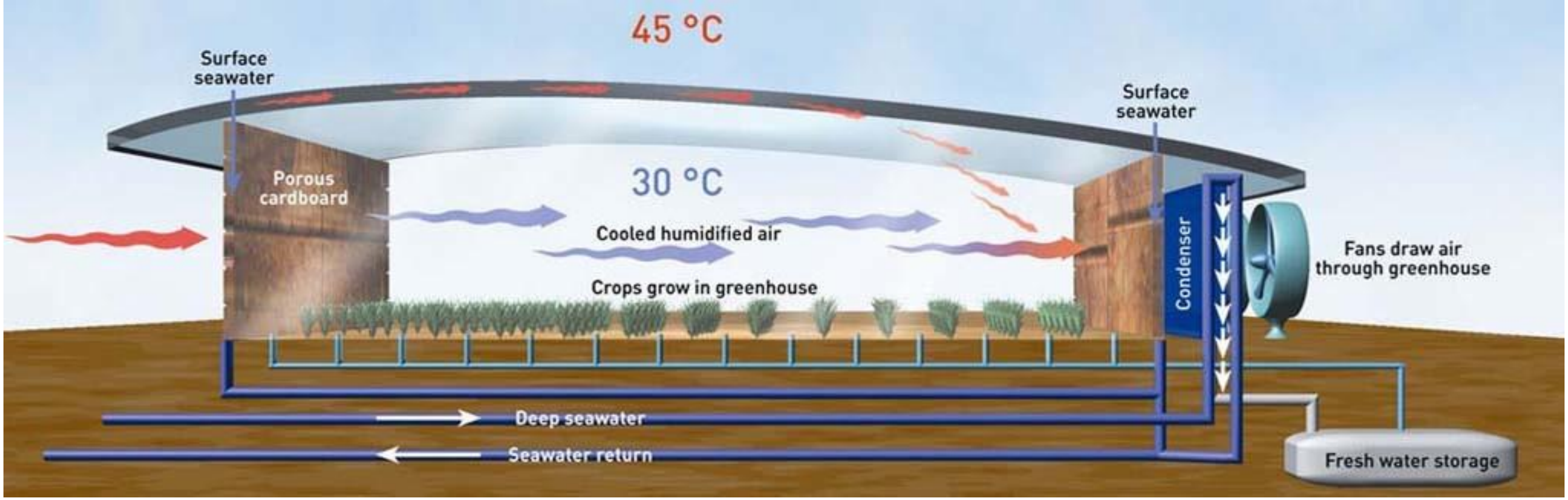
- Promotes the **optimal growth of high-value crops** such as salad tomatoes, cucumbers, peppers, or flowers.
- **Output per unit area** can be increased by 10 to 20 times that of growing plants outside
- **Saltwater**-cooled greenhouses provide suitable growing conditions that enable **year-round cultivation of high-value vegetable crops**
- Provide climate and crop control typical of very high productivity commercial greenhouses **while avoiding traditional cooling methods' high environmental and economic costs**.
- Using seawater to provide **evaporative cooling** and humidification minimizes the crops' water requirements and maximizes yields with a minimal carbon footprint
- The saltwater can be utilized in the greenhouses until it reaches a salt concentration of approximately **7-12%**

1. Seawater-Cooled Greenhouses

- The basic principle is that the **incoming air is conditioned through pads** and pushed with fans into the growing environment using **inflatable ducts** under the crops ensuring good air distribution
- Therefore, the greenhouse is under **positive pressure** to prevent untreated air from entering the space. The air is pushed out through openings at a high level.

1. Seawater-Cooled Greenhouses

- **When it is hot outside**, incoming air is pulled over evaporative **honeycombed cardboard pads** with **saltwater running over them**. The hot air is cooled by evaporation to produce cool and humid conditions in the greenhouse
- **When it is cool and humid outside**, the greenhouse can be heated in a conventional way using heating pipes on the ground and waste heat from other processes can be used to evaporate water and create humid air. As it cools, the moisture condenses to form fresh water (to grow crops) and provide heat at night to the greenhouse

