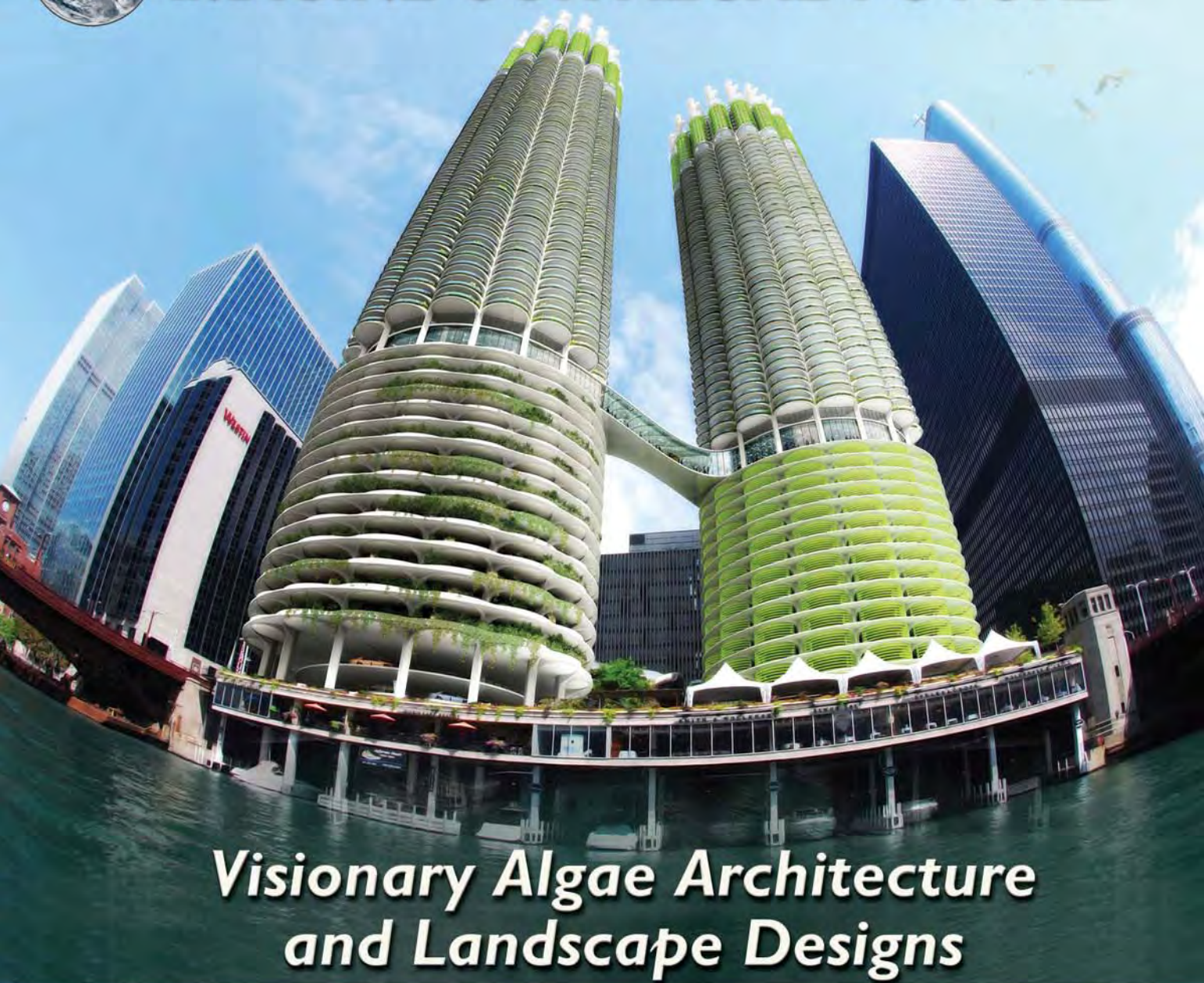




# **IMAGINE OUR ALGAE FUTURE**



## ***Visionary Algae Architecture and Landscape Designs***

***Robert Henrikson***

***Mark Edwards***



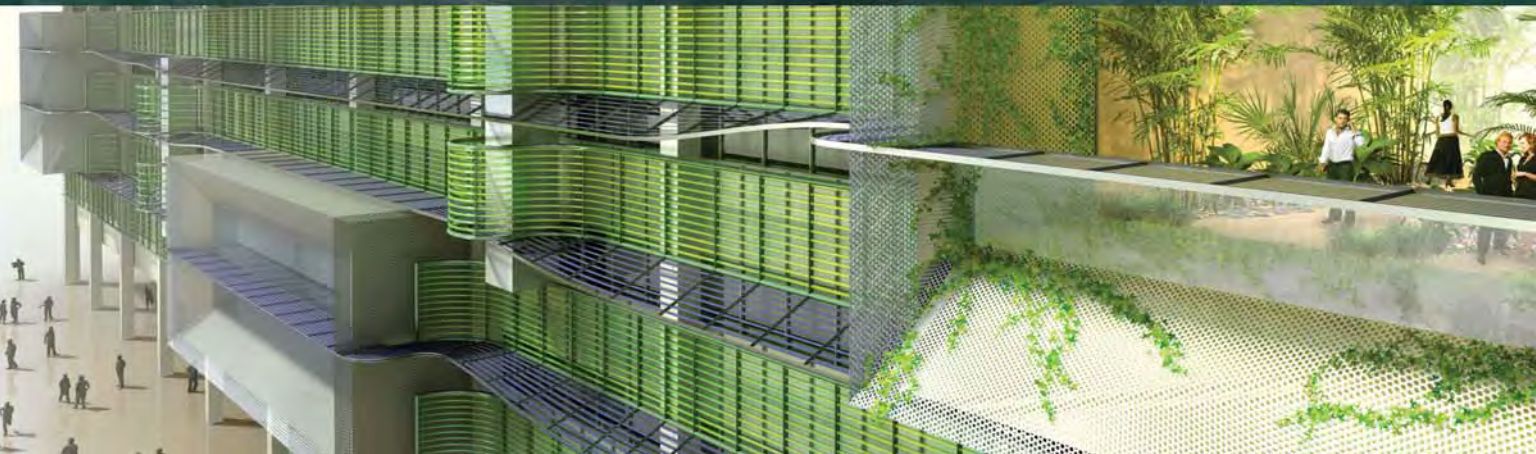


*How will growing algae  
change the world  
and improve our lives?*

Imagine our future living in cities where buildings are covered with photosynthetic skins and vertical gardens, collecting the sun's energy and producing food and energy for urban citizens. Imagine greening desert coastlines and producing food for millions of people. Imagine algae systems that recycle polluting wastes into high value animal food, fuel and biofertilizers.



Algae Competition is a global challenge to design our future with algae food and energy systems.





# IMAGINE OUR ALGAE FUTURE

# *Visionary Algae Architecture and Landscape Designs*

# International Algae Competition

Robert Henrikson and Mark Edwards



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*Visionary Algae Architecture and Landscape Designs*

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Robert Henrikson and Mark Edwards

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*Christian Canonico*



Production landscape for warm  
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Federal Building in Los Angeles  
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by *Chew Teik Hee*



BioOctonic utility tower in  
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AlgO, Regeneration of the  
Baie de Morlaix in France by  
seaweed by *Isabelle Bardèche*



Algae powered mushroom  
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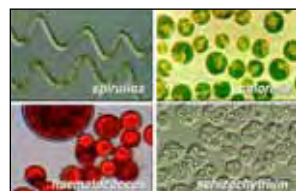
# IMAGINE OUR ALGAE FUTURE

## *Visionary Algae Architecture and Landscape Designs*

### International Algae Competition

*Robert Henrikson and Mark Edwards*

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## **International Algae Competition**

### ***A Global Challenge to Design Visionary Algae Food and Energy Systems***

#### ***Vision***

We envision a future with food democracy, where people globally have access to the knowledge and inputs to produce affordable good food and energy for their family and community locally.

International Algae Competition ([algaecompetition.com](http://algaecompetition.com)) offers an open source collaboratory to expand and share design ideas for algae production landscapes, sustainable and affordable algae production systems for food, feed, energy, nutrients, water remediation, carbon capture and fine medicines, and superb new algae foods.

#### ***Objectives***

- Catalyze opportunities for local algae microfarm systems in communities, rooftops, backyards, public spaces, farms, villages, towns and cities.
- Enthuse algae innovators to engage their hearts and minds to create algae solutions to vital social challenges.
- Enable political, community and business leaders to create wise social policies for resource preservation and environmental restoration with algae.
- Motivate our next generation to careers in sustainable and affordable food, feed, fertilizer, nutraceuticals, vaccines and medicines.
- Encourage consumption at the low end of the food chain, which enhances health for people, producers and our planet.
- Inspire people globally to visualize the beautiful colors and shapes of algae that will grace our future cities, parks, farms, gardens and tables.





# Imagine Our Algae Future

How will growing algae change the world and improve our lives?

Robert Henrikson



*Algae Competition is a prism for visioning the future of algae*

Imagine our future living in cities where buildings are covered with photosynthetic membranes and vertical gardens, collecting the sun's energy and producing food and bioproducts for urban citizens. Imagine greening desert coastlines and producing food for millions of people. Imagine algae systems that recover and recycle polluting wastes into high value animal food, fuel and biofertilizers.

Our future with algae offers rich and diverse opportunities that will impact every aspect of our lives. As a participatory design game, Algae Competition invited global citizens to design their own future with the foods they eat, systems that grow algae, and landscapes and cityscapes they dream of living in. This book showcases some of these amazing visions of our future.

Algae were the first photosynthetic life form on this blue green planet, beginning 3.6 billion years ago, creating an oxygen-rich atmosphere so higher life could evolve. Our vast oceans and forests are the lungs of our planet, breathing in carbon, breathing out oxygen and regulating global climate.

Because algae are over 20 times more productive than conventional plants, awareness has grown that growing algae can create future abundance.

For thousands of years in our history, humans have harvested algae like seaweed along the coastlines. Near lakes and rivers across the world, people harvested freshwater microscopic algae for food and biofertilizers. Just in the past 30 years, with the commercialization of microalgae beginning in the 1970s, thousands of new algae-based products have emerged.

## *An algae rainforest under Arctic ice*

Algae contribute to the health of our planet in ways we are just discovering. Recently a NASA-sponsored expedition in the Arctic Ocean discovered algae-rich water flourishing beneath three feet of ice. According to scientists, this area of water is richer in marine plants than any other ocean region. This startling discovery was like finding a rainforest in the desert. Thinning ice has enabled the sun to reach the water beneath it, leading to massive plant growth which may help to offset effects of global warming.



In the past five years, more than a billion dollars has flowed into algae biofuel development. Even though commercial biofuel from algae may be years away, this investment is creating innovations, making algae production more affordable, stimulating interest in growing algae for many products. Big investments in algae production will grow our future food and its own packaging.

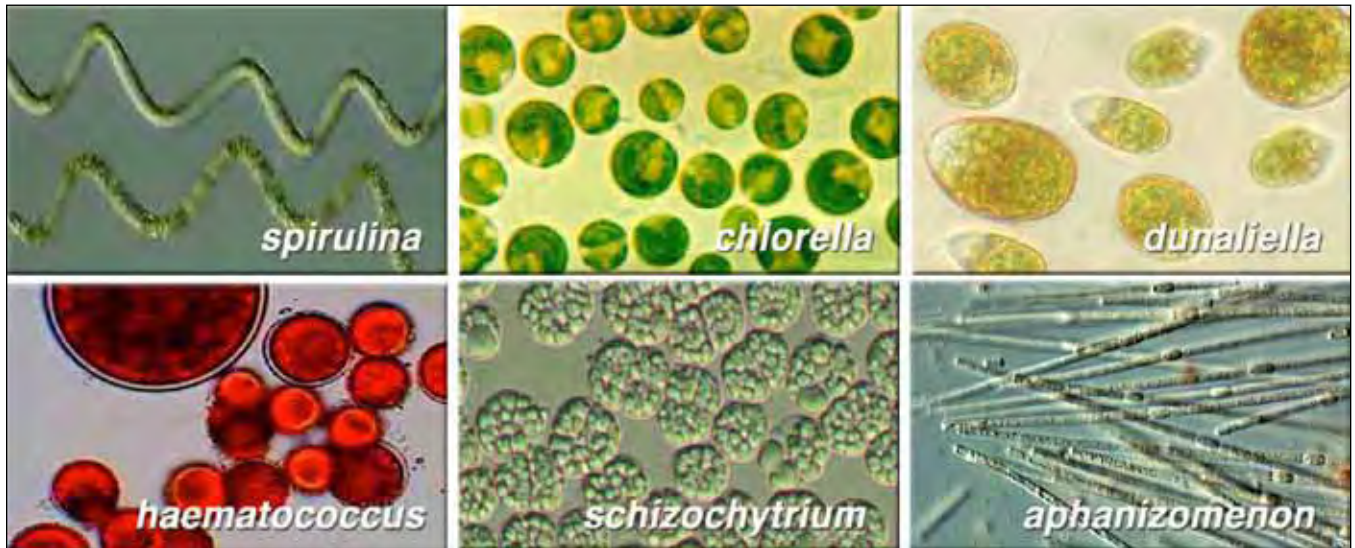


Each gram of algae we consume as food, fuel or packaging replaces material that may use 20 times more resources. We are unsustainably consuming resources, facing global instability from climate change, scarcity and conflict. Growing algae offers a future beyond scarcity toward sustainability and abundance. Here's a peek into this future.



## Algae Are Everywhere

Thousands of algae species cover the earth



There may be more than 300,000 species of algae, living everywhere. They range in size from a single cell to giant kelp over 150 feet long. Most algae live off sunlight through photosynthesis, but some live off organic matter like bacteria.

Larger algae, like seaweed, are macroalgae. They already play an important economic role. About 70 species are used for food, food additives, animal feed, fertilizers and biochemicals.

Microalgae can only be seen under a microscope. Some serve a vital role for breaking down sewage, improving soil structure and fertility and generating methane and fuels for energy. Others are grown for animal and aquaculture feeds, human foods, biochemicals and pharmaceuticals.

Ocean microalgae, known as phytoplankton, are the base of the food chain supporting all life. The rich upwelling of nutrients caused by major currents meeting the continental shelf and nutrients from river basins sustain phytoplankton growth.

Microalgae are everywhere - in water, soils, on rocks and plants. Blue-green algae are the most primitive and contain no nucleus or chloroplast. Their cell walls are composed of soft mucopolysaccharides. Blue-green algae do not sexually reproduce; they simply divide.

Microalgae for food and feed products are *spirulina* (blue-green), *chlorella* (green), *dunaliella* (red), *haematococcus* (green), *schizochytrium* (marine) and *aphanizomenon flos-aquae* (blue-green).

*Spirulina* has been the most widely cultivated algae since the 1970s. Thousands of tons have been sold each year for the past 40 years as a food and feed supplement. There are large commercial farms in the USA, China, India, Mexico, Myanmar and other countries, and many smaller village scale and micro farms in Europe, Africa and Asia.

*Chlorella* was the first microalgae to be commercially cultivated beginning in the 1970s and sold as a food supplement. Commercial farms in Taiwan, Southern Japan and Indonesia produce much of the world supply.

*Dunaliella* thrives in water even saltier than the ocean. Too salty to be eaten as a whole food, its beta carotene is extracted as an oil or powder and sold as a natural food supplement and antioxidant and a color for aquaculture feeds.

*Haematococcus* is grown in both outdoor ponds and closed systems for astaxanthin, a carotenoid pigment, extracted as a fish feed supplement to color salmon flesh and as a human anti-oxidant food supplement.

*Schizochytrium* is a marine microalgae grown in vats by fermentation, developed as a source of docosahexaenoic acid (DHA), used as a supplement in a wide variety of infant formulas, food and beverages and animal feed products.

*Aphanizomenon flos-aquae* is a nitrogen-fixing blue-green algae. Harvested from Klamath Lake in Oregon, it is sold a food supplement.



## Algae Food Products

Thousands widely available today. More are coming.



Popular food supplements and nutraceuticals from haematococcus, dunaliella, spirulina, chlorella.

*Many people have no idea how many everyday products already contain algae*

Microalgae like *spirulina*, *chlorella*, *aphanizomenon flos-aqua* and extracts of *dunaliella* and *haematococcus* are already marketed as dried powder, flakes, capsules and tablets and as ingredients in many other products in health and natural food stores, online and through direct marketing.

Many kinds of macroalgae like *nori*, *wakame*, *dulse*, *hijiki*, *kombu*, *ulva*, *chondrus*, *kelp* and other edible seaweed are served fresh in Asian and vegetarian restaurants, sold in dried sheets and flakes in stores, and widely used in many conventional products as functional ingredients such as thickeners.

*The future of algae foods may include its own algae bio-packaging*

Today algae are being called the *biofuel of the future*. Over 30 years ago, *spirulina* was called the *food of the future*. Growing algae currently costs several times more than traditional foods. Annual world microalgae output may have reached 10,000 tons of *spirulina*, *chlorella*, *dunaliella* and *haematococcus*. Even big commercial algae farms are relatively small- less than 100 hectares in size.

High value food and specialty products from algae have flourished. Today, algae compounds are ingredients in thousands of products for food, feed, colors, nutraceuticals, medicinals, cosmetics and personal care, biofertilizers and fine chemicals.



Algae as a food ingredient, source of natural pigments and colors, and DHA Oil from schizochytrium in infant formulas, prenatal supplements, food and beverage products.



Algae as a superfood ingredient in protein powders, super green drink mixes, energy bars and drinks.

# Algae's Substantial Promise

Mark Edwards

## *Algae offer substantial solutions for the betterment of human societies*

Algae are the most plentiful plant on earth and produce roughly 40% of the total biomass daily. Most of the algae biomass is eaten because 100 times more organisms consume algae than any other food source. Algae also produce about 70% of the world's oxygen daily, substantially more than all the forests and fields combined.

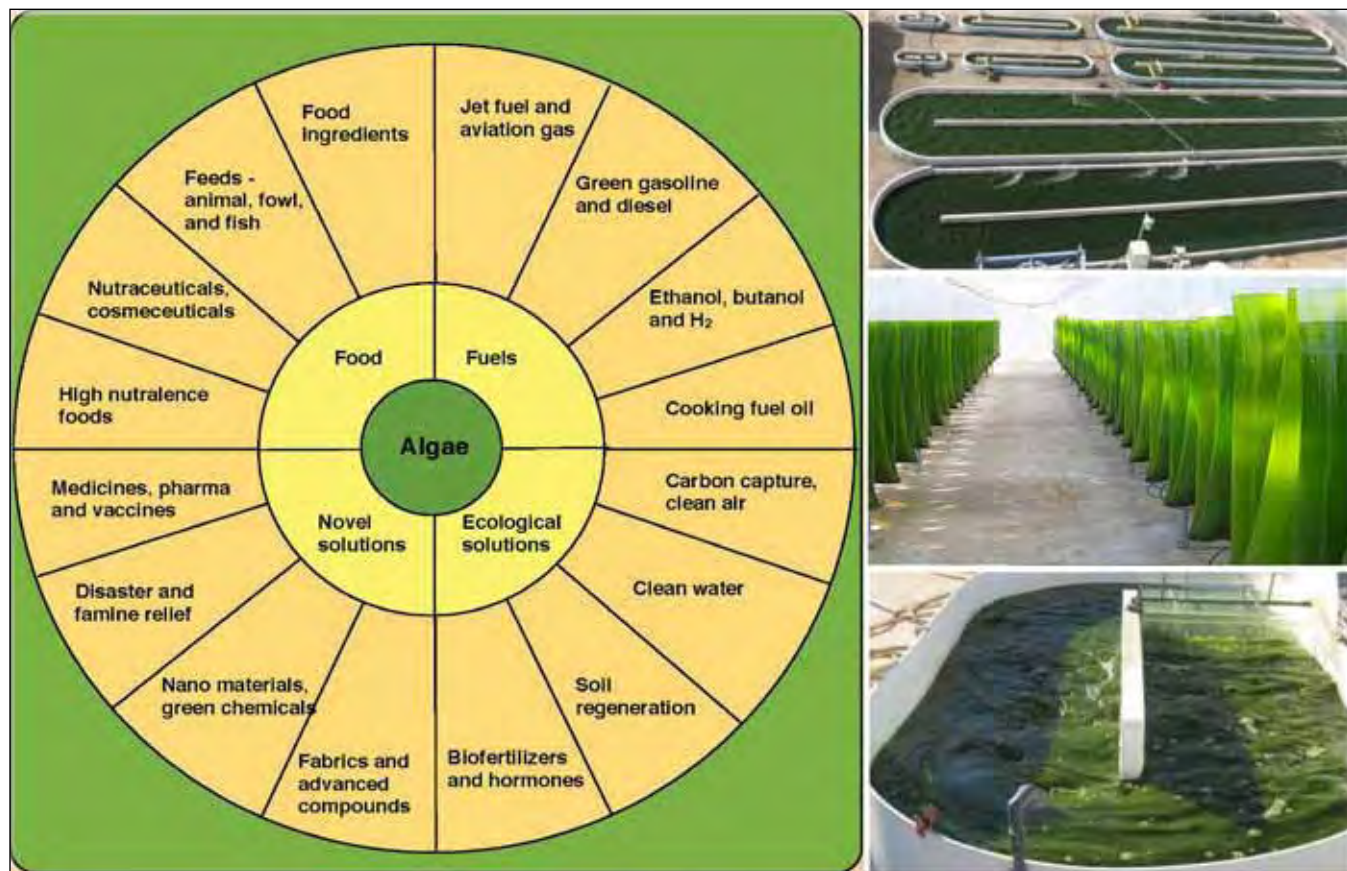
Algae grow abundantly all over the earth. Forests of kelp grow underneath the North Pole. Microalgae grow under the ice at both poles, in and under high mountain glaciers, as well as the hottest deserts. Algae grow a crust matrix on desert soil that holds the soil and resists wind and water erosion.

Our earliest ancestors ate algae for the protein, omega-3 oils, micronutrients and vitamins that were locally available year-round. Access to macroalgae, often called sea vegetables, enabled human migration out of East Africa.

Certain varieties of algae were reserved for the Emperor of China in the 1100s. A few centuries later, another specie was reserved for the samurai, the fiercest Japanese warriors. Today, Olympic athletes from China and other countries commonly take algae supplements because they provide superior stamina and speed recovery from injury.

Algae are the great enablers and will allow growers to create foods, feeds, fibers, fuels, fertilizers, nutraceuticals, cosmeceuticals, pharmaceuticals, vaccines, and advanced medicines. Algae growers can produce rich biomass while cleaning air, water and soils.

Distributed scalable algae production systems will assist people who suffer from natural disasters to begin producing clean food and medicines quickly. Similar algae growing systems provided through foreign aid will enable impoverished people to grow their own food, cooking oil, animal feeds and medicines.





## Algae Foods

Today, most foods are produced using industrial agriculture that consumes massive amounts of natural resources and severely pollutes the environment. Algae food growers can use minimal fossil resources including fertile soil, fresh water, fuel, inorganic fertilizers, without using any pesticides, herbicides, fungicides or agricultural poisons. Abundance growing methods leave the store of natural resources for our children and provide clean environments for future generations.

Algae biofertilizers can enhance nutrient density, known as *nutralence*, of field crops by 300%. Field crops such as tomatoes lack taste, color and texture because they suffer from 'hidden hunger' - the lack of micronutrients. Algae biofertilizers can remediate hidden hunger, resulting in tastier produce. In a melon taste test at Arizona State University, algae fertilized melons were preferred 17:1 to controls.

Since land plants evolved from algae 500 million years ago, all the colors, tastes and compounds found in land plants can be produced from algae. In most cases, algae will have significantly more digestible protein and nutrients than land plants. For example, some algae species offer three times the protein per pound compared with corn. Some algae have twice the protein of meat, with a healthier nutrient profile and minimal fat or cholesterol.

Algae foods can end nutrient dilution, which causes empty calories and the current epidemic of obesity and diabetes. Algae eaten directly or added to foods can enhance *nutralence* by 300 to 500%.

Algae-based food and feed additives, such as omega-3 fatty acids and a wide spectrum of valuable micronutrients, will create new classes of functional foods to improve human and animal health and vitality. Algae will enable health food supplements to become integrated with food processing. Nutrients delivered by algae offer superior absorption to enhance health.

Today, about 33% of the algae grown globally goes to aquaculture. Recent studies show fish grow faster, healthier, and more stress tolerant with algae than food grain diets. This makes sense since algae are the natural diet for fish in nature. Taste tests show algae feeds improve color, taste and sensory appeal of seafood.

## Algae biofuel

Any fuels made from fossil fuels can be made from algae because crude oil, coal and shale are simply

Algae Map for Food, Biofuels and Novel Solutions		
Food	Biofuels	Novel Solutions
<b>Primary</b> <ul style="list-style-type: none"> <li>Protein</li> <li>Lipids – oils</li> <li>Carbohydrates</li> <li>Nucleic acids</li> </ul>	<b>Primary</b> <ul style="list-style-type: none"> <li>Gasoline</li> <li>Clean diesel</li> <li>Methanol/ethanol</li> <li>JP-8 jet fuel</li> </ul>	<b>Air</b> <ul style="list-style-type: none"> <li>Carbon sequestration</li> <li>Carbon capture/recycle</li> <li>Capture sulfur</li> <li>Capture heavy metals</li> </ul>
<b>Secondary</b> <ul style="list-style-type: none"> <li>Flour</li> <li>Meat enhancer</li> <li>Ice cream</li> <li>Milk substitute</li> <li>Sugar substitute</li> <li>Sea vegetables</li> <li>Food ingredients</li> <li>Emulsifiers and thickeners</li> <li>Novel flavors and textures</li> <li>Pigments</li> <li>Health foods</li> <li>Nutraceuticals</li> <li>Omega 3s</li> </ul>	<b>Secondary</b> <ul style="list-style-type: none"> <li>Aviation gasoline</li> <li>Alcohols</li> <li>Hydrogen</li> <li>Asphalt</li> <li>Plastics, biodegradable</li> <li>Rubber substitute</li> </ul> <b>Biofertilizers</b> <ul style="list-style-type: none"> <li>Organic N-P-K</li> <li>Bioavailable target nutrients</li> <li>Micronutrients</li> <li>Plant hormones</li> <li>Soil organics</li> <li>Build soil structure</li> <li>Improve porosity</li> <li>Plant growth regulators</li> <li>Natural pesticides</li> <li>Natural herbicides</li> </ul>	<b>Water – clean</b> <ul style="list-style-type: none"> <li>Waste streams – municipal, industrial, farm, brine and ocean</li> <li>Recover heavy metals</li> </ul> <b>Cosmetics</b> <ul style="list-style-type: none"> <li>Moisturizers</li> <li>Skin care</li> </ul>
<b>Feed and fodder</b> <ul style="list-style-type: none"> <li>Pets, fish, fowl</li> <li>Meat animals</li> <li>Micronutrients</li> <li>Medicines and vaccines</li> </ul>		<b>Local algae production</b> <ul style="list-style-type: none"> <li>Foreign aid</li> <li>Disaster relief</li> <li>Hunger and poverty</li> </ul> <b>Medicines</b> <ul style="list-style-type: none"> <li>HIV / AIDS and SARS</li> <li>Vaccines</li> <li>Antibiotics /antiviral</li> <li>Burns and bruises</li> <li>Stomach remedies</li> <li>Anti-cancer toxins</li> <li>Pharmaceuticals</li> <li>Advanced compounds</li> </ul>

fossilized algae. Algae biofuel growers are attempting to produce gasoline, ethanol, green diesel and jet fuel in a matter of weeks rather than the 400 million years required by nature. Algae-based fuels will help countries reduce imported oil.

Algae biofuels are particularly useful as liquid transportation fuels. Algae will supplement and replace fuel oils, lubricants, surfactants, adhesives, asphalt, and other products currently made from fossil fuels. Algae components will serve manufacturers of bioplastics that are cheaper, stronger, and more flexible than industrial plastics, yet are biodegradable.

## Pollution Solutions

The oldest algae application in North America is wastewater remediation. Algae cultivated in wastewater absorbs organic wastes and nutrients, producing clean water after the algae is removed.

## Imagine Our Algae Future

A current application for algae technologies focuses on carbon capture. Each ton of algae consumes two tons of CO<sub>2</sub>. Algae companies are eager to site production units near CO<sub>2</sub> emitters such as power plants, cement and manufacturing plants, ethanol refineries and breweries.

Over the past 40 years, industrial agriculture has degraded soil fertility, and the Earth has lost over 30% of its fertile soils. But algae used as a biofertilizer can help farmers restore croplands. Farmers cultivate algae indigenous to their fields, concentrate the culture and flow the nutrient rich biomass directly to the field by irrigation or sprayer. Algae biofertilizer is immediately available. Farmers can produce higher quality crops and leave the land in better condition than they found it.

### Novel Solutions

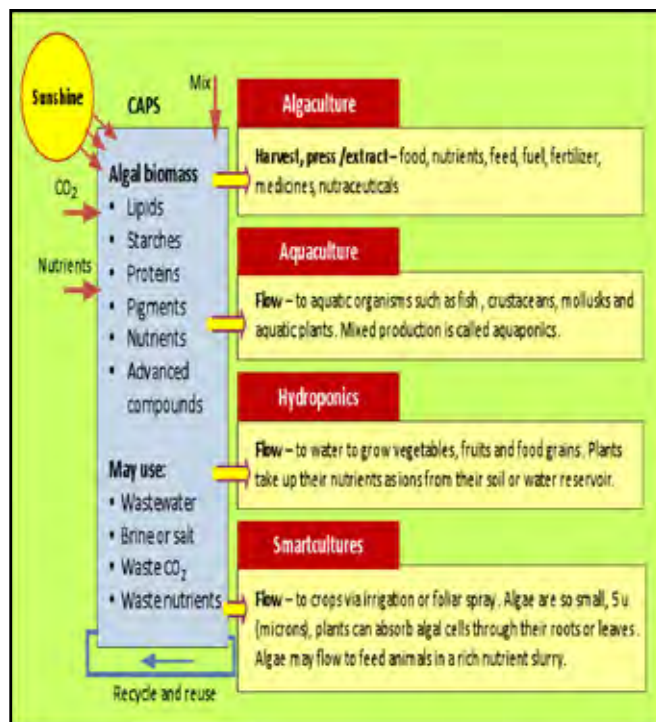
Manufacturers will use algae fibers to make fabrics for clothes, coverings, and carpets. Algae components will be manufactured into advanced materials such as composites to be fabricated into packaging, building materials and biodegradable products such as emollients and moisturizers.

New algae-based compounds will begin to dominate cosmeceuticals with enhanced characteristics for anti-wrinkling, anti-aging, sun protection, skin health, moisturizers and scalp enhancers.

The model for foreign aid and disaster relief will change from dependence to enablement. Current aid programs typically grow food in a food-rich country and use that country's transportation to transfer food to the country of need, reinforcing dependency and unsustainability. Field studies show this model costs 500% more than growing the food in the country in need.

The new aid model transfers technology to grow algae in scalable microfarms locally. Growers site their microfarm near waste streams and recover and repurpose nutrients in a rich algae biomass. Growers will be aided by an expert system that monitors their culture and provides suggestions for optimizing productivity. Growers gain independence as they provide food, feeds, fertilizers, and medicines for their families and communities.

The highest value for algae lies in medicine. Most current medicines are manufactured from plants or animals and are expensive and time-consuming to produce. Scientists are searching for algae equivalent compounds for pharmaceuticals, medicines and vaccines that can be grown in a matter of weeks at lower cost than traditional medicines.



Algae compounds are being tested therapeutically on nearly every body organ, with positive results.

In many cases, packaging, storage and transportation add 50% or more to the cost of medicines. In the future, distributed microfarms will enable growers to cultivate algae with embedded medicines and vaccines. This distributed model avoids costs associated with packaging and transportation.

### Path forward

Algae will transform human societies with abundant production to create food and other forms of energy with minimal use of fossil resources. Consumers will have choices for tastier foods that are two or three times higher in nutraceuticals and 50% lower in fat than conventional foods.

Algae will provide affordable and sustainable cooking and heating oils. Algae-based oils burn with no black soot that could save several million lives a year. Large algae producers will grow sustainable biofuels for liquid transportation fuels.

Algae will transform our environments. Algae-based technologies will clean our water, air, and regenerate degraded soils. The green chemistry industry will adopt algae products to migrate to sustainable, ecological-friendly products. Algae offer a healthier future for people, producers, and our planet. Our nontrivial social challenge focuses on unlocking algae's magnificent promises and making them our reality today.



# Why Imagine Our Algae Future?

Mark Edwards

Algae are marvelous living organisms that can endow human societies with a broad spectrum of valuable solutions. Algae are overlooked because the cell size is tiny, typically only about five microns. What people cannot see, they tend to ignore. People often do not know what they want until they can see it. Imagining our algae future makes algae's contribution tangible.

## Algae Innovations

Algae farming will be ubiquitous by 2025 because algae can recover and repurpose farm or garden waste streams and make conventional agriculture more effective. As growers use abundant inputs that will not run out, this will lower costs and significantly diminish waste and pollution.

Algae will be used for food, feed, fertilizer, nutraceuticals, cosmeceuticals, pharmaceuticals, vaccines and fine medicines. Algae will also provide several new industries with green chemicals and nano materials. Algae fuels will also play a role in our global energy mix.

We believe algae microfarms will revolutionize human societies and transform health, hunger, malnutrition and poverty while regenerating polluted ecosystems. Globally distributed microfarms will motivate people to innovate and solve the technology barriers.



We created Tiny Mighty AI to convey algae's value proposition to our next generation. *The Tiny Plant the Saved our Planet* is the incredible true story of Tiny Mighty AI and shares how AI converted our CO<sub>2</sub>-rich atmosphere into sufficient oxygen to support life. AI saves our planet again by becoming the first food and feeding other creatures to grow and develop. Can AI save us again by sequestering CO<sub>2</sub> and providing food, feed, fuel and medicine solutions? *You bet AI can!*

## Imagine what one tablespoon of algae can do

If every child could get one spoonful of algae each day, we could reduce malnutrition by 50%. Algae can remediate the principal nutrient deficiencies.



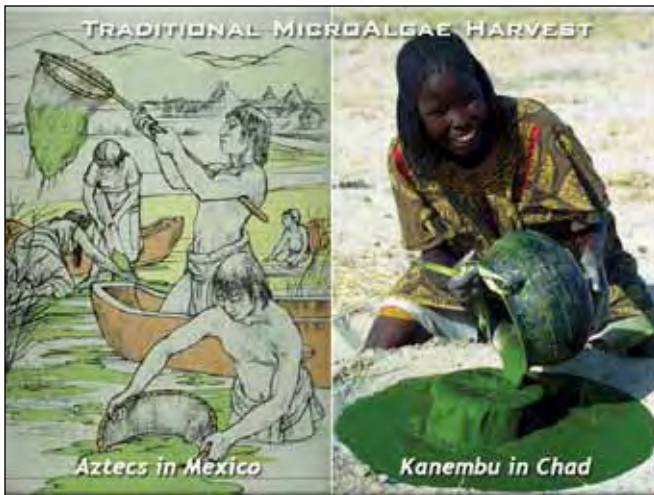
Hidden hunger from nutrient deficiencies imposes a huge toll on society, according to the UN World Health Organization (WHO):

- Vitamin and mineral deficiencies account for 10% of the global health burden - second to clean water.
- Children with micronutrient deficiencies suffer impaired development, disease and premature death.
- Over 2 million children die unnecessarily each year because they lack vitamin A, zinc or other nutrients.
- Over 18 million babies are born mentally impaired due to iodine deficiency each year.
- Iron deficiency undermines the health and energy of 40% of women in the developing world. Severe anemia kills more than 50,000 women a year during childbirth.

Algae provide a low fat, low calorie, nearly cholesterol-free source of protein. Some algae, such as spirulina, contain up to 70% protein by dry weight - twice the protein of meat. Unlike meat, most algae varieties provide the full complement of nine essential amino acids. The low fat content, only 5-10%, is a fraction of other protein sources. Algae are an excellent plant source of glutamic acid, an amino acid that promotes intestinal health and immune function.

Each tablespoon of algae has roughly double the protein of a tablespoon of a food grain. Algae concentrate many other nutrients beyond the nutrients found in grains. Algae absorb a wealth of minerals. These macronutrients include sodium, calcium, magnesium, potassium, chlorine, sulfur and phosphorus while the micronutrients include iodine, iron, zinc, copper, selenium, molybdenum, fluoride, manganese, boron, nickel and cobalt.

Algae demonstrate nutrallence, as the biomass concentrates nutrients at substantially higher levels than land plants.



### ***Algae in human food history***

Algae played pivotal roles in human evolution and survival. Early human societies evolved along coastlines, rivers and lakes and depended on algae for food and medicines. The nutrient-rich biomass was plentiful year-round and easy to harvest. Many groups ate algae directly and probably ingested algae in their drinking water. Algae give water a sweet taste that would have been very attractive when the early human diet contained predominately dry, hard, bitter and sour tastes.

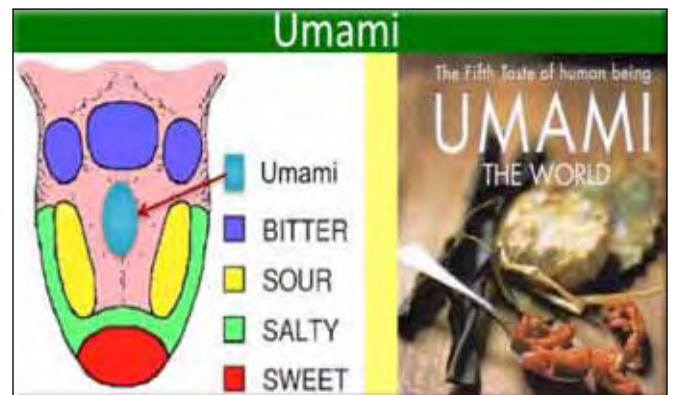
Algae provided a rich and nearly complete source of nutrition - a complex blend of nutrients that no other food source, plant or animal, could offer. Analogous to modern-day vitamin supplements, actually algae are a more robust, natural, and inclusive blend of healthful nutrition. Algae are a superior protein source, particularly the red, green and blue-green algae, up to 70% protein (dry weight), higher than soybean (36%) and corn (23%). Algae nutrallence benefited our ancestors year round.

### ***Algae's rich savory taste***

Sweetness dominates the human palate today, as illustrated by modern convenience foods. The human tongue has a fifth taste receptor, umami (savory or hearty), which would have been available primarily from algae in early hominid diets. The unique taste comes from three proteinogenic amino acids: glutamic, inosinic and guanylic. Algae synthesize the hearty umami taste. Algae feeders such as fin and shellfish concentrate the savory taste that would have made these foods favored by early hominids. Today, milk, aged cheese, and some meat products offer the umami taste.

The attractive savory taste of algae may have sparked brain enlargement in early humans because algae provide the critical long-chained fatty acids needed for brain development. Larger brains differentiated our ancestors from their cousins and enabled higher cognitive skills that aided survival.

Algae produce the rich umami taste with glutamate, which plays a key role in human cellular metabolism and digestion. Digestion breaks down proteins into amino acids which serve as metabolic fuel for other functional roles in the body. Glutamate is the most abundant excitatory neurotransmitter in the vertebrate nervous system and regulates several brain functions. Glutamate's role in body and brain functions is so critical that the logical explanation for the umami taste bud, called the mGluR4 receptor, was to attract our ancestors to glutamate. Algae are an excellent plant source of glutamic acid, an amino acid that promotes intestinal health and immune function.



Algae's attractive taste may have helped us become human by attracting our ancestors to algae and the Omega-3s that sparked brain enlargement.

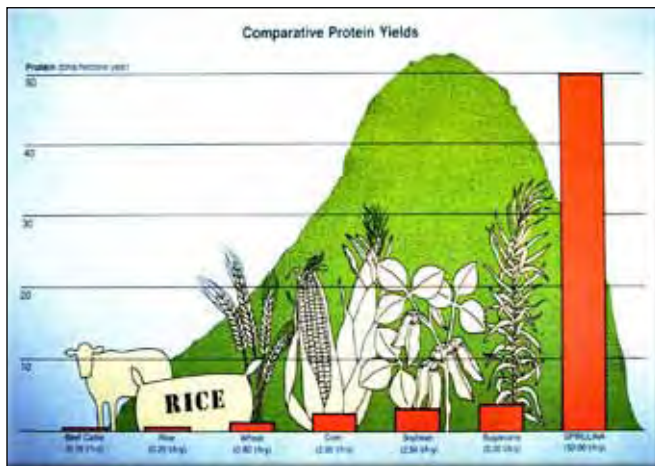


# Algae Production, Products & Potential

## Resource advantages in land, water and energy

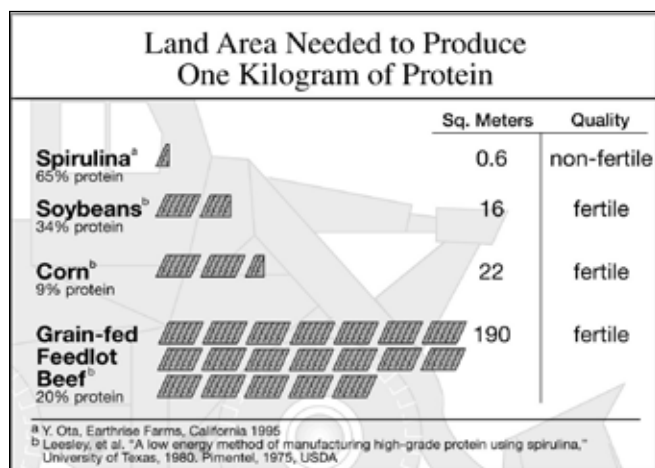
### Environmentally sound algae cultivation

Understanding the role of microscopic algae, the foundation of life, can help us develop restorative models of personal and planetary health. Algae are an essential part of Earth's self-regulating life support system. Innovative schemes and dreams using algae promise to help regreen the desert, refertilize depleted soils, farm the oceans and encourage biodiversity.