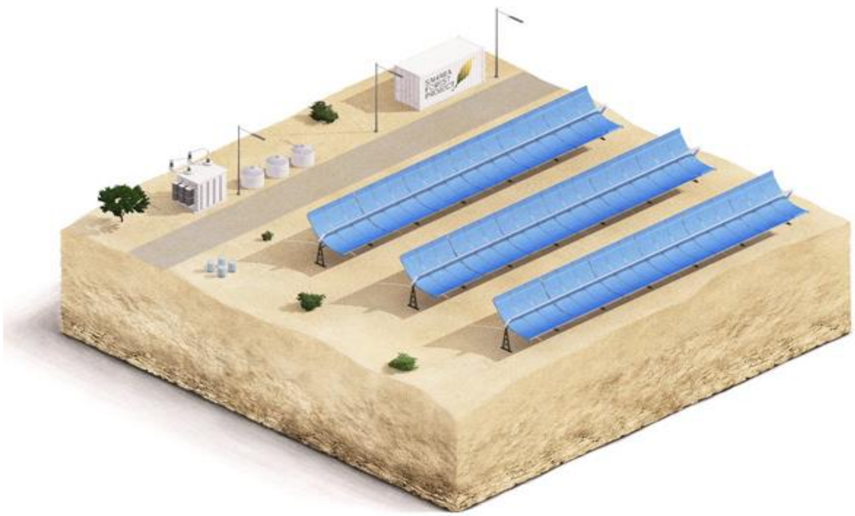


1. Seawater-Cooled Greenhouses

- **Hydroponic** growing is utilized reducing water requirements by up to 50% compared to soil-based methods
- A **fertigation** (fertilization + irrigation) system will deliver each plant with precisely the water and nutrients it needs, tailored to its stage of growth.
- The **high-humidity environment** of the greenhouse will improve water performance even further by significantly reducing the thermal and water stress on the plants.
- Overall water requirements for evaporative cooling are not reduced – **but because the cooling takes place outside the plant, seawater can be used instead of precious freshwater**. Under these conditions, the plant can devote its internal resources to grow more fully, leading to higher yields and water efficiencies

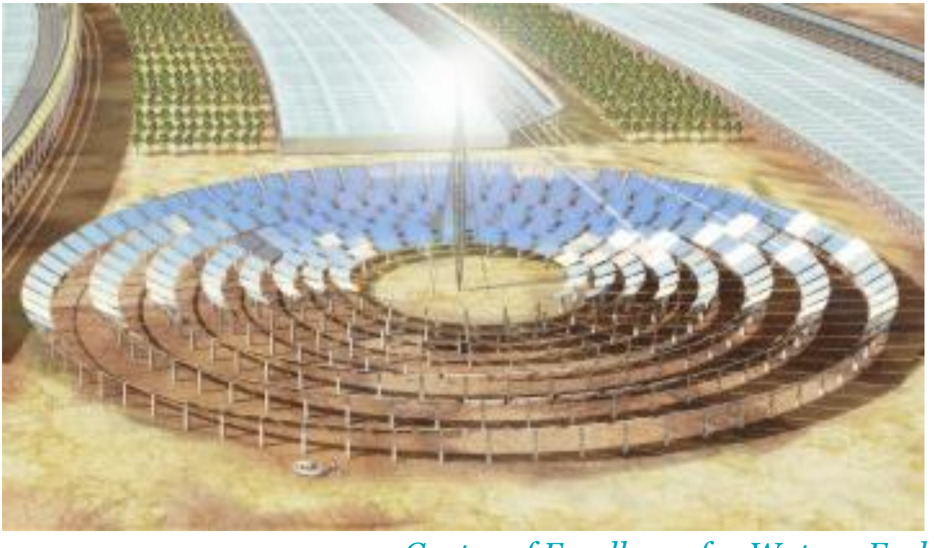
2. Solar Power

- The solar power technologies convert sunlight into electricity, either directly using **Photovoltaics** (**PV**), or indirectly using **Concentrated Solar Power** (**CSP**) to provide electricity and heat generation
- Both PV-systems and CSP-systems benefit from the integration with other SFP-technologies
- In SFP, Seawater-cooled greenhouses and CSP technology are linked together, where the water-thirsty cooling towers of a typical CSP plant are replaced with a seawater cooling system that utilizes the **greenhouse roofs to dissipate the waste heat** from the CSP process



2. Solar Power

- There are several arrangements of mirrors that can be utilized to focus the energy to achieve the high temperatures required.
- **Tower systems** use a field of mirrors that can be steered in two dimensions to focus the sunlight onto a receiver on top of a tower (CSP).
- **Trough systems** used **curved mirrors formed into parabolas to focus the sun onto a pipe receiver mounted at the focal point**. The mirrors are steered in one dimension to follow the elevation of the sun. Finally, Fresnel systems use an array of long flat mirrors mounted horizontally that rotate to focus onto a pipe suspended above the mirrors.



Tower system

Trough system

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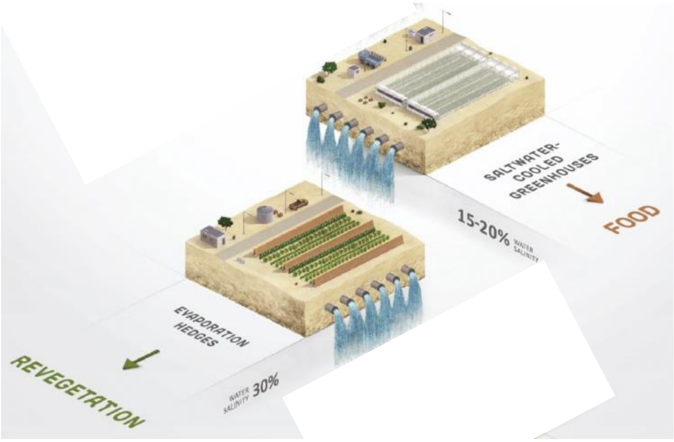
3. Revegetation

- Desert revegetation is catalyzed by a combination of **efficient watering regimes** and **soil reclamation** techniques
- The external cultivation areas host both **native desert** species and **water efficient food and fodder crops**
- **Native species** can be utilized as new sources of **fodder** and **bioenergy**, or for **carbon sequestration and soil conditioning**
- **Nitrogen-fixing and salt-removing desert plants** can be deployed to improve soil conditions, boost crop yields, and reduce requirements for mineral fertilizers
- More than **50 different kinds of desert plants**, vegetables and grain crops have successfully been cultivated outdoors throughout 365 days of annual operations

3. Revegetation

- Water coming out from the greenhouses (10% brine) still has an evaporative cooling and humidification potential (salt solutions do not become saturated until they reach concentrations of about **30%**)
- Rather than disposing this water, it is put to further work as a **humidity provider** in the facility
- The 10% brine will be piped from the greenhouses to an array of **evaporative hedges**. These hedges will:
  - concentrate the brine by evaporating water
  - provide evaporative cooling and humidification to areas downwind of their position
- These humidified spaces will provide a place for **outdoor vegetation**. The plants can take advantage of the cooler, more humid, and wind-sheltered environment provided by the hedges, making it possible to grow a broader range of crops than in open conditions
- Estimates and testing suggest that the irrigation requirement of plants grown within this area will be **reduced up to 40%**



3. Revegetation

Carbon Storage Advantage

- By revegetating low-productivity desert areas, SFP will **sequester carbon** from the atmosphere into its plants, roots, and soil.
- Such practices represent a unique possibility for **removing CO_2 from the atmosphere and storing it in biological material** in a previously barren land – a genuinely carbon-negative solution
- Such measures have the potential to be an effective tool on a global scale in limiting the effect of **global warming**