Algae cultivation does not cause pollution, soil erosion, water contamination or forest destruction. Algae can be grown without toxic pesticides and herbicides.

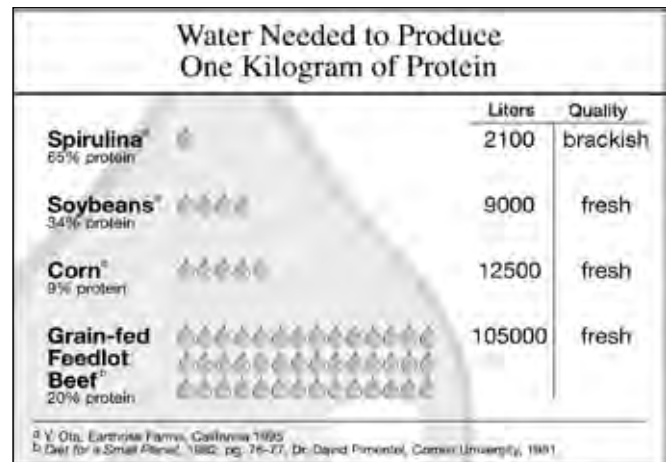
It has been recognized for 40 years that algae productivity can be 20 times more productive than conventional crops. The following charts show a comparison of the land, water and energy needed to grow a kilo of protein from spirulina algae and conventional crops such as soybeans, corn and beef.



### Land and soil are conserved

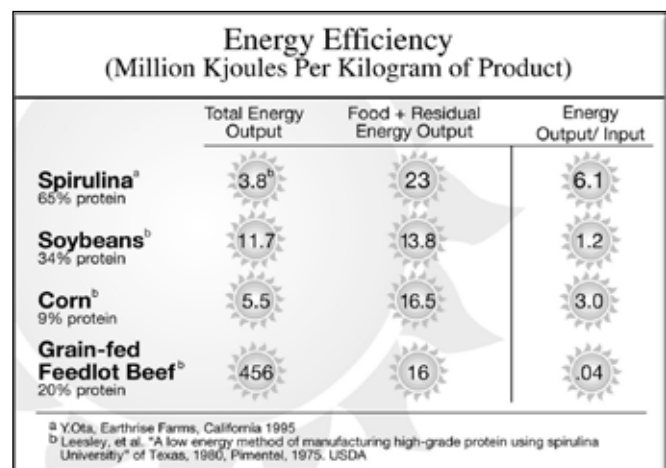
Spirulina is 60% protein and can be cultivated on marginal, unusable and non-fertile land. Its rapid growth means spirulina protein needs 20 times less land than soybeans, 40 times less than corn, and 200 times less than beef cattle.

Spirulina offers more nutrition per acre than any other food, but does not require fertile soil.



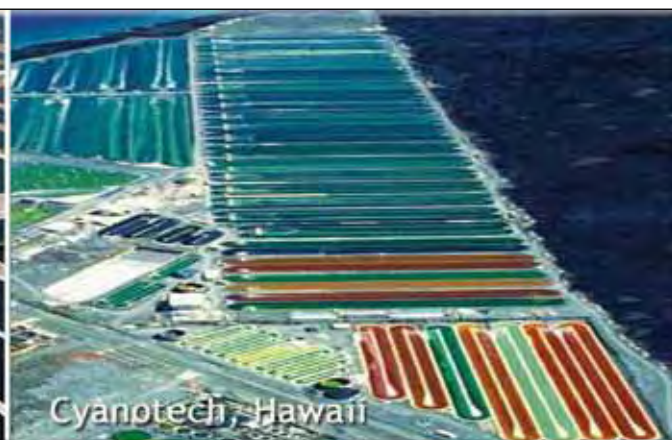
### More efficient water use

Fresh water is one of the world's most critical resources. Growing algae for food will become more attractive since it does not require fresh water. Spirulina can use brackish or alkaline water, unsuitable for agriculture. Even though algae grows in water, it uses far less water per kilo of protein than other common foods. Spirulina protein uses 1/3 the water as soy, 1/5 as corn, and only 1/50 the water needed for beef protein.



## Algae Production Systems Today

### Outdoor pond production for nutraceuticals, food, feed and fuel



Commercial algae production may be 10,000 tons or more per year and 98% is grown in open ponds, mainly using raceways with paddlewheels. The primary commercial algae are *spirulina*, *chlorella*, *dunaliella* and *haematococcus*, and most is grown for high value food supplements.

#### *Spirulina (arthrospira) production*

Most commercial farms growing *spirulina* over the past 30 years use shallow raceway ponds circulated by paddlewheels. Ponds vary in size up to 5000 square meters (about 1.25 acres) or larger, and water depth is typically 15 to 25 centimeters.

Earthrise Nutritionals in California, USA was established in 1981 and expanded to cover 108 acres. Owned by Dainippon Ink & Chemicals of Japan, by the mid 1990's Earthrise had the world's largest production capacity of 500 tons per year.

Cyanotech in Hawaii, USA opened in 1985 on the Big Island with a capacity of 400 tons of *spirulina* per year as well as growing *haematococcus* for astaxanthin for human and animal food.

Parry Nutraceuticals in India began *spirulina* production in Tamilnadu in 1996 and expanded into astaxanthin from *haematococcus* in 2003.

Boonsom Farm in Thailand near Chiang Mai has produced *spirulina* finished products for the regional market in Thailand and Asian countries for the past 20 years.

Harvest from natural lakes has been underway in Myanmar for over 20 years. Capacity is 200 tons per year, producing one million bottles of nutritional supplements, crackers, cosmetics and beer.

Today China produces an estimated 50% of the world's output for the domestic and export markets. There are numerous growers across Southern China and Hainan Island. China is the world's largest *spirulina* producer.

There is commercial production in outdoor ponds in many other countries today including Taiwan, Australia, Vietnam, Israel, Bangladesh, Philippines, Cuba, Chile, Martinique, Peru, Ecuador, Brazil, Spain, Portugal and France.





## Outdoor Pond Production Systems

### The big 4: spirulina, chlorella, dunaliella and haematococcus



Hainan, China



Yaeyama, Japan

#### *Chlorella vulgaris* for food supplements

Early research in the 1960s focused on *chlorella*. This green microalgae evolved a billion years after blue-green algae like *spirulina* and is a small spherical cell with a nucleus. The first commercial algae production was *chlorella* beginning in Japan in the 1970s.

Many farms developed circular ponds rather than raceway ponds. *Chlorella* grows in more normal pH water than *spirulina* and because *chlorella* is more easily contaminated, farmers use a batch growing and harvest system, unlike the continuous growing and harvesting of *spirulina* all season long. Tiny *chlorella* cells are typically harvested by more expensive centrifuges, unlike *spirulina* which is harvested by microscreens. Because of these limitations, *spirulina* has become more widely grown around the world.

Thousands of tons of *chlorella* have been sold each year for the past 30 years, primarily as food supplements. Farms in Taiwan, Southern Japan and Southeast Asia produce almost all the world supply.

#### *Dunaliella salina* for beta-carotene

*Dunaliella* thrives in hot climates and water even saltier than the ocean. *Dunaliella* is grown in vast salt evaporation ponds in Western Australia and in raceway ponds near the Dead Sea in Israel. This microalgae is too salty to be eaten as a whole food, but its beta carotene is extracted as an oil or powder and sold as a food supplement and antioxidant and as a color for aquaculture feeds.

#### *Haematococcus pluvialis* for astaxanthin

*Haematococcus* is grown in both outdoor ponds and closed systems for astaxanthin, a carotenoid pigment, extracted as a fish feed supplement to color salmon flesh. More recently it has become recognized as a popular antioxidant human food supplement. Cyanotech in Hawaii has achieved successful outdoor cultivation in raceway ponds.

#### Other blue-green algae food supplements

*Aphanizomenon flos-aquae* is harvested from Klamath Lake in Oregon USA and *Nostoc* is grown in Asia and South America.



Cognis, Australia



NatureBeta, Israel

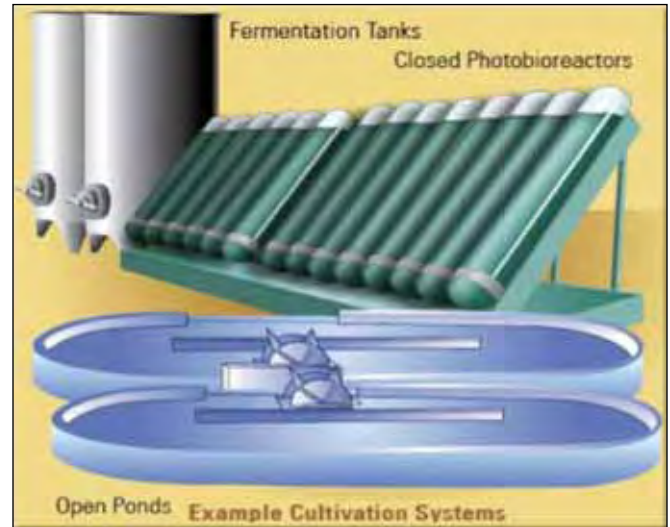
## Photobioreactors and Closed Systems For high value nutraceutical and chemical products

### *Photobioreactor and tube systems*

Many algae are subject to contamination by competing algae and other microorganisms. Maintaining a pure culture outdoors can be challenging.

Photobioreactors, tank, tube, plate and bag systems have been developed to grow algae in closed systems to reduce risk of contamination, to grow higher value algae that require more cultivation control, or to grow in colder climates.

Bioreactors have higher capital costs than outdoor ponds, and companies are using them for higher-value algae products and their extracts such as *chlorella*, *haematococcus*, *nannochloropsis*, and *isochrysis* for pharmaceutical, industrial, cosmetic and aquacultural applications.



In highly populated areas like urban centers where space is limited, and in cooler climates, tubular growing systems allow designers to add artificial light and heat sources for higher productivity. The concept of photobioreactors has stimulated the imagination of engineers, architects and builders to design vertical photobioreactors on the out-

sides and rooftops of buildings, integrating algae systems with building architecture. Many designs submitted to the International Algae Competition included vertical algae farms on buildings with photosynthetic membranes growing algae for food and energy. Others designed photobioreactors into eco-communities and educational centers.





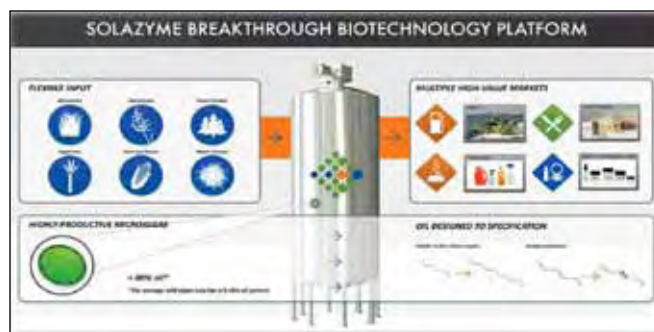
# Industrial Fermentation Systems

## Producing algae oils for food, feed and fuel

### Fermentation systems

Fermentation is used for bacteria like yeast. Rather than growing using photosynthesis through sunlight or artificial light, an autotrophic process, fermentation is a heterotrophic process, growing by obtaining carbon through organic compounds.

Companies like DSM Martek and Solazyme grow algae using fermentation. The feedstocks include sugar and cellulose. Industrial fermentation is decades old established technology, and this has allowed algae fermentation companies rapid commercialization without the risks of outdoor cultivation or novel photobioreactor technology.



Solazyme has developed an industrial biotechnology platform that harnesses the prolific oil-producing ability of microalgae, using industrial fermentation equipment to efficiently scale and accelerate microalgae's natural oil production time to just a few days.

This platform is feedstock flexible and can utilize a variety of plant-based sugars, such as sugarcane-based sucrose, corn-based dextrose, and sugar from other biomass sources including cellulose. Oils can be tailored to address key performance properties of petroleum and other natural oils. Target markets are alternative fuels, chemicals, nutritionals and personal care products.



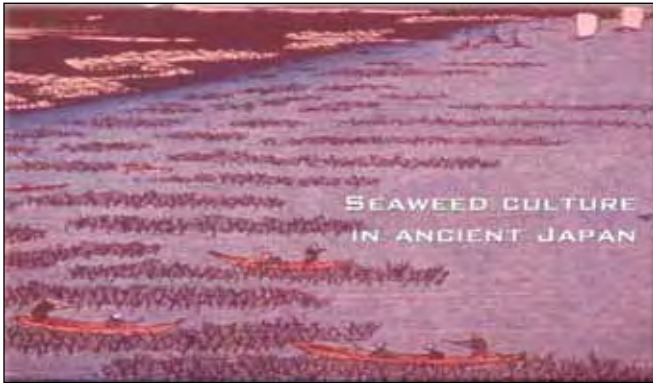
Martek Biosciences was a pioneer using fermentation technology to grow algae and is an innovator in the research and development of products derived from microalgae.

Martek, now part of DSM, developed and patented two fermentable strains of marine microalgae, *schizochytrium* and *cryptocodinium*, which produce oils rich in docosahexaenoic acid, DHA, an omega-3 that supports brain, eye and heart health throughout all stages of life. DHA is an important nutrient for optimal infant development and is used in 99% of U.S. infant formulas and a range of human and animal food products.

## Seaweed and Marine Algae Industry

### Harvesting and processing macroalgae

Seaweeds are the world's largest mariculture crop. They are primary producers and key links in the food webs of coastal and estuarine ecosystems, and are used in many applications that affect our daily lives. About 220 species of seaweeds are cultivated worldwide, primarily in Asia. It has been estimated that the productivity of seaweed communities is equal to or greater than the most productive terrestrial plant communities.



Seaweeds are part of a broad group of algae that share a few characteristics. They photosynthesize and provide oxygen. They do not make flowers, and their anatomy is relatively simple, with no roots, stems, leaves or vascular tissues, and simple reproductive structures. Marine algae include microscopic algae from unicellular phytoplankton to macroalgae like giant kelp, *Macrocystis pyrifera*, largest of all algae, growing up to 50 meters long.



Seaweeds are used in many ways, making them part of our everyday lives. In orange juice, a microscopic mesh of carrageenans extracted from red seaweeds keeps the pulp in suspension. Toothpaste would be a liquid without alginates extracted from brown seaweeds.

#### Seaweed Mariculture

There are approximately 10,500 known species of seaweeds. Around 500 have been used for centuries for human food and medicine, directly or indirectly as extracted phycocolloids.



The largest group of organisms cultured at sea is seaweeds, representing 46% of total world mariculture, while fish aquaculture represents only 9%. Almost all cultivated seaweeds come from China, Indonesia, Philippines, Korea and Japan. Today 94% of the world's seaweed supply comes from cultivation. The seaweed industry is best known for phycocolloids - the gelling, thickening, emulsifying, binding and stabilizing agents known as carrageenans, agars and alginates.



Use as a sea vegetable for human consumption is growing. Already well known as nori wrapping for sushi and floating pieces in soups, seaweeds are becoming popular in salads and garnishes. Extracts are widely used in cosmetics and skin care creams because they help soft and healthy skin. Seaweeds are used as ingredients in aquaculture and animal feed to replace fish meal and oil.

Courtesy of Dr. Thierry Chopin, University of New Brunswick, Canadian Integrated Multi-Trophic Aquaculture Network.

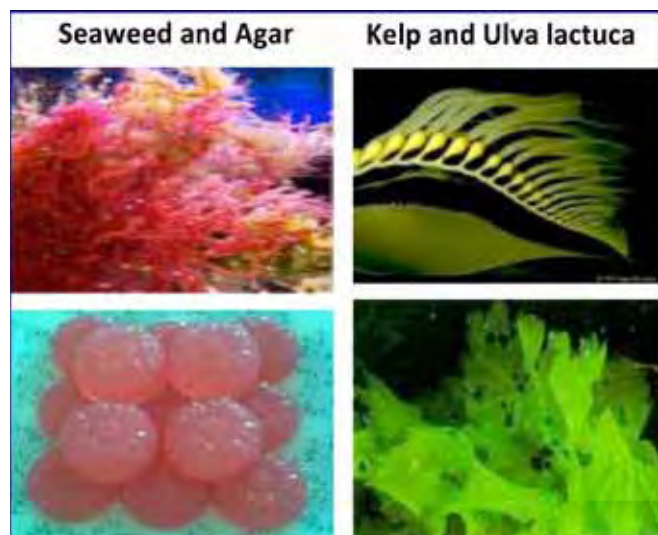


## Algae Extracts for Cosmeceuticals

### Skin creams, shampoos, cleansers and personal care products

Cosmeceuticals refer to the combination of cosmetics and pharmaceuticals. Cosmeceuticals are cosmetic products with biologically active ingredients purporting to have medical or drug-like benefits and are applied topically, such as creams, lotions and ointments. Many contain extracts from marine algae and microalgae like *spirulina* and *chlorella*.

Indigenous people used algae as we do today for natural treatment of skin moisture, bruises, burns, bites, stings, cuts, wounds, joint pain, headaches and indigestion. The use of algae in lichens for pigments and dyes pre-dates Julius Caesar. The classic red color of Roman tunics came from pigments extracted from the lichen *urchilles*. Roman women valued the plant and used it as rouge to give their faces a sensual color. Algal oils and pigments are used today as cosmetics and skin moisturizers, similar to the use of aloe and jojoba oil.



About 90% of modern cosmetics contain algal extracts including agar, carrageenans and alginates. Agar is mainly used as a preservative for meat and fish and as a gelling agent in food. Carrageenans are used in colorings, cosmetics, toothpastes, ice cream, pet foods, lotions, and as stabilizing agents in dairy products. Brown algae (kelp) is a source of alginic acid, used as a thickening, stabilizing and emulsifying agent in lotions, skin creams, ice creams, dairy products, rubber, paint, shaving creams, adhesives, and other products in the textile industry.

Algae commonly found in cosmetics include *kelp*, *ulva lactuca*, *ascophyllum*, *Laminaria longicruris*, *laminaria saccharine*, *laminaria digitata*, *alaria esculenta*, *porphyra*, *chondrus crispus*, and *mastocarpus stellatus*. Currently, many tons of seaweeds are harvested from natural stands to produce cosmetics and other products.

Marine algae cosmeceutical compounds are used as emulsifiers, preservatives, thickeners, fragrances, colors, stabilizers, moisturizers, shampoos, soaps, lipstick and imitation tans.

The use of some microalgae species, especially *spirulina* and *chlorella*, is well established in the skin care market. Their extracts are found in anti-aging creams, refreshing or regenerating care products, in sun protection and hair care products. Some of the properties based on algae extracts include repairing the signs of early skin aging and exerting a skin tightening effect.

Organic algae cosmetics provide advanced compounds that smooth, protect, heal and promote skin regeneration. Algae produce a wide range of valuable antioxidants in a spectrum of anti-aging formulations. As new advanced cosmeceutical compounds are discovered in algae, growers can produce them quickly and economically.

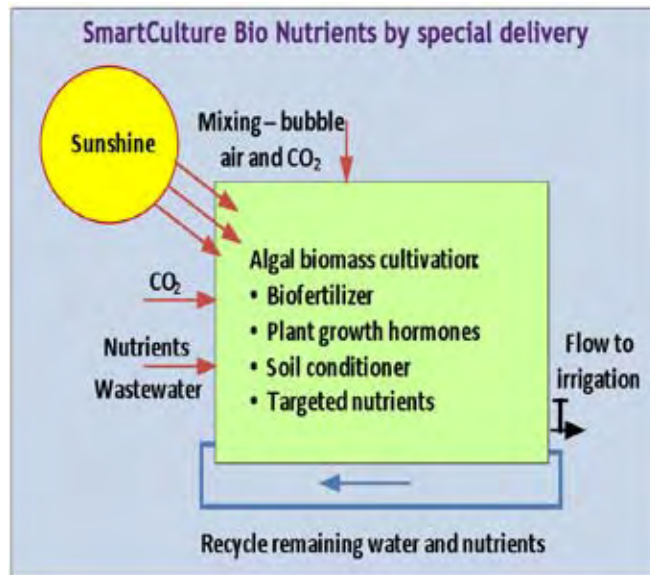
## Algae Natural Biofertilizers

### SmartCultures for crops and for restoring soil fertility

Algal biofertilizers or inoculants are a low cost, effective, environment-friendly and renewable source of plant nutrients that supplement and may even replace chemical fertilizers. Microalgae live in symbiosis with lichens and mosses and make up cryptogamic crusts, which are major sources of biologically fixed nitrogen. Soil crusts act as a protective covering to minimize topsoil erosion from water and wind and provide soil structure necessary for seed germination.

Algae are ubiquitous members of soil microflora and offer numerous advantages as biofertilizers. Algae do not compete with crops or other soil microflora for carbon since algae capture carbon along with nitrogen from the air. Algae do not compete with crops for energy because neither can absorb more than a small fraction of the available sunlight. Fixed nitrogen and other nutrients in algae become bioavailable to crops as a combination of leached nitrogen from living filaments and mineralization of decaying algal biomass.

Algae stimulate production of natural plant growth hormones that accelerate cell division and elongation, producing taller, greener and lusher plants that produce higher yields. Algae stimulate plants to secrete compounds that repress harmful bacteria, fungi and other pests. In some cases, algae operate as a catalyst that helps plants manufacture natural insect repellent on their leaves.



Beneficial microorganisms maintain ecological balance in nature's carbon, nitrogen, sulfur and phosphorus cycles. Soil microorganisms play a pivotal role in building and enriching fertile soils. Algae increase soil porosity by growing polysaccharide sheaths, which makes room for the colonization of soil microbes. Higher porosity enables plants to reach deeper for water and nutrients for healthier crops. In tests with melons, consumers preferred the taste of melons grown with natural algae biofertilizers.

Value Proposition	
<b>Improves crop:</b> <ul style="list-style-type: none"> <li>Germination rate 20%</li> <li>Time to maturity 20%</li> <li>Health and vitality 30%</li> <li>Yield and quality 30%</li> <li>Size and weight 20%</li> </ul>	<b>Improves market value:</b> <ul style="list-style-type: none"> <li>Taste and aroma 20%</li> <li>Vitamins and minerals 50%</li> <li>Digestible nutrients 50%</li> <li>Color 20%</li> <li>Shelf life 25%</li> </ul>
<b>Smartcultures</b>	
<b>Reduces production costs:</b> <ul style="list-style-type: none"> <li>Tillage 30%</li> <li>Diesel fuel 30%</li> <li>Irrigation water 20%</li> <li>Fertilizer 20 to 50%</li> <li>Pesticide/herbicide 40%</li> <li>Fungicide 70%</li> </ul>	<b>Enhances soil:</b> <ul style="list-style-type: none"> <li>Porosity 500%</li> <li>Microbes 500%</li> <li>Erosion resistance 40%</li> <li>Bioavailable nutrients 40%</li> <li>Organic material 20%/yr</li> <li>Moisture retention 30%</li> </ul>

**Algae deliver superior nutrients**



# Aquaculture and Animal Feed Industry

## Growing algae to feed fish, shrimp, mollusks, animals and pets



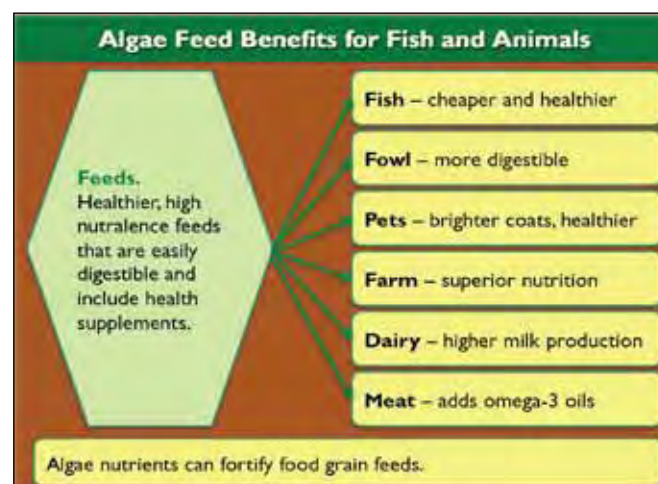
About one-third of all cultivated algae is used in aquaculture to feed mollusks such as oysters, scallops, clams and mussels, and shellfish such as abalone. Algae are used to feed zooplankton which feed a wide variety of shellfish and finfish. Many aquaculture farms grow algae next to fish ponds and feed directly to fish avoiding the high cost of food grains and transportation.

As oceans are being depleted of wild fish, the fish farming industry is growing quickly year-by-year, surpassing the wild fish catch. But the cost of fish meal to feed farmed fish continues to rise. Fish farmers will be motivated to replace fish meal with algae meal as algae costs fall.

Adding algae to fish feeds solves two big problems for growers. With better health and nutrition from algae, fish are less susceptible to infections and disease, and skin texture and flavor are improved. Overall, algae supplemented farmed fish have better growth rates, improved quality and color, better survival rates, reduced medication requirements and reduced effluent waste.

For more than thirty years, algae like *spirulina* have been widely used in aquarium, tropical and ornamental food formulas. Algae offer a great profile of natural vitamins, minerals and essential fatty acids for healthy development and natural pigments for enhanced skin coloring.

Zoos feed ornamental birds like flamingo and ibis a diet rich in *spirulina* algae for improved health and color. Canary, finch, parrot, lovebird and other bird breeders use algae supplements to increase color, growth and fertility. Algae feed increases survival and health of young chickens.



Some owners of highly valued racehorses use algae in their feed for faster times and quicker recovery, but trainers tend to keep results secret. Other reports claim algae may improve disease resistance and fertility in prized pigs and cows. For dogs and cats, algae improves coat and healthy skin and builds disease resistance.



Algae in aquarium tropical fish foods. Spirulina algae in ornamental pond fish feeds for health, nutrition and coloration. DHA omega-3 oil from algae in pet and animal foods.

## Algae for Biofuel, Bioplastics and Chemicals

### Huge investments in search of third generation biofuel

Modern societies are built around cheap energy that has been extracted for about 150 years. Our food, shelter, transportation and lifestyle consume massive amounts of fossil fuels. Globally, peak oil occurred in 2008 even though demand for fossil fuels continues to increase. Consequently, fuel prices continue to rise while supplies diminish. Fossil fuels are composed of algae fossilized under tremendous pressure and heat over 400 million years. Therefore, anything made from fossil fuels can be made from algae. Algae biofuel production is sustainable and occurs in weeks rather than eons.



Algae biofuels are not a practical substitute for coal or natural gas for making electricity. Algae biofuels are excellent substitutes for liquid transportation fuels that include ethanol, biobutanol, hydrogen, gasoline, diesel, aviation gas and jet fuel.

Fossil fuel extraction and use creates economic and ecological damage. Most cheap crude oil has been extracted from easily accessed land areas. Additional supplies lie in difficult terrain. Hard to access oil supplies not only drive up oil prices but amplify the probability of spills that create ecological catastrophes. Extracting and burning fossil fuels not only create a heavy carbon load for the atmosphere but also spread damaging black soot particulates on ice packs, cities and homes.



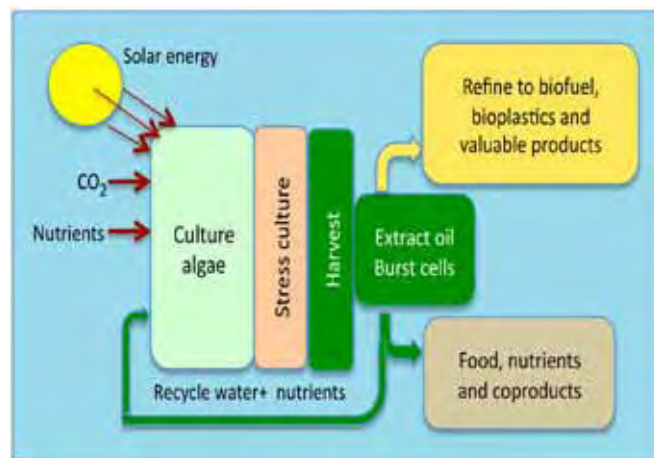
Algae liquid transportation fuels provide three critical values for human societies. They can:

- Be produced with abundant rather than fossil resources, thereby saving fossil resources.
- Recover, recycle and repurpose waste stream nutrients, avoiding pollution and regenerating air, soils and water while producing biofuels.
- Recycle carbon dioxide, reducing the carbon load while burning clean, with no black soot particulates. (Algae biofuels burn cleanly because they are not fossilized; they are similar to vegetable oil.)

#### *How are algae biofuels made?*

Algae are most productive when cells have access to solar energy. Algae that produce oil tend to move closer to the top of the water column because oil is lighter than water, so oil production enables access to more photons that fuel photosynthesis.

Algae scientists scan thousands of algae cells to find those that produce robustly and rapidly while offering high oil content, often around 40%. Some producers stress the algae by withholding a nutrient such as nitrogen, which causes the algae to protect itself by overproducing oil.



Harvested algae biomass undergoes lysis, which bursts the cells and enables the oils to float to the surface. Lysis may occur by solvents such as hexane, or enzymes, electrical, mechanical pressure or lasers. Carbon dioxide acts as the supercritical fluid when pressurized and heated to change its composition from gas to liquid. Supercritical CO<sub>2</sub>, mixed with the algae, extracts nearly 100% of the oil, but is more costly than other methods.



Producers refine the algae oil to make biofuel, bioplastics or fine green chemicals. Oil refining uses transesterification on the fatty acid chains. An alcohol, such as methanol, and an ester compound are mixed to create a reaction to produce a different type of alcohol and ester. The same process is used to make polyester fabrics. Esters are chemical compounds in which an acid has had one of its hydroxy groups - a molecule of hydrogen and oxygen bonded together - replaced by a molecule of oxygen. The transesterification chemical reaction converts algae oil to biodiesel.

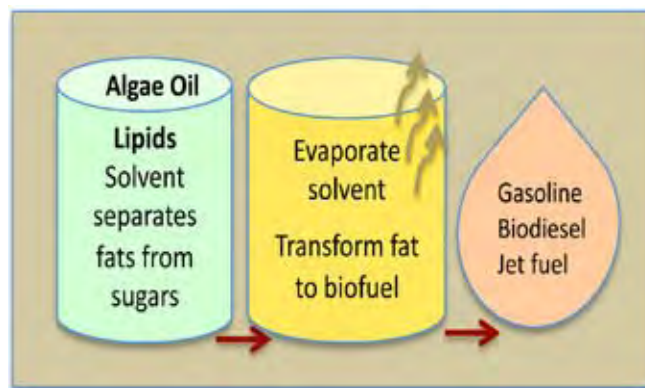
Considerable R&D focuses on alternative methods to convert algae oil extracts to biofuels including enzymatic conversion, catalytic cracking and sweating algae oil. Enzymatic conversion employs natural or synthetic enzymes to do the transesterification work. Catalytic cracking converts the high-boiling, high-molecular weight hydrocarbon fractions of fossil crude oil petroleum to gasoline and other products. Catalytic cracking produces more gasoline with a higher octane than thermal cracking and provides more valuable compounds.



Sweating algae oil offers novel solutions to several challenges. Growers choose an algae species that has no cell wall such as blue-green algae, cyanobacteria, or a highly permeable cell wall. Producers use either GMO algae or accelerated evolution to train algae to release oil naturally. The algae culture does not have to be harvested, saving considerable time and cost. Growers 'milk' the algae and the oil rises to the top of the water column where a skimmer removes the oil. The algae oil can then be refined. Alternatively, a few algae companies have developed genetically modified species that sweat 90-octane gasoline that requires no conversion.

The residual biomass, mostly protein and carbohydrates, may be used for food, feed, nutrients,

fertilizers or many other products. Large-scale algae biofuel production will generate substantial feed for animals and plants. Typically, biofuel protein coproducts are insufficiently clean for use in human foods. However, one of the strongest benefits from biofuel production is the R&D lift that will benefit all algae producers.



### *Why not now?*

Major algae biofuel ventures today, such as Sapphire, Synthetic Genomics, Solazyme and Algenol, are pursuing dramatically different paths to achieve commercial cost effective biofuel. What algae species: blue green, green or marine algae? What production method: outdoor ponds, photobioreactors or fermentation? What nutrient sources: water quality, waste streams, recovered industrial CO<sub>2</sub>? What process method: harvesting, lysing, chemical, sweating, or flocculation? What end product: biodiesel, ethanol, butanol? Which among these will become the successful paths to commercialization?

Companies have invested millions trying to develop algae biofuels, but scale-up from the laboratory is far more complex than expected. Total scale for biofuel cultivation may require hundreds and possibly thousands of hectares. Construction costs require investment of hundreds of millions of dollars and operational costs are significant. With current technologies, the probability of a large-scale culture crash poses high risk for investors.

Each step of the algae-to-biofuels process needs additional refinements including species selection, inoculation, culture growth, culture metrics and automation, harvesting, dewatering, oil separation and refinement. Breakthroughs in each of these areas may make algae biofuel production reliable and economically competitive within a few years. Fortunately, excellent minds are working on algae innovations that will benefit us all.

## How algae production costs will come down

*Robert Henrikson*

### *An exciting time for algae production*

Algae ventures have successfully raised millions for research and development for algae biofuels based on early promises. To deliver competitive algae biofuel, companies will need to crush costs lower than \$1/kg! Will they deliver cost competitive algae biofuels within this decade?

So far algae biofuels have been an expensive R&D project. The challenge scaling up begins now. Funding required for scale up is huge, and the lack of access to funding will trigger a shakeout. Watch these pathways unfold as the algae biofuel industry moves toward realistic business models.

- Algae ventures with deep financial backing from big oil, government and capital markets, and with technology that works, will be prepared to stay the course.
- Some are already repositioning their business model to develop more valuable and more immediate 'co-products' from algae.
- Companies who realize they can't make it to biofuel commercialization will license or sell off assets such as algae research, cultivation know-how, intellectual property, technology or systems.
- Some big corporate partners will bail. The executive decision will be: "had a good look, but now we are moving on to more immediately profitable opportunities."
- Some ventures will continue touting their proprietary IP or GMO breakthrough to keep R&D funds or government grants coming, hoping that they can sell out before they run out of funding.
- More ventures will shut down. Survivors will pick off infrastructure, technology and talent.

The scramble intensifies for algae ventures to show how their business model can produce algae at a reasonable cost for markets that are real and immediate. To survive, many algae biofuel companies will redirect financial resources toward more immediate income streams from algae products.

Big investments in algae biofuels are bringing big benefits. Breakthroughs from understanding algae cultivation and new technology will lower algae production costs and open new markets for higher value food and feed products. We are entering an exciting time for algae business development.



### *Innovations and breakthroughs will change how algae has been produced for 30 years*

How? Largely through biomimicry- better understanding of how nature works.

- Discover better performing cultures. Screen, identify and engineer strains of algae with superior properties, faster growth rates, and ability to grow in low light and low temperature and high saline, brackish or ocean water.
- Develop simpler design and technology. Rethink, redesign and reengineer growing, harvesting, processing and drying to reduce capital costs for equipment, operating costs and power use.
- Use marginal land and water like nature. To grow on the large scale needed to produce biofuels, find remnant flat land and ocean, saline, brackish or waste water located near nutrient resources.
- Use waste nutrients like nature. Recycle waste CO<sub>2</sub> effluent, animal and plant wastes. Ferment agricultural, animal, industrial and waste streams into carbon, nitrogen, phosphorus, potassium and micronutrients to feed the algae.
- Use all the algae biomass like nature. Start with the end product and work backwards. What products can be sold, for how much, and how will markets be developed for those products?
- Create multiple revenue streams to offset costs. Environmental services like CO<sub>2</sub> and pollution mitigation, wastewater treatment, biomass and waste heat and carbon offsets. Non-fuel algae revenues may include oil and lipids for animal feeds, biofertilizers, chemicals, bio-plastics, nutraceuticals, pharmaceuticals and medicinals.
- Automate and decentralize with web-based remote monitoring and operating systems to lower cost of personnel and operations, lower scale required for profitability, lower investment and risk.
- Exploit the unexpected- *carpe diem*.



# Algae Wastewater Treatment Systems

## High rate ponds for nutrient recovery and biofuel feedstock



Early algae ponds for municipal waste water treatment were built in the 1960s in California by algae pioneer William Oswald. Paddlewheel mixing was introduced in the 1970s. High rate ponds with paddlewheels were installed at several wastewater plants. This raceway and paddlewheel design was adopted by commercial *spirulina* farms such as Earthrise. The largest algae wastewater treatment and biofuel project in world was constructed in Christchurch, New Zealand.

In algae wastewater treatment, removal or harvesting of microalgae by simple and inexpensive ways such as bioflocculation, rather than by chemical flocculation, has proved challenging.

Other challenges limit the potential of algae waste treatment technology. These include the high land area requirement for open algae ponds near wastewater sites, current restrictive waste treatment and disposal regulations, and the availability of low cost or recycled CO<sub>2</sub> from power plants or other sources to fertilize the algae for optimal productivity and for efficient nitrogen and phosphorus nutrient removal, key issues for sustainable wastewater treatment.

Commercial-scale algae-to-biofuel facilities will need to grow and harvest microalgae economically to compete with petroleum based fuels. More research on resolving the challenges recovering nutrients from waste streams to feed algae will be essential to reduce the costs of growing algae for biofuel.

Conventional methods for wastewater and sewage treatment are expensive and rely on high-cost chemicals and heavy inputs of energy. Around the world, municipalities and utilities spend large sums to treat wastewater and sewage and remove pollutants and impurities. Algae systems can be cost effective, sustainable, long-term solutions.

Algae grow well off waste stream nutrients, whether agricultural, animal, or human. The algae can be local species that naturally grow in that ecosystem. Algae transform nutrient-rich and oxygen-depleted water into oxygen-rich water for bacteria to oxidize the organics, remove and recover nitrogen and phosphorus while producing algae biomass, which can be used as biofuel feedstock or agricultural fertilizer. All while cleaning up the water.



## Small Scale Algae Production Systems

### Appropriate technology in the developing world

As a supplement, *spirulina* algae offers remarkable benefits for undernourished people, especially children. Over the past 30 years, numerous projects have been growing *spirulina* in villages in Africa, Asia and South America.



#### *An experimental project 25 years ago: The Integrated Village System in Togo*

The remote village of Farende participated in an experimental appropriate technology project developed by Dr. Ripley D. Fox. Solar panels powered pond paddlewheels. A small 100 m<sup>2</sup> pond could supplement the diet of 100 children a day. Pouring pond water through a screen, *spirulina* became a paste, then was solar dried and distributed at the health clinic. Undernourished children took *spirulina* as a daily supplement. One tablespoon a day mixed with water brought remarkable results.

The design for this Health and Energy System won the prestigious 1987 European Award for Appropriate Environmental Technology, sponsored by the EEC and the UN Environmental Program.



#### *Many farms in developing countries today*

There are now many small scale *spirulina* algae systems in Africa, Asia and South America, including Chad, Morocco, India, Kenya, Togo, Tunisia, Burkina Faso, Mali, Algeria, Benin, Reunion, Senegal, Brazil and other countries.



Antenna Technologies of France and Switzerland is promoting *spirulina* against malnutrition with projects in Africa and Asia, with a mission to make algae more affordable. Today there are farms initiated by Antenna in these countries: Burkina Faso, Cambodia, Laos, Madagascar, Mali, Mauritania, Niger, Central African Republic and India, and of these, eight farms are running by themselves.





# Algae Microfarms for Local Economies

## Microfarm entrepreneurs take off in France

Over the past 30 years, many people have asked how they can grow *spirulina* themselves in their own back yard. In France there are about 100 *spirulina* microfarmers and a school curriculum for growing algae. Growers are producing their own products and selling directly in their local region.



Since the 1980s, French NGOs have been operating small scale *spirulina* algae systems in Africa and Asia. Upon returning to France, some NGO workers began small scale production at home.

By 2001 the first greenhouse microfarm producing 300 kg per season was operating in the South of France. In 2002, Jean-Paul Jourdan published his manual "*Cultivez Votre Spiruline*" (*Grow Your Own Spirulina*). In 2005, a spirulina school was established in Hyères to train entrepreneurs to grow their own algae business. In 2008 the Fédération des Spiruliniers was established with 80 members to develop guidelines for quality control and good manufacturing practice.



By 2010, 100 microfarmers were operating from the Mediterranean to Normandy, and the microfarm movement had spread to Spain.



Soon, remote sensing devices and smart phone apps will assist the basic functions of culture health monitoring and diagnosis. Growing food in cities and urban areas may become critical as fuel costs rise, making transported food increasingly expensive. On a small land area, a community could meet a portion of its food requirements from microalgae, freeing cropland for community recreation or reforestation.



Unlike plans for algae biofuel that envision mega farms, *spirulina* can be produced on a small scale. New technologies and systems design will make microfarming less costly, easier and more accessible for even more people around the world. Ecological communities can combine algae production and aquaculture with organic gardens.



## Novel Algae Growing Systems and Harvest Technology



Harvesting algae involves separation of tiny algae cells from the live culture. Algae growers are interested in cost effective solutions that use less energy and are more efficient.

The AZCati test bed features raceway ponds and column and flat plate photo bioreactors and other novel systems built by NanoVoltaix, an engineering services provider to the cleantech sector.



Evodos has designed new products for mechanical separation using minimal energy consumption without chemicals or consumables. Evodos machines harvest the algae as a fresh paste, a living organism free of extracellular water. This paste is compact and gives the longest possible shelf life with a minimum volume. Success has been demonstrated on multiple small algae from *chlorella* to *nannochloropsis*. The effluent water after harvest has excellent re-use potential.

Evodos centrifugal machines use patented spiral plate technology with an effectiveness of 99%, running at high flow rate with a low energy requirement in comparison with traditional centrifuges. [www.evodos.eu](http://www.evodos.eu).



NanoVoltaix (NVI) focuses on commercialization of disruptive technologies and production methods. The company name reflects the core belief that nanotechnology will be instrumental in realizing commercially viable solutions to some of the world's most pressing resource problems, and will enable novel products in a wide range of fields, including solar (photovoltaics) and biofuels.

In the algae space, NVI provides engineering and design services, as well as volume manufacturing of commercially viable, production scale photo-bioreactors for use in the production of algae for biofuels and nutraceuticals, and program management of large scale design-build and construction projects. [www.nanovoltaix.com](http://www.nanovoltaix.com).





## Algae Research and Incubation Centers

### Arizona Center for Algae Technology and Innovation



One of the most impressive research centers is the Arizona Center for Algae Technology and Innovation located at Arizona State University Polytechnic Campus in Mesa Arizona. AZCATI serves as a hub for research, testing and commercialization of algae-based products. These include biofuels, pharmaceuticals, nutraceuticals and other algae biomass products.



AZCATI services include:

- strain identification and evaluation
- culture systems design and evaluation
- culture maintenance, operation, protocol
- chemical and biochemical analysis
- design recommendations for system integration
- nutrient scaling, sustainability, management
- equipment evaluation, methods development
- co-products identification and analysis



AZCATI serves as a learning environment for the next generation of scientists and engineers. It provides open test and evaluation facilities for the algae industry and research community. It can assess the performance of individual and combined unit operations across the algae value chain.

Here is a fabulous array of algae technologies from raceway ponds to photobioreactor tubes, bags, plates and hybrid systems growing many species of algae. Production ponds and photobioreactors like these will move into future landscapes, living buildings with green photosynthetic membranes, and into communities for local food and energy.



*Azcati grand opening in February 2012*



*Algae harvest demonstration*





# International Algae Competition

## Visionary Designs for Algae Food and Energy Systems



### *What will our future with algae look like and how will it work?*

The 2011 International Algae Competition posed this question as a global challenge to design visionary algae food and energy systems of the future. The competition encouraged anyone, anywhere in the world, to apply their creativity to design our future landscapes, growing systems and new foods. Over a nine-month period, 140 participants responded, representing 40 countries and they submitted some amazing designs, projects and food ideas.

### *An open source collaboratory*

Sufficient knowledge about algae production exists today to support successful cultivation. Unfortunately, much of the best knowledge rests with a few elite scientists and entrepreneurs who sequester their research findings due to intellectual property limitations.

The algae industry today is fractured as each company acts to protect intellectual property behind a wall of secrecy. Scientists are prevented by non-disclosure agreements to collaborate with others or share breakthroughs and real costs of productivity metrics. This secrecy leads to mistakes in algae production that are repeated multiple times. Companies do not readily share mistakes for fear the next round of funding will dissolve. This degree of secrecy concentrates rather than expands knowledge, and slows innovation.

Algae Competition objectives are to create an open source collaboratory that expands and shares a vision for algae in our future with design ideas for algae production landscapes, sustainable and affordable algae production systems for medicines, food, feed, energy, nutrients, water remediation, carbon capture and new algae foods. As an open source competition, entries are showcased online.



Participants represented 40 countries: Australia, Bosnia and Herzegovina, Brunei, Cambodia, Canada, Chad, China, Colombia, Congo, Croatia, Cyprus, Czech Republic, Ecuador, France, Germany, Haiti, Hong Kong, Iceland, India, Indonesia, Italy, Kenya, Kosovo, Malaysia, Myanmar, New Zealand, Netherlands, Norway, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Togo, United Arab Emirates, United Kingdom, USA, Zimbabwe.

The organizers, Robert Henrikson and Mark Edwards, assembled panels of distinguished jurors from diverse backgrounds to evaluate entries in the three tracks of the competition. From 40 finalists, seven prize winners were announced. Beyond these prizes, competition winners, finalists and many entries were recognized in subsequent media news releases, articles, videos, publications and exhibitions.

# International Algae Competition Tracks

## Algae Landscape Design, Production Systems and Food Development

### 1. Algae Landscape and Architecture Design

*How will algae production be designed into future landscapes, buildings and communities? What will they look like and how will they work?*

Algae Competition invited algae enthusiasts, architects, designers, visionaries, builders, students and teams to design integrated algae production into future landscapes, farms, coastlines, cities, buildings and eco-communities.

Algae Landscape Design categories ranged from urban landscapes, integrated commercial farms, community microfarms, village farms, vertical farms, green walls, suburban landscapes, rooftops, parks, gardens, greenhouses, model communities, sea and ocean landscapes.

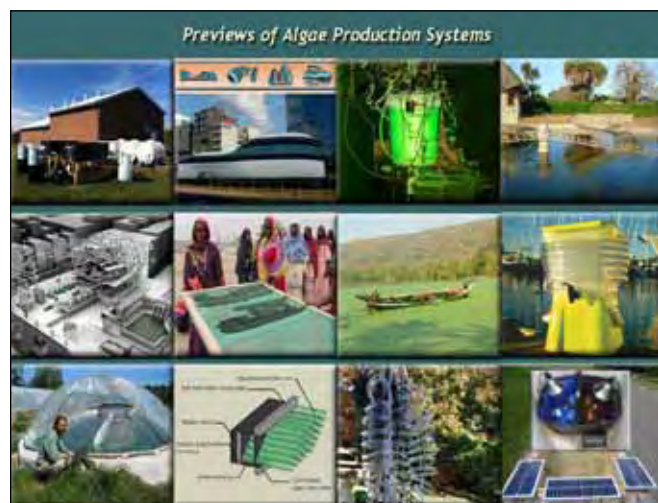


### 2. Algae Production Systems (APS)

*What are the best designs, engineering and systems to work effectively and economically on a community scale or distributed model?*

Algae Competition invited entrepreneurs, engineers, systems designers, builders, students and teams to develop working models and designs for algae production systems and microfarms.

Algae Production System (APS) categories ranged from open raceway ponds, open and closed hybrids, closed system tubes, bags, tanks, plates, personal micro farms, community size farms, village scale farms, large commercial farms and lake farms.

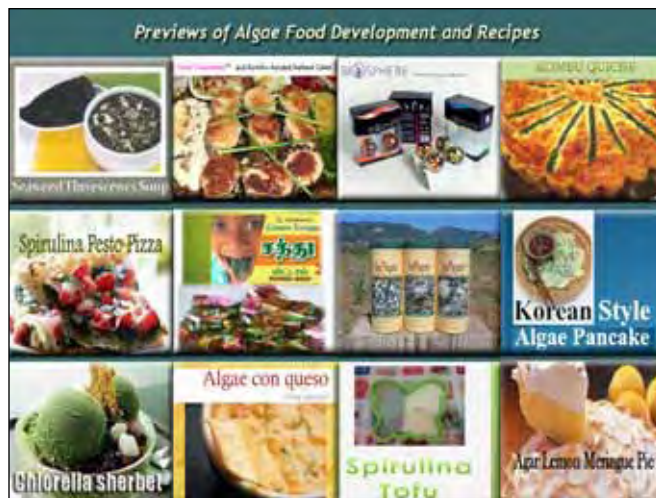


### 3. Algae Food Development and Recipes

*What will be the next algae foods and recipes and future uses of algae as food and feed ingredients that will transform our health?*

Algae Competition invited algae enthusiasts, chefs, cooks, food developers, algae eaters, students and teams to create menus, new foods and food products using algae as a featured ingredient.

Food development and recipe categories ranged from main courses, desserts, ice creams, cereals, grains, nutrition drinks, shakes, appetizers, chips, snacks, breads, pasta, noodles, energy bars, soups, stews, dips, condiments, raw foods, food supplements, salads and fresh algae.





## Algae Competition Exhibitions



After the Algae Competition, the award winning and best landscape designs, algae production systems and algae food entries will tour to international exhibitions. For venues in museums, science centers and conferences, the exhibition will offer a multi-media and multi-sensory experience around the theme of how growing algae will change the world and improve our lives.

Exhibitions will feature algae designs, algae models and new algae foods:

- 1) Algae landscape and architecture designs of the future on wall murals and video monitors,
- 2) Algae production micro ponds and bioreactors on the floor and grounds, and
- 3) Algae food and beverages for delicious taste sensations for openings and scheduled events.

## Algae Competition Video Channel



The Algae Competition YouTube Channel offers current and historical videos produced by Robert Henrikson about algae production systems and food products, as well as videos submitted by participants in the 2011 Algae Competition.

Channel Playlist includes these videos: The Future of Algae (2012). The Future of Spirulina Microfarms. A Conversation with Jean-Paul Jourdan (2011). An Integrated Spirulina Algae Microfarm

in France (2011). How To Eat Fresh Spirulina in Aquamole Dips (2011). 2011 International Algae Competition (2010). Commercial Spirulina Algae Farm in Thailand (2010). Family Spirulina Algae Farm in France (2002). Spirulina Algae Picnic in South of France (2002). Tour Earthrise Spirulina Farm in California (1996). Village Spirulina Farm in West Africa (1989). First Commercial Spirulina Farm in California (1983).

## **International Algae Competition Winners** **Algae Landscape Design, Production Systems and Food Development**



### **Abundance Prize and Best Video**

**Green Loop: Marina City global algae retrofitting in Chicago**

**by Influx\_Studio/ Aétrangère, Mario Caceres, Christian Canonico. Images by Inimagenable.**

An algae based strategy for a new sustainable model in urban areas. Re-visioning an iconic building from the past century fossil fuel economy. An environmental vision committed to the Chicago Climate Action Plan. Growing algae, absorbing CO<sub>2</sub>, harvesting energy, filtering water and producing food.

### **Algae Landscape and Architecture Design**



#### **First Prize**

Urban algae culture in Gangxiacun, Shenzhen, China by Kady, Wong Hoi Kei & Kate, Lau Hoi Ying & Perry Li.



#### **First Prize**

Process Zero: Retrofit Resolution. GSA Federal Building in Los Angeles by HOK/Vanderweil, Sean Quinn Lead Architect.



# International Algae Competition Winners

## Algae Landscape Design, Production Systems and Food Development

Appreciation Prize voted by participants

Algae powered mushroom farm  
by 10 Design Group, Ted Givins.



### Algae Production Systems



**First Prize:** Circular tank technology to reduce production costs by Vincent Guigon, Antenna Technologies, Geneva.



**First Prize:** Organic spirulina microfarm with biogas plant in Normandy, France by Laurent Lecesve, Hybrid énergies & Eco-Systèmes.

### Algae Food Development and Recipes



**First Prize:** Biosphere Instant soup concept: algae inside an alginate sphere by Lucie Bolzec.



**First Prize:** Dances with Algae by Lynn Cornish, Scott Hubley, Romela Nickerson, Josie Todd.

## International Algae Competition Finalists

### Algae Landscape and Architecture Design



Algae powered mushroom farm in Congo, Africa by *10 Design Group, Ted Givins.*



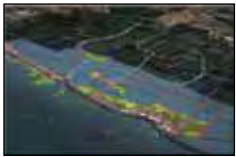
AlgÔ, or the regeneration of the Baie de Morlaix, France by seaweed by *Isabelle Bardèche.*



Algae school on Huiquan Bay, in Qingdao China by *Bi Yupeng.*



Ecologies of (Bio)Diversity: A self sustaining tower for London by *David Edwards.*



Shoreline regeneration by algae cultivation in Cigu, Taiwan by *Yen Chang Huang.*



Green Miles. I-40 near Knoxville, Tennessee by *Kathryn Hier.*



Algae energy exhibition park, in Jingzhou, Hubei, China by *Chen Jie & Gong Ying.*



[Infra]Structural algae ecology for Taipei, Taiwan by *Aleksandrina Rizova & Richard Beckett.*



Process Zero: Retrofit Resolution. GSA Federal Building in Los Angeles by *HOK/Vanderweil, Sean Quinn.*



ALGAL&SCAPE: Study of polder Schieveen near Rotterdam, Netherlands by *Federico Curiél.*



Persatuan Arkitek Malaysia (PAM) Centre in Malaysia by *Chew Teik Hee.*



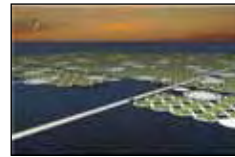
Urban algae culture in Shenzhen, China by *Kady, Wong Hoi Kei & Kate, Lau Hoi Ying & Perry Li.*



Eco-Pod: modular algae bio-reactor in Boston by *Squared Design Lab: & Höweler+Yoon Architecture.*



Carbon dioxide eliminating floating green park in Hong Kong by *Adrian Yee Cheung Lo.*



Production landscape for warm coastal areas of the world by *Ho Wing Ho.*



Algaegarden celebrates the beauty and potential of algae by *Heather Ring, B. Parker, S. Fredericks.*



Algatherapeia center in San Sebastian, Spain by *Judit Aragonés Balboa.*



Eco-Laboratory: Algae micro-farm center in Seattle by *Mark Buehrer, 2020 Engineering Inc.*



Hydral Housing units with modular hydrogen producing panels. by *Thomas Kosbau.*



Green Loop: Marina City algae retrofitting in Chicago by *Influx\_Studio/Aétrangère, Mario Caceres, Christian Canonico.*



# International Algae Competition Finalists

## Algae Food Development and Recipes and Algae Production Systems



H'ors d'oeuvres d'algues - Oz style in Australia *by Pia Winberg and Friday.*



Dances With Algae- marine algal foods *by Lynn Cornish, S. Hubley, R. Nickerson, J, Todd.*



In'Spir- naturopathic condiment from Provence, France *by Cédric Coquet.*



Wakame pesto and sundried tomato baby bocconcini *by Jasmin Baron.*



Spirulina tofu in Singapore *by Sun-Up Bean Food PTE LTD.*

From 140 creative, fascinating and remarkable entries, through combined scoring of distinguished jurors, Algae Competition selected:  
Algae Landscape Designs 20 Finalists  
Algae Production Systems 7 Finalists  
Algae Foods and Recipes 14 Finalists



Korean style algal pancake *by JiSun Lee.*



Spirulina tacos al pastor *by Spencer Drew.*



Mermaid pasta *by Raymond Gordon.*



Savory kombu, pork and shrimp soup & brown bread with kombu *by Lily Julow.*



Nori and almond crusted tart with mushrooms and artichoke hearts *by Andre Alban.*



Spirulina Green Tongue Candies in India *by Duraikkannan Selvendran, Antenna.*



Savory nori shortbread cookies & blue green truffles *by Amy Angelo.*



Dulce cashew granola *by Jessi Apfe.*



Biosphere instant soup concept in France *by Lucie Bolzec, Delis Design Studio.*



Algae production system of natural spirulina lakes in Myanmar *by Min Thein, Myanmar Pharmaceutical.*



Circular tank technology to reduce production costs *by Vincent Guigon, Antenna Technologies, Geneva.*



Algaewheel-based algae cultivation *by University of Illinois at Urbana Champaign.*



Organic spirulina microfarm with biogas plant in France *by Laurent Lecesve, Hybrid énergies & Eco-Systèmes.*



Improved technology, production and marketing of *dihé* in Chad *by Mahamat Sorto, Food Consultant, FAO.*



Algae production system using night cycle LED in Minnesota *by Josh Wolf.*



Boonsom spirulina farm: leading producer in Thailand *by Jiamjit Boonsom.*





## Algae Production Systems

### Outdoor spirulina algae production for food



#### Improved production and marketing in Chad

Kanem women have harvested *spirulina* from lake regions near lake Chad using traditional methods for centuries. About 1600 ladies harvest from 16 wadis, small natural alkaline soda lakes, and produce about 400 tons of *dihé* per year. Improvements in harvesting, good manufacturing practice and marketing of *dihé* have helped living conditions of communities around Lake Chad. Harvesting *spirulina* through filter cloths and dehydrating in solar dryers increased to 10 tons in 2010.



#### Boonsom Farm, leading producer in Thailand

For over 20 years, Green Diamond has owned and operated three farms around Thailand. Boonsom Farm near Chiang Mai offers the rural community an opportunity for a better life. Keys are sunlight, clean water, environment and the work force. Boonsom employs hundreds of people in research, cultivation, harvesting and production. Staff has lunch meals, health insurance, cooperative store, credit union, health and lifestyle training and bonuses for bicycling to work.



#### Circular tank technology in Africa and Asia

Antenna Technologies of France is an NGO promoting spirulina against malnutrition with projects in Africa and Asia, with a mission to make *spirulina* more affordable. Today there are about 10 farms initiated by Antenna running by themselves in 8 countries. Antenna developed circular tank technology with a rotating central axis using wind or solar energy for stirring and cleaning to reduce costs by 20% through long lasting maintenance of culture quality without purges.



#### Algae production in spirulina lakes in Myanmar

Based on 22 years experience, sustainable *spirulina* production from four lakes has been achieved. Algae is continuously harvested without depletion of biomass. Lake water is pumped into lakeside cultivation ponds for 10 months of production. In March and April, *spirulina* blooms on the lake 12-18 inches thick and is harvested by boats for 50% of annual production. Capacity is 200 tons per year, producing one million bottles of supplements, as well as crackers, cosmetics and beer.



### Kanembou Spirulina Ladies of Chad

We are a group of 1581 women traditionnally harvesting Spirulina from the wild in Wadis located in the Kanem and Lake regions of Chad. With our nearly **400 tons/year production**, we are also proud to be **one of the largest world producers of Spirulina**. Our product is retailed on the local market at the average rate of **7.5 euros/kg**, making it the **cheapest Spirulina product available**



Our production ponds are 16 small natural alkaline soda lakes, located in a very remote, unpolluted and pristine environment. Spirulina grows spontaneously in those pieces of salty waters, where no additives, not even fertilizers, are added.

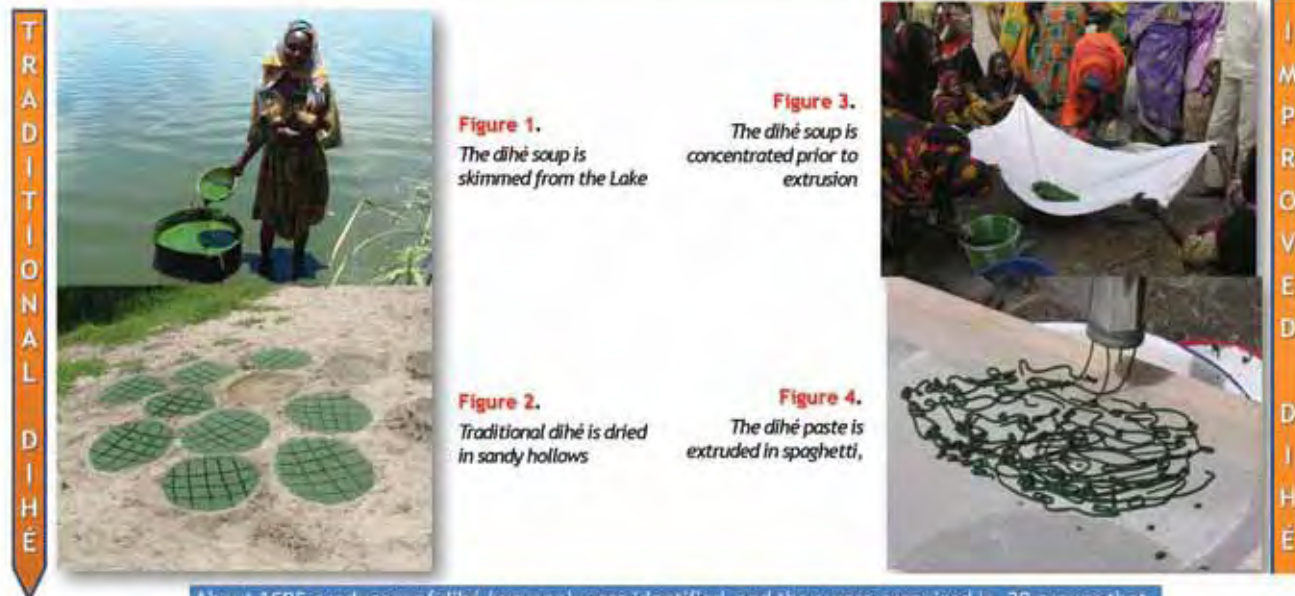


Spirulina ladies of Chad by Georges Bonnin

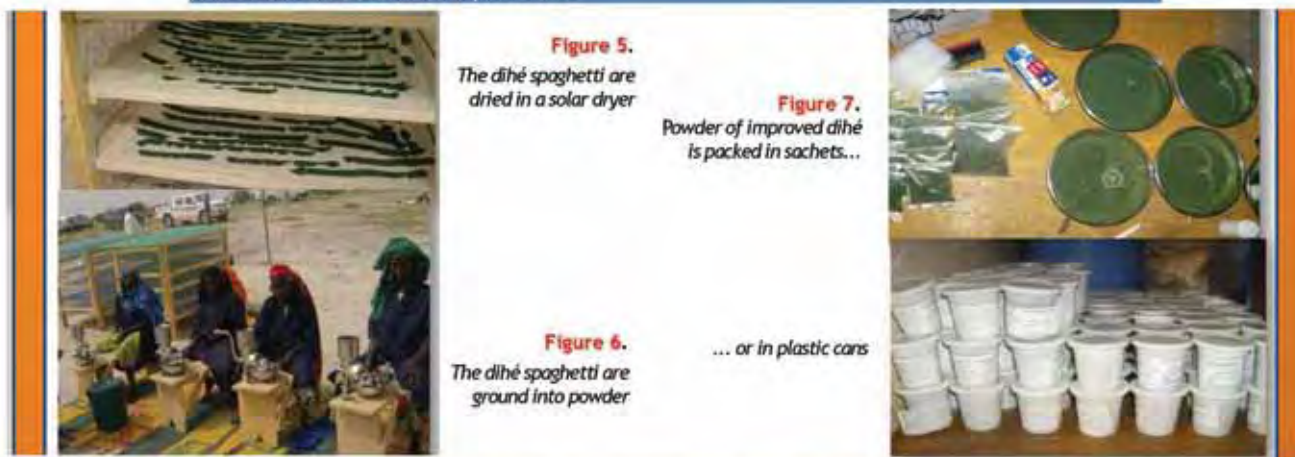


**Improving living conditions of rural populations and communities of Lake Chad through the implementation of the pilot project of the development of dihé (spirulina) in Chad funded by the European Union: The experience of FAO and the Ministry of Agriculture and Irrigation of Chad**  
**By Mahamat SORTO, Food Technology researcher, Consultant, FAO-Chad**

The Pilot Project of development of "dihé (spirulina)" in Chad is funded by the European Union and implemented by FAO and the Ministry of agriculture and Irrigation of Chad between 2007 and 2010. The project aimed to improve the living conditions of vulnerable populations in the Lake Chad, especially women and youth throughout activities such as the improvement of the quality of the production of dihé, the promotion of the commercialization of dihé and the reinforcement of the capacity building of producers of dihé.



About 1685 producers of dihé (women) were identified and they were organized in 20 groups that have been recognized officially by the authorities. 600 of 1685 producers are trained in good practice of harvesting, drying and packaging dihé (GMP) and good hygiene practice (GHP). A lot of quantities of solar driers, sieves, extrusion machines, milling machines and packaging tools etc ..., have been distributed to the producers.



the income of women has increased dramatically. The sale of improved dihé (1 kg of improved dihé is sold at FCFA 5000 against FCFA 1000 for the traditional dihé) enabled the storage of more than 500 bags of maize, the purchase of millet mills for the villages (more than 3 mills), the purchase of modern clothes, jewelry and gold, kitchenware, purchase of boats (over 5) and nets for the spouses of producers, the construction of new houses in the villages, buying mattresses, beds, blankets, mosquito nets, plastic mats, cushions, buying clothes for children, the purchase of mobile phones (over 60) and the creation of small businesses...

**Improved technology, production and marketing of dihé in Chad by Mahamat Sorto**





## Boonsom Spirulina Farm

We have chosen the location of our farm to be in the hills at the foot of the mountains that surround Chiangmai City in Thailand. Our water source comes from wells on site that has been tested to be drinking water standards. The weather is warm with plenty of sun 8 month out of a year, even during the rainy season; we still have plenty of sunshine.

The key factors in choosing a site for a Spirulina farm are Sunlight, Clean Water and Environment. However, Khun Jiamjit also incorporates a forth element: The Work force. Our farm is not dependent on expensive machinery or high tech equipment. Under the direction and training of Khun Jiamjit we utilize 100s of people in our research, cultivation, harvesting and production of our product.

Laboratory  
development (test  
tubes and flask)



Nursery development (plastic bags and barrel tanks) in a shaded place



Nursery development (Nursery ponds) under clear plastic cover

Nutrients and CO2 are  
maintained to optimum  
levels



Boonsom Farm, leading producer of spirulina in Thailand



**Development ponds (small – medium ponds)**



**Harvest ponds (large open ponds)**



**Harvest (syphon system to netting system)**



De-Water Process : washing-shaking-spinning  
Drying System (tray, cart and oven)  
From there we grind the spirulina into a powder to be made in to tablet or capsules



by Jiamjit Boonsom



## ANTENNA Today

### Stirring system in raceway ponds



- Stirring system in raceway ponds can either be completely **manual**, requiring no energy but staff dedicated to it.
- Stirring system in raceway ponds can either be **automated**, requiring an energy source (electricity) to enable continuous rotation of the paddle wheels

Manual stirring in India



Stirring in Mali (electric energy)



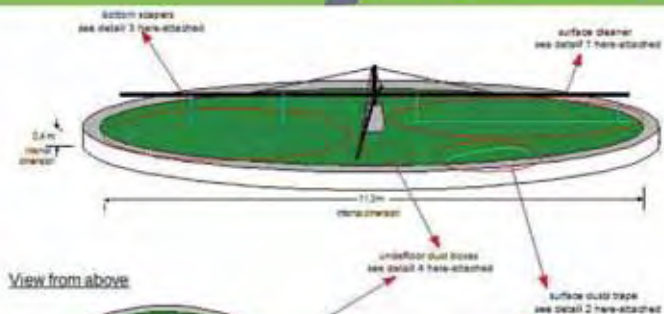
- Mud deposits must be cleaned manually, either through a net and/or through a system of purges that entails heavy water and inputs consumption

## ANTENNA Prospective

### Circular tanks: General presentation

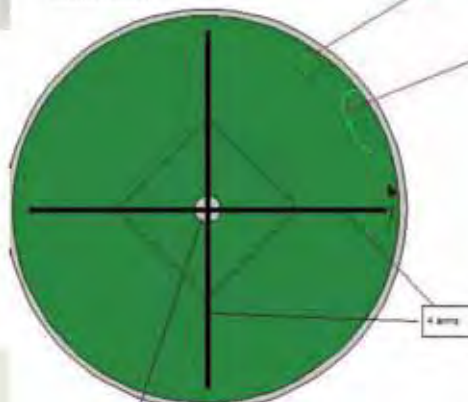


- The tank is equipped with a rotating system of 4 arms fixed on a central axle.
- 3 arms carry « bottom scrapers » and 1 arm carries a floating device



View from above

Elevation view



Circular tank technology to reduce production costs



## ANTENNA Prospective

### Circular tanks: General presentation

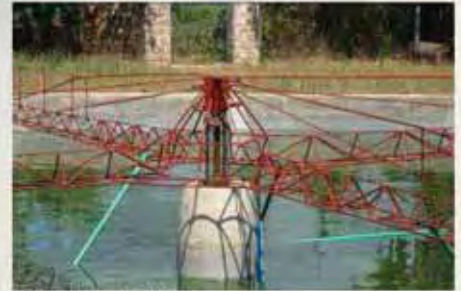


The specificity of this type of circular tank is the use of a free renewable energy for :

- ✓ Water stirring
- ✓ Continuous cleaning



Circular tank in Kenya

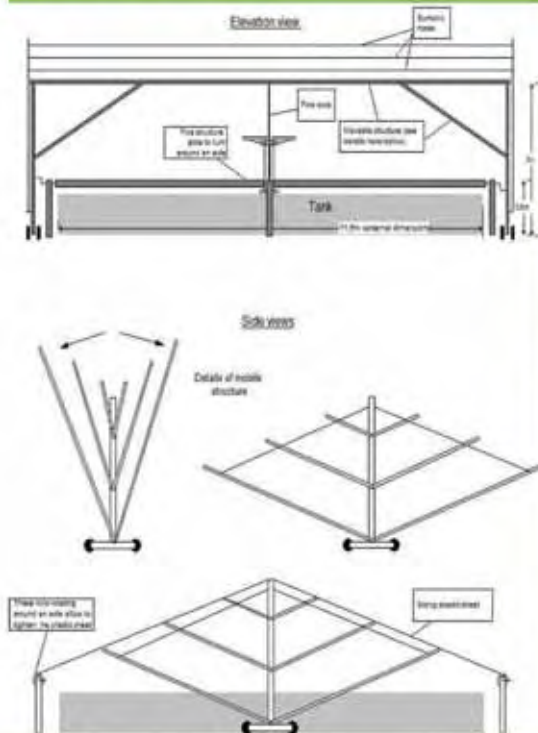


Circular tank in Kenya

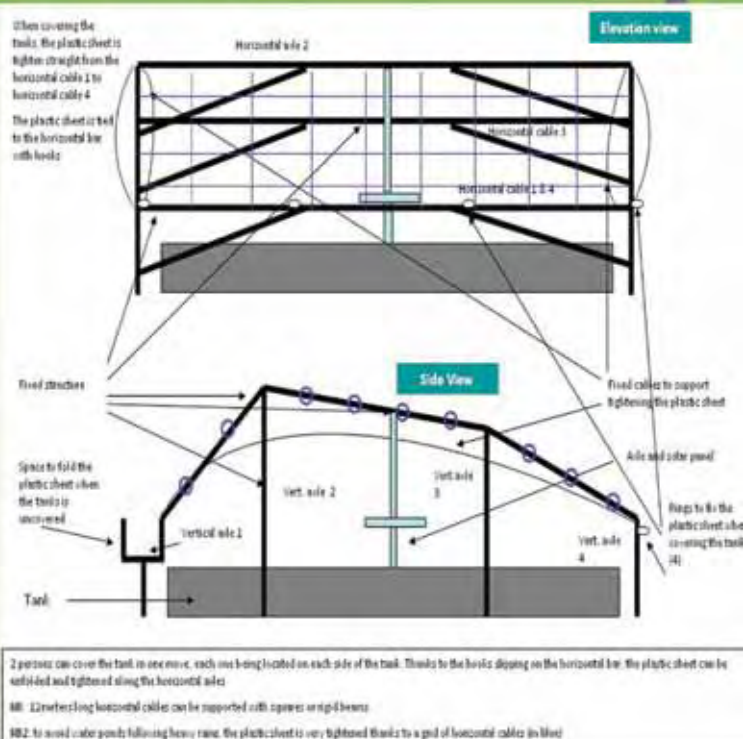
Circular tank India



#### Circular Tanks Covering / proposal 1



#### Circular Tanks Covering / proposal 2



by Vincent Guigon, Antenna Technologies, Geneva



## Algae Production System of Natural Spirulina Lakes in Myanmar



Algae production system of natural spirulina lakes in Myanmar by Min Thein



## Algae Production Systems

### Experimental algae ponds and bioreactors



Organic spirulina microfarm with biogas plant in Normandy, France

Developed by Hybrid énergies & Eco-Systèmes, this farm has four 50m<sup>2</sup> ponds, micro-digester, heat pump with network connected to digester and ponds, harvesting room with press and solar dryer, and a culture laboratory. The digester will use cow and horse manure for nutrients to grow *spirulina* organically. HyES is part of the Fédération de Spiruliniers de France, small-scale *spirulina* farmers promoting a new agricultural business model.



Algaewheel algae cultivation for environmental enhancing energy at University of Illinois

This novel approach integrates algal wastewater treatment with hydrothermal liquefaction of biomass to biocrude oil, resolving two bottlenecks: contamination of high-oil algae species with low-oil algae and bacteria, and high energy input for dewatering biomass. The demonstration project at the Swine Research Center at Urbana Champaign shows the algaewheel system can treat wastewater and produce biomass simultaneously.



Algae production system using night cycle LED in Minnesota

Josh Wolf has designed a combination of blue, red and green lighting during algae's night cycle to increase growth rate. This innovative system has artificial and natural lighting working together, a solar powered system, a new recycled algae drying method, and night and day aeration. Using recycled pop cans painted black creates a solar evaporator. Next step is scaling up.



Algaetech's Algae Integrated Management System (AIMSYS<sup>™</sup>) in Malaysia

AIMSYS is a method for designing an algae cultivation system for biofuel, food, feed, and high value products. The major highlight of this design is the web-based system monitoring and control of parameters such as pH, salinity, nutrient concentration and dissolved oxygen. AIMSYS is a single system for culturing and processing algae with four main operational processes: 1) Preparation, 2) Culturing, 3) Harvesting, and 4) Processing.

# Organic Spirulina micro-farm Eco-System, combined to a biogas plant

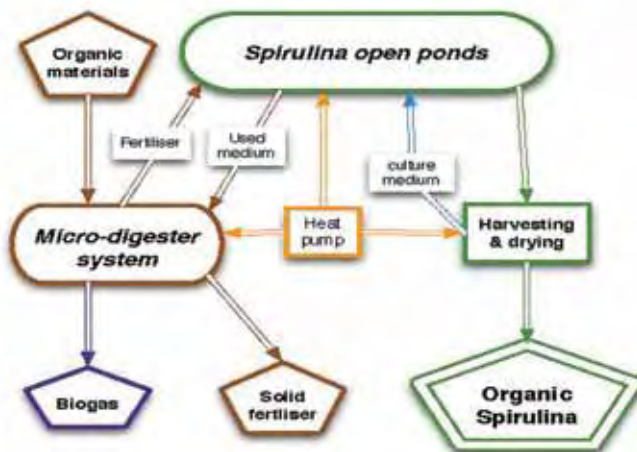


Figure 3: Heat use in a micro-farm

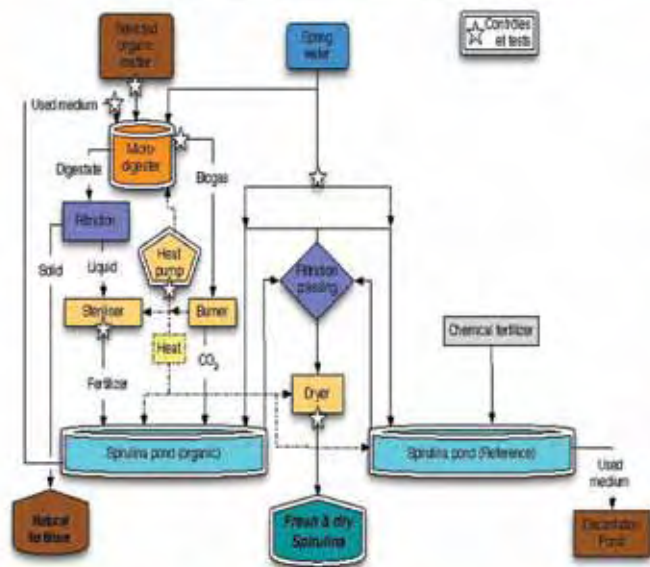


Figure 3: Experimental set-up

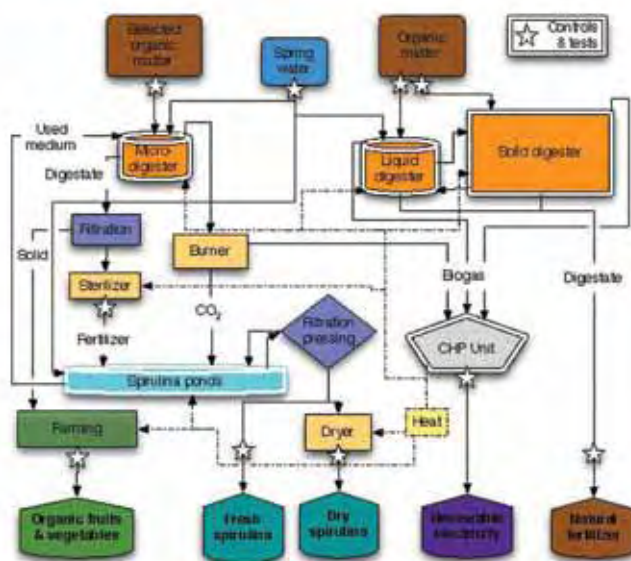


Figure 4: Overview of the system



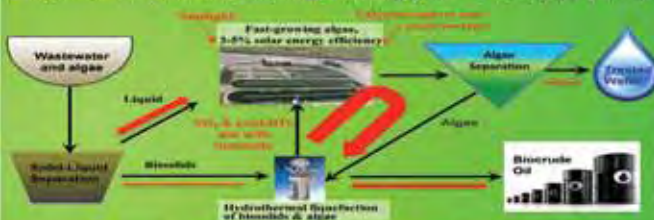
Organic spirulina microfarm with biogas plant in Normandy, France by Laurent Lecesve.



## Algae-wheel-based Algae Cultivation for Environment Enhancing Energy

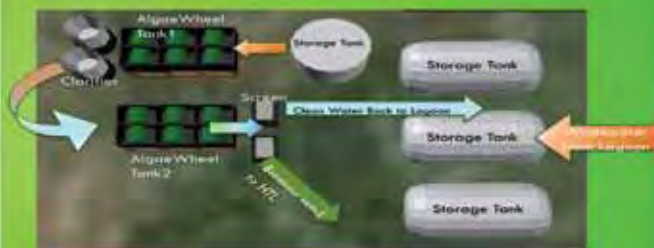


### Algae wastewater treatment & HTL <sup>HTL</sup> Environment Enhancing Energy (E<sup>2</sup>-Energy) Loop



The E<sup>2</sup>-Energy Road Map: Waste bio-solids are converted into bio-crude oil via HTL. HTL wastewater recovers most of the nutrients, which are fed to fast-growing algae, which recycle back into the HTL and are converted to oil. Algae growth cleans the water and sequesters CO<sub>2</sub> from the atmosphere and HTL.

### Demonstration Project Setup



### Algae-wheel System

- Designed by Algae-wheel Technology, LLC
- Symbiotic growth of algae and bacteria improve biomass productivity
- More surface area exposed to sunlight, preventing photo-inhibition
- Algal biomass fall off the rotating wheels making it easy to harvest biomass



### E<sup>2</sup>-Energy Demonstration Project HTL System

- Currently located 1.5 miles away from SRC
- Past experiments show more than 30% of biomass can be converted into bio-crude oil, even low lipid biomass.
- 30-90% of the nutrient in biomass will accumulate in post-HTL wastewater and recycle back to algae-wheel tank
- Haven't collected enough algal biomass from SRC for processing



## Benefits of Combining Algae with Wastewater Treatment

- Reduce the cost of algae cultivation and wastewater treatment
  - Algal wastewater treatment provides superior nutrient removal to traditional methods
  - Symbiotic relationship between algae and bacteria increase biomass production
- Easier to harvest algae
  - Enhanced algae form algae biofilm which can be easily harvested by scouring
- The revenue of wastewater treatment can offset the cost of biofuel
  - From \$350/barrel to \$28/barrel (Lundquist, 2010)



But how low lipid algal biomass produce biofuel?

### E<sup>2</sup>-Energy Demonstration Project

- Purpose:
  - Demonstrate the full potential of E<sup>2</sup> Energy
  - Test operation parameters
  - Reduce wastewater treatment cost
  - Generate bio-crude oil to offset farm energy use
- Site Description
  - UIUC Swine Research Center (SRC)
  - Wastewater production: 10,000 gal/day
  - Wastewater treatment expense: \$20,000/year



### E<sup>2</sup>-Energy Demonstration Project Algae Cultivation System

- Two Algae-wheel tanks have been set up next to manure retention lagoon, and started operation on Sep 28<sup>th</sup>
- Current process capacity: 300 gallon/day
- Algae seeded from local wastewater treatment plant
- Biomass can be collected by 0.2 mm screen before discharged



### Algae-wheel System Results

- First week operation shows 50-75% COD removal rate and ~60% ammonia removal
- Expecting the system can achieve >90% COD removal and >90% ammonia removal after longer period of operation
- Estimated total biomass productivity is 1.2 kg/day



1. System influent wastewater
2. Water after first algae-wheel tank
3. Water after clarifier
4. Water after second algae-wheel tank
5. Discharge water (after screen)

### Conclusion

- E<sup>2</sup>-Energy process has potential to resolve the current major limitations to the economic feasibility of large-scale algal biofuel production.
  - Low-lipid content algae can be converted efficiently into valuable fuels.
  - Energy for dewatering is minimized since the liquefaction oils self-separate from the water in wet biomass feedstocks.
- SRC demonstration project shows algae-wheel system can treat swine wastewater and produce biomass simultaneously. This could save SRC \$20,000 in annual wastewater treatment fee while producing crude oil.