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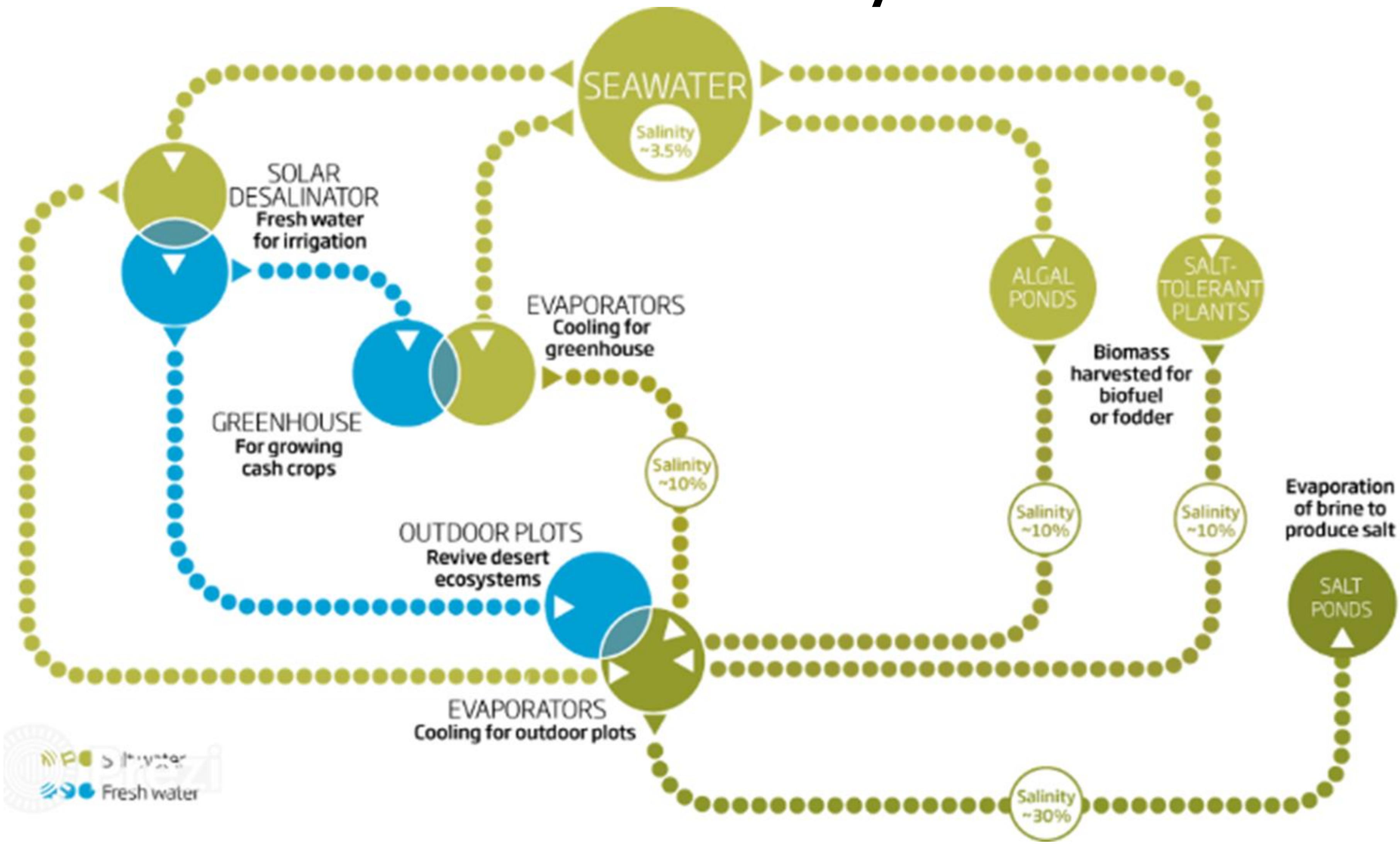
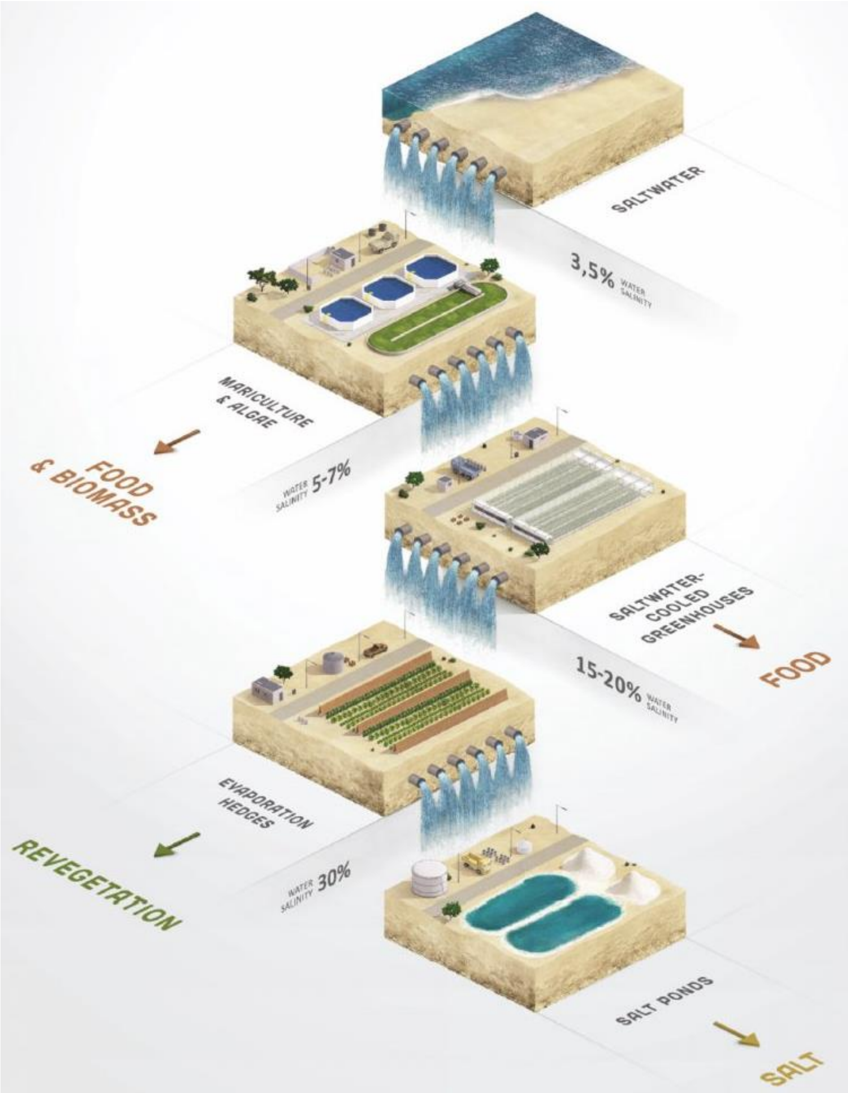
SFP Water Cycle