## Algae Production System

Josh Wolf  
10<sup>th</sup> grade  
Elk River High School  
Elk River, Minnesota

### Researched Growth Methods

#### Open pond system



- More growth consistency
- Lower yields-light penetration
- Less labor intensive
- Lower cost per gram

#### Photo-bioreactor



- Higher cost per gram
- Higher growth rate
- Easier growth manipulation
- Less risk of contamination

### What's New?

- Artificial and natural lighting working together
- New way to look at LED lighting techniques
- Solar powered system
- Completely recycled system
- New, recycled, algae drying method
- Night and day aeration

### What's Next?

After presenting my project to my science teacher, he is willing to help me take this production process to the next step. We are working on purchasing land in Nowthen, Minnesota and creating a 1/2 acre production site. From current growth models, this production system will be capable of producing about 10,000kg of algal biomass per day. The algae will be pressed and converted into biodiesel fuel. The proceeds will go to a science based scholarship trust fund helping kids interested in science go to college

### We need your help!

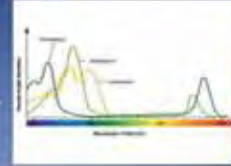
- We're currently looking for companies willing to sponsor our project. If you or your business is interested in helping out, contact me at
- [Wolfjosh0@gmail.com](mailto:Wolfjosh0@gmail.com)
- Come check out the progress of my project at
- <http://www.facebook.com/AlgaeFuel>

## New Growth Method

- Using blue and red LED's for growth has been done before.
- However I'm using blue, red, and green lighting during algae's Calvin (night) cycle when it transfers CO<sub>2</sub> into sugars, not only during the day.
- In this small set up, there was 1.6g of algal growth per day per 100ml sample (days 2-5).
- This is an astonishing improvement on current photo-bioreactor systems today.



My own red and blue growth test



Absorption spectrum of Chlorophyll a, b, and c. This graph shows photosynthetic efficiency

## Scaling Up!

- This tank is 1.2m wide by 4.9m long and is 0.50m deep.
- It holds about 2,950 liters.
- It's completely run on solar!
- Using the blue and red LED lighting method (hooked onto the white pipes seen at the bottom of the tank) there was 9.3 grams of growth per day per 1L sample (days 2-5).
- That's a total of 72kg of growth per day!
- This provides an outstanding improvement on current open-pond systems.



## Recycled Drying Method

- Using recycled pop cans painted black creates a solar evaporator.
- This evaporator dries out 3 Kg of algae biomass in 4 hours.
- The algae is spread on the metal film behind the layer of pop cans.
- The convection heat takes out most of the water (10% water content) exiting out of holes at the top.



I started off researching algae in August 2008 as part of a curiosity about sequestration. After I made a small model using 2 liter bottles and an air pump I wanted to try and make a bigger tank. I made a wooden frame box with a plexi-glass lid. The box would then be filled with algae water and be pumped with air from the bottom. I tried to get approval to take these boxes to roofs in the nearest city to me (Minneapolis) to clean smog while producing algal biomass I would filter and give out as mulch. This became my first ambitious algae project in high school but the project was turned down due to liability issues with putting these tanks on rooftops.

I searched for other projects to do when I came across *Botryococcus Braunii*, an extremely high oil content algal cell that could be converted to biodiesel. I wanted to see how I could maximize the growth to produce the highest amount of lipids I could. This led to months and now a year and a half of research to produce a high functioning system. I researched that by using blue and red lighting to grow algae would maximize lipid production because it would efficiently use those wavelengths of energy in photosynthesis. By creating my own model I found that it did minutely increase growth, but there had to be something better.

Eventually I came to the conclusion that after growing algae in bright light (or blue and red light) that if you use a combination of blue, red, and green lighting during the algae's night cycle, it will still slowly carry out photosynthesis while the cells "Calvin Cycle" of turning CO<sub>2</sub> into sugars efficiency greatly increased. I found this added night cycle of lighting, that the algae grew about 1 gram more in a 100mL sample per day for 4 days. At the end of this experiment, I measured that the growth of algae in a 1.89 liter bottle over 5 days had 120 GRAMS OF DRY ALGAE BIOMASS!

The implications of this technology extrapolated to a multi acre farm (holding millions of gallons of water) is impeccable!

Algae production system using night cycle LED by Josh Wolf.



## Algae Integrated Management System (AIMsys™) Introduction

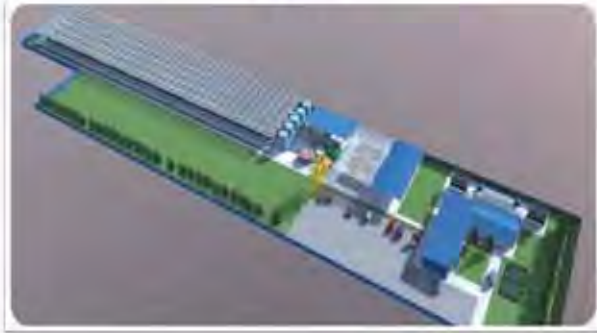


- Algaetech's Algae Integrated Management System (AIMsys™) is an approach method for designing a single cultivation system for various products such as biofuel, food, feed, and High-value Products.
- AIMsys also denotes the method of integration of various systems into a single system which cultivator and processes algae into dry powder for further refining process based on the product.
- The AIMsys™ offers:
  - High quality sensors
  - Triggers or alarms for any lowest or inconsistent conditions
  - Remote control system for monitoring and immediate corrective action
  - Customized report and analysis

AIMsys™ is divided and composed of four main operational processes:



### Layout



## Algae Integrated Management System (AIMsys™) Key Processes and Equipment

### Stage 1: Culturing/Cultivation - Process

- The following process is culturing, which is also known as the Photo-Bioreactor (PBR) stage and it comprises of two categories:
  - Dark stage:** The media is first injected into the **RESERVOIR TANK** with the algae; this stage is called as the dark stage. This tank acts as a circulation buffer for the algae culture in the circulation process of the PBR.
  - Light stage:** The light stage takes place in the **PHOTO-BIOREACTOR TANK**, enabling the cultures to undergo photosynthesis and cell division, which allows the biomass to increase.



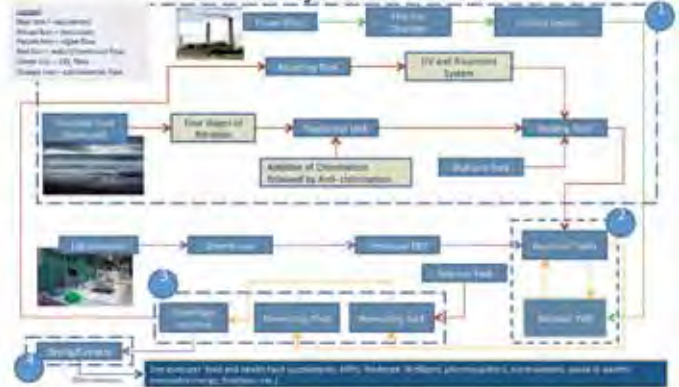
## Algae Integrated Management System (AIMsys™) Key Processes and Equipment

### Stage 4: Bio-Refining - Equipment

- (1) Biomass Drying**  
The wet biomass will undergo either a natural drying process using sunlight or other drying processes using a spray dryer, drier or drum rotary. The final product will be obtained in flake form. The flakes will be crushed into small particles. This will be then formed into algae cake which is also known as dry biomass.
- (2) Refining**  
Depending on the intended purpose of the algae (for e.g. Bio-diesel), the dried biomass will be put through further refining. For example, the biomass may be fed through a solvent apparatus and purification for diesel extraction.



## Algae Integrated Management System (AIMsys™) Overview of Process Flowchart



## Algae Integrated Management System (AIMsys™) Key Processes and Equipment

### Stage 1: Preparation - Equipment

- (1) Seawater Tank**  
This is to store seawater.
- (2) Treating Water Tank**  
The seawater is sterilized in the treatment tank just before culturing by chloramination/dechloramination.
- (3) Holding Tank**  
The function of this tank is to store the cleaned and treated water before it is utilized in the following processes. The capacity of stored water is 35m³.
- (4) Nutrient Tank**  
This is where the nutrient (macro nutrients, micro nutrients, vitamins etc) are stored. The nutrients will pump together when the water enters the reservoir tanks.



## Algae Integrated Management System (AIMsys™) Key Processes and Equipment



### AIMsys™ Sensors

Location	Sensors
Seawater Tank	pH sensor, level sensor, salinity sensor, temperature sensor, flowmeter
Treating Water Tank	pH sensor, level sensor, temperature sensor
Holding Tank	pH sensor, temperature sensor, level/pressure sensor
Nutrient Tank	pH sensor, temperature sensor, level sensor, flowmeter
Reservoir And Photo-Bioreactor (PBR)	ORP, pH sensor, level/pressure sensor, temperature sensor, cooling system (PBR), oxygen capture line, PBR system, DO probe
CO <sub>2</sub>	Flow gas, flowrate controller attached one every mixing reservoir tank
Harvesting Tank	pH sensor, level sensor, temperature sensor
Harvesting Pond	pH sensor, temperature sensor





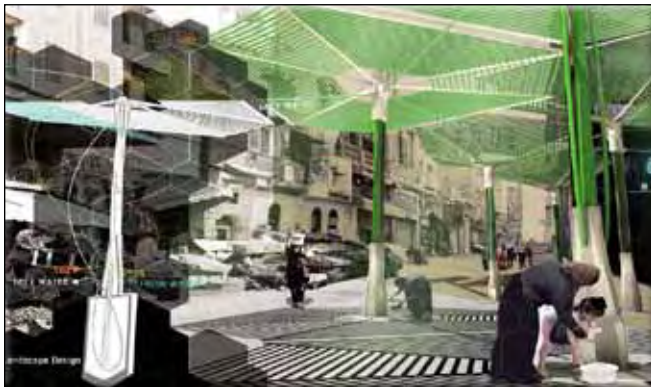
## Algae Landscape Design and Architecture

Enhancing quality of life in the developing world



### Algae powered mushroom farm in Congo, Africa

A mobile mushroom farm can be placed anywhere in the world to support micro-economic development in poverty stricken regions. The farm will grow mushrooms because of easy cultivation and high yield. Algae will be a food source and provide fertilizer. Two target groups are urban homeless and rural poor. Congo-Kinshasa in Africa was selected for the first farm. The farms are lightweight, easily shipped and hand carried to sites. Four farms can be shipped in a 40' container.



### Restore: Symbiosis within a community

Restore is an algal shading device that uses algae's photosynthetic process to purify water and air, while producing biomass in the form of cooking oil for household consumption. During the day the canopy opens up to face the sun, providing shade for the street, and at night folds up to provide a view of the stars, while the bioluminescent algae continues to flow through the tube system emitting a radiant glow. Restore is intended for desert climates with limited access to clean water.



### Project Bio-Slum in Jakarta, Indonesia

Located in the wetland of WadukPluit in the Jakarta Penjarangan slums, Bio-Slum offers an alternative to palm oil for biodiesel, avoiding deforestation. The project fuses algae into daily activities, with an upper green layer shading the residents below. It works within the current urban landscape through the addition of algae canals, algae pools and algae reservoirs. Algalaculture offers a means to produce biofuel, harmonizing production and consumption.



### Growth for recovering communities in Haiti

Algae Connects is a systems solution for clean water and food production in communities affected by disasters. One component is the algae connector, a device that uses algae to absorb water pollutants, filters algae from water and transports cleaned water. The Bio-Inspired Design Community is developing a solution with algae that addresses problems in Haiti after the 2011 earthquake. A roadmap describes barriers impeding progress and interventions to overcome those barriers.





## ALGAE POWERED MUSHROOM FARM

Our goal is to design a mobile algae powered mushroom farm that can be placed anywhere in the world and will support the development of micro-economic development in poverty stricken regions. The farm will grow mushrooms because of their easy cultivation and high yield production. The algae will also be used as a food source and to provide organic fertilizer for the mushrooms. The two main target groups to support the farms would be urban homeless and the poor of rural communities. We chose to explore the development of the farm in a rural environment, and selected the Congo-Kinshasa region of Africa for the first farm. The area has one of the poorest populations in the world. The area has abundant rainfall and can easily provide the water needed to grow the algae. The algae powered mushroom farm becomes a micro-economic intervention to help provide a stable food source, purify water, create small profit centers for villages, and most importantly teach a new farming skill/trade. We would most likely use several varieties of algae including a Blue Green Algae, Chlorella, and Chlamydomonas Rein. The algae would be used for food, as organic fertilizer for the mushrooms, to purify rain and river water, and to provide biofuel to operate the mushroom farm.

The algae will be housed in 16cm tubes that wrap the exterior south side and roof of the structure. A simple valve at the bottom of each tube will be used to drain the algae into a filter at the end of each day. The algae would be dried on racks. The algae would be feed primarily by river water and by the CO<sub>2</sub> given off from the mushrooms.

Mushrooms provide a simple easy crop to grow with a high sale value. A local mushroom variety or a button mushroom would be used. One square meter of area can produce 30 kilos of mushrooms and would generate 7 harvests a year. The algae would be used as organic fertilizer for the mushrooms. The carbon dioxide given off from the mushrooms would be pumped into the algae tubes to feed the algae. So the combination of the two plant species would help feed each other, and both can be used as food for the villagers.

The farms are designed to be lightweight and easily shipped and carried by hand to rural sites. Four farms can be shipped per 40' shipping container.

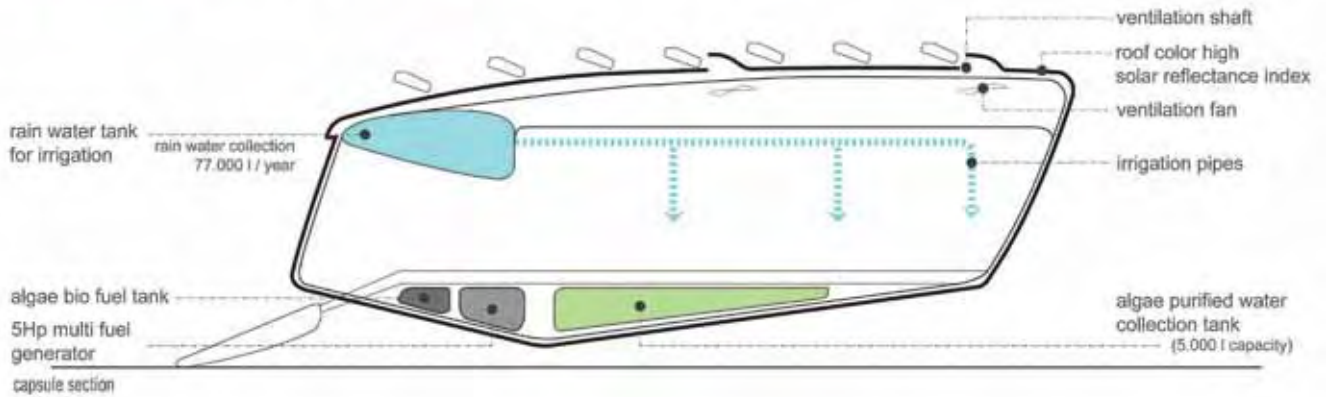
The farms consist of a simple box clad in an insulated aluminum panels. This skin provides the insulation, façade skin, and water barrier in one very lightweight material. A lightweight aluminum frame supports the façade panels and a series of shelves upon which the mushrooms are cultivated. A series of plastic tubes that contain the algae will wrap the exterior of the aluminum box. The power for the mechanical and lighting system will be generated by biodiesel produced from the algae-minimal solar panels will be used as a back-up power source.



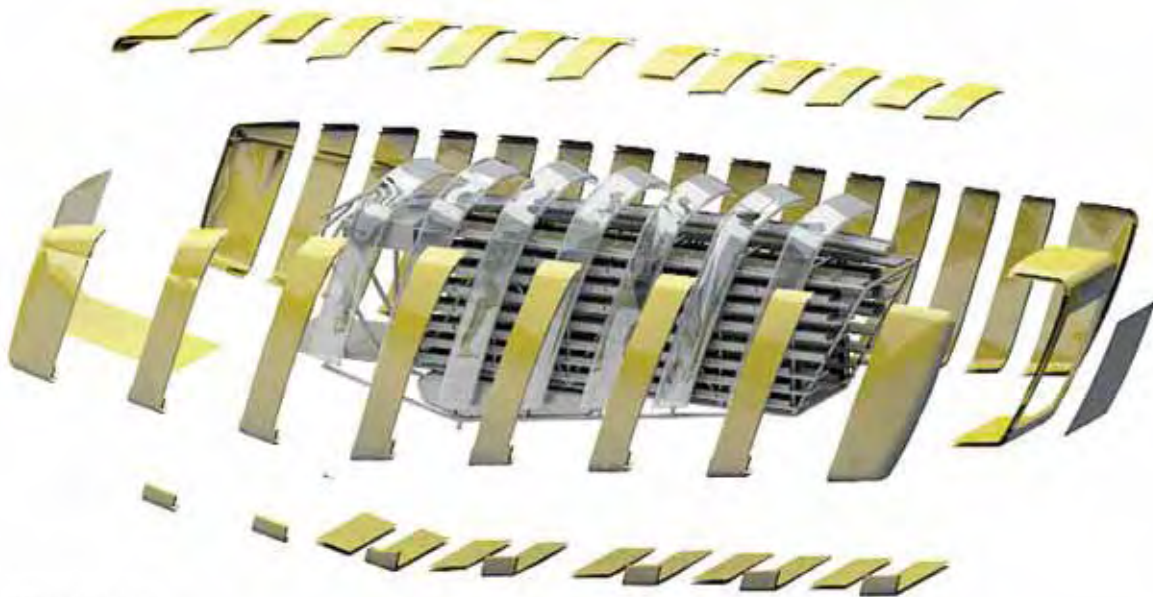
Algae powered mushroom farm in Congo, Africa



# ALGAE POWERED MUSHROOM FARM



assembly schematics AX0



assembly schematics phases



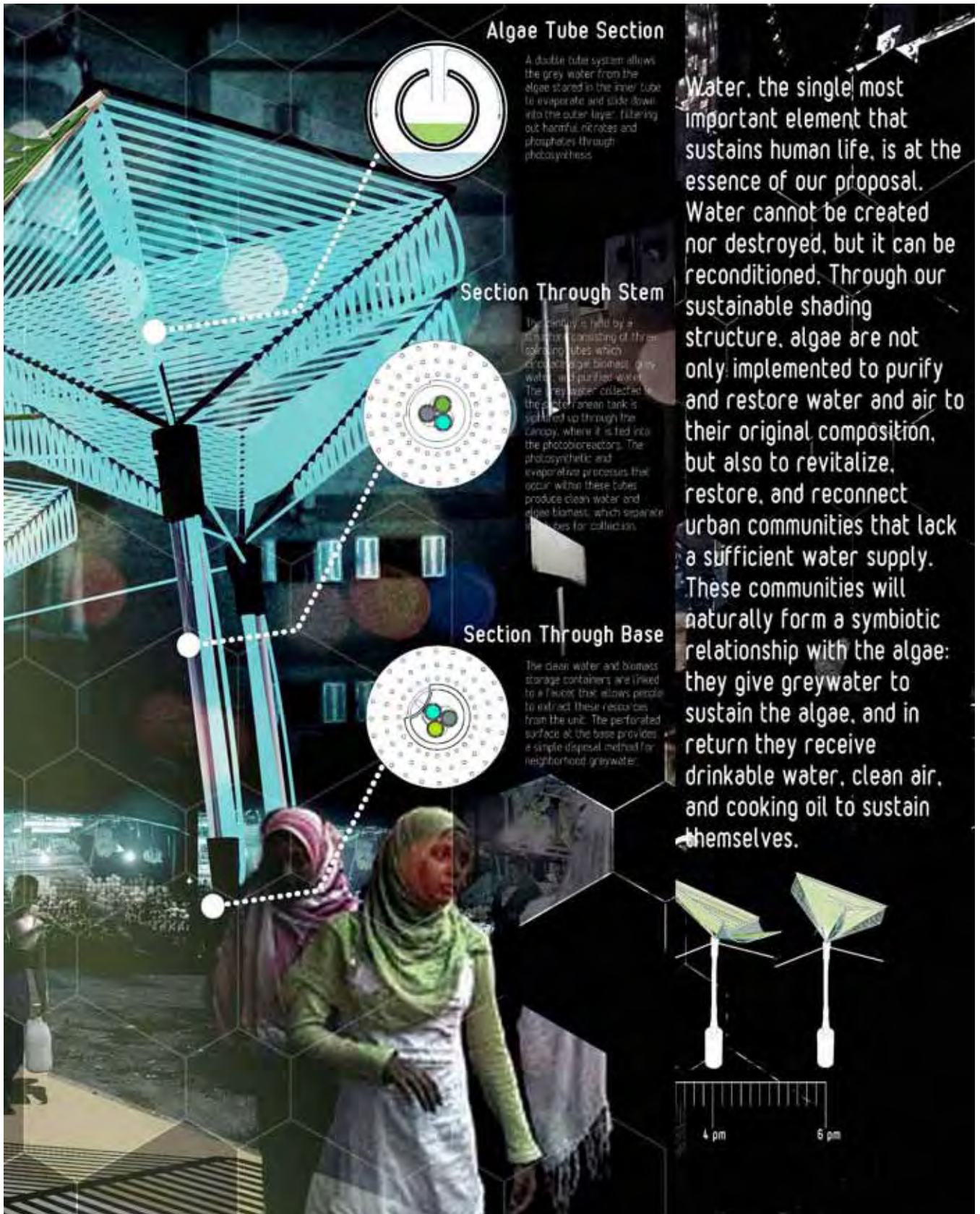
by 10 Design Group, Ted Givins





Restore: Symbiosis within a community





by ArquitectonicaGEO: C. Zavesky, R. Conover, G. Fort, F. Romero, A. Montás



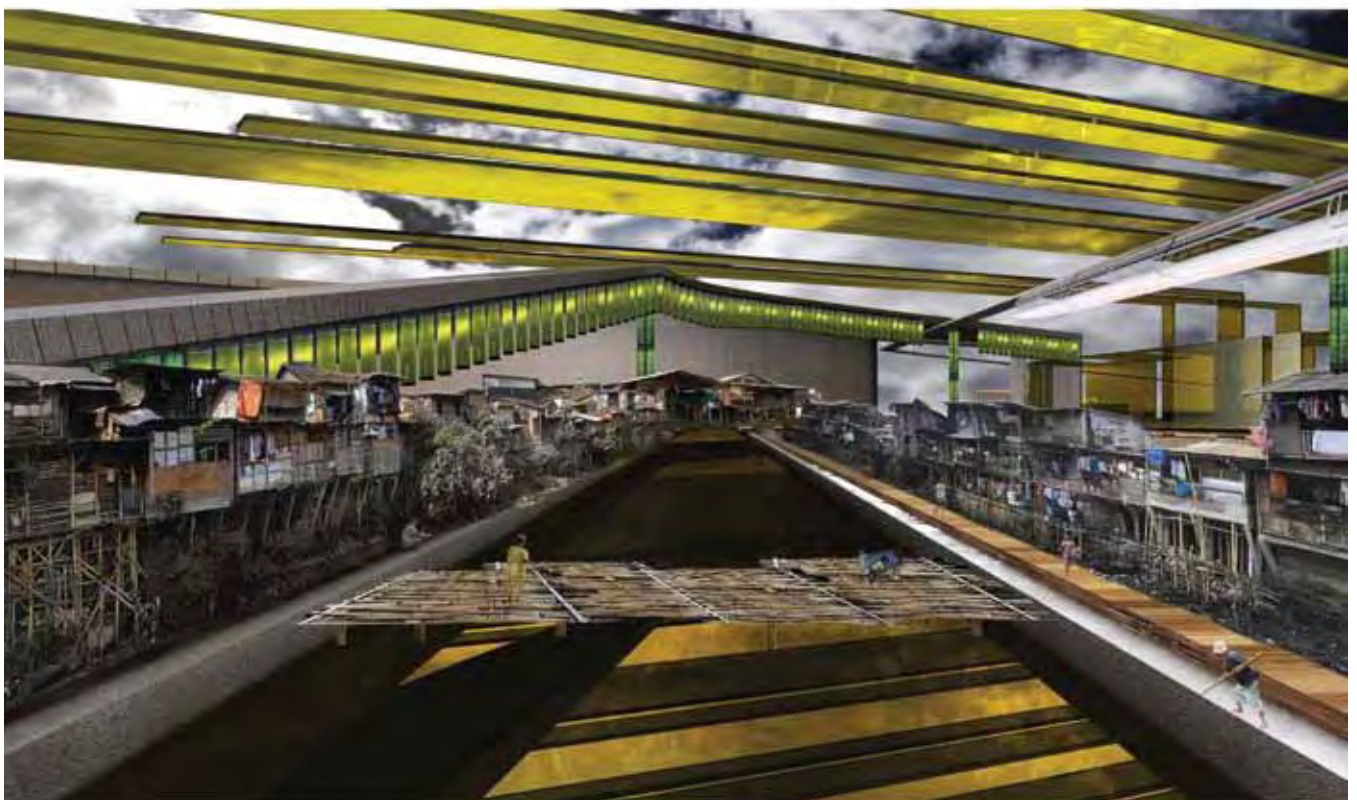


## Project Bio-Slum

Project Bio-Slum locates itself within the Indonesian wetland of WadukPluit in the slums of the Jakarta Penjaringan district. The project addresses and seeks to mollify certain climate change issues, local environmental and sanitary concerns, as well as local poverty issues. In essence, the project gives an alternative scenario which engages algaculture with both urban settings and issues.

Pervasive environmentally degrading activities such as deforestation, peatland and wetland destruction, as well as forest fires have resulted in Indonesia's placement among the top three emitters of greenhouse gases in the world (DFID 2007). As recently as 2008, Indonesia was declared as the country with the fastest rate of deforestation (Greenpeace 2008). Primarily, greenhouse gas emissions stem from this vast deforestation (ibid; Williamson 2007). However, although emissions from energy and industrial sectors are currently nominal in comparison, they are increasing at a rapid rate.

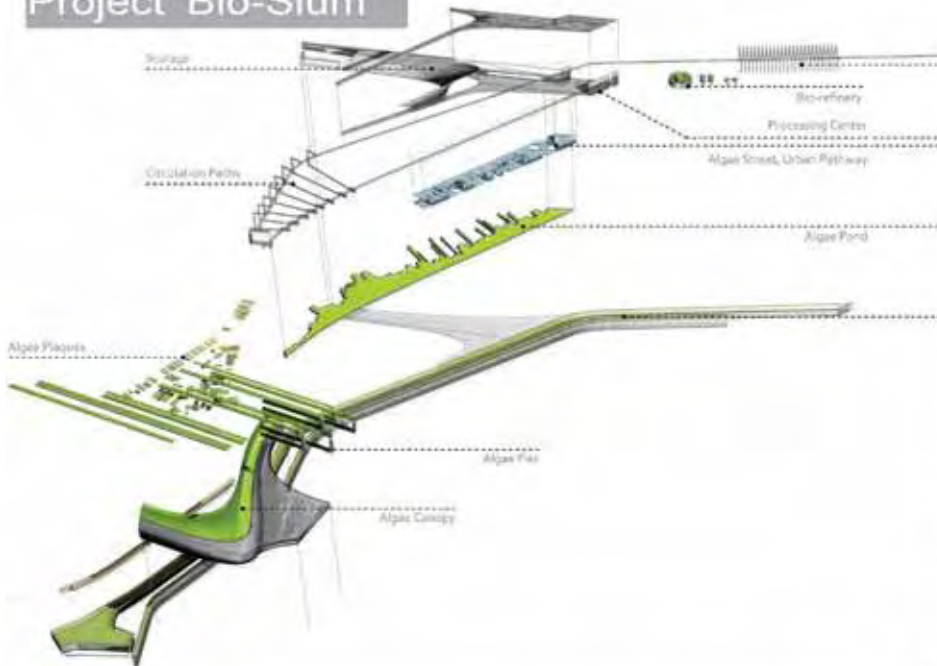
The project offers an engagement between algae farming and the very conditions of the proposed site. It integrates daily life into the process of algaculture, which in turn provides what is needed for the cycles of production and enriches the conditions of the inhabitants. Therefore, ultimately harmonizing and tying production and consumption



Project Bio-Slum in Jakarta, Indonesia

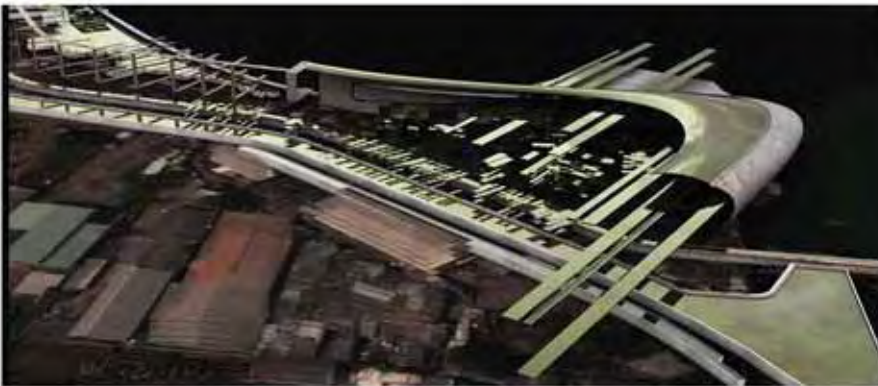


## Project Bio-Slum



Project Bio-Slum presents an alternative to palm oil production in terms of meeting the increasing demand for biodiesel. Instead of requiring the use of new land, the proposed project works within the current urban landscape, thus avoiding deforestation. The project offers a productive infrastructural network which is tied into the existing scheme on the site as the project is integrated into the existing crisscrossed systems through the addition of algae canals, algae pools and algae reservoirs. Algae culture, which is implemented into the infrastructural mesh, offers a means to mass produce biofuel. The cultivated bioenergy could be used either on site or alternatively as a source of income and thus a means of mollifying the high levels of unemployment in the territory. Additionally, the project has the potential to spark an increase in knowledge of environmental matters on the site as well as broader climate change issues.

Due to a weak infrastructural background, the site is currently subject to precarious conditions as access to clean water and sewage or waste treatment is absent (Conley 2008). While providing the infrastructural needs on site, such as wetland treatment, sewage systems, transportation and circulation links, the project aims to make efficient use of the collected matter to be used in algae farming such as waste water or the carbon dioxide released by wetland treatment on the shoreline. The project proposes additional circulation pathways, open spaces, and squares that are embodied with algaculture. Furthermore, the project uses the dynamics of the slum area and fuses algal activities into the scope of daily activities. The algal infrastructure relates with the site as a horizontal expansion at some points, creating an upper green layer where larger spaces can be realized in providing shading to the residential areas below.



by Tolga Hazan

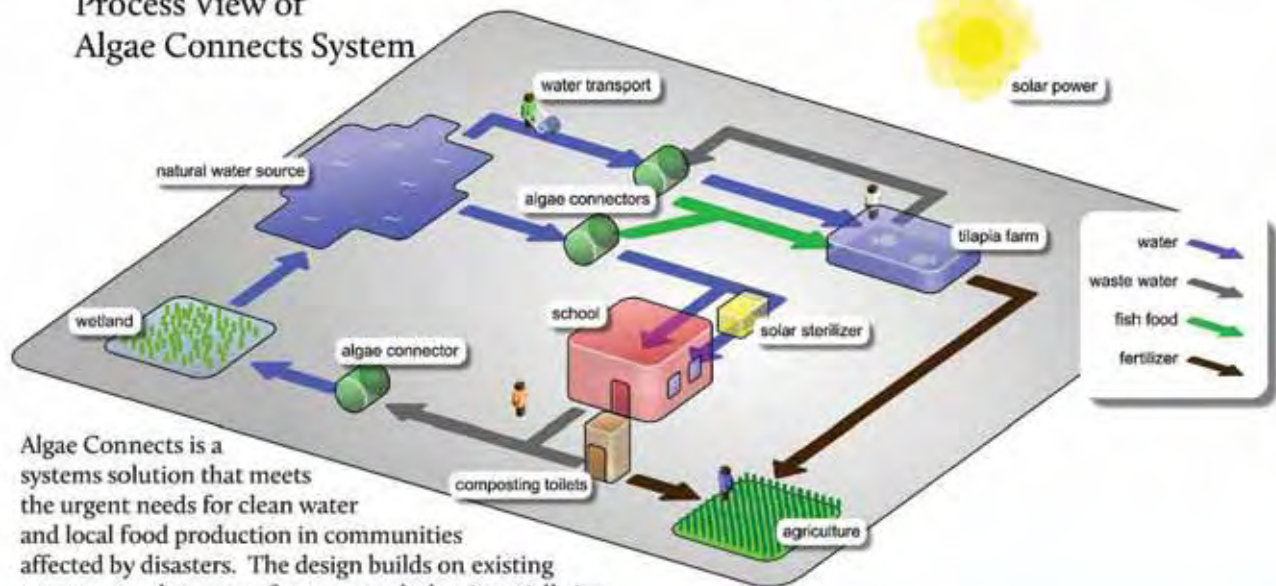


# Algae Connects

Stimulating a Future of Growth for  
Recovering Communities



## Process View of Algae Connects System



Algae Connects is a systems solution that meets the urgent needs for clean water and local food production in communities affected by disasters. The design builds on existing resources and supports future growth that is socially just, environmentally sensitive and economically viable.



Stimulating growth for recovering communities in Haiti by Algae Connects, Norbert Hoeller & team



## Algae Landscape Design and Architecture

### Restoring natural environments and polluted landscapes



#### The Wilderness Catalysts in Czech Republic

Cultivating and discharging cyanobacteria as a catalyst for natural wildlife is a method of intervention for extremely devastated landscapes. Due to its adaptive features, NASA proposed cyanobacteria as a basis for creating life on Mars. It is used as a soil conditioner and biofertilizer to improve sandy soil. This project is proposed for the brown coal basins in Czech Republic. *Nostoc* cyanobacteria can survive these conditions, absorb soil toxicity, and serve as biomass for further succession.



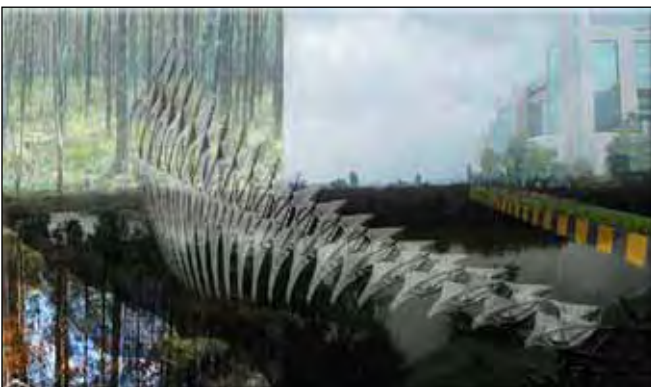
#### Shoreline regeneration by algae in Cigu, Taiwan

Historically, Taijiang Inland Sea was surrounded by offshore sandbanks, home to thousands of fishing boats. Now lagoon and sandbanks are disappearing. Algae is the base of the food chain and is needed to build a new ecosystem. Fish farm emission water will grow algae to construct an eco-loop, using oyster shells to make an algae cultivating oyster reef, creating wetland to attract wild fish, crabs and animals, and planting mangrove and coastal plants to attract wild birds.



#### The Green Pit and German Expo Pavilion

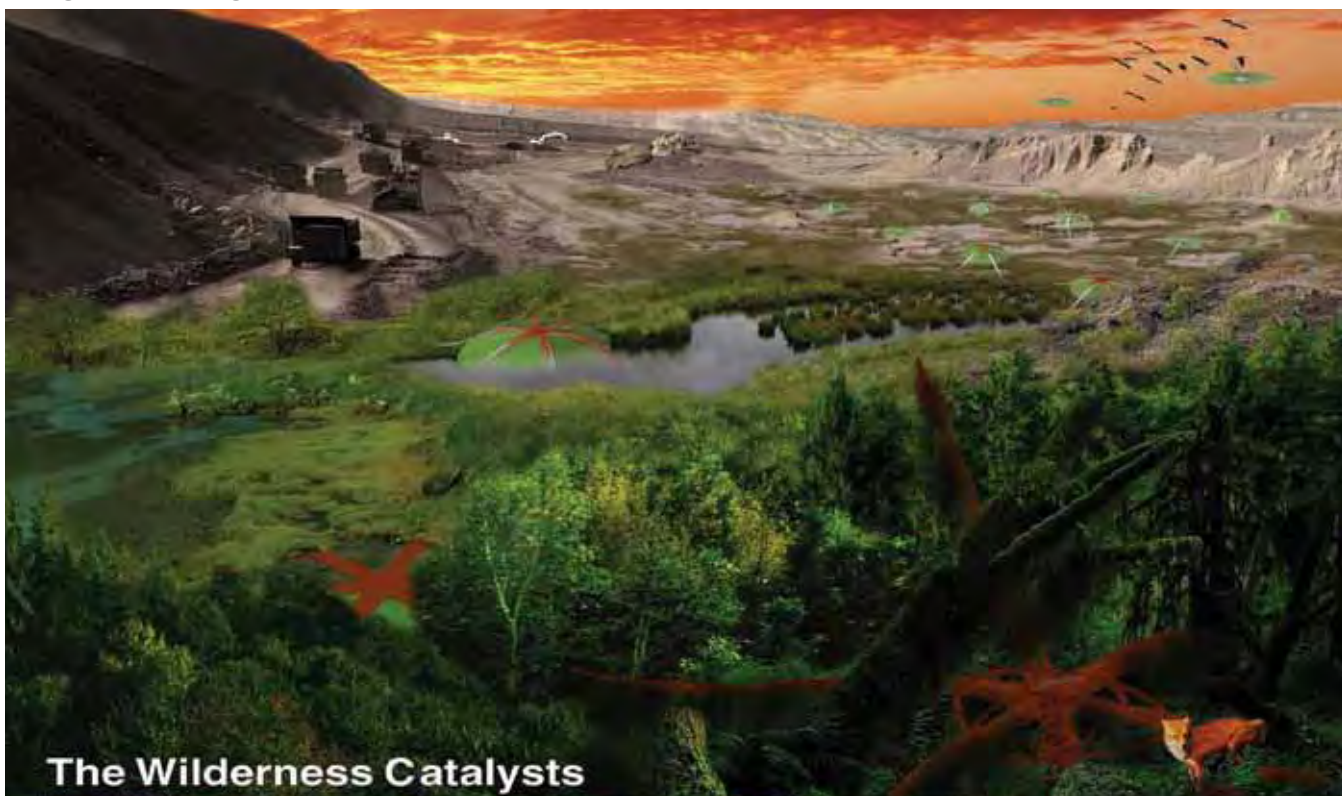
Many former coal mines in Germany are abandoned and flooded. Consequently, by 2015, Germany will be the country with the most artificial lakes in Europe. This approach is to flood pit mines and use them as cultivated areas for microalgae. In many cases, CO<sub>2</sub>-emitting coal-burning power plants can be found in the neighborhood of those mines. The 'Green Pit' Pavilion represents past, present and future and consists of an oversized bio-reactor for micro-algae.



#### A new marshscape in Mumbai, India

*Echoes of an Ecos.* From algae incubators to bio-filters, a living machine: a hybrid algaescape in Mumbai's marshes, a connecting tissue between the urban fabric and the ecological mesh of a marsh. The function of this hybrid landscape is to act as water collector and filter, the primary function of a marshland, by weaving algae for energy production into the urban fabric. *"Ecology and urbanization pirouette around each other in an intellectual ballet"*.





## The Wilderness Catalysts



### brown coal basins - North Bohemia

After the mine is exploited a crater remains on the surface and the re-cultivation process is started. Usually the aim is to create agricultural land and recreational areas. Most of the mines are flooded with water what brings another layer of engineering works to the site and causes further changes in the natural environment of the area and the river ecosystem.

There are existing concepts of leaving those places fully back to nature and in many cases the reclaiming proceeds faster than the mining itself. However this fails to perform in locations with exposed toxic soil. The mine Bilina is the most cited example of such. For the reason of high presence of stripping rocks there is an occurrence of phytotoxic areas with large amount of coal mass. Areas like this are unsuitable for life.

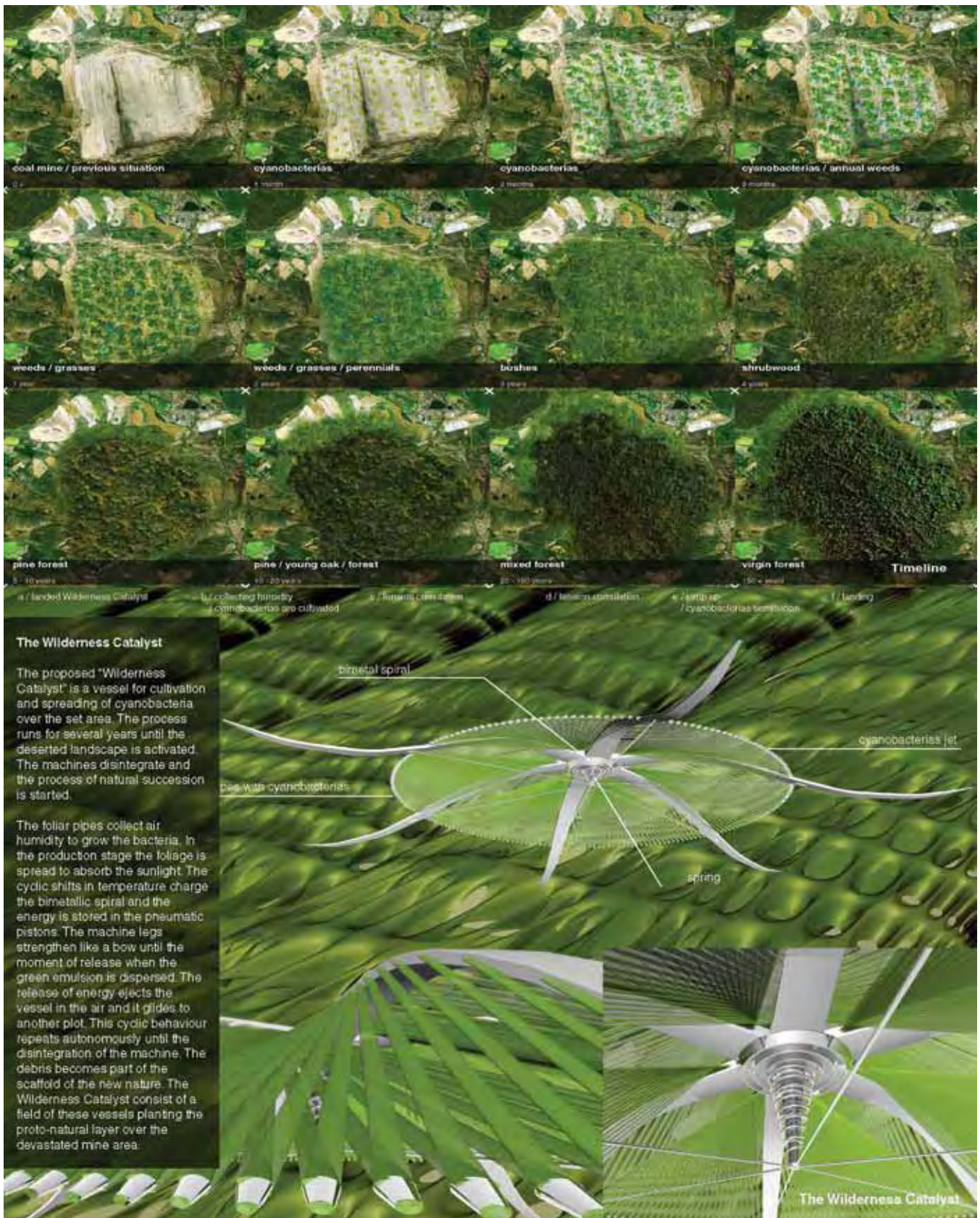
The nostoc genus of cyanobacteria can survive these conditions and absorb the toxicity of such soil and therefore be the catalyst of new life.

The proposed "Wilderness Catalyst" is a vessel for cultivation and spreading of cyanobacteria over the set area. The process runs for several years until the deserted landscape is activated. The machines disintegrate and the process of natural succession is started. The field of these vessels plants the proto-natural layer over the devastated mine area. Taking into account the topological shape of the Bilina locality and the predominant wind direction, the principal movement direction of the vessels is eastwards. The starting nodes are concentrated on the west edge of the mine and gradually fall off towards the east. This organization guarantees even distribution of the bacterial layer and precipitate the start of the process of recovery.

### Bilina coal basin

## The Wilderness Catalysts in Czech Republic





by Collaborative Collective: M. Davidová, K. Hanzlík, M. Dlouhá, M. Krejčí, J. Zatlukajova

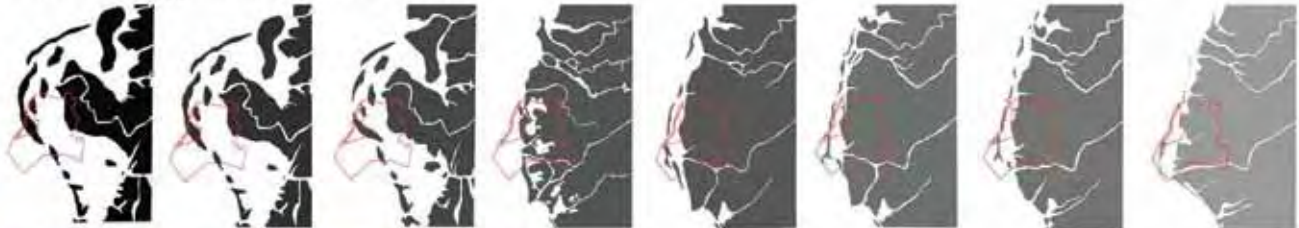


# A Sinking Shore Story

## the shoreline regeneration by algae cultivating in Cigu

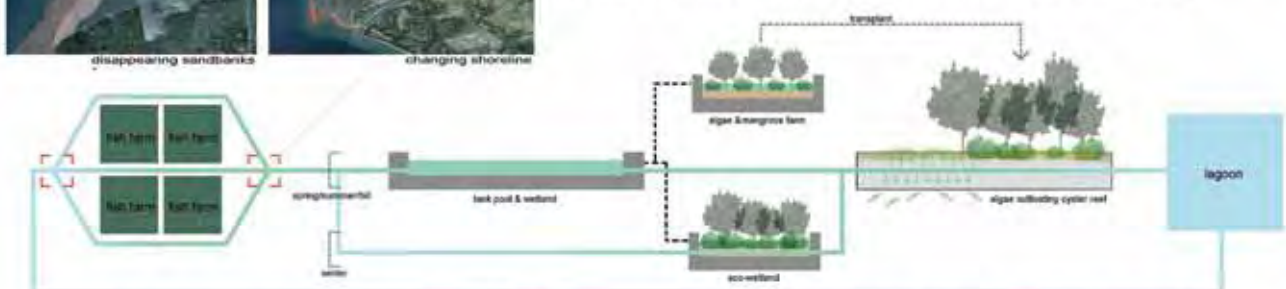
In history, Taijiang Inland Sea, a vast water surrounded by seven offshore sandbanks, has the large scale which allows it to ship thousands of boat.

As time goes by, there was some dramatic landscape changing in Taijiang. Now the Taijiang inland sea becomes the biggest lagoon in Taiwan, it locates in Cigu and surrounded by three sandbanks. This lagoon as a natural fish farm supports Cigu become the biggest fishing area in Taiwan.



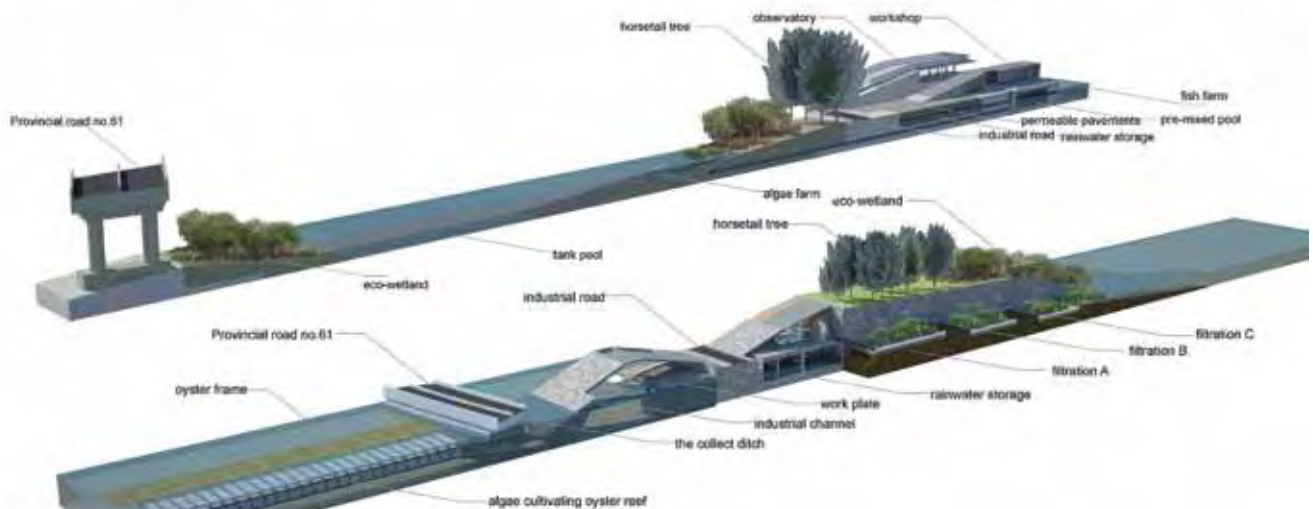
However, because of the building of the sediment dam and the sea level rise, the three sandbanks are disappearing. That means the lagoon will disappear with the sandbanks. If lagoon is gone, the fisheries in Cigu will have a huge impact.

Besides, the changing of the shoreline will expose Cigu to the great waves, strong wind, and flooding. Therefore, before the lagoon disappears entirely, the new shoreline should be created to sustain the fisheries and environment.



Collect the fish farm emission water and use its eutrophicated ingredient to grow the algae to construct a basic eco-loop and plant mangrove and coastal plants, also, create wetland to attract wild animal, the eco-wetland can produce bioorganic water all the year. In winter, there would have enough eutrophicated water for the oyster.

Use the abandoned oyster shell to make algae cultivating oyster reef, the reef can help sand and algae to attach, the emission of eutrophicated water flows through it, the eutrophicated ingredients not only help the algae and mangrove grow but attract wild fish, crab, and oyster, then transplant the coastal plants grew by the fish farm emission water, as time goes by, the plants could provide wild bird to hide and the little creature could be birds' food, a new shoreline ecosystem is building.



Shoreline regeneration by algae cultivation in Cigu, Taiwan



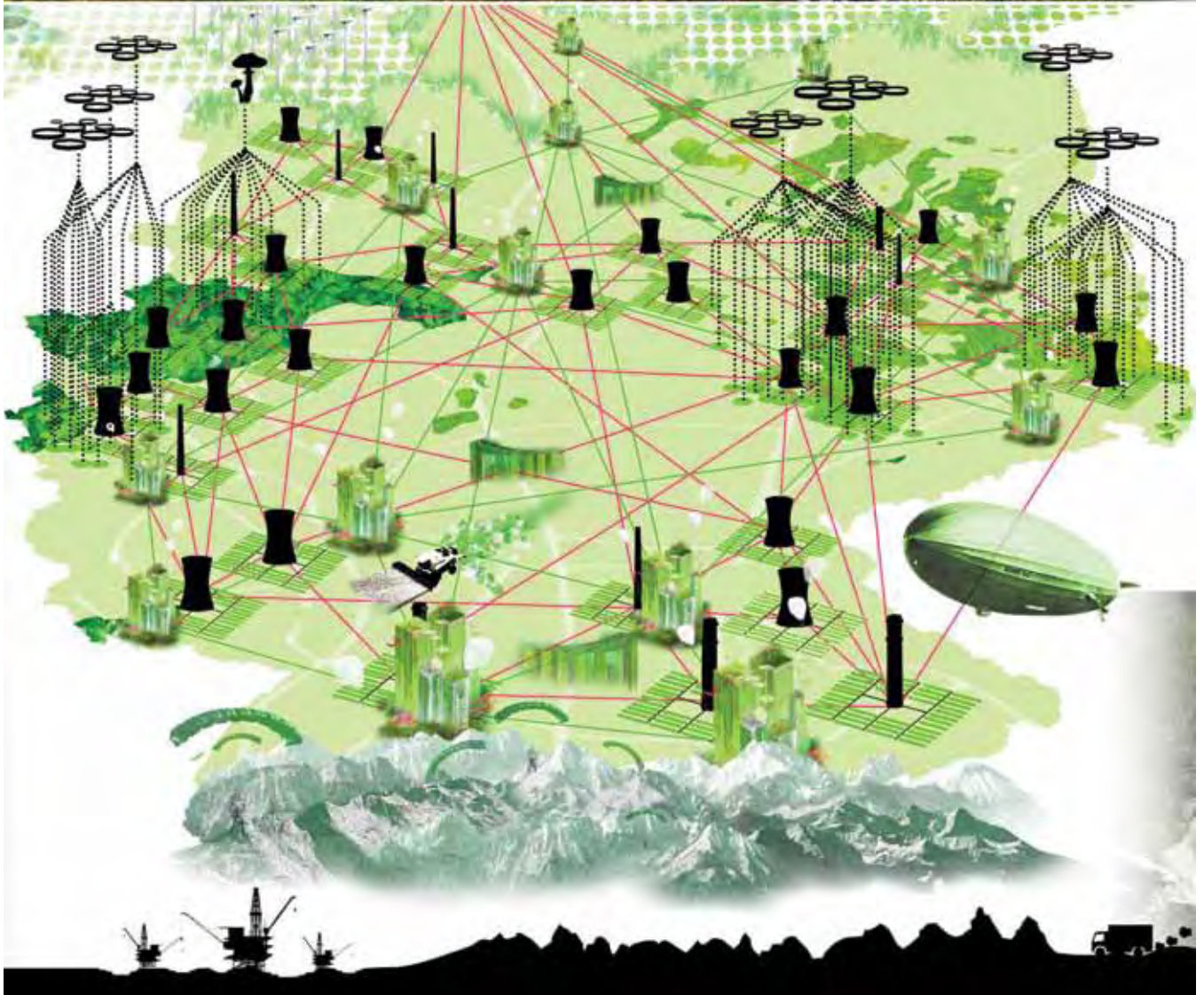


by Yen Chang Huang



*Green coal - the Pit lake - Farm*

# Grüne Zeche (the green pit)



The Green Pit and German Expo Pavilion 2015 Milan





by Hannes Maier



INCIDENTAL PLANNING

TEMPORAL CHANGES - SUCCESSION

EVOLVING CITY

ENERGY PODS EXPERIMENTAL CITY

EMERGENT SYSTEM EXPERIMENTAL CITY

AQUACULTURE POCKETS

ALGAE INCUBATOR

EXPERIMENTAL CITY

THE SCHOOLS AS THE GENERATOR FOR THE SYSTEM

ALGAE GROWTH CORRIDOR

THE LIVING BUILDING THE AGRICULTURAL AND AQUACULTURE TOWNS

EXPERIMENTAL CITY

PLANT DISTRIBUTION

HYPERLOCAL PLANT POCKETS

EXPERIMENTAL CITY

IN BUILDING

CULTURAL CORRIDOR

N

68



## Algae Landscape Design and Architecture

Innovating the traditional seaweed and marine algae industry



### AlgÔ, the regeneration of Baie de Morlaix in France

The Baie de Morlaix in Brittany is regarded as one of the last French estuaries not totally destroyed by human impact. It is famous for its goemoniers, 19th century seaweed collectors who went to sea to gather seaweed for medical purposes and natural fertilizers for agriculture. Nowadays they have all but disappeared and the seaweed population is poor and damaged. AlgÔ is a proposed floating seaweed farm, a fiber concrete structure with aerogel insulation and natural ventilation.



### Master plan for floating new town in Scotland

Seaweed farming has a rich heritage in Scotland on remote islands. Harvesting seaweed this way requires a huge consumption of land and is labour intensive. This is a master plan with an algae farm integrated in the town landscape in the estuary of the Firth of Forth in Edinburgh. Daily life continues alongside the cultivation of fuel. Photobioreactor tubes weave around buildings and link islands of the new town. This urban farm provides biomass to fuel the energy needs of the inhabitants.



### Rigs to Reefs in the North Sea

Converting the North Sea 'Frigg' Oil Rig into an Algae Powered Whale Sanctuary. Many North Sea oil rigs built in the 60s and 70s have a short lifespan. Can another use for these colossal structures be found instead of being scrapped? Rigs to Reefs attempts an energy swap from black to green, moving on from our oil addiction to a more environmentally friendly energy commodity, algae. Floating sea walkways establish a marine ecosystem attracting sea life and whales for visitors.



### Seaweed ethanol distilleries in Scotland

*Macro-Algae in the Micro Community*, utilizing Scotland's natural resources to generate sustainable economies. To reverse the decline in the seaweed industry, this project would reestablish an industry based on ethanol biorefineries. Differing scales of communities on the West Coast of Scotland would support the fuel demands of remote and rural communities and provide the socio-economic benefits generated by a new industry, generating fuel, fertilizer and bioplastics.

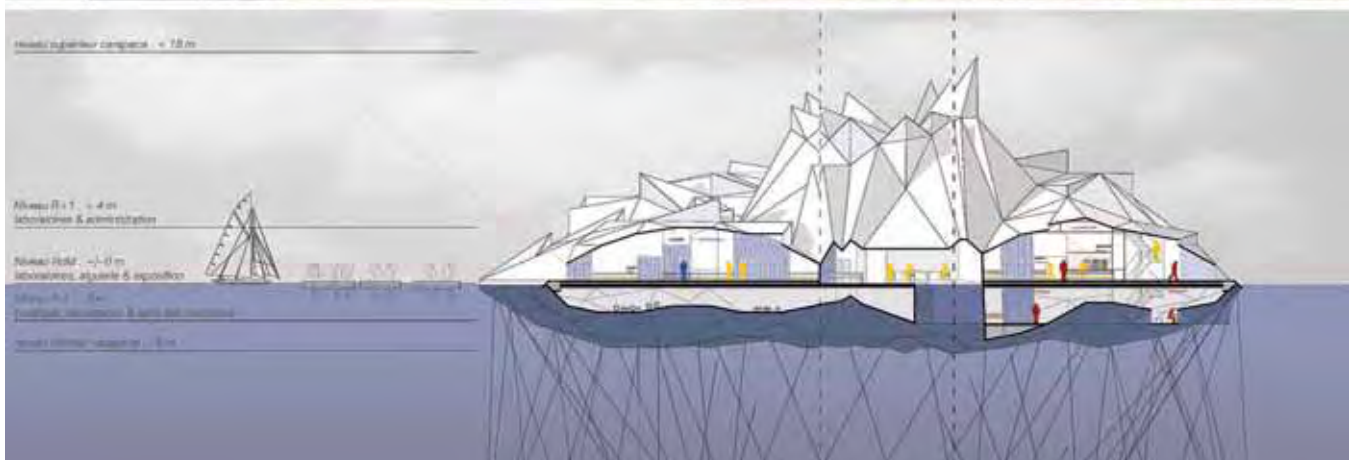


## AlgÔ, Or the regeneration of the Baie de Morlaix by seaweed

AlgÔ is an answer to a question about environmental risk, a major risk of the 21st century.

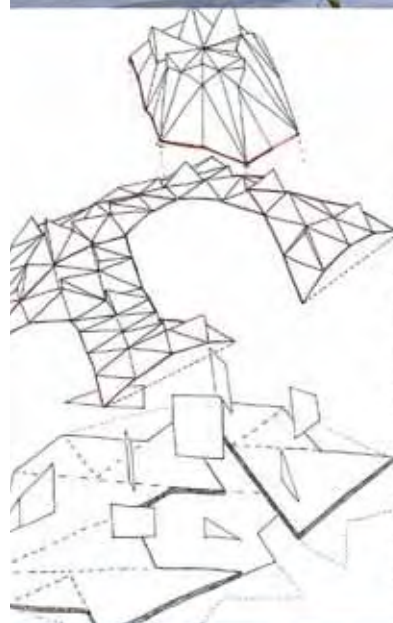
Seaweed, with its unique properties, could drastically improve the quality of life in the Baie de Morlaix.

AlgÔ is the implantation, in the Baie de Morlaix, of a floating seaweed farm.



AlgÔ, or the regeneration of the Baie de Morlaix in France by seaweed

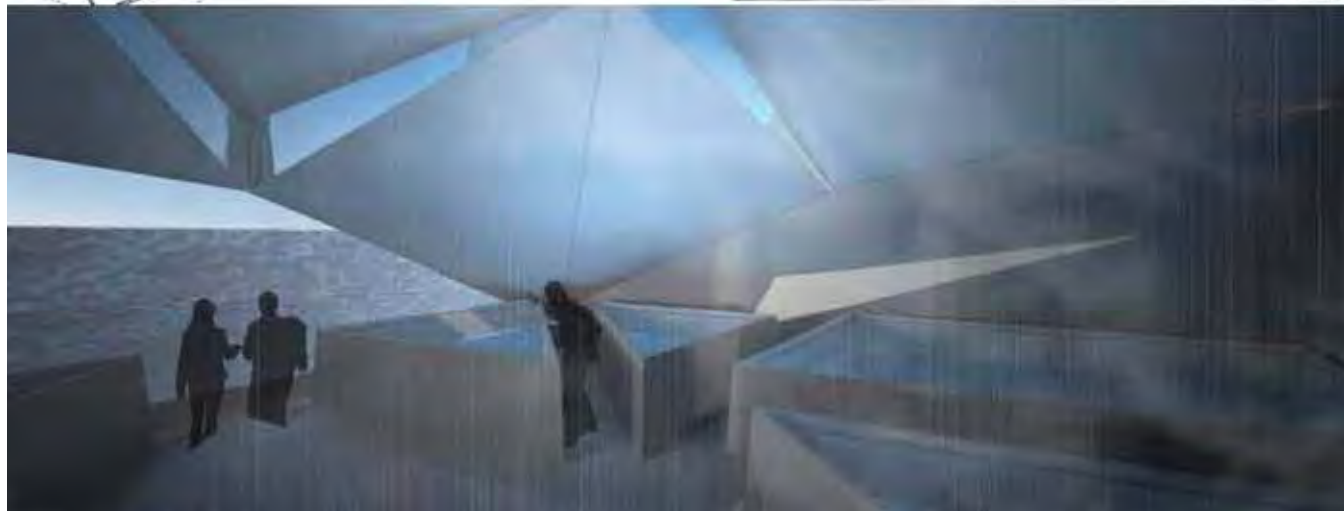




### ALGÔ: A REGENERATED BAY

It's a prefabricated structure in Fiber Concrete of Ultra High Performance which allows a great resistance and flexibility. Each part of the structure is made of thin triangles (17mm wide) clipped one to another. Aerogel insulation and natural ventilation in the shell can regulate the temperature and humidity of AlgÔ.

Technical obligations of this particular site lead to the use of this material that can perfectly be recycled and reused in ordinary concrete later on.



by Isabelle Bardèche

## Imagine Our Algae Future



This is a conceptual algae landscape design for an imagined town floating in the estuary of the Firth of Forth, Edinburgh, Scotland.

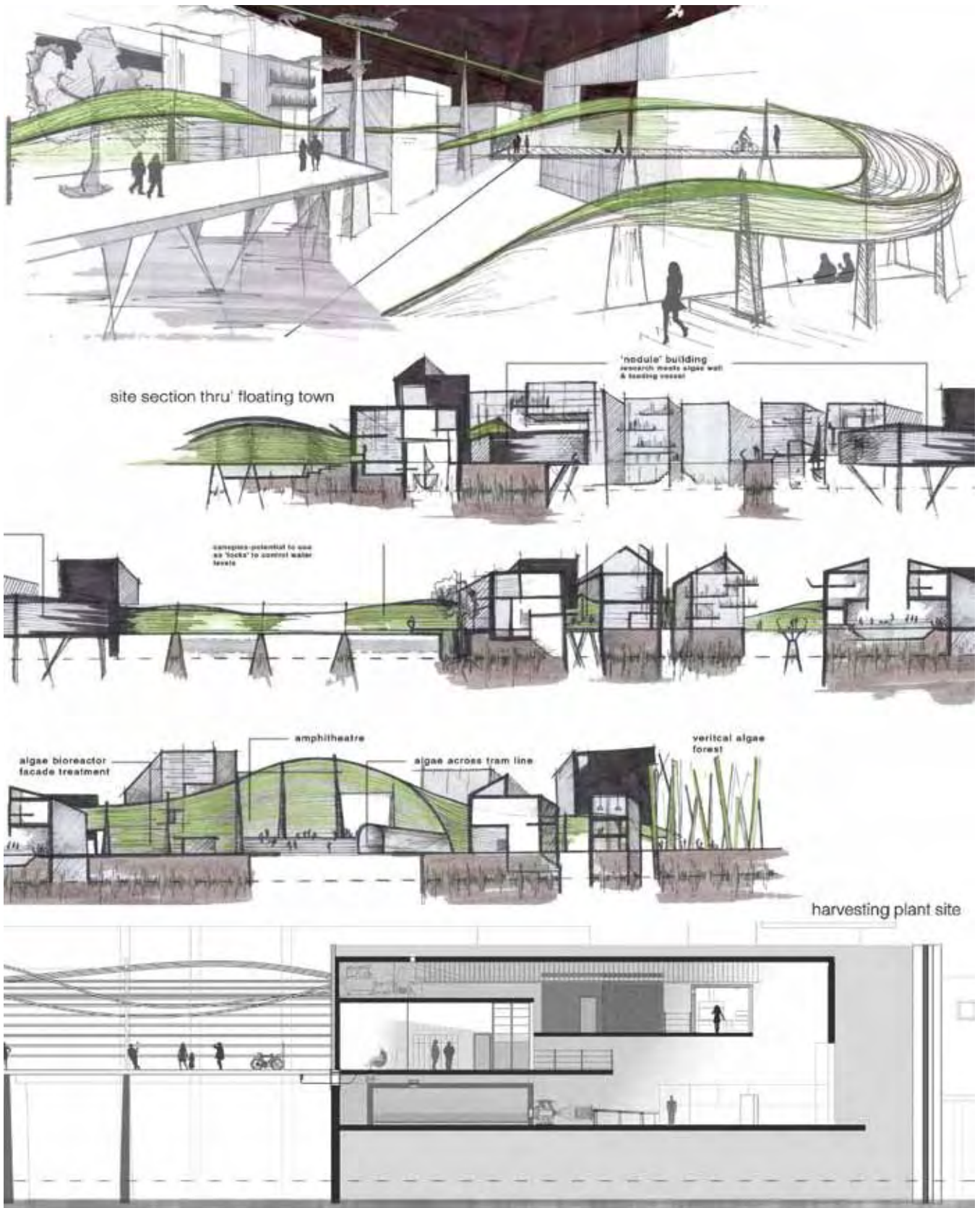
The tendrils of the algae farm will provide architectural infrastructure woven through the urban grain to generate sufficient biomass to fuel all the energy needs of the floating town.

The process is a continuous ecological cycle that circulates in illuminated phototubular bioreactors. The architecture of the algae farm responds to the needs of the people through the exploitation of the natural resource in a progressive move forward.

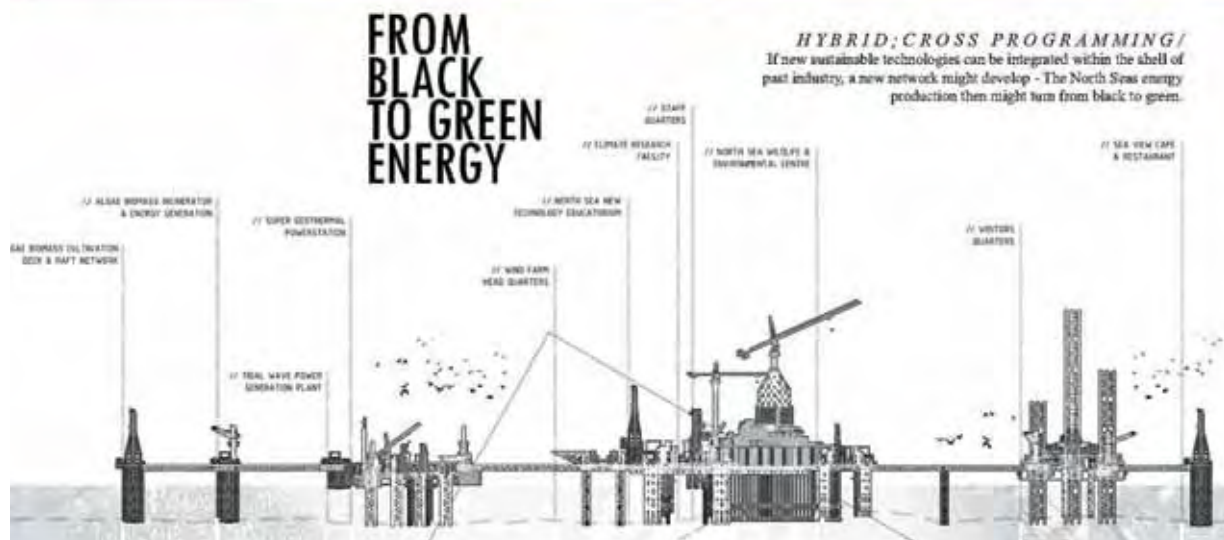
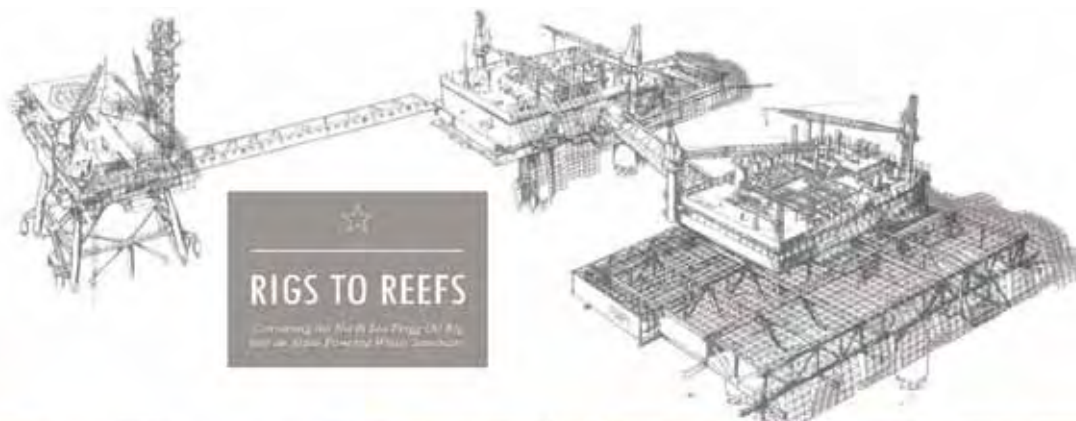


Master plan for floating new town in Edinburgh, Scotland





by Bebhinn Burke



Rigs to Reefs: Converting the North Sea 'Frigg' oil rig into an algae powered whale sanctuary



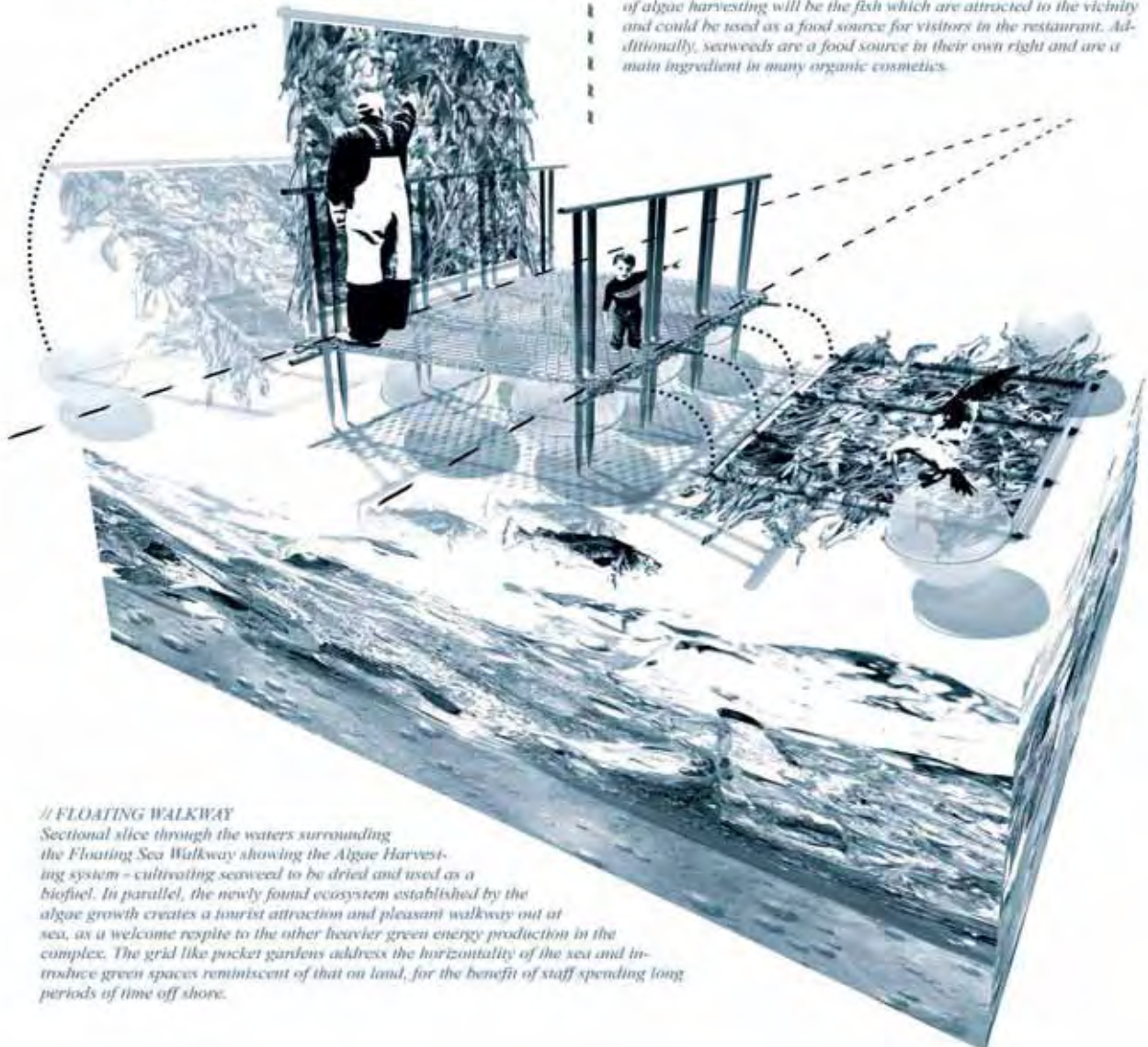


## Biofuel

Algae harvesting rafts at both sides of the floating sea walkway each have their own catchment nets which allow effective cultivation of seaweed. *Sargassum* and *Sargassum*, herded to the right parts of the ocean, will grow up to 40ft every year, absorbing about 36 tonnes of carbon dioxide in the process. These seaweeds are also popular fare for a variety of fish. The algae absorbs prodigious quantities of greenhouse gases and converts them to oxygen before being harvested 12 months later and then dried as a rich source of biomass energy. When blasted with superheated steam, seaweed discharges hydrogen and carbon monoxide gases that can be used to create a biofuel which in turn, discharges no extra carbon dioxide when burnt.

## Tourism

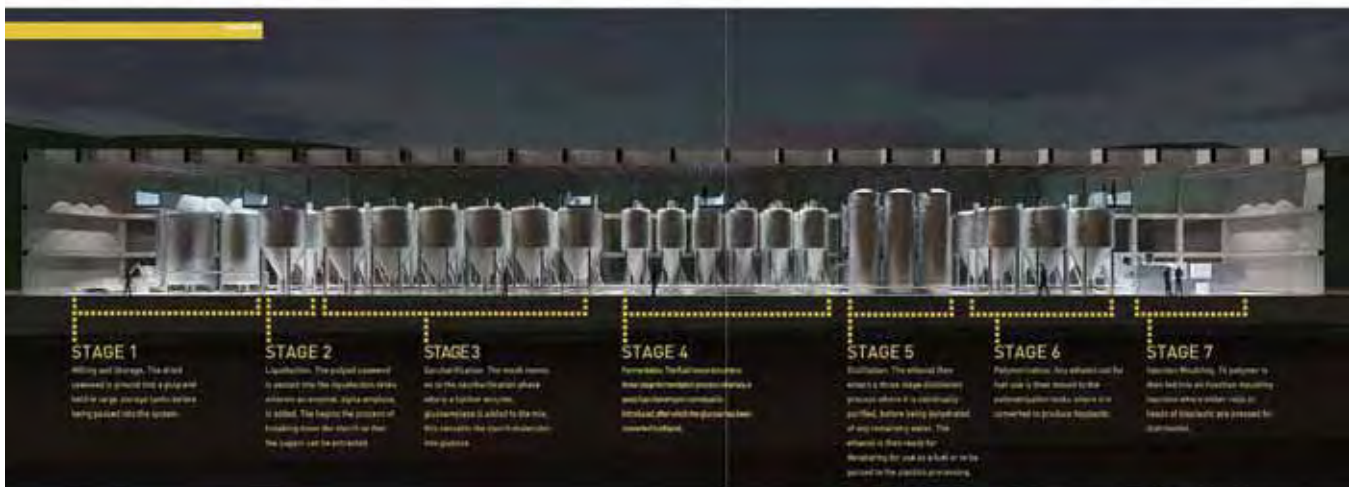
The floating sea walkways establish their own ecosystem since the selected species of algae contain the very building blocks of the food chain upon which all sea life depends. Fish,urchins and seals feed on the micro organisms associated with algae growth which in turn will bring sea birds such as Gulls and even the rarer Puffin and Guillemot. Creating this cycle of life will be an attraction in its own right creating much needed greenery and giving a context of sorts to an otherwise bleak and endless horizon. The pocket gardens on sea then, will be a fitting addition to the reuse of the oil rigs by addressing the planar horizontality of the sea as a natural contrast to the behemoth-like man made structures which spring from it's depths. By-products of algae harvesting will be the fish which are attracted to the vicinity and could be used as a food source for visitors in the restaurant. Additionally, seaweeds are a food source in their own right and are a main ingredient in many organic cosmetics.



### // FLOATING WALKWAY

Sectional slice through the waters surrounding the Floating Sea Walkway showing the Algae Harvesting system - cultivating seaweed to be dried and used as a biofuel. In parallel, the newly found ecosystem established by the algae growth creates a tourist attraction and pleasant walkway out at sea, as a welcome respite to the other heavier green energy production in the complex. The grid like pocket gardens address the horizontality of the sea and introduce green spaces reminiscent of that on land, for the benefit of staff spending long periods of time off shore.

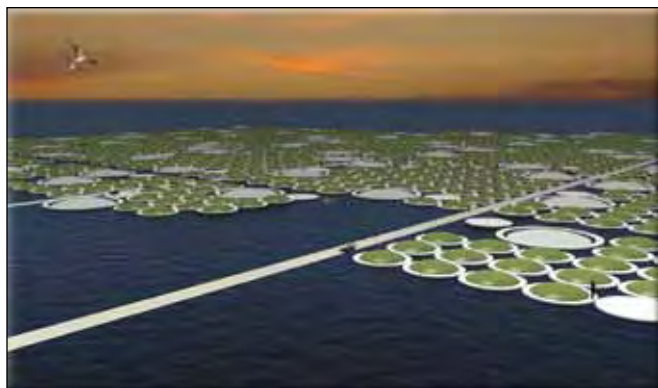






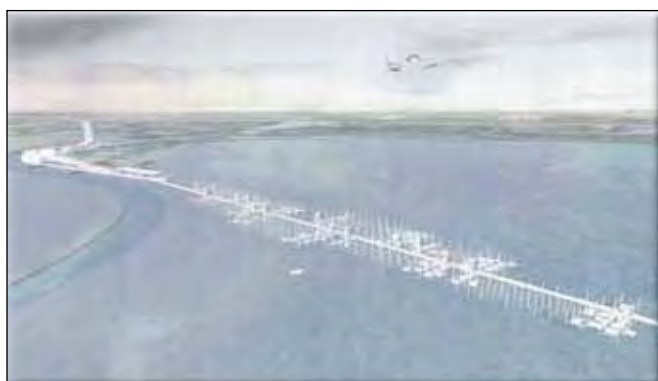
## Algae Landscape Design and Architecture

### Changing coastlines with algae biofuel production



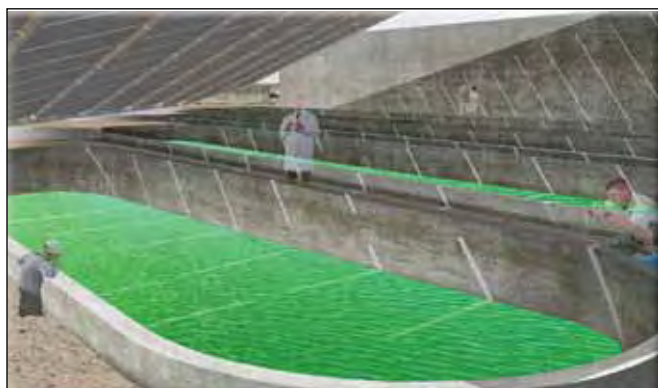
#### Production landscape for warm coastal areas

The offshore algae cell farm powers the city nearby and its by-products benefit onshore agriculture. In daytime, rings of floating hydrogen producing algae cells, growing *chlamydomonas*, produce electricity and are inflated by gases. At night, the gases inflate onshore greenhouses as heat for plants inside. The offshore algae farm is the energy generator for the onshore farmland. As energy demands increase, the offshore algae cells will proliferate to increase the energy supply.



#### ECO2 Systems - Algaegardens in the old salt works of Cadiz, Spain

The idea is the creation of a biodiesel region out of the provided structures of old unused saltgardens. Saline microalgae farms produce biodiesel. In the unused salt works, algae is combined with crops of salt, farmed fish and saline agriculture for algae biofuel and hydrogen, food, building materials, bioplastics, dyes, pigments, medicine, cosmetics and fertilizer. Microalgae farms are air filters and macroalgae farms are water filters.



#### Algae biofuel production facility in Abu Dhabi

The site is coastal desert on the outskirts of Abu Dhabi in the UAE. A local source of biodiesel would reduce emissions from massive transport corridors in the area. Algae growth would dramatically improve coastal environments damaged by construction run-off. Inland ponds provide more optimum conditions for growing oil rich algae. Solar photovoltaic panels installed as shading above ponds would generate light for algae to photosynthesize at night.