Saltwater Infrastructure

The Sahara Forest Project has the potential to operate **without discharge of brine back to the sea**



SFP Technology Extensions

Technology Extension

- Mariculture
- Algae
- Traditional Desalination
- Bio-Energy
- Livestock Farming
- Halophytes
- Integrating waste CO_2
- Salt Extraction

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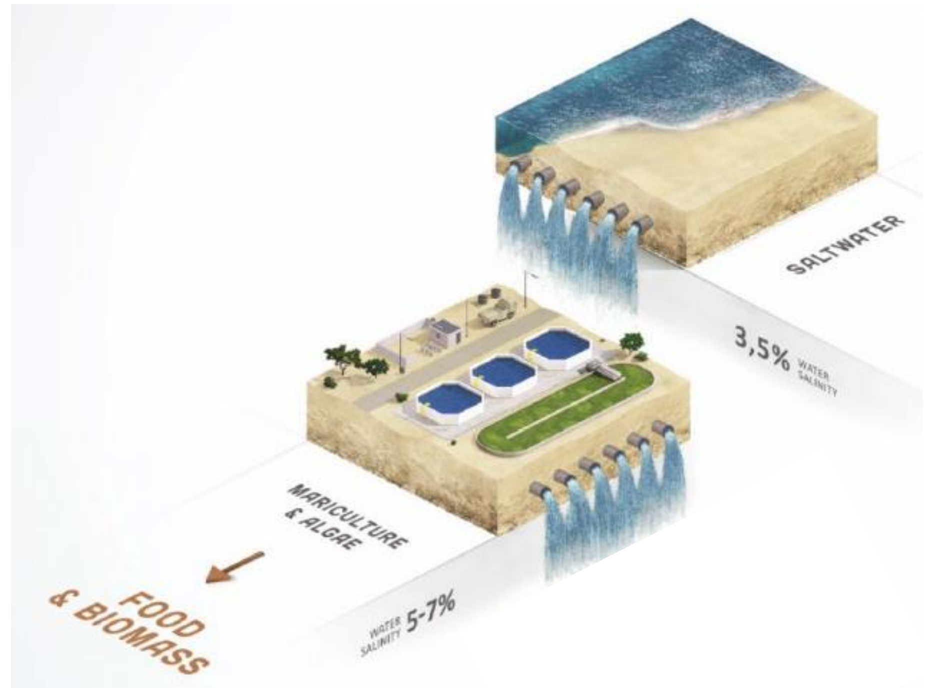
1. Mariculture

- The farming of **fish, snails, shrimp** and other aquatic animals for food can utilize seawater to produce high-value food
- The mariculture ponds will be fed with fresh seawater **directly from the seawater intake**. This is necessary because most marine organisms cannot tolerate the higher salinities found downstream in the SFP system.
- Fish or shrimp, or other animals are raised in open ponds. As evaporative losses increase the salinity of a pond, the water is cycled out and refreshed with fresh seawater.
- Upon its removal, the **wastewater from the pond is only mildly more saline than seawater – 5–5.5% salt** – and is enriched in nutrients (organic waste). In this state, it is **ideal for feeding into algae ponds**.
- Algae can often tolerate mild increases in salinity and thrive on the nutrients in the organic wastes.
- By the time the water passes through the algae cultivation facility, it will have been **naturally purified from all its wastes and ready for use in the greenhouse cooling systems**.
- To close the loop, the **oil- and nutrient-rich algae can be fed back to the marine organisms**, providing a high-performing feed for the farmed animals.