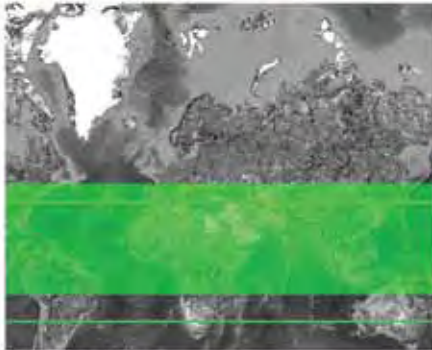
#### Bio-farming in the Gulf of Mexico in Louisiana

This self-replicating floating algae farm is composed of robotic bio-plastic photo-bioreactor tubes in hexagons. The PBR tube processes run through an automated network controlled by fluidic switches and actuators - a modulated series of closed feedback loops. The project will oxygenate dead zones in the Gulf, utilizing the Mississippi River's heavy loads of nitrogen and phosphorous and capturing CO2 emissions from processing plants in Texas and Louisiana.

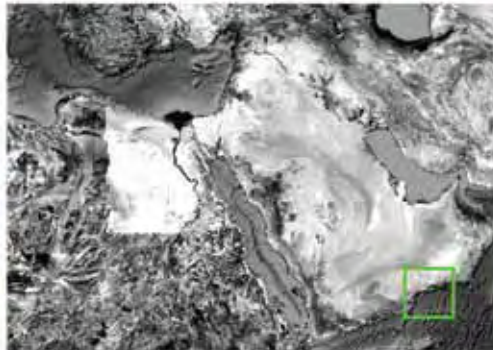


# PRODUCTION LANDSCAPE

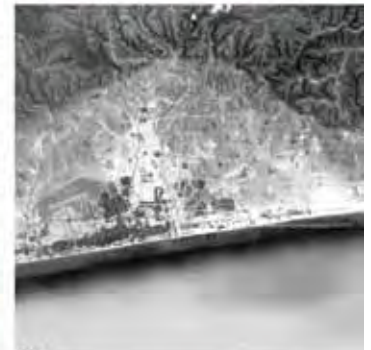
LARGE SCALE PRODUCTION INFRASTRUCTURE + FIELD EFFECT + PROGRAMMATIC INTERATIONSHIP



Solar Insolation



South-East Arab

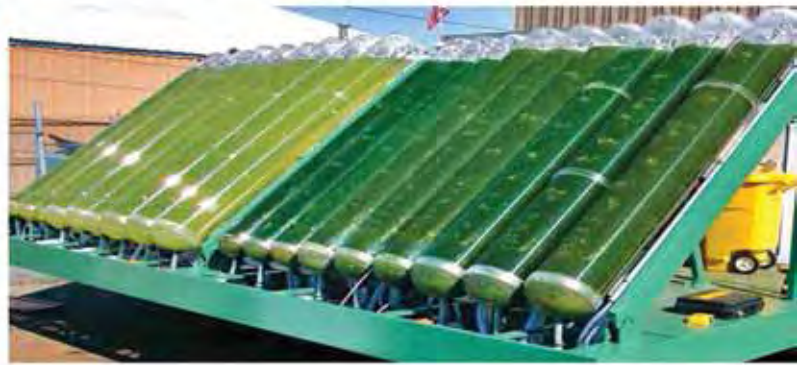


Site

▲ Although the algae could grow in different conditions but the efficiency would be higher when sufficient sunlight is provided. Located within the solar insolation zone, the coast along would be the most suitable location for the algae technology to start with. The chosen site is next to a city with agriculture, the offshore would be the algae cell farm providing electricity for the city nearby and the onshore farming.



*Chlamydomonas reinhardtii* (a green-algae)

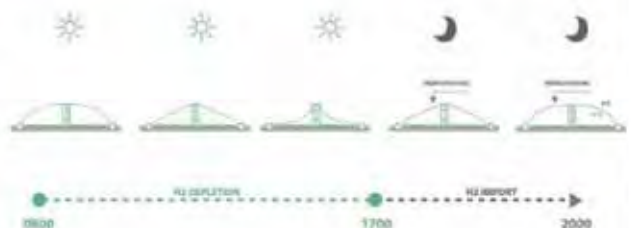


▲ "A microscopic green algae -- known to scientists as *Chlamydomonas reinhardtii*, and to regular folk as pond scum -- was discovered more than 60 years ago to split water into hydrogen and oxygen under controlled conditions. A recent breakthrough in controlling the algae's hydrogen yield has prompted a Berkeley, California, company to try to be first to commercialize production." , Algae: Power Plant of the Future? (<http://www.wired.com/science/discoveries/news/2002/08/54456>)

## Schematic Design

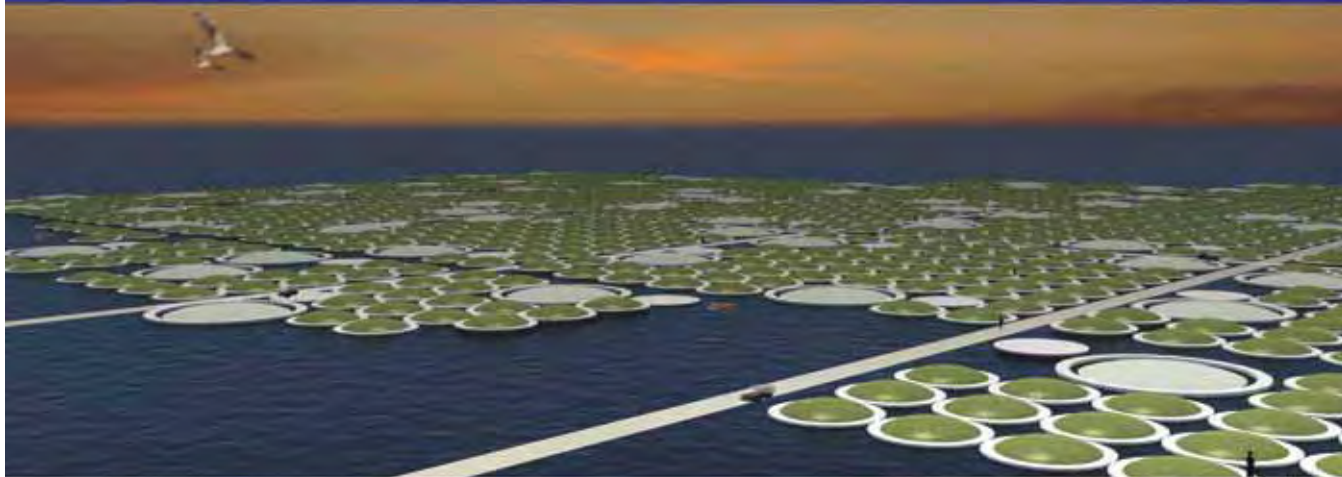
► During day time, the algae cells produce oxygen and hydrogen and inflate the cell and transfer the gas to membrane at night.

► During night time, the gas produced from the algae cells in the day time would inflate the greenhouse and as a heat insulator for the plants inside. during day time, the gases inside the membrane will be used up for generating electricity and water for irrigation.

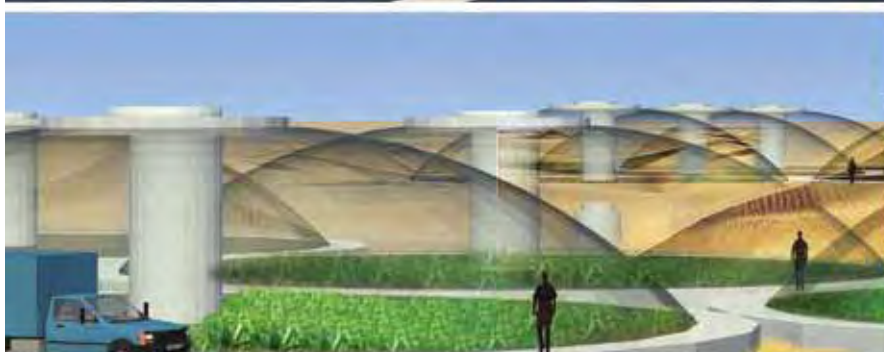


Production landscape for warm coastal areas of the world





◀Perspective rendering of onshore farmland



▶Onshore farming pattern; 6 greenhouses are set in one group, the road system surrounds the greenhouse and make each greenhouse directly access to the road which increase the efficiency. The space between the farm and road provides the loading/ unloading area for the trucks.



by Ho Wing Ho





80





by Melanie Hammer

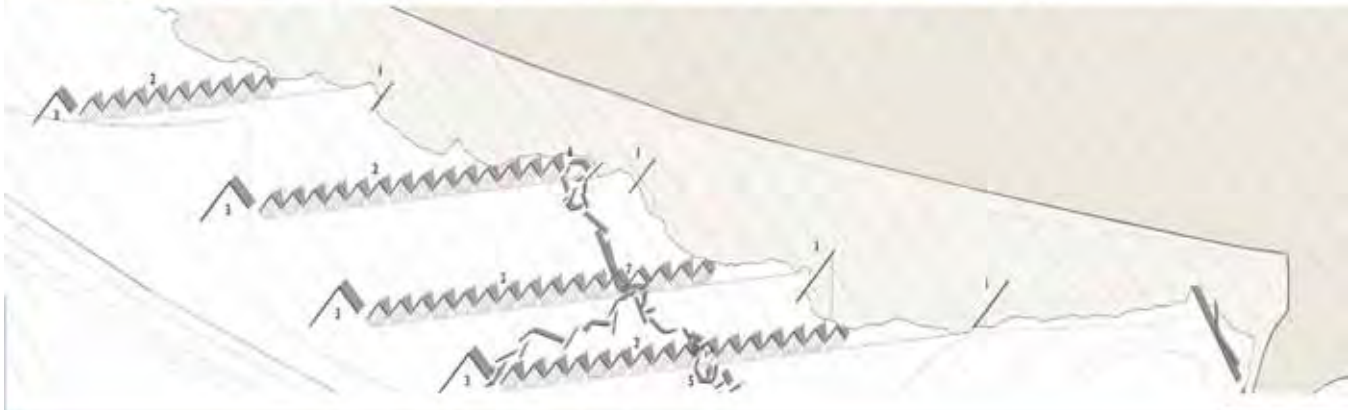
## MANIPULATING COAST

Algae Biofuel Production and Research Facility, Abu Dhabi.

When we think of Abu Dhabi and the United Arab Emirates, we conjure images of huge-scale construction and development resulting from a rapidly expanding economy. Despite the nation's relatively impressive reputation regarding renewable energy production, the urban sprawl spilling from its coastal cities is causing significant damage to the marine environment. This project seeks to situate an algae production facility to resist the expansion of these urban centres whilst repairing the ecological damage done by construction run-off.

The project behaves as a manipulation of the coastline: extending the fertile inter-tidal zone into the barren desert scrub of the inner site. By doing so, the area in which algae can be produced is greatly, and sensitively, extended. Reversible concrete channels run from the coast, allowing tidal water to flood algae ponds twice a day. This process supplies the algae with the nutrients it needs to grow, whilst absorbing the harmful chemicals resulting from construction run-off, thus improving the marine ecology. Mediation strategies are employed in the internal algae ponds as a means to optimise conditions for algae growth: shading strategies to limit photo-inhibition, lighting systems allowing the algae to photosynthesise through the night, and thermal regulation to limit the diurnal and annual temperature variation. By mounting photo-voltaic cells as the shading system, electricity is generated to power the lighting systems, and to sell back into the electrical grid. This profit allows for the continuing expansion of the algae-field, funded by supplying zero-carbon energy for use in the urban centres along the coast.

This production programme runs in conjunction with a research programme, centred in the on-site research laboratory, which aims to improve the efficiency of algae production on this scale. The research programme would examine the efficiency of growing different strains of algae under different conditions, with the eventual aim being a completely optimised annual growth plan, producing the maximum amount of biofuel possible on the site, under the varying annual conditions.



Manipulating Coast. Algae biofuel production and research facility in Abu Dhabi

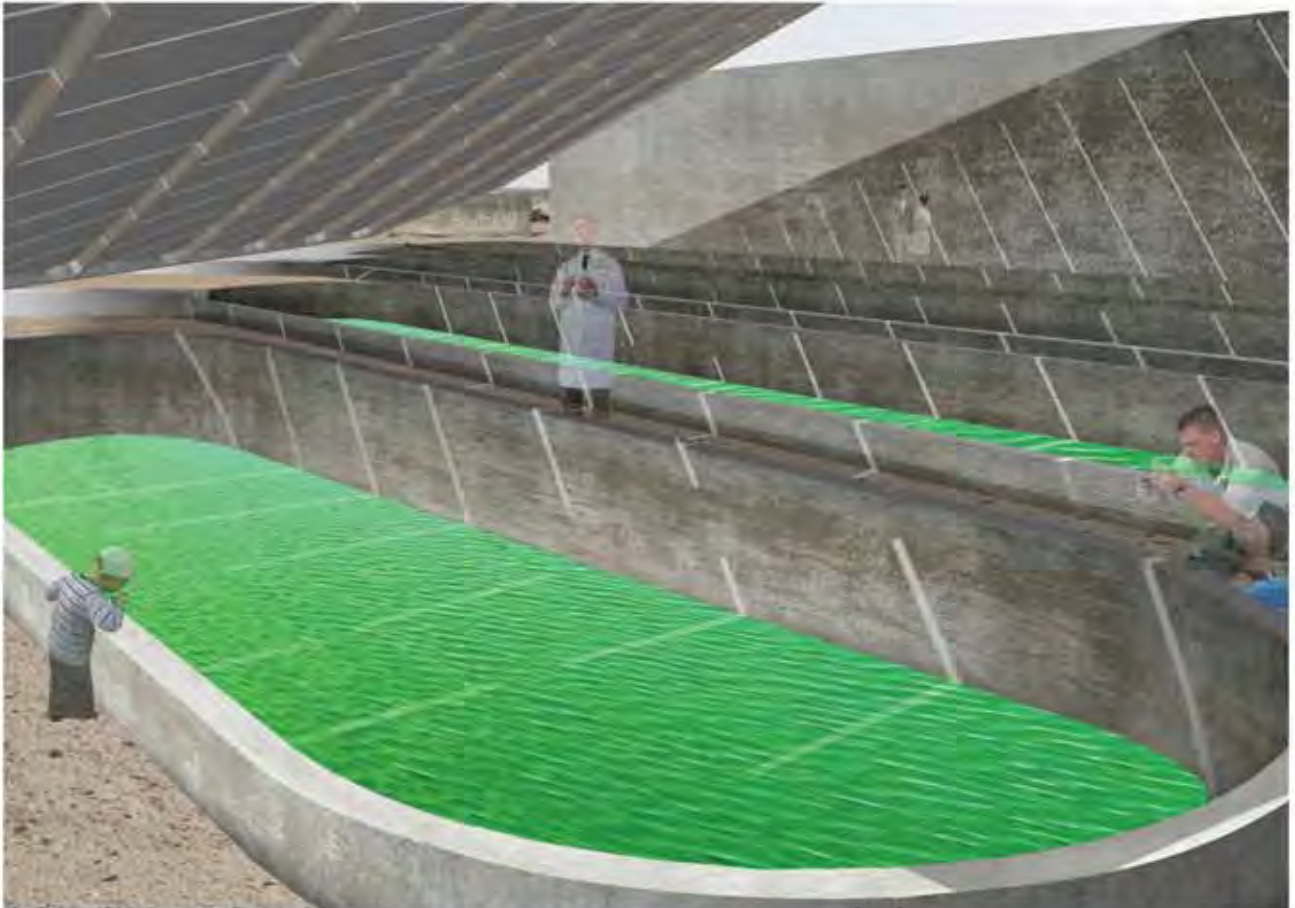


## MANIPULATING COAST

Algae Biofuel Production and Research Facility, Abu Dhabi.

Alongside the production and research programmes, an education programme seeks to raise the profile of algae biofuel by illustrating the positive effects of algae biofuel production and use to the public. The concrete planes which act as the public circulation introduce a second material language. By doing so, they make conceivable the intangible forces acting on the site: allowing sand to pile up illustrating its material behaviour; the desire to stay in the shade generating different paths at different times of day; shelter from, and exposure to, the wind highlighting air movement.

Combined with this, different displays would be set up at different points on the site; generating a concise educational narrative. The first occupied "pavilion" shown in the plan would provide an introduction to the nature of algae production and the specific mitigations employed on site, whilst the proximity to the ponds themselves would aid this agenda. The public display area shown below would provide an understanding of the research and processing programmes, whilst the coastal pavilion would educate visitors in the effects of urban sprawl on coastal and marine ecologies, and the means by which the facility is counteracting them.



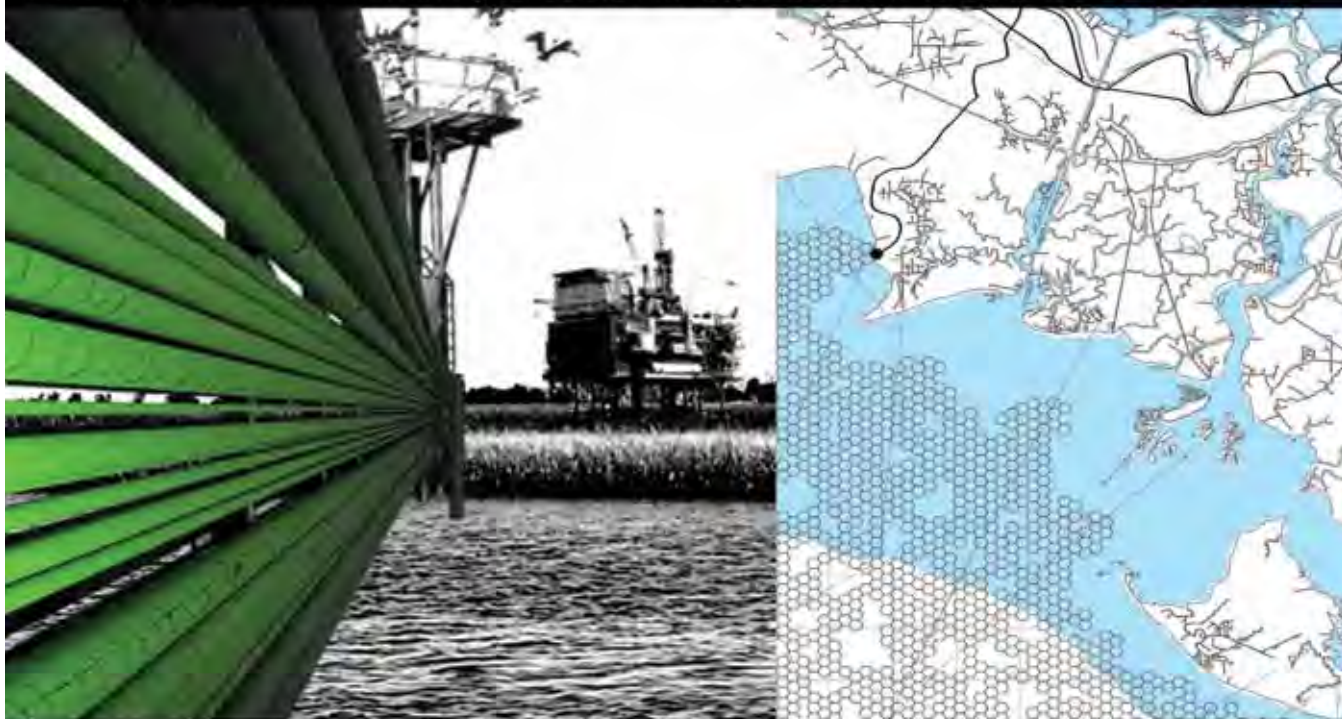
by Jamie Henry



# AUTOMATED BLOOM

## BIO-FARMING IN THE GULF OF MEXICO / LOUISIANA, USA

AUTOMATED BLOOM is an operative landscape, strategically located in open water in the Gulf of Mexico off the Atchafalaya Bay. This area is the only part of Louisiana's coast to be gaining landmass. In an attempt to address and target multiple issues, the techno-scientific structure appropriates the United States' existing oil infrastructure - including platforms, refineries and pipelines.



The floating algae farm is primarily composed of bio-plastic photobioreactor tubes in a hexagonal formation. The geometry of the module catalyzes sediment accretion, which occurs when water bifurcates and loses velocity; the sizing of the tubes increases surface area exposure to light. Rudimentary robots tend the BLOOM and distribute tubes to its outer edges, continually constructing new hexagons and self-replicating. The PBR tubes' algal processes run through an automated network controlled by fluidic switches and actuators - effectively a modulated series of closed feedback loops. For example, if a culture becomes contaminated, the flows and paths between hexagons and the mainland can be rerouted. Offshore platforms are already equipped with numerous sensors and data-logging programs to monitor such environmental inputs as wave height.

The project will oxygenate hypoxic areas ('dead zones') in the Gulf, utilizing the Mississippi River's heavy loads of nitrogen and phosphorous as nutrients supplementing growth, in addition to capturing carbon dioxide emissions from processing plants in Texas and Louisiana. While the scale of the project encourages numerous passive benefits, such as providing layover points for aviary migration, it also allows for opportunities to interweave symbiotic activities like multi-trophic aquaculture. Overall, the implementation of a massive algae-scape would need a trans-disciplinary group to negotiate and reconcile existing layers of infrastructure, industry and ecology. By retrofitting the system it is slowly replacing, the parasitic algae farm subversively asserts its post-Industrial agenda.

Automated Bloom: Bio-farming in the Gulf of Mexico in Louisiana by Greg Barton



## **Algae Landscape Design and Architecture**

**Changing landscapes with algae biofuel production**



### **ALGAL&SCAPE: Study of polder Schieveen near Rotterdam, Netherlands**

A sustainable strategy for large scale microalgae harvesting using the polders, reclaimed land enclosed by dykes. The Netherlands could benefit from this transformation of the polders, ensuring enough production of fuel for Dutch needs and even more to be stored or exported. This proposal is a general strategy for polders, applied now in the specific case of polder Schieveen, in the outskirts of Rotterdam, the Netherlands.



### **A Crude Island: Transformation of Inglewood oil fields in Los Angeles**

Radically shift this 950 acre barren oilfield landscape into a new Los Angeles Central Park. Step 1- disassemble oil based technologies and infrastructure. Step 2- reconfigure infrastructure for algae biofuel production. Step 3- use biofuel to run a precision cultivation system to restore the original biodiversity. This long term landscape transformation creates a Los Angeles Central Park on the corpses of oil-based technologies.



### **Canadian infrastructural futures**

This project posits algae sourced biofuels could graft onto the existing petroleum infrastructure paradigm. The Saute St. Marie Ontario Intermodal Transport Terminal would have two massive production fields for biodiesel and hydrogen production. The regional supply node at Revelstoke Dam in B.C. would have a paired hydrogen and biodiesel station with integrated shipping terminals that sits on the dike portion of the dam.



### **Algae @ Work: Rethinking fueling stations**

Algae@Work proposes to replace gas station networks throughout our cities with a closed-loop biological system of algae biofuel stations. Storm water collected and stored on site can be cultured with high-lipid algae, the top producer of biofuel source crops. This is designed to replace the outmoded gas station and convenience store with a system to produce biofuel combined with tilapia farming to provide nutrients for optimal development.



# ALGAL&SCAPE: A SUSTAINABLE LANDSCAPE

## A SUSTAINABLE STRATEGY FOR LARGE SCALE MICRO-ALGAE HARVESTING

A STUDY CASE : POLDER SCHIEVEEN, ROTTERDAM, THE NETHERLANDS

The proposal illustrates a strategy to optimize the realization of large-scale **algae harvesting parks** for the production of **bio-fuel**.

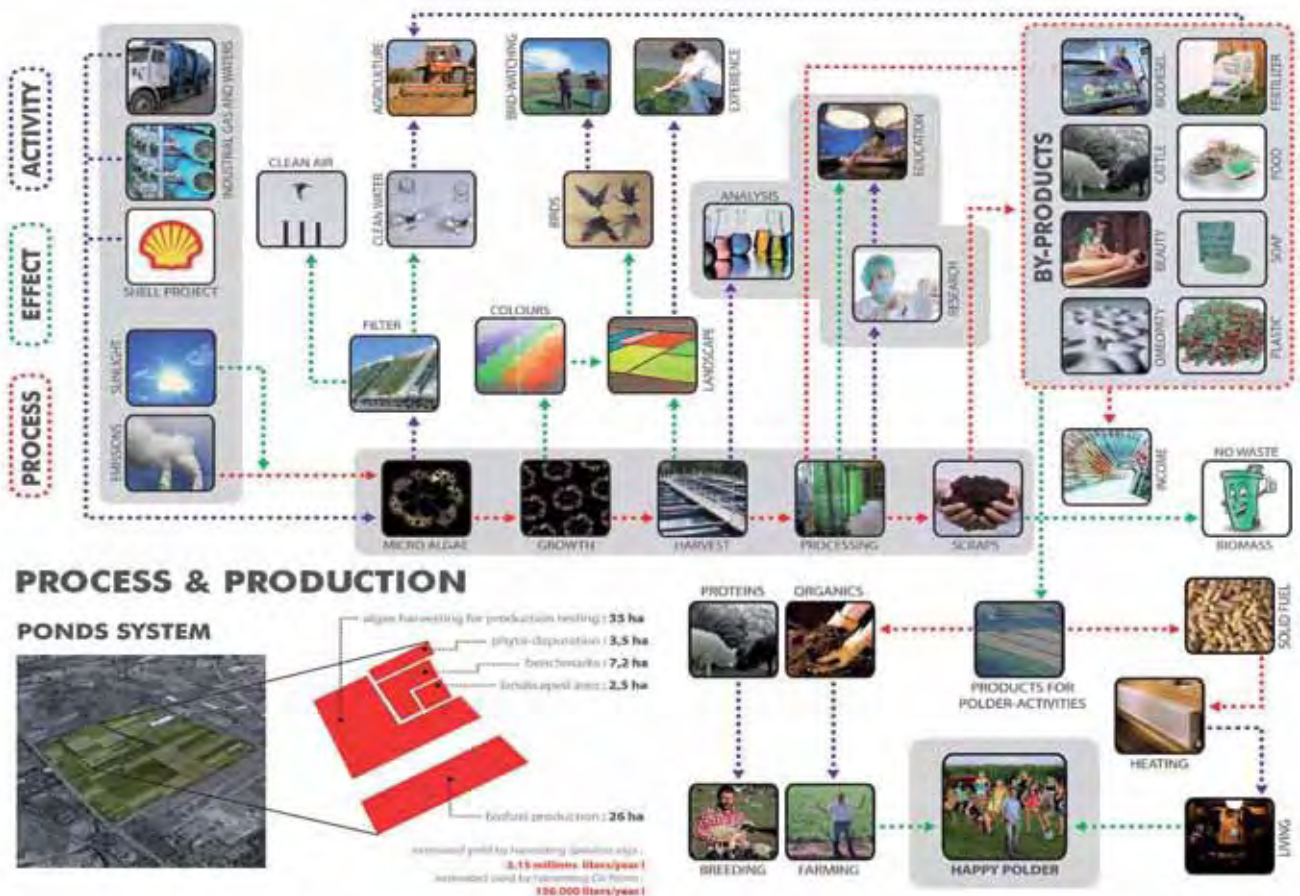
Nowadays these large scale interventions are still very high in their costs of creation, therefore still not attractive enough for big investors, and the bio-fuel produced is therefore not on the market, in a matter of costs and final prices.

Main issues affecting these costs are the need of **large empty areas** (when available, these are usually not too well interconnected infrastructurally or simply too far and isolated), the need of a lot of digging or diking for the **canalizations** (especially if we long for open-air harvesting ponds), and the need of a continuous stream of 2 main elements:  $H_2O$  and  $CO_2$ .

can a large scale **algae farm** be realized within a metropolitan area, reducing its **construction costs**, turned into a more efficient **productive reality**, preserve the **natural environment**, respect the **local existing context**, and satisfy the needs of a **metropolis in expansion**?



POLDER SCHIEVEEN, 2010



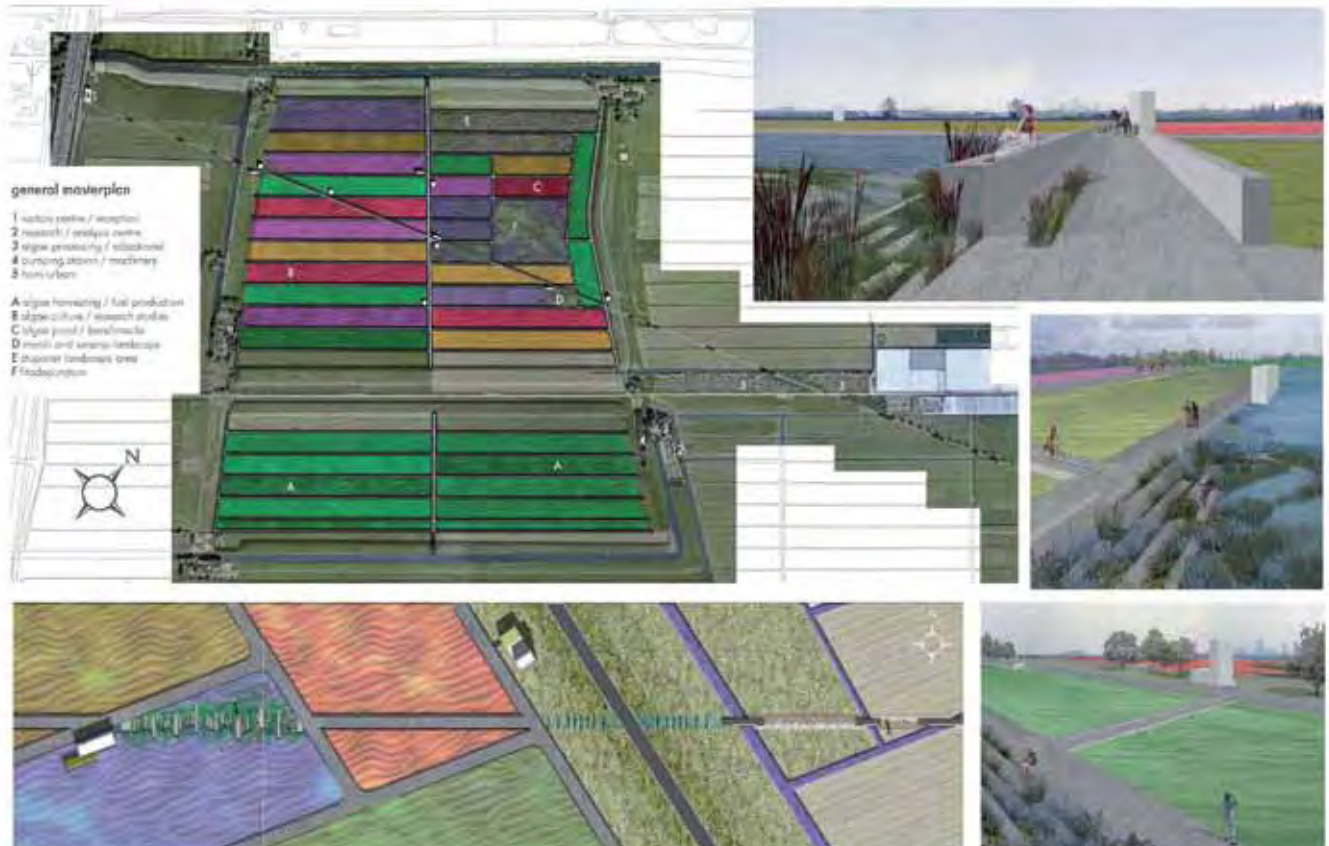
ALGAL&SCAPE: Study of polder Schieveen near Rotterdam, Netherlands



# ALGAL&SCAPE: A SUSTAINABLE LANDSCAPE

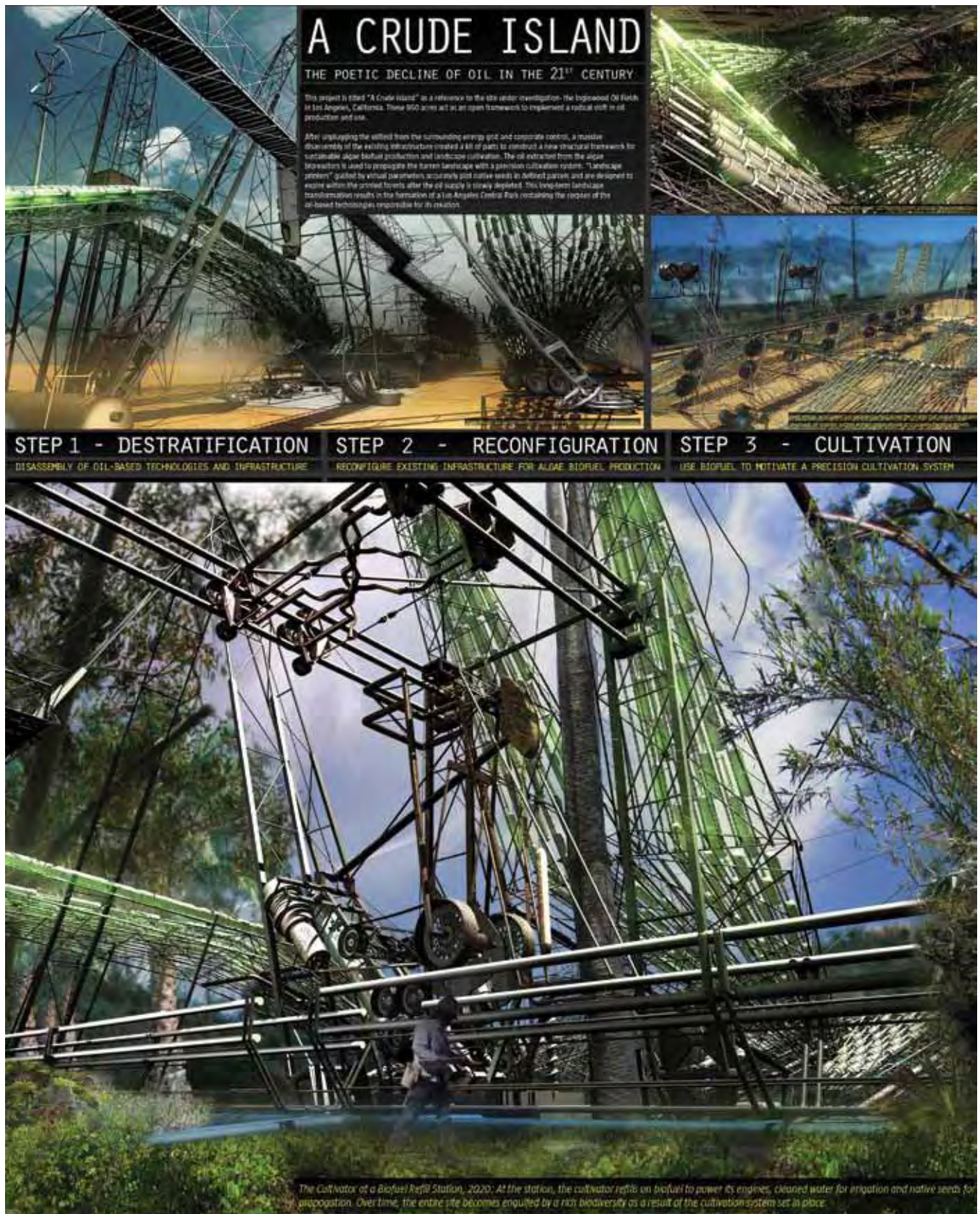
## A SUSTAINABLE STRATEGY FOR LARGE SCALE MICRO-ALGAE HARVESTING

A STUDY CASE : POLDER SCHIEVEEN, ROTTERDAM, THE NETHERLANDS



by Federico Curiel



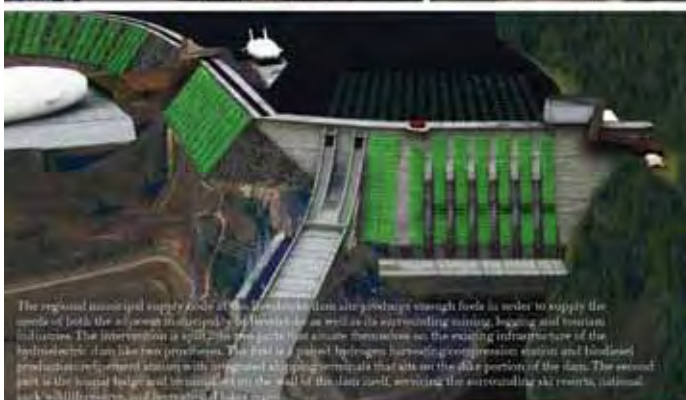


A Crude Island: Transformation of Inglewood oil fields by Jason Immarraju



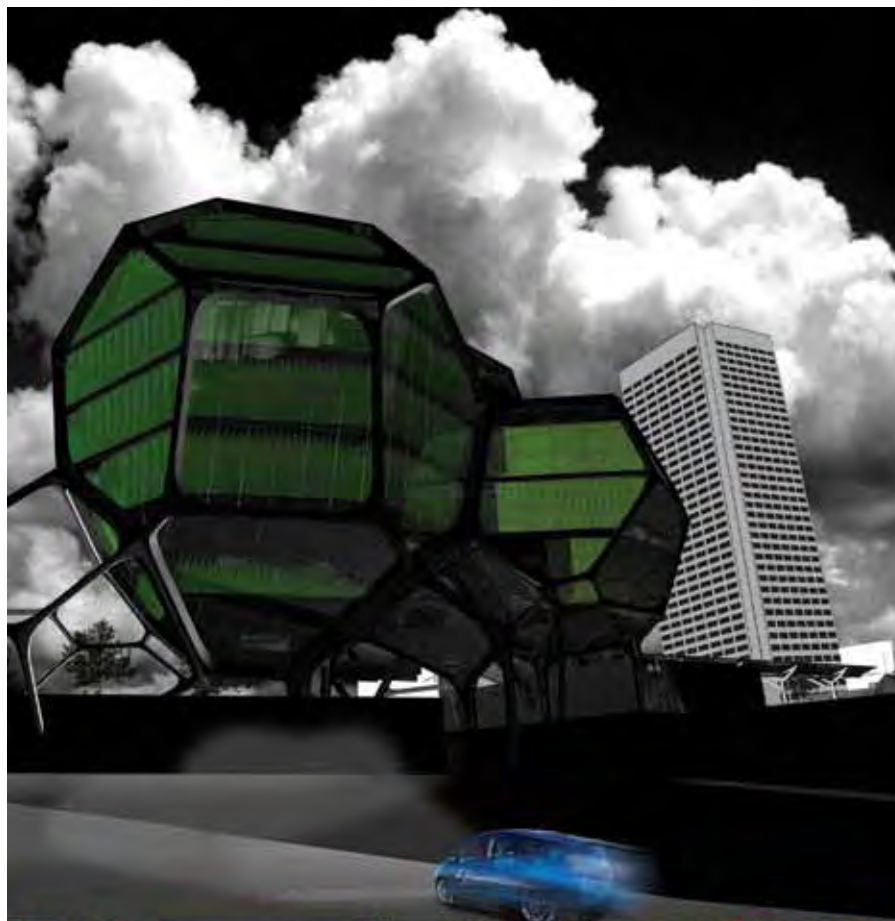
# Canadian Infrastructural Futures

Capitalising on the productivity of algae, seaweed, landfills, this project posits the possibility of a system that could graft onto the existing petroleum paradigm. It presents itself not as an independent alternative but a possible strategic development of existing industrial and economic processes thoughtfully networked for ecological benefit.



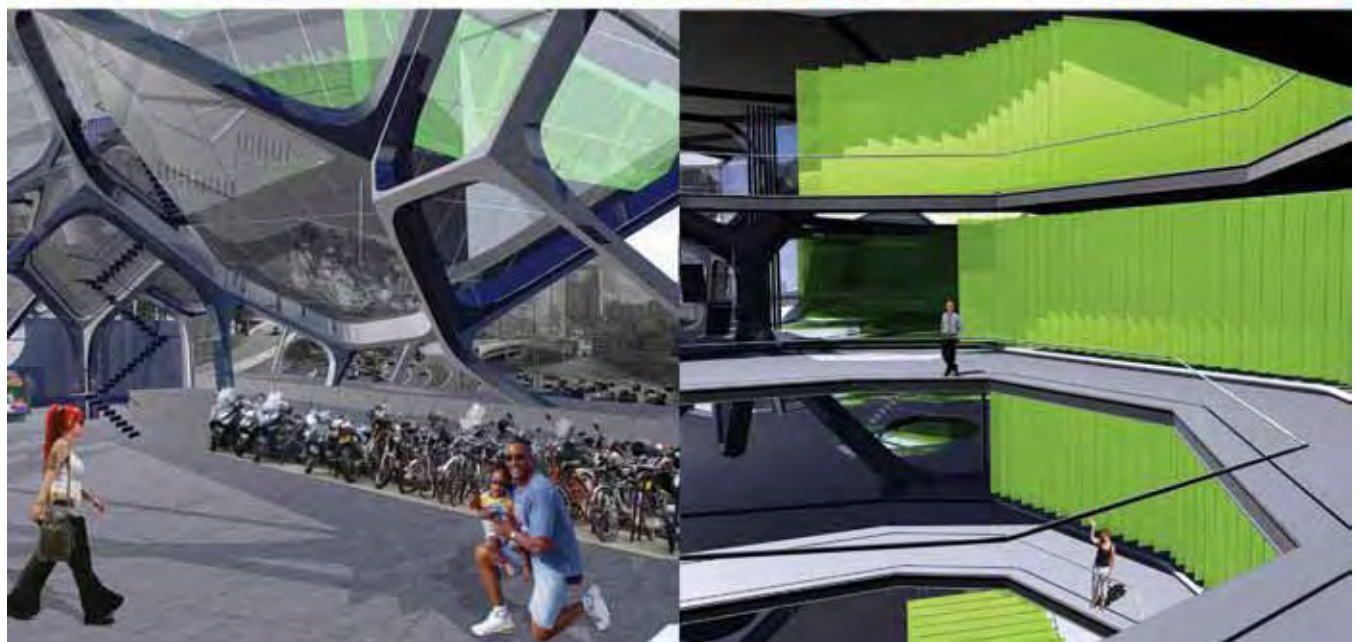
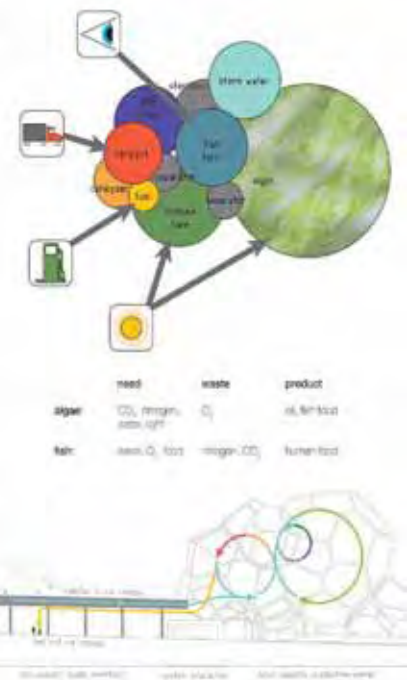
Canadian infrastructural futures by Sando Thordarson and Stephen Addeo





## algae @ work

replacing gas station networks with a closed-loop biological system for local production of algae biofuel



Algae @ Work: Rethinking fueling stations by David E. Beil



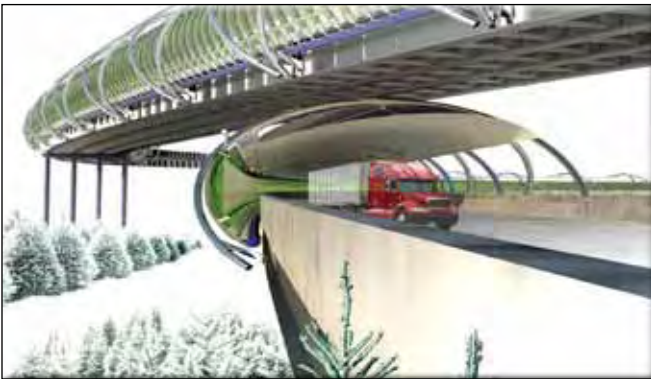
## Algae Landscape Design and Architecture

### Capturing and reusing CO2 emissions in transport networks



#### AsterioFuel algae fuel stations in Spain

The AsterioFuel network of geodesic domes, replicating the pattern of diatoms, is designed for absorbing CO2 emissions and producing renewable fuels. The domes absorb CO2, grow diatom algae (*asterionella formosa*) to provide energy for vehicles and offer shade covering for pedestrians in public spaces. The most suitable road systems to spread the AsterioFuel network in Barcelona are the two main lanes that embrace the city by the sea and the mountains called the 'Rondas'.



#### Green Miles. I-40 near Knoxville, Tennessee

The negative outputs of gasoline are catalysts for bio-fueled transportation, relying on coniferous trees and algae. The goals are threefold: to offset daily and accumulated atmospheric carbon emissions, to recharge aquifers with water not polluted from highway runoff, and to provide biofuel for an emerging system. The project begins with planting thousands of trees in the in-between spaces and installing an algae bioreactor system onto the side of the existing interstate infrastructure.



#### Parasital Bioreactors

Closing the loop with hybrid machine infrastructure along roads to capture emissions to grow algae for renewable fuel. Capturing by humidity swing sorbent placed in panels inside a metal porous body formed by multiple overlapped hollow spheres. Growing algae inside glass capsules on top of every capturing balloon. Every unit can fit in a 1.5 meter grid cell, allowing an efficient structure to take many shapes and adapt to different support surfaces.



#### Carbon recycling structure in Los Angeles

Developed in the early 20th century, the iconic cul-de-sac was used to slow traffic within a community. Many cul-de-sacs near LAX Airport today remain vacant and unused. The proposed Silo-de-Sac carbon recycling structure houses autos while it siphons carbon dioxide from within the structure to feed algae which creates biofuel on the exterior skin. Algae oil can be extracted and refined for various purposes including transportation fuels.



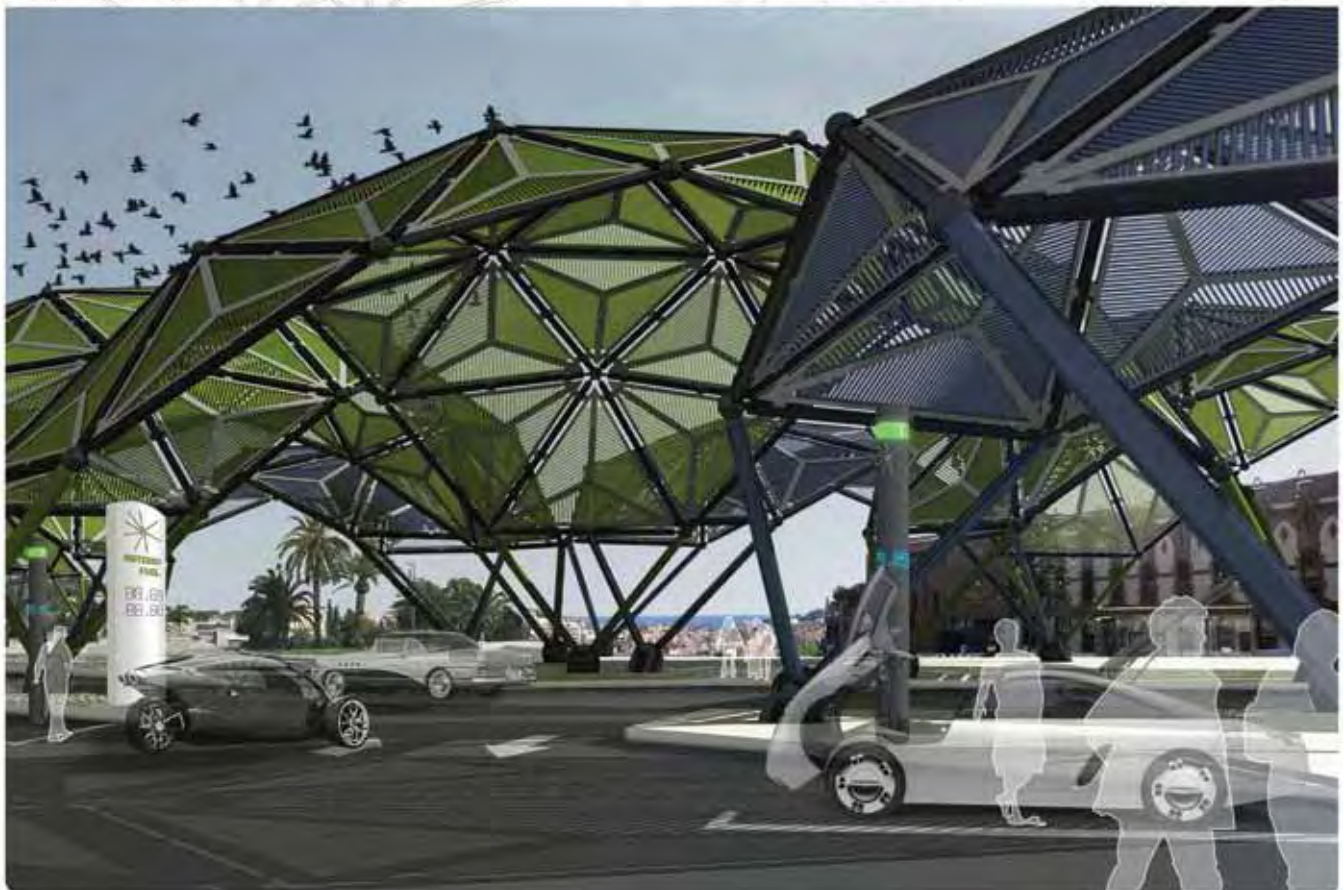
# ASTERIOFUEL

## Algae Fuel Stations in Urban Areas

Diatoms are a major group of algae, and are one of the most common types of phytoplankton. Most diatoms are unicellular, although they can exist as colonies in the shape of filaments or ribbons (e.g. *Fragillaria*), fans (e.g. *Meridion*), zigzags (e.g. *Tabellaria*), or stellate colonies (e.g. *Asterionella*). Diatoms are producers within the food chain. A characteristic feature of diatom cells is that they are encased within a unique cell wall made of silica (hydrated silicon dioxide) called a frustule. These frustules show a wide diversity in form, but usually consist of two asymmetrical sides with a split between them, hence the group name.

One of the main points of these algae is the capacity of transforming CO<sub>2</sub> into energy, using the sun light, in the process named Photosynthesis. In the research of new energy sources, this capacity brings us a big opportunity, and why not, we can introduce this catalyst in the neuralgic centers of our society. *Asterionella Formosa* responds perfectly to the requirements of these "city catalysts", for its capacity of aggregation and generation of bigger systems, and for its slender shape.

From this potential that algae have, arises AsterioFuel a new energy system based on sunlight, to take atmospherical Co<sub>2</sub> and convert it in energy for the existing transport technology of our cities. The cycle is closed when the Co<sub>2</sub> generated by these means of transport is used again to produce more energy.



Asteriofuel algae fuel stations in urban areas like Barcelona Spain





## Barcelona network

The AsterioFuel network is designed specially to be implemented in leading cities in the urban and technological field that are also interested in absorbing CO2 emissions as well as making a firm bet for renewable fuels.

The city of Barcelona, in which in this particular case the project is developed, meets all the above conditions.

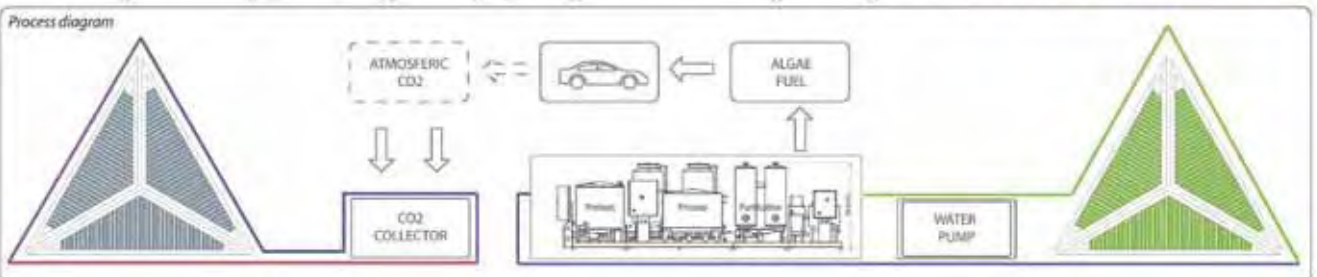
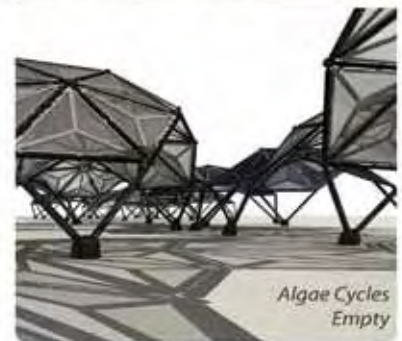
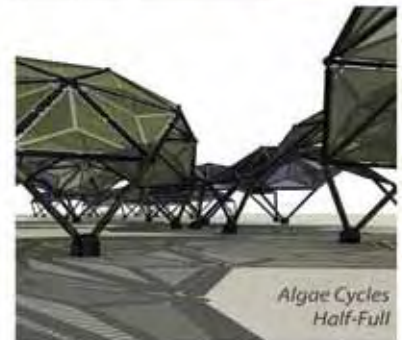
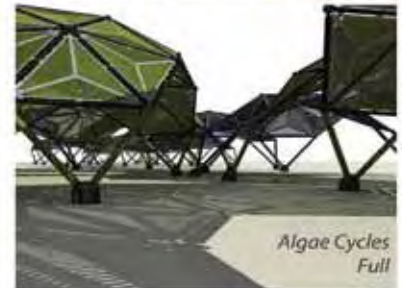
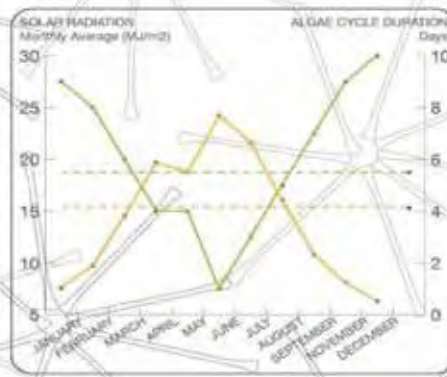
The most suitable road system to spread AsterioFuel network in Barcelona is the two main segregated lanes that embrace the city by the sea and the mountains called the "Rondas" (Ronda de Dalt and Ronda Litoral). On the sides of the "Rondas" we find several public spaces with residential, administrative and commercial uses that make the car traffic and people converge in the same place but at different speeds and high levels.

Since we have both traffics, human and vehicles, converging is the key point to have the AsterioFuel network to absorb CO2, provide energy to the vehicles as well as shade and covering to the pedestrians in the public spaces.

## Growth cycles

Algae have a growth cycle in between 2 and 10 days, depending on the solar radiation they receive. As in the different seasons there is a different rate of radiation, the cycles of AsterioFuel will be always changing, and so will be the shades in the public space. Similar to the well known summer-winter cycle of the trees, but much faster and unpredictable.

The pennate Asterionella cell can be extrapolated as the main unit to a cylindrical bar made of steel. This bar is the basic piece of a spatial mesh forming geodesic domes. More specifically domes based upon the pattern of edges and vertices of an icosahedron with frequencies between 2 and 3 and bar lengths around 6 meters.



by Ignacio Montojo



# GREEN MILES [I-40: 386-388]

## A HIGHWAY BETWEEN GASOLINE AND BIO-FUELS

### THE PROBLEM

The negative effects of the gasoline-powered vehicle on the environment calls for a change in the interstate transportation system. However, the change will not be immediate. Our society is decades out from the implementation of a viable, new system.



### THE SOLUTION

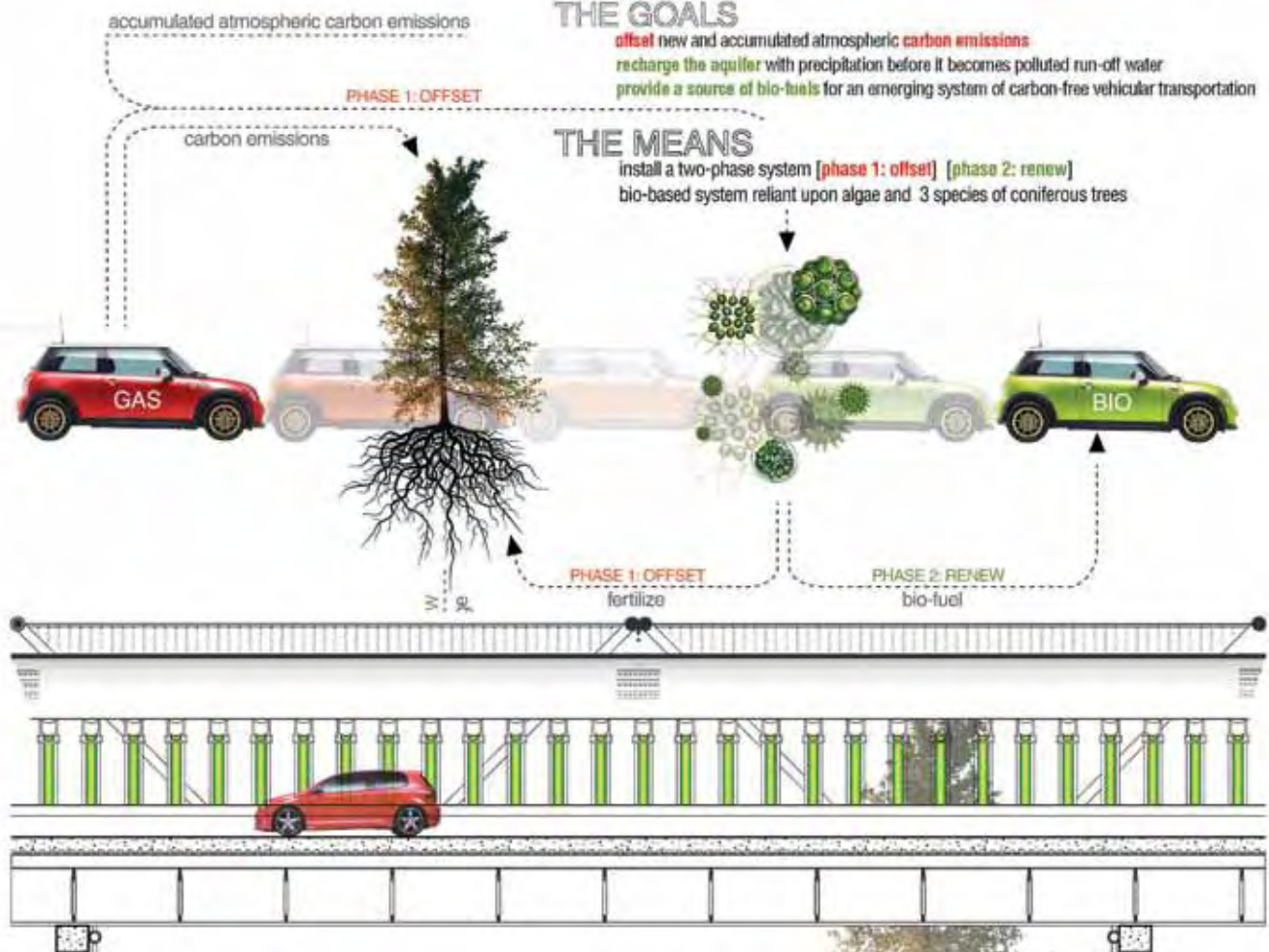
Green Miles [I-40: 386-388] is the prototype of a system that acts as a transition between gasoline-powered and bio-fueled transportation. Instead of passively waiting for change to occur, this system proposes the **use of the negative outputs** of the current system as a **catalyst** for the implementation of a better system.

### THE GOALS

**offset** new and accumulated atmospheric carbon emissions  
**recharge the aquifer** with precipitation before it becomes polluted run-off water  
**provide a source of bio-fuels** for an emerging system of carbon-free vehicular transportation

### THE MEANS

install a two-phase system [**phase 1: offset**] [**phase 2: renew**]  
bio-based system reliant upon algae and 3 species of coniferous trees



Green Miles. I-40 near Knoxville, Tennessee



## THE SYSTEM [phase 1.1 and 2.1]

three species of conifers (highest carbon intake among trees) are planted in the unused, "in-between" spaces of the site, each species placed with respect to a variety of site characteristics

the trees will immediately begin to **offset carbon emissions** and **regenerate the aquifer** as the trees mature, they will need less fertilizer and will offset greater amounts of accumulated atmospheric carbon emissions.



## THE SYSTEM [phase 1.2 and 2.2]

a system of algae bioreactors with solar-powered components is installed onto the existing infrastructure of the interstate overpasses and ramps.

the algae will immediately begin to **offset carbon emissions** and will initially be pumped through irrigation pipes to **fertilize** the surrounding planted trees which are continuing to **offset carbon emissions**.

eventually, the maturing trees will need less fertilizer and nutrients, and the algae bioreactors will be increasingly used in the **production of bio-fuels**.



## THE SYSTEM [algae bioreactor performance in Phase 1]

the algae bioreactor system is based on a passive, fill-and-release method of performance

algae doubles in volume daily, growing at a rate proportional to sunlight exposure, decreasing in rate when the density of algae in the reactor prohibits light from entering the inner portions of the bioreactor tubes

during significant precipitation, water flow into the tubes triggers pressure-based release valves, and the algae-water mixture flows down into irrigation pipes to fertilize the surrounding trees

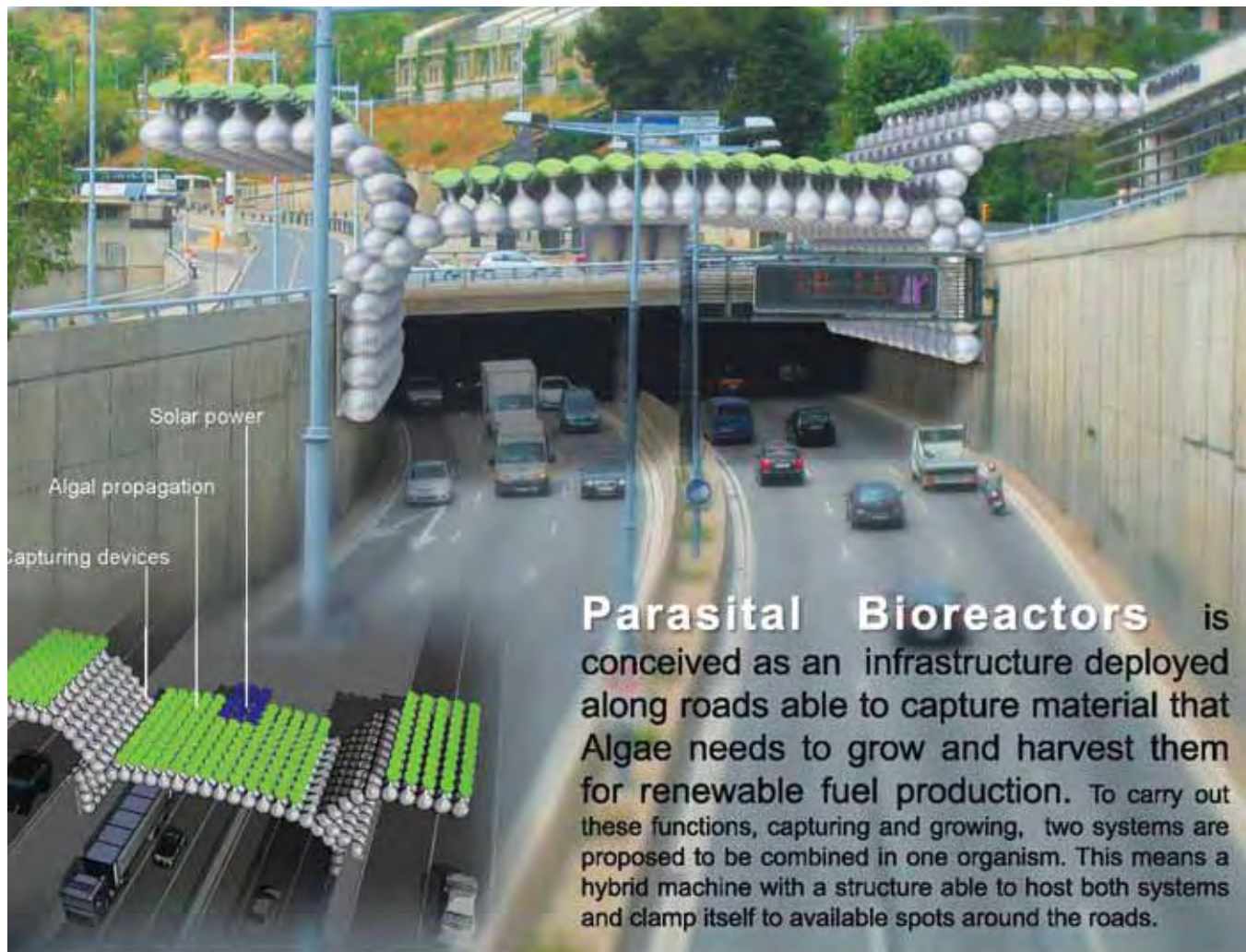


## SUMMARY

Green Miles is a self-sustaining system that gradually, yet actively, transitions the harmful infrastructural norm of gasoline-powered transportation into an environmentally beneficial one. It relies on biological elements to accomplish this - coniferous trees and algae. In turn, these natural elements work symbiotically to directly utilize the negative environmental aspects of waste water and polluted air in order to create outcomes that will benefit the local context and create a viable solution for a bio-fuel powered transportation system in years to come.

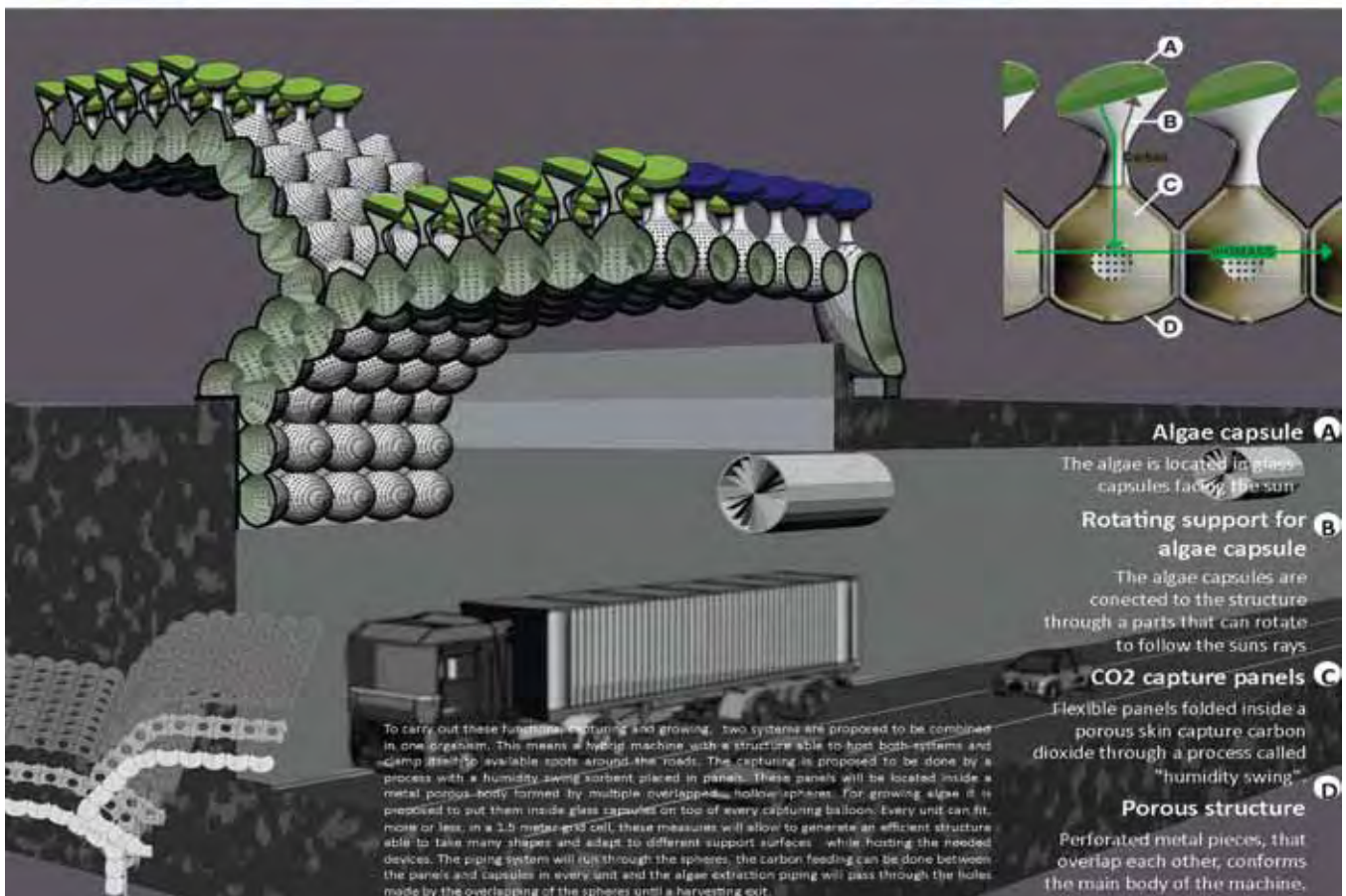
by Kathryn Hier





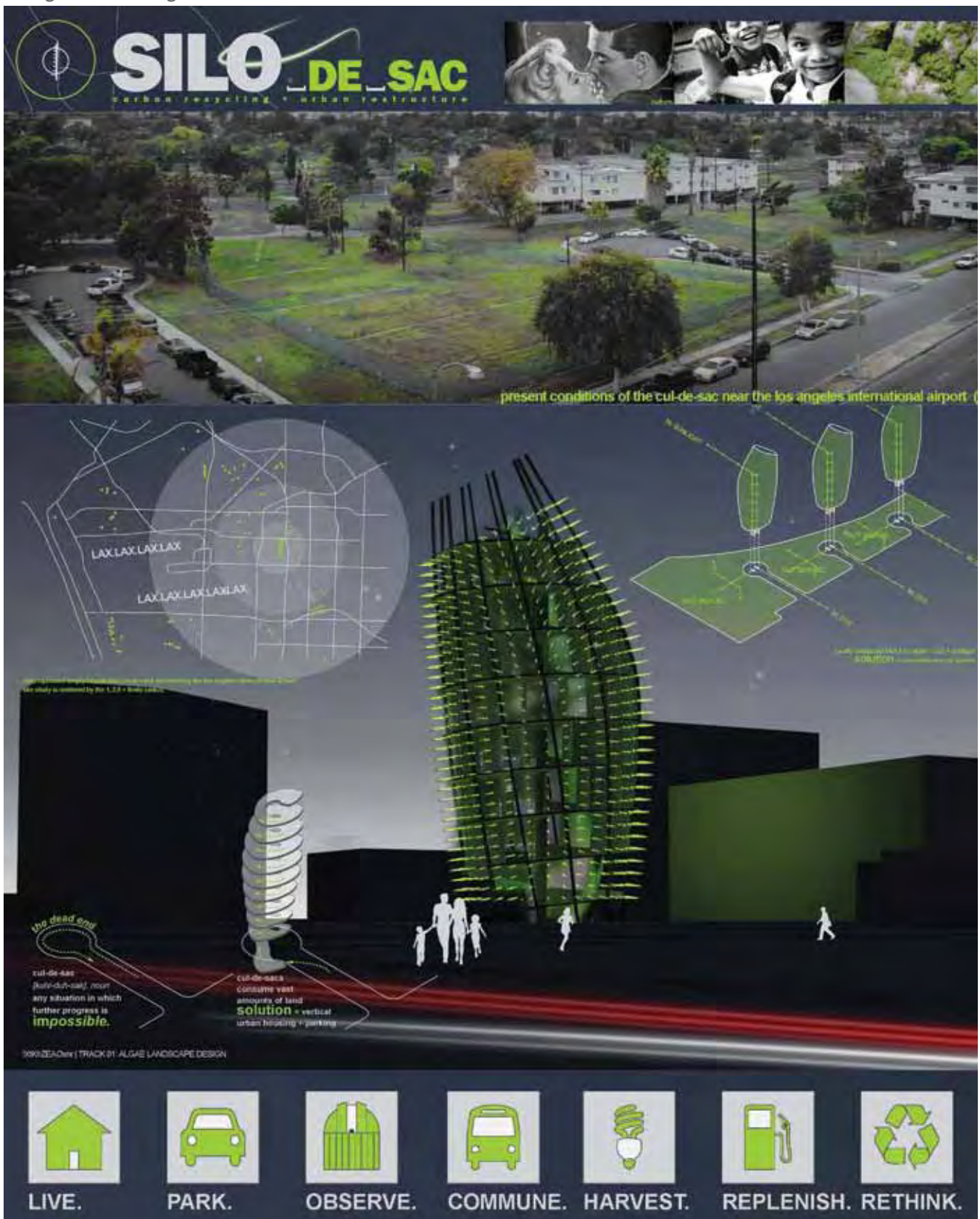
Parasital Bioreactors





by Manuel Hernandez





The Silo-de-Sac, carbon recycling structure in Los Angeles by Kevin Le



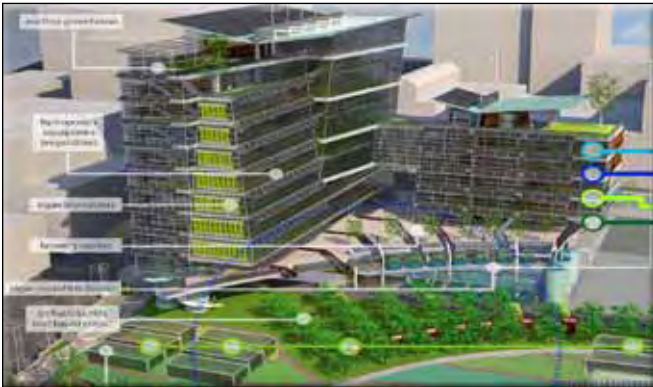
# Algae Landscape Design and Architecture

## Creating algae based eco communities



### Eco-Community on San Giorgio Island in Venice

Many islands that once belonged to Venice have now been abandoned and are slowly passing into private ownership. A sustainable solution for San Giorgio in Venice Lagoon is to create an eco-community that lives and works there. A Hydrotherapy Centre will be powered by algae harvested from the lagoon as algae grows in massive quantities, causing bad odor. A *spirulina* microfarm will provide health supplements & spa infusions and become a training center for cultivating algae.



### Eco-Laboratory algae microfarm center in Seattle

This is a living building with algaculture, hydroponics, aquaculture, aeroponics and aquaponics, and includes a rooftop garden, algae bioreactors, farmers market, community gardens, orchards and greenhouses. The Algae Microfarm Center is the heart of the community. It controls operations for managing the collection, storage, treatment, mixing, production, separation, processing and preparation of water and nutrient sources used and reused within the building site.



### Community on Winongo Riverbank in Indonesia

Kampung Algae: an algae village community in the densely populated township of Yogyakarta. The village design would help the community create food and employment with a new type of agriculture - *spirulina*, featuring vertical algae panels on village house walls. Construction of the Algae Bridge in the second stage brings together community production, processing and research. It utilizes water as algae growing media to support production, improve water quality and increase green land and open space.

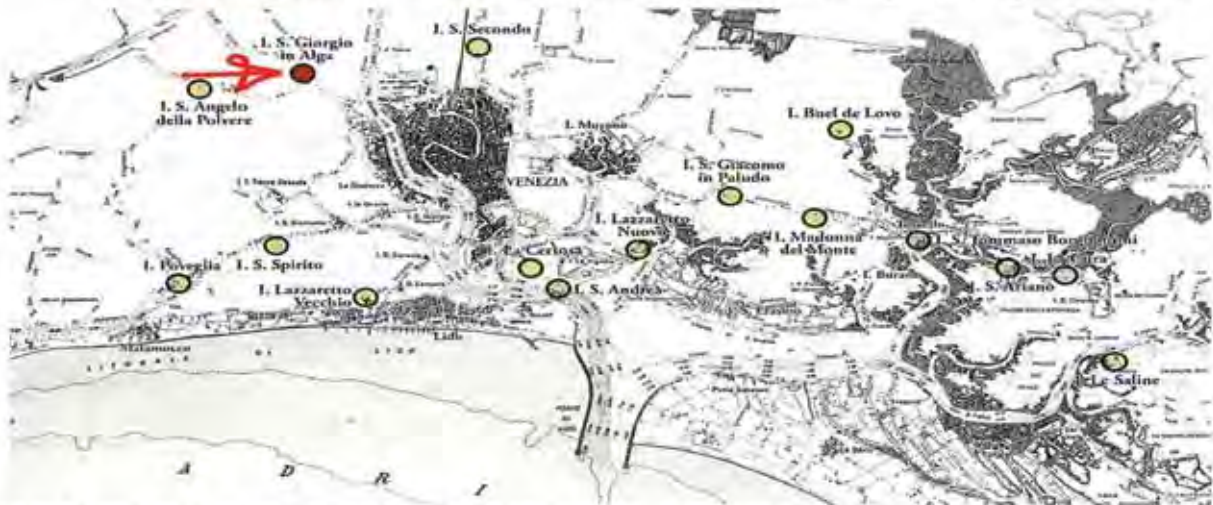


### Algae bio-fuel eco-community in Kosovo

For central Prishtina, the busiest part of the capital with the least greenery, this eco-community is designed with 7 floors for residential space, 17 apartments, each with a green roof garden to grow produce for their consumption or sell in the market. A market encourages local production and healthy living, and a café, cinema and restaurant reinforce traditional culture. The eco-community building is linked to the algae building with a glass roof to produce biofuel, food and compost.



## Design Proposal of an Eco-Community in San Giorgio in Alga, Venice



Saint Giorgio in Algae has been an abandoned island of ruins and green in the Lagoon



The Eco-community of *San Giorgio in Algae*, is powered by the plethora of algae that exists in the Lagoon. The small organic algae farm, on the island, provides spirulina noodles/tablets as health supplements and algae infusions for the hydrotherapy centre, small spa & nutrition consultation centre, and external therapy pools.



1. Main Entrance to the Island
2. Hydrotherapy Centre
3. Boat House
4. Small Spa & health consultation centre
5. Reflecting Pool
6. Light House
7. External Therapy Pools/Showers
8. Housing for Staff
9. Small Algae Farm
10. Algae Processing unit
11. Gathering Place

## Eco-Community on San Giorgio Island in Venice, Italy





by Chryssanthi Dafopoulou



# eco•laboratory: phase II algae micro



## Sustainable Water Source Definitions

potable water  
drinking water  
filtered & disinfected  
rainwater  
collected on site  
blackwater  
combined human waste  
brownwater  
feces w/o urine; nutrients  
yellowwater  
urine; nutrient rich  
greywater  
sinks, showers, laundry  
greenwater  
algae production  
food waste  
organic biomass



## 02 Urban Agriculture



complex commercial scale	VERTICAL FARMING	growing crops efficiently in vertical systems
	AEROPONICS	growing plants in an air culture w/ water nutrient mist
	AQUAPONICS	farming fish/plants in a symbiotic closed loop system
	AQUACULTURE	fish/shrimp farming in controlled tank environment
	HYDROPONICS	growing plants in a water nutrient solution/no soil
	ALGACULTURE	algae hydroponics; food, fuel, food, fertilizers, medicine
	PERMACULTURE	integrated food systems; crops and animals
	ORCHARDS & VINEYARDS	using public/private open space to grow fruit crops
	COMMUNITY GARDENS	collectively managed gardens on common land
	ROOFTOP GARDENS	gardens located on top of building roofs
simple community scale	KITCHEN BACK YARD GARDENS	a localized garden growing house hold food
	CONTAINER GARDEN	growing plants in containers

Registration # 1185  
Track 1 Algae Landscape Design

Eco-Laboratory: Phase II algae microfarm center in Seattle



# farm center

## Living Building Challenge 2.0

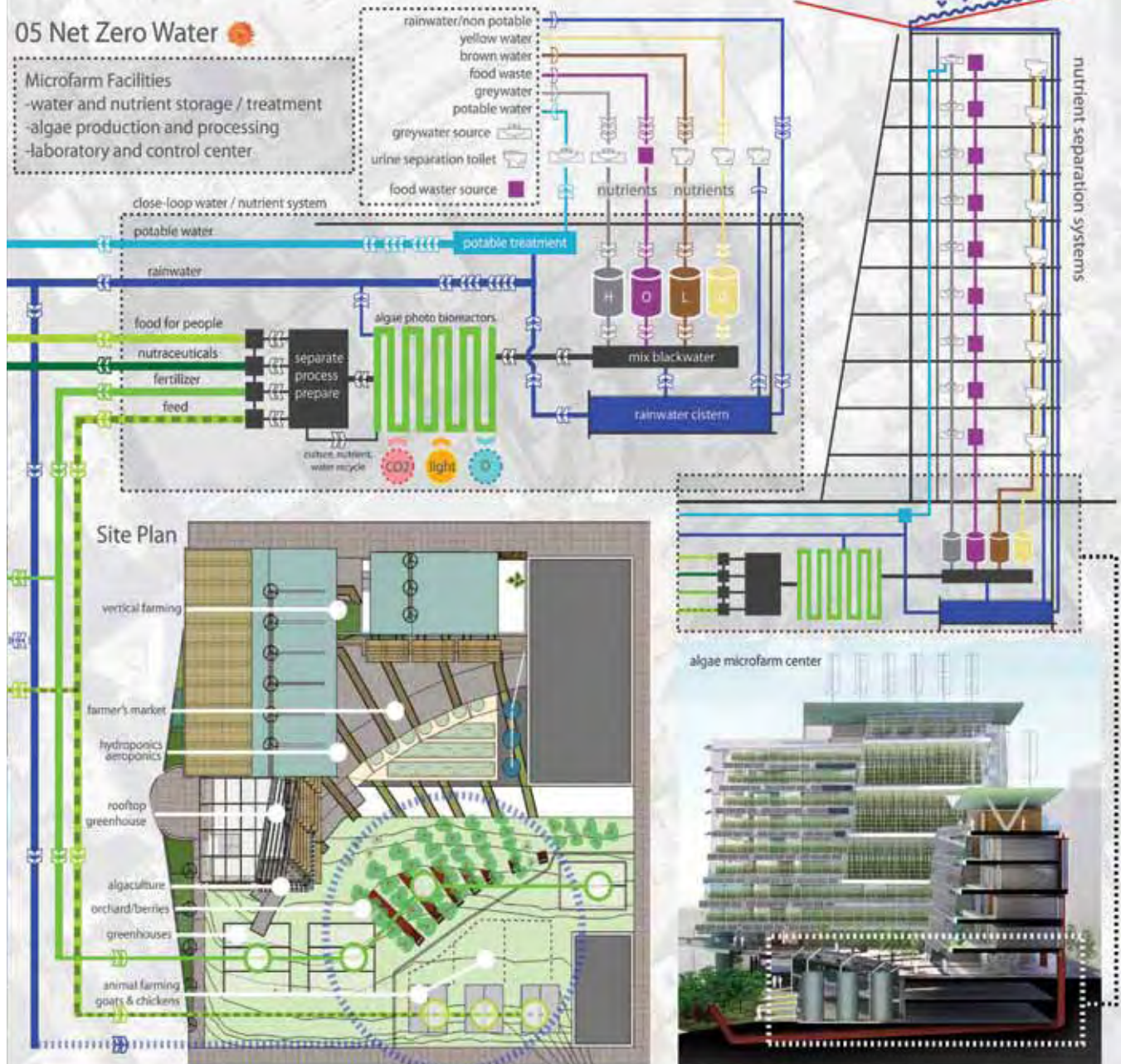
2011 International Algae Competition



### 05 Net Zero Water

#### Microfarm Facilities

- water and nutrient storage / treatment
- algae production and processing
- laboratory and control center



Algaculture growing food, fuel, feed, fertilizer & medicine



Hydroponics growing plants in water nutrient solution



Aquaculture fish/shrimp farming in controlled tank environment



Aeroponics growing plants in an air culture with water/nutrient mist



Aquaponics Farming plants/fish in a closed-loop symbiotic systems



Vertical Farming growing crops efficiently in vertical systems

by Mark Buehrer, 2020 Engineering Inc.