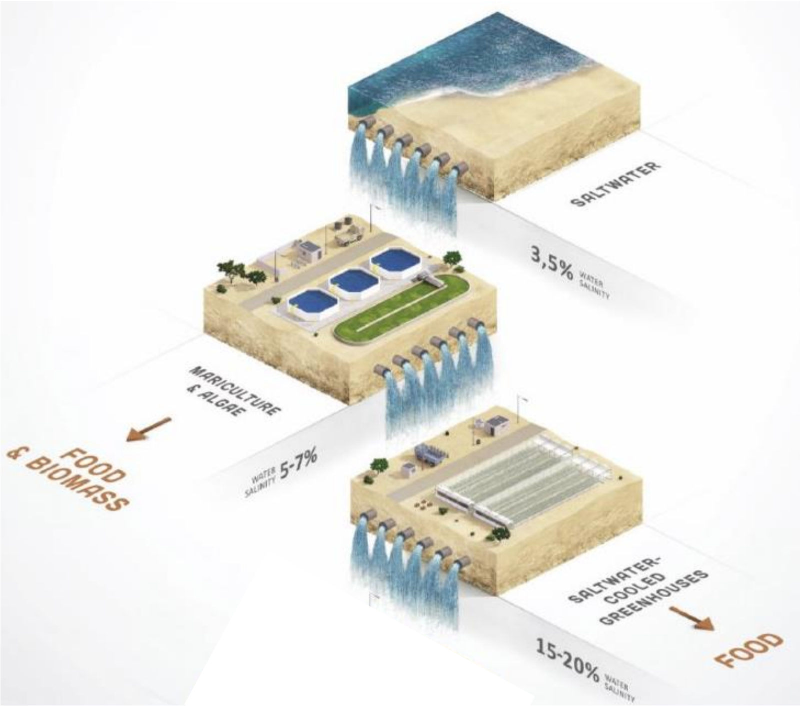


1. Mariculture

- The cultivation of **freshwater** species, such as Tilapia, is possible
- Typical cultivation systems use a **Recirculating** – but not closed – infrastructure that runs on a constant flow of freshwater through the system (RAS)
- Pure freshwater enters the system, and water is enriched with nutrients from the fish waste leaves. The only actual water consumption is through **evaporative losses** from the cultivation pond,
- The valuable freshwater serve a double purpose where **the nutrient-enriched freshwater outflow from the fish farm can be applied directly to irrigate the growing crops without significant filtering or sterilization**
- This allows a straightforward, **low-cost, and low-energy recycling of nutrients from the fish farm while reducing fertilizer requirements in the external planting areas**
- As in the marine mariculture systems, the nutrient-rich algae grown can be used to feed the fish
- In the case of a freshwater aquaculture system, this can be a valuable pathway to **transfer nutrients** from the salt water-based algae and mariculture systems to the freshwater-based agricultural system.

2. Algae

- Sharing seawater infrastructure opens up a new range of more advantageous locations and commercial possibilities for algae cultivation
- In SFP, algae facilities **hardly use any of seawater** as algae are grown in it for a few days, during which time a small amount of the water is lost to **evaporation**
- At harvesting, **only about 5%** of the water is taken with the algae, which is removed for further processing and drying, leaving more than 90% of the water algae- and nutrient-free, with a salinity only slightly higher than seawater (5–7%)
- At those salinities, the water is still very well suited to provide **evaporative cooling and humidification for salt water-cooled greenhouses** and later be further evaporated on the **outdoor hedges** to provide humidity and cooling to the agricultural growing spaces.
- **Waste brine** from the algae facility **will become an input** into the core operations of the SFP system

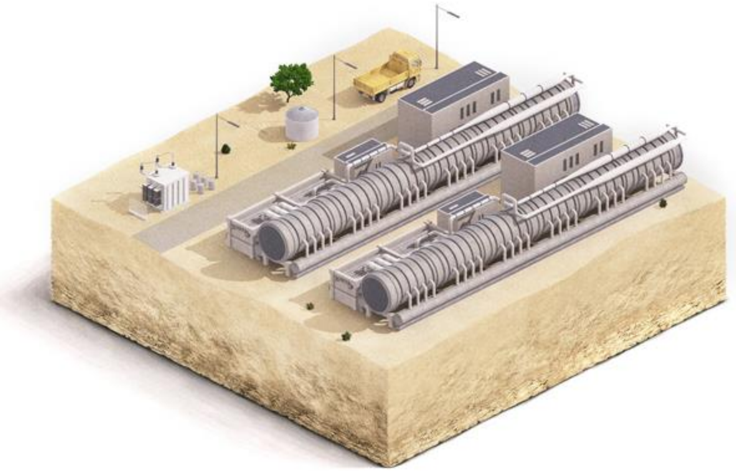


2. Algae

- Marine algae are one of the most promising future sources of bioenergy and nutrients. This is due to:
  - **efficient photosynthesis** and high surface yields
  - using non-agricultural land or **seawater** for cultivation
  - increased **lipid content**
  - interesting molecular profiles for **fuel production**
  - technical improvements of **cultivation systems**
- Algae are a **natural fit** into the SFP, requiring lots of sunlight and seawater, the two core inputs to the facility
- One of the critical challenges for making the production of algal bio-fuels profitable is enabling the production of saltwater algae in locations **not located** directly on the coast
- Typically, algae facilities require around **2 kg of CO_2** for every kg of algae they generate. Maximizing growth rates in algal facilities needs an external source of CO_2 to be supplemented to the system. It would be highly advantageous if this CO_2 could be sourced as a **waste product from a nearby industrial process** rather than bought as a commodity or transported long distances

3. Traditional Desalination

- The energy of the CSP component can power a traditional desalination plant producing freshwater
- The brine release from the desalination plant will be channeled to the **saltwater infrastructure** avoiding the brine release to the sea
- Three fundamental desalination types are suggested
  - Multiple-effect distillation (**MED**) – using high-grade waste heat
  - Multi-stage flash distillation (**MSF**) – using high-grade waste heat
  - Reverse osmosis (**RO**) using electricity
- Operating a thermal desalination plant requires taking 'waste' heat from the CSP, which reduces the efficiency of electricity generation but allows **large-scale production of freshwater**
- These processes work on the principle of **distillation** and require cooling to drive the condensation of freshwater, where **saltwater-cooled greenhouse will provide this cooling**
- Alternatively, **electricity produced by the CSP system may be used to power an RO desalination plant**



4. Bio-energy

- Biomass-based energy is a vital component to **reduce the effects of global warming**
- Despite its promise, the realistic potential of bioenergy is **limited** if it is derived from **traditional terrestrial crops**, such as corn
- **Any produce that competes with food production for access to arable land and freshwater for irrigation can never be responsibly deployed on large scales necessary for energy applications**
- SFP provides the opportunity to cultivate crops on desert lands that are naturally **unproductive for food**, using only **seawater** and its derivatives
- Because desalinated water can be used within SFP to grow valuable food and fodder, the most interesting sources of biomass for energy purposes have following characteristics:
  - Can be **grown in or rinsed with salt water**
  - Can grow **in soils too saline for food crops**
  - High in **energy content**
  - Can **thrive in the humidified hedge growing spaces with little or no irrigation**
- Examples are **algae**, **halophytes**, and some particular desert species
- The best species for bioenergy cultivation will be characterized in field trials at SFP facilities and assessed by their:
  - **biomass production efficiency**
  - **freshwater requirements**
  - **energy density**
  - **ability to provide other ecosystem services**

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5. Livestock Farming

- Grazing livestock such as **sheep, goats, and camels** may provide an efficient way to harvest grown fodder
- **Grazing is less costly than harvesting and packaging** fodder for sale offsite, and the grazing animals return nutrients to the soil directly through their **manure**.
- Most native fodder species are well suited for grazing, and **highly nutritional alfalfa** can also be grazed in a controlled manner
- Allowing controlled grazing on parts of the land revegetated with fodder will provide **locally grown food** to livestock where **animal feed is primarily imported**

6. Halophytes

- Halophytes are plants that can **tolerate** or even thrive in **salty growing conditions**
- Halophytes are of because:
  - they may be the only plants initially **capable of producing in salty desert regions** so they may provide a water-efficient means for **soil remediation** in brackish soils
  - they provide opportunities to **cultivate fodder and energy crops using saltwater** (even seawater) for irrigation
  - they act as **sand stabilizers and windbreakers**

7. Integrating Waste CO_2

- CO_2 emissions are not only a waste but also a pollutant, contributing to global climate change
- CO_2 is a **valuable resource** for boosting the growth of **terrestrial and marine crops**
- It is a significant **input** into SFP's horticultural operations and **algae ponds**
- CO_2 (a polluting waste stream from industry) can be converted into a **food and bioenergy resource**
- Waste CO_2 can be used **in growing algae strains** that can thrive on exhaust gas
- Waste CO_2 can be **injected into algae ponds** without significant purification or concentration
- Any biomass-fuelled electricity generation will produce CO_2 emissions that can be directly used in the SFP facility to generate more biomass and food

8. Salt Extraction

- Once brine reaches concentrations approaching **30%** in the evaporative hedges, almost 90% of the freshwater content will have been removed so brine is too concentrated to continue evaporation
- The brine will then be left in salt **evaporation ponds** (ordinary commercial salt production)
- **Salt evaporation ponds, also called salterns or salt pans**, are shallow artificial ponds traditionally designed to produce salts from seawater or other brines
- The brine from the evaporative hedges will be fed into salt ponds. The remaining water will be drawn out through natural evaporation, allowing the salt to be harvested
- SFP aims to be a zero-discharge facility, **with salt as a commercial product**

Sahara Forest Project

A single SFP-facility with **50 MW** of Concentrated Solar Power and **50 ha of seawater greenhouses** would annually produce

- 34,000 tons of vegetables
- employ over 800 people
- export 155 GWh of electricity

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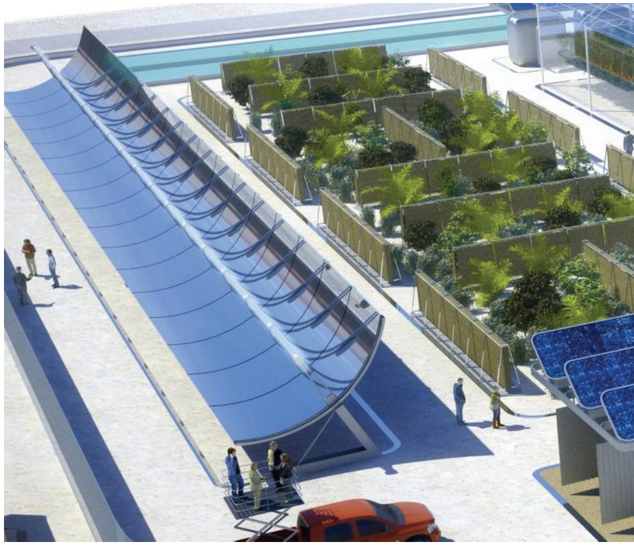
Sahara Forest Project



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Sahara Forest Project

- Combines
  - solar thermal technologies with technologies for saltwater evaporation,
  - condensation of freshwater
  - modern production of food and biomass without displacing existing agriculture or natural vegetation
- Optimum location for a SFP-facility are:
  - Arid
  - Sunny
  - little agricultural activity or natural vegetation
- A single SFP-facility with 50 MW of concentrated solar power and 50 ha of seawater greenhouses would annually produce
  - 34,000 tons of vegetables,
  - employ over 800 people,
  - export 155 GWh of electricity
  - sequester (banish) more than 8,250 tons of CO_2

Sahara Forest Project

- A combination of environmental technologies to enable restorative growth and creation of green jobs through profitable production of
  - Food
  - Freshwater
  - Bio-fuels
  - electricity
- While society still strives to realize that *sustainable solutions must replace the traditional extractive use of resources, the Sahara Forest Project demonstrates the potential for restorative practices.*
- Designed to utilize what we have enough of to produce what we need more of, using
  - Deserts
  - Saltwater
  - CO_2
- A unique combination of existing low-tech environmental solutions based on tested principles that are combined to create highly desirable synergies.

Sahara Forest Project

- https://www.saharaforestproject.com/technology-extentions/

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