# Kampung Algae

## problem statement

### Less of food



UN: Population keep raising up to 6,7 billion since 1000 years ago until 2009.  
(KR News paper, 9/21/2011)



Tempo: At least 1,632 children in Yogyakarta under 5 years old have no food nutrients.  
(www.tempo.co.id, 5/27/2005)



KR: 777 hectare failed in harvesting cause of dryness in West of Java.  
(KR News paper, 9/21/2011)



Febriana Shinta: 200 hectares of agriculture area change to be housing land in Yogyakarta.  
(www.kbr68h.com/berita, 7/19/2011)



UNESCO: World water crisis in 2020  
(KR News paper, 9/21/2011)

### Less of (quality) farming land



## concept



Innovation agriculture with combining spirulina and house to be home industry. Algae ponds become walls of house and the space was made by, become a laboratory, work space or social space included. Like architecture template, these ponds adhering with the wall, border of the house or canopy of the path.



## purposed solution

### Present Proposed



#### Replacement

12 m distance from riverside used to bring back the ecological area for lack of vegetation grow up. The water will be stored on Winongo river and in the deep of land.

1 story building will be eliminate by demarcation of river and accommodated in the new place where the building are 2 or 3 stories.

#### Requirement

Algae needs water, sun light, and some nutrient for its life. Because of spirulina need a lot of water, this community have to prepare access and availability to get the water. In consequence, treatment Winongo river as water resource really needed.

Application algae ponds will located on public space, kampung path, and walls of the house & self. Much more, good more.

## Site Selection

Kricak, Sidomulyo, Badran (Yogyakarta)



Lot of people's activities in Winongo river give life pulse for their own lives in many sector. Its better when we can make this river and water flow contained can usefull with treat it back better like before when the water can drink directly, used to take a bath, or just play and recreation on side path from the river. Bring back some space to breath and get lot of fresh air will be a great thing for our lives.





**An Appropriate Algae Village Farm Base On The New Micro Farms Community of Winongo Riverbank, Indonesia**



Combining algae ponds with the Houses's walls of kampung in Yogyakarta city with over population would be an opportunity. Lot of poeple mean much more houses. Beside creating industry creative with algae walls pond, this society provide their own food at home. Not only in their house, but also at public space and wall space in this large kampung. All item public space wall and canopy out door will manage with 'koperasi' system where this system compatible at Indonesian Economy situation.



This building project comes after the 'infiltration' of the settlement can be done well. The results of the public can be accommodated and managed more in because it has a complete and advanced facilities. Algae Bridge, so the name of the diberika, will connect the villages are separated by a river into the container joint venture to build a village where they live.



**Algae Bridge**



by Wiryadi Sabdatama, Islamic University of Indonesia



# Urban Algae Bio-Fuel Production And Eco-Community in Prishtina, Kosovo



In the last 10 years Prishtina has seen a building boom, however from research there are close to zero eco-communities of any kind in the city. We have therefore found a perfect site in the Central city area and designed a whole new eco-community to encourage Europe's youngest country with also the youngest population to turn to a sustainable way of living.



Long Section of building A and B



Rich Fertiliser for helping the vegetable crops to grow healthier



Oxygen

Oxygen

Clean air and fresh vegetables ready to be sold to the locals

1. Section plan.
2. Section plan. This plan shows the building's footprint from a side-on perspective, showing the internal structure and the layout of the building.
3. Section plan. This plan shows the building's footprint from a side-on perspective, showing the internal structure and the layout of the building.
4. Section plan. This plan shows the building's footprint from a side-on perspective, showing the internal structure and the layout of the building.
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Urban algae bio-fuel production eco-community in Kosovo by Arben Jashari & Diana Jashari



## Algae Landscape Design and Architecture

### Showcasing algae research and recreation parks



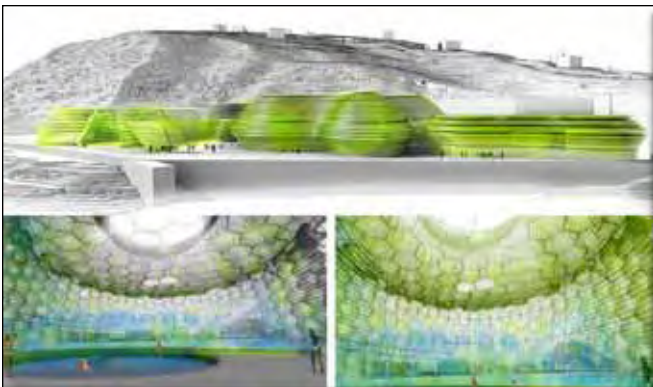
#### Algae energy exhibition park in Hubei, China

The site along the Hanjiang river in Jingzhou was a coal-fired power plant, with coal ash covering 50% of the whole area, severely impacting air, land, and water quality of the nearby communities. Treated CO<sub>2</sub> from the industrial zone feeds the algae systems to produce energy for the park. The design of the algae park will provide the public a comfortable park and popularize the recovery of the environment using microalgae and alternative energy technology.



#### The Seeds @ Coney Island in Singapore

In 2010, Singapore designated Punggol New Town as the first Eco-Town with 96,000 potential dwelling units as a test-bed for green urban solutions in energy, waste and water management. Across from Punggol is Coney Island, with the potential for Seed- a green park. Rain and surface runoff will be collected for algae for biofuel, water and *spirulina*. Play Tree, Water Bubbles, Sun Pipe and Wind Tree are interactive landscape elements that also harvest algae.



#### Algaetherapeia center in San Sebastian, Spain

This proposal seeks to create a research center for algae typical of the Basque coast for use in medical, food and industrial applications. A photo bioreactor skin generates the energy for all building operations: therapy baths, solarium, kitchens, classrooms and research laboratory. The tubular photo bioreactor becomes the axis of the architecture and the skin of the façade, the energy generator and the image of space and place. The enclosure is arranged in circular geometries.



#### Energy afterlife to energy in Reykjanes, Iceland

*Choreographing Algae, Plants and People with Geothermal Effluent.* Creating a new landscape using the heat now diverted to the ocean, utilizing three programs: algae cultivation, re-vegetation strategies and human interaction in a thermal resource park. Different algae species require specific temperatures to survive and thrive. The orchestration of the thermal gradient supports a range of 'Extreme Algae'. This project is an opportunity to create a unique destination park.



# ALGAE ENERGY EXHIBITION PARK CONCEPT DESIGN

Algae may change our lives

## Present situation

Located on the riverside of Hanjiang river in Jingzhou, Hubei province of China, the base of the case used to be a local coal-fired power plant and material yard with some farmland, covering an area of about 1016751 square meters. The thermal power plant was deserted since the beginning of the century. The surface of the power plant is covered with coal ash with an area of about 568978 square meters, which is more than 50% of the whole area. The dust from the plant directly made severe impact on the water nearby. The air, the farmland, and the communities around were seriously polluted by the coal ash which often flew with the wind. Although several clean ups were made to improve the ecological conditions here by hydraulic way, the improvement effect is limited. It demands stronger human interventions to improve the living environment.



Satellite map



Polluted area



Contaminated land

## Site plan



## Current situation analysis and countermeasure

In order to avoid the waste of resources and repetitive constructions, the site of the design should be scientifically analyzed. According to the different situations, the specific targeted modifications are classified as follows:

1. Reservation: selective reserve the original plants with good landscape, including: a lake, a small amount of trees, some shrubs, bryophytes in environment-restoration area.
2. Removal: the thermal power plant remainders and the construction waste should be demolished and carried away; the coal ash should be buried deep according to the terrain condition.
3. Transformation: transform the original serious-polluted areas into building bases; transform the original less-polluted areas into landscape sites.

■ Reserving area   
 ■ Removing area   
 ■ Transforming for building bases   
 ■ Transforming for landscape sites

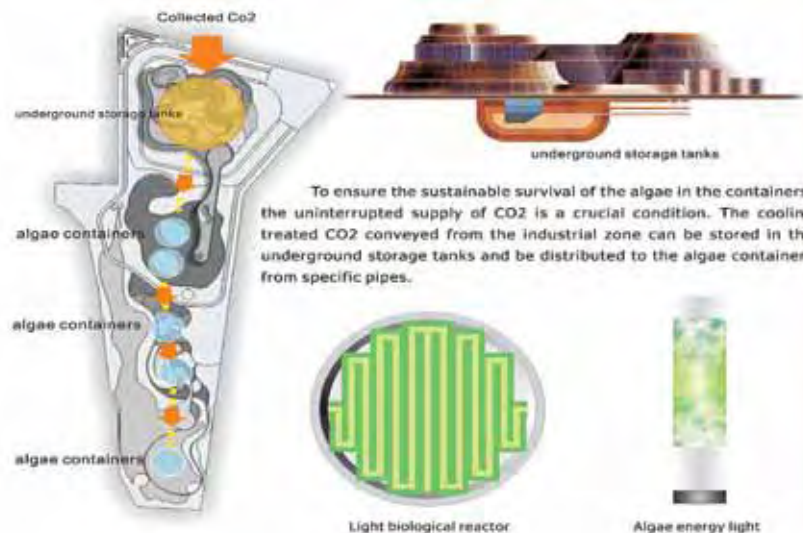


## Design description

The design is based on the design principle of landscape architecture, micro-algae technology and environmental engineering technology. In the reconstruction of the thermal power plant and the ash field, the design tries to realize the recovery and ascension of the natural environment by using micro algae technology, to present the advantages and the development of the use of the micro-algae technology in certain industries in the future, and to prove that the urban development and the environment can be friendly and harmoniously unified.

Algae energy exhibition park in Jingzhou, Hubei, China





## Soil-improvement

After the completion of the basic construction, the micro-algae technology may be used to improve the landscape on the barren soil.

In the sunlight conditions, the PH level of the soil may change in about 30 days, and the organic matter of the soil may increase when algae grows. These may provide suitable living conditions for other living things by improving the soil fertility.

## Light biological reactor

Suitable micro algae may fix and reduce carbon emissions effectively by biological CO<sub>2</sub> fixation method. Meanwhile, it is a environmentally friendly, economic way in comprehensive utilizing the biological energy and the algal body protein and other biological materials produced by micro algae.

## Algae energy light

Algae can be tapped for low levels of continuous electricity – perfect for the minimal power requirements of an elementary lighting fixture. Plenty sunshine sustainable supply of carbon dioxide and enough water in transparent glass container. Algae energy lights can be widely used in the park.

- A. Algae energy light
- B. Aerial view
- C. Algae energy technology exhibition center
- D. Light biological reactor group
- E. Waterside from west



by Chen Jie & Gong Ying



current 'natural filtration' process

Rain/ runoff → Rain garden/ Wetlands → Water bodies

spirulina

Spirulina can be harvested and used to reap economic returns for R&D and for the expenses of the island

water

Water harvested can be used for irrigation and used to sustain plants on the island

bio- fuels

Bio-fuels can be used for transportation and to sustain the island's electricity consumption

the SEED: self- sustainable

The three components will combine to form the 'SEED', which will make Coney self-sustainable. If successful, the Seed will be spread across Singapore, making individual towns self sustainable.

# algae- the seed at coney island

the idea:  
an additional layer

To delay and intercept the original process by adding another layer and function to the process.

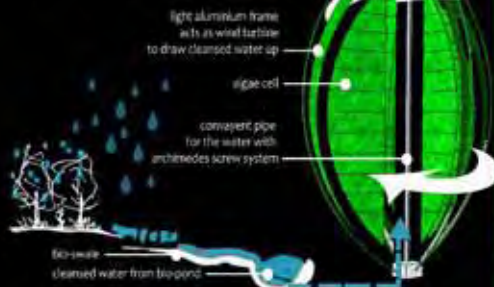
coney island masterplan:  
algae paradise

The Seeds @ Coney Island in Singapore

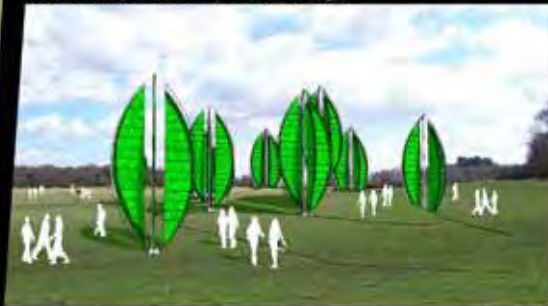


## the wind tree

the tree cares the environment



Iconic landscape element is always something we look forward, and yet, it's efficiently functional to harvest our algae



1128  
landscape design

who doesn't want to play anyway? and better yet, the more you play, the more you do for the environment!

## let's conclude!



an exciting thrilling boardwalk experience

accessible floating pontoon for visitors to get closer to water and enjoy a walk experience at the boardwalk in between the "waterbub"

algae cell

main pipe from main land

water turbine powered by the under current to generate power to draw water from the main land



some eco-friendly bubble

## the water bubble

by Yurika Chua, LandscapeLab Design Co.

# Algatherapeia



600 workers / researchers



1300 people / capacity



1500m<sup>2</sup> of algae treatments



Gastronomy based on algae and sea water intake



6840m<sup>2</sup> program

800m<sup>2</sup> contemplation space walk



coast marine species + photobioreactor tubes = Skin architecture of algal biomass



conical volume

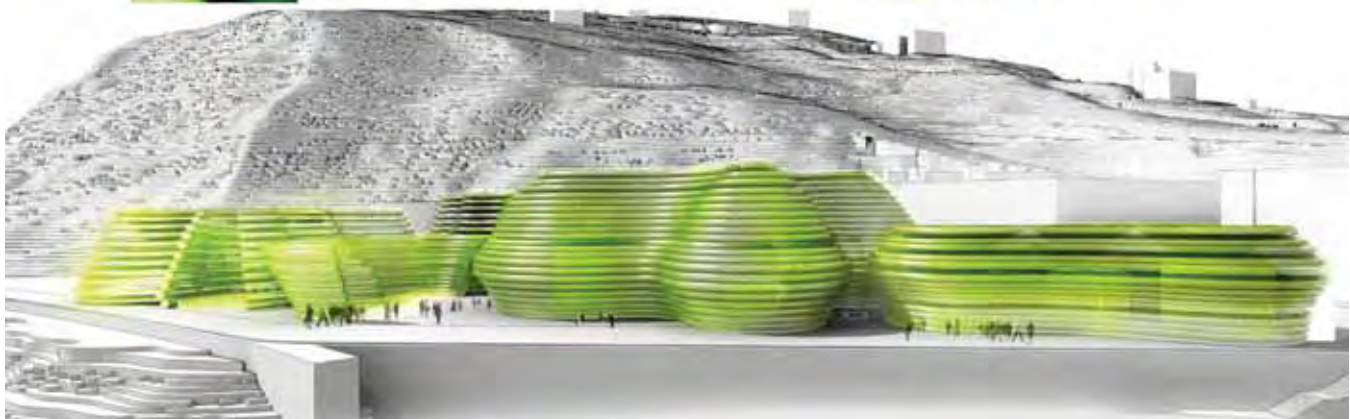


membrane +  
programmational cores



tubular volume:  
skin of photobioreactor

I AM  
green  
energy



Algatherapeia center in San Sebastian, Spain

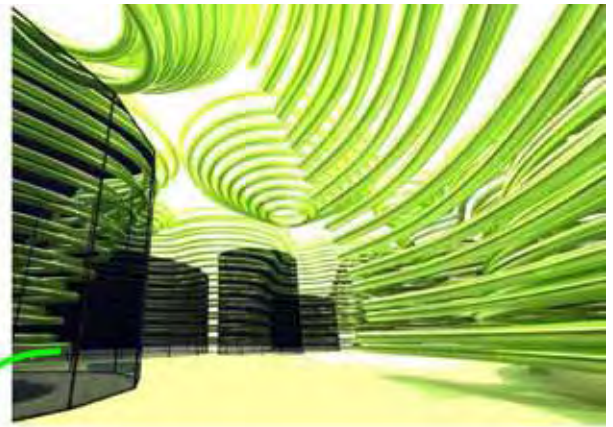


# Algatherapeia

photobioreactor skin generates the necessary energy for the building can produce its own energy.

photobioreactor skin adapts to the program requirements, the need for more or less light through the separation of the tubes that make up the facade.

skin architecture and generating green energy.

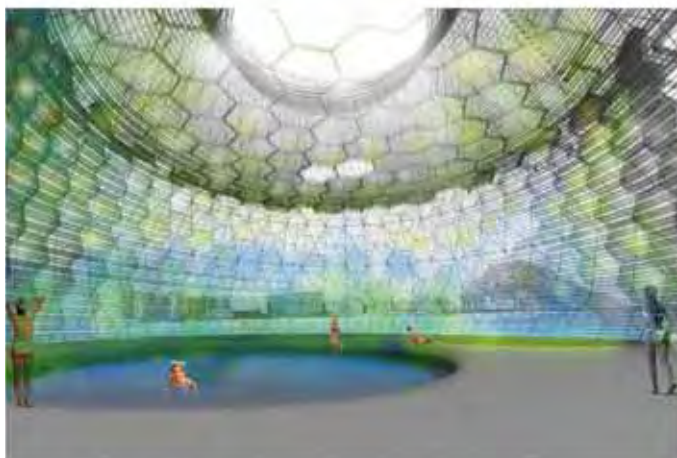
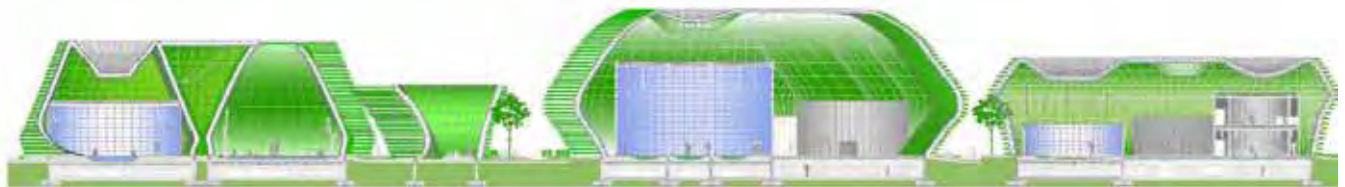


inside outside

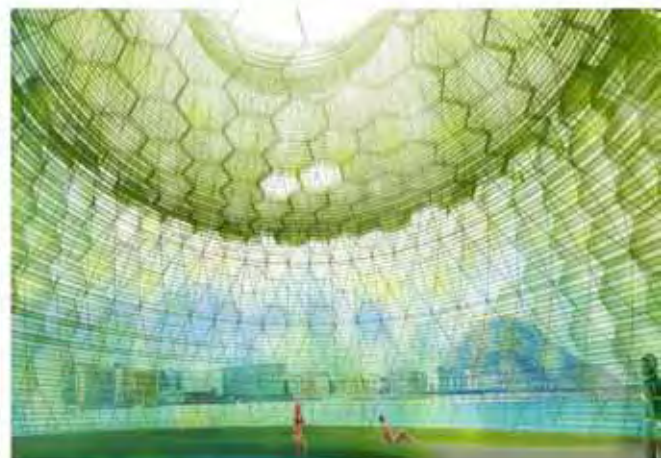
outside inside



## architectural photobioreactor skin



changing atmospheres



show environment

by Judit Aragonés Balboa





**Energy Afterlife to Energy [RE]Production  
Choreographing Algae, Plants, and People with the Geothermal Effluent of  
Reykjanes, Iceland**

The project entry, titled *Energy Afterlife to Energy [RE]Production: Choreographing Algae, Plants, and People with the Geothermal Gradient of Reykjavik, Iceland*, seeks to create a new landscape developed around the extension and compression of a temperature gradient provided by the effluent of a geothermal energy production process. Geothermal energy processes and uses consistently yield a byproduct—geothermal effluent. The case study and site of the project, Reykjavik Power Plant, withdraws 300°C thermal brine from 1,600-3,000m below grade to extract steam which runs through two 50 MW turbines to generate electricity. The thermal brine is 190°C after the steam separation process. It is next piped to a cooler where it is mixed with 8°C sea water, becomes 57°C, and is sent to the Atlantic Ocean. This hot water possesses the potential to yield an alternative outcome—rather than attempting to quickly divert the water out to sea, its temperature gradient can be used and extended as a thermal device in the landscape to create micro-habitats, climates, ecologies, and economies. The project explores temperature and heat as an invisible, phenomenological design material in the landscape by exploiting its basic thermal principles of conduction, convection, and radiation. The temperature gradient inherent in geothermal effluent is used as the source of this exploration to interweave algae cultivation and production, revegetation strategies, and temperature's experiential qualities as a thermal resource park—salty pools, steam baths, and saunas paired with associated algal, flora, and fauna communities whose transferred heat energy fuels one another.



Energy afterlife to energy [re]production in Reykjavik, Iceland by Catherine deAlmeida



## Algae Landscape Design and Architecture

### Installing algae schools and educational art facilities



#### Algae school on Huiquan Bay in Qingdao China

This public art installation for education and enlightenment is a transparent glass factory which uses *haematococcus* to produce astaxanthin, a powerful antioxidant. The transparent glass is overhead so visitors can enjoy the algae transforming its color dramatically during its growth. Sunshine above the glass pool creates gorgeous light and shadow which doubles the visual beauty. Solar waterwheels automatically adapt to the growth rate of algae.



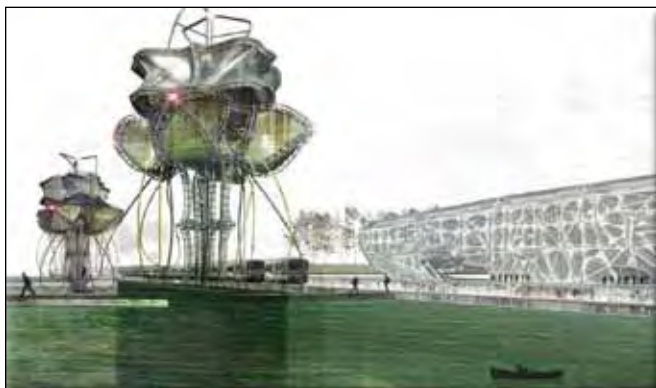
#### Algaegarden celebrates algae in Quebec Canada

Algaegarden leads the visitor to appreciate algae both as an alternative to oil and as a source of food and nutrition. Bicycle pumps invite visitors to participate in aerating the algae. The spectrum ranges from reds to greens to bioluminescent algae. Featured algae are *haematococcus*, *dunaliella*, *chlorella*, *spirulina*, *nannochloropsis*, *phaeodactylum* and *pyrocystis*. The algaegarden was selected to be part of the 2011 Metis International Garden Festival in Quebec.



#### Living Machine at Sacramento Discovery Center

The key feature of the Botanical Discovery Center is the Science Pavilion, which collects and uses water from the two rivers nearby for use in its algae production ponds. The Living Machine is an architectural entity whose function encompasses diversion of river water through algae ponds inside and within the skin of the building. The process used for energy or fuel creation, culinary purposes, oxygen creation or detoxification, are all drawn from algae.



#### Varsity think tank in Oxbridge, England

A speculative proposal comprised of a new rail link within the disjointed Varsity Line with a research platform based on experimental water-based infrastructure. Food production, fuel cultivation and waste treatment, the three major utilities on which society is dependent, are being dealt with as three separate ecologies. The research program is based on the extended hydrocycle of the algae photo-bioreactor and other water-based technologies.

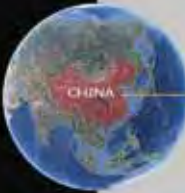
## Algae School

the art of survival

### Description Summary

Algae School is a public art installations which has the function of education and enlightenment. It is a transparent glass factory which uses *Haematococcus pluvialis* produce astaxanthin. Algae School is silent criticism of the people in the near aquarium to meet their visual simply, and attract the public's attention back to the ocean's kindness of feeding on human. Algae School try to awaken the public's concern for the survival and reflection of the Illusory utopia city by the beauty of art, its education function for the public are reflected here, so named for the Algae School.

### Location




Qingdao



Huiquan Bay



Marine Animal Circus  
Qingdao Underwater World



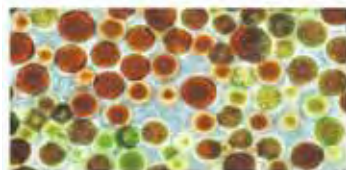
Algae School

## Background





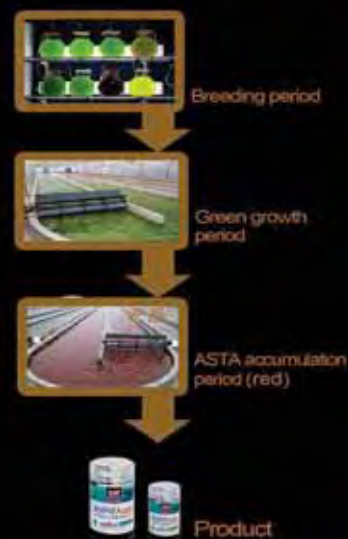
**Astaxanthin (ASTA)** is the most powerful antioxidants found in antioxidant by this far. Its activity is 1000 times of vitamin E, 20 times of lycopene. Oxidative damage is the mother of all injuries, so prevention of oxidative damage effectively may terminate or slow the disease's occurrence and development. So it is of great significance to the future of human health. Farmed *Haematococcus pluvialis* (as shown below) is the best source of ASTA currently.



### large-scale farms of ASTA



### ASTA production process (mature technology)



Algae school on Huiquan Bay in Qingdao China



# Algae School

the art of survival

## Structure

- self-adaptive steel substratum
- glass partitions
- algae medium
- glass pool
- glass gourd
- pillar
- bamboo boardwalk
- breeding pool
- fence
- drain and exit
- recycling structure of Marine Animal Circuit
- growing structure of Marine Animal Circuit

## Schematic

Process map

plan

Micrographs

- Breeding period
- Green growth period
- ASTA accumulation period
- Harvest period

## harvest & enjoy way 1

cheer!

Harvested in a greenhouse for reproduction while promoting algae to culture to release ASTA

algae juice (ASTA-rich) + fruits =

## harvest & enjoy way 2

vegetarian salmon

The traditional way of getting unisaturated is eating wild salmon, which makes excessive commercial fishing as a result, wild salmon is endangered and marine ecological balance has been destroyed.

To protect the ocean, we should increase the amount of artificial breeding and look for substitutes at the same time.

As is shown, we can use algae juice (ASTA-rich), soy, cream and flaxseed oil as raw material to make vegetarian salmon which can simulate the nutritional composition of wild salmon.

The special salmon is free for visitors to enjoy, in order to promote healthy ideas and ecological spirit of public.

The white part is mixture of cream and flaxseed oil, folic acid combined in flaxseed oil can replace the DHA and EPA in salmon.

The red part is mixture of algae juice and soy milk (like making tofu). It contains natural ASTA, it shows red and looks like real salmon meat.

by Bi Yupeng



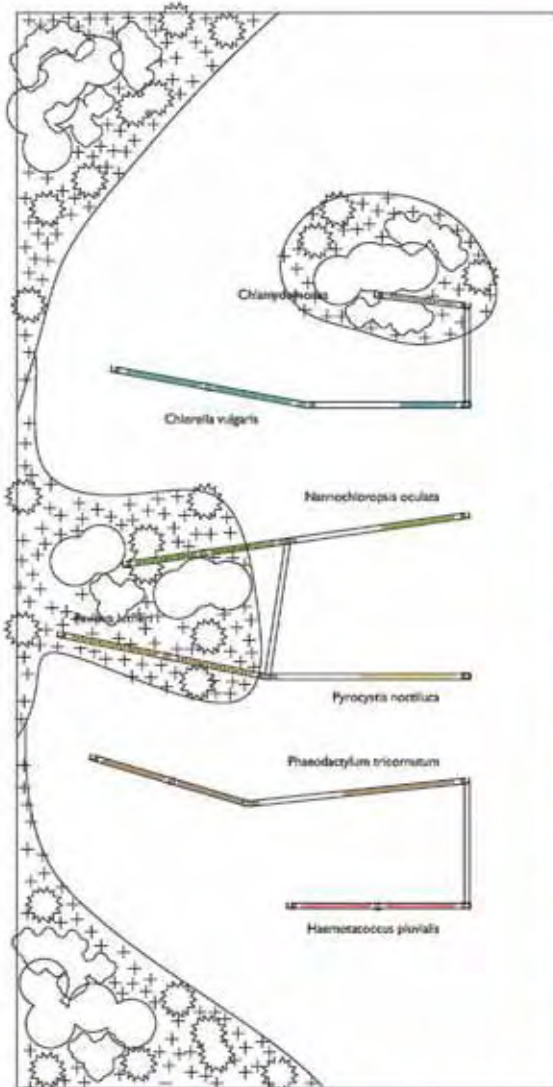


algaegarden celebrates the beauty and productive potential of algae through a design that underlines its diversity and meaning. This garden stands between the landscape, the artistic and the scientific world, presenting algae organized by colour and species in curtains of tubes hanging from steel frames. The spectrum ranges from reds to greens to bioluminescent algae, which can glow a bright blue. The algae, often considered a nuisance in the garden pond, here become an object of beauty and curiosity. The garden leads the visitor to appreciate algae both as an alternative to oil and a source of food and nutrition. Referencing a pond edge, the garden is lined with pond grasses, and displays algae specimens, most that can be sourced locally. Bicycle pumps invite visitors to participate in the process of aerating the algae, creating a spectacular display of bubbles throughout the tubes. The garden explores the diversity of an often-overlooked plant, and demonstrate possibilities for how algae might become an evocative and productive part of our daily lives.



Algaegarden celebrates the beauty and productive potential of algae in Quebec Canada

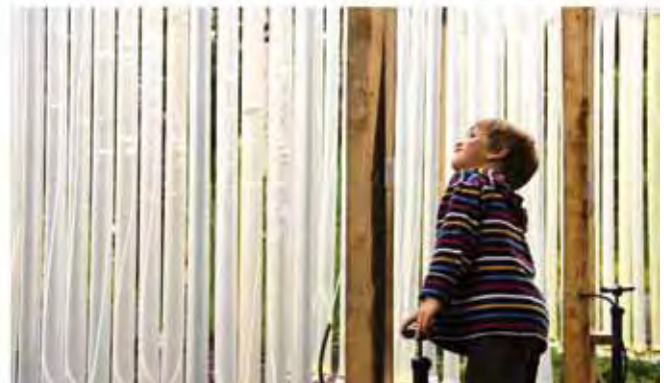




		<b>Haematococcus pluvialis</b> Rich in carotenoids, the pigments in this algae are often added to food.			<b>Nannochloropsis oculata</b> An algae with a tough cell wall, it is used as fish food, but also has biofuel potential.
		<b>Dunaliella salina</b> Grows in super salty waters, this algae also makes pigments useful in food and cosmetics.			<b>Spirulina</b> Used even by the Aztecs as a rich source of protein and nutrients.
		<b>Phaeodactylum tricornutum</b> Lives in the ocean and has 3 different shapes: oval, banana or triangular depending on the conditions.			<b>Pyrocystis lunula</b> Brown by day, fluorescent by night. Millions of these algae are responsible for the eerie glow of bays in Costa Rica.
		<b>Chlorella vulgaris</b> Rich in chlorophyll and protein, this is often used as a food supplement as well as being rich in oil.	 <a href="http://www.algaegarden.wordpress.com">www.algaegarden.wordpress.com</a>		



The garden was selected to be part of the 2011 Metis International Garden Festival in Quebec. It is open to the public from June 25 to October 2, 2011 on the site of Les Jardins de Métis/Reford Gardens, and has been invited to return for the Summer of 2012. Out of 25 international gardens at the festival, Algae-garden has consistently been within the top 3 of the People's Choice. Prototypes of the algae-garden could also be found in the Urban Physic Garden and the FarmShop in London, and as feature project for IDEX/NeoCon Canada.



by Heather Ring, Brenda Parker, Synnove Fredericks



# SACRAMENTO BOTANICAL DISCOVERY CENTER

Set in the year 2030, the Sacramento Botanical Discovery Center will be created to accommodate the California High-Speed Rail [CHSR] project as a vital Northern California terminal, spanning close to 600 miles between the southernmost terminal in San Diego and saving approximately 441 lbs of carbon emissions that are released during each trip by car.

The 270 acres allocated for the development provides the most central location for a transportation hub, but more importantly, with its proximity to the Sacramento and American Rivers as well as the number of academic institutions, will have the potential to address the environmental, technological and urban conditions of the day.

Programmatically, the proposal encompasses the high-speed rail terminal, a performing arts center, an athletic / recreational facility, and a science pavilion; whose functions entail both water treatment through algal production as well as a research / development facility where relevant technologies may be investigated by the scientists and students of Sacramento, and its neighboring districts.



The Sacramento Botanical Discovery Center's key feature is its Science Pavilion, which collects and uses water from the two rivers nearby for use in its algae production ponds. The water intake draws water upwards into the building where it can be taken into a number of separate, isolated ponds, arranged in a closed raceway where each strain can be kept without risk of crossing multiple strains in a single pond. This methodology provides a few advantages; firstly and foremostly, the individual ponds can be controlled accurately without fear of affecting other algae projects that may be going on in other laboratories. The ability to control the amount of water as well as its chemical and biological composition, exposure to light and control of temperature and pressure, will allow to precise, scientific work to be done in an environment that specifically emphasizes the clinical nature of the research and its study.

The water drawn by the pumps emerge at the laboratories in the uppermost part of the building, where it can be analyzed and documented regularly, and begins its life cycles through the living machine process. This water can be taken to any pond in the building through a series of pipes and ducts which have been designed to maximize flexibility and versatility. In addition to this, the ponds themselves can be integrated into the living machine processes, allowing for ponds that are at a higher point in the machine to be drained into sequentially lower ponds, where algae can be bred, modified and experimented with, as per the necessities of the scientists and students.

With the various species of algae, many different factors must be taken into consideration to allow for the most efficient and productive environment for growth. With certain strains such as *Spirulina* blooming much more readily at higher temperatures, and other strains blooming at lower temperatures, the efficiency of the living machine can be increased to become more productive when more algae is needed to be produced. With a large facility that allows sunlight to penetrate throughout the spaces, it will be a simple task to provide addition lighting and heating requirements, which will change as the seasons change.

## Living Machine at the Sacramento Botanical Discovery Center





## THE LIVING MACHINE

The concept of the LIVING MACHINE is drawn from a combination of a few different ideas. The first major portion of the living machine embodies the MACHINE half of the word. It features the strengths that are present in industrial processes, such as a large volume of production done primarily in assembly lines, with the mechanical systems necessary to accommodate live process.

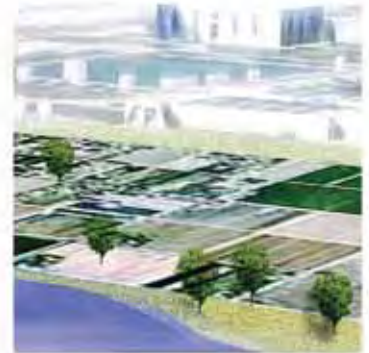
Elements of industrial and workflow design allow for the living machine to be a very flexible industrial component. With ponds that can be isolated, made larger or smaller, or even connected in a series, as may be required for certain detoxification or experimental studies, the capacity to modify and customize production situations allows for the scientist and student users to progress further in their research with fewer necessity for ancillary production systems.



kinetic freeway overpass



wind turbines



urban farm



photovoltaic panel arrays

The site encompasses 270 acres of brownfield, industrial land North of downtown Sacramento, adjacent to both the American and Sacramento rivers, however, provides no access to either.

This project seeks to incorporate these water bodies into the topography, and integrate its detoxification into "The Living Machine" — a flexible algae farming system within the Science Pavilion.



micro delta

by Andre Beaudoin

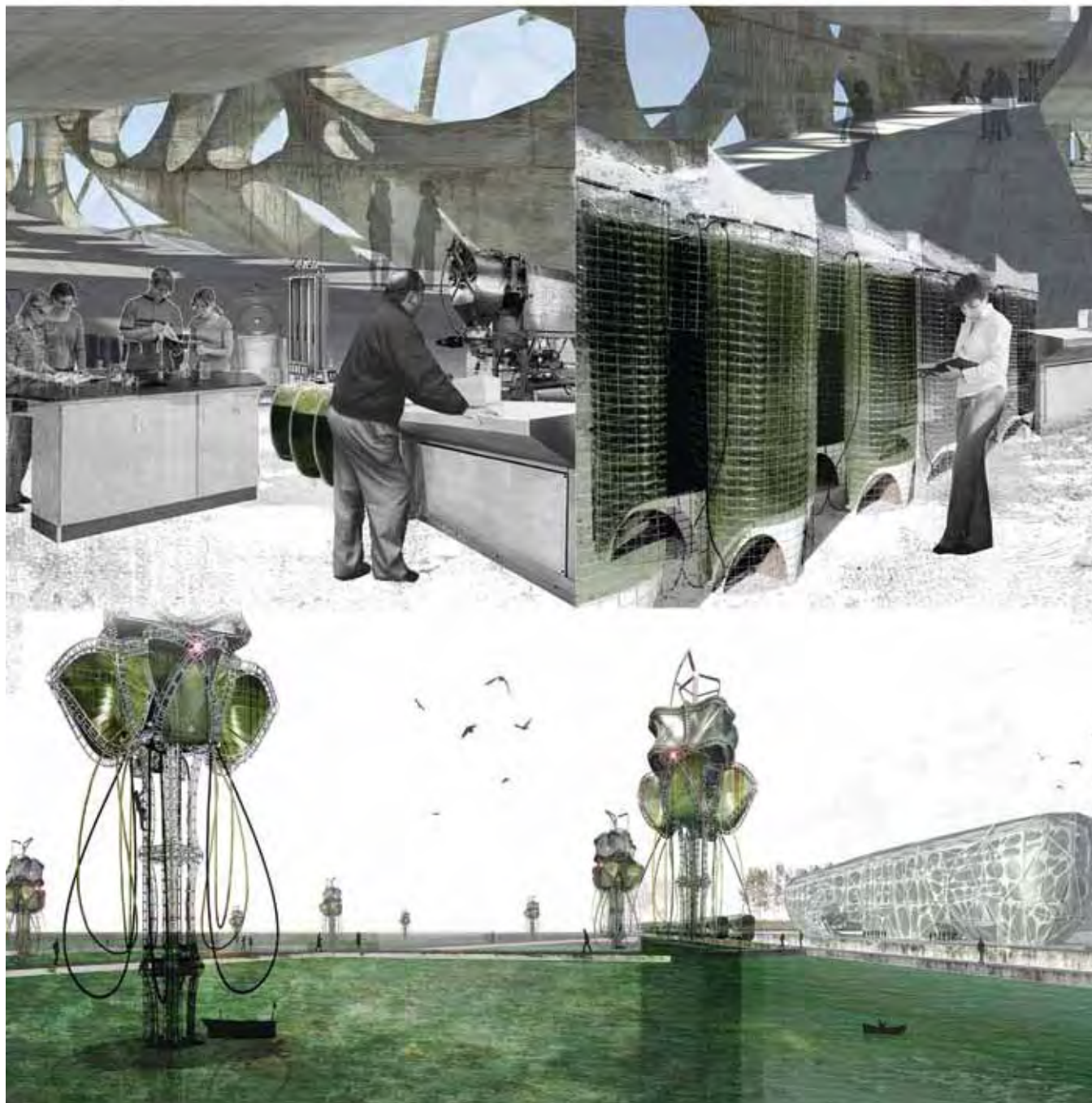


**VarsityThinktank** sets out to explore the Thinkbelt ideology of scientific education that becomes 'a source of employment, wealth and delight' for posterity. It is a speculative proposal comprised of a new rail link within the disjointed Varsity Line, where a collective research platform based on an experimental water-based infrastructure would be implanted.

## **VarsityThinktank**

Under the current fiscal and ecological crunch, new scientific research may provide alternative solutions to the food, energy, waste disposal demands of the expanding 'eco' communities, and satisfy the knowledge-based economy initiative of the Oxford-Cambridge Arc. The collective nature of the research facility along with the reconnection of the Varsity Line would aid in the reconciliation of Oxbridge, situated on each end of the Varsity Line, to compete with the now in favour Ivy League. Supported by the institutional muscles of Oxbridge and other universities in the region, the platform would become the launching pad for new ideas.

Food production, fuel cultivation and waste treatment - the three major utilities which society is dependent on are being dealt with as three separate ecologies. The research program is based on the extended hydro-cycle of the algae photo-bioreactor and other water-based technologies to make a mutual-supportive infrastructure. This forms a comprehensive research program through studying the reciprocating potentials of these technologies.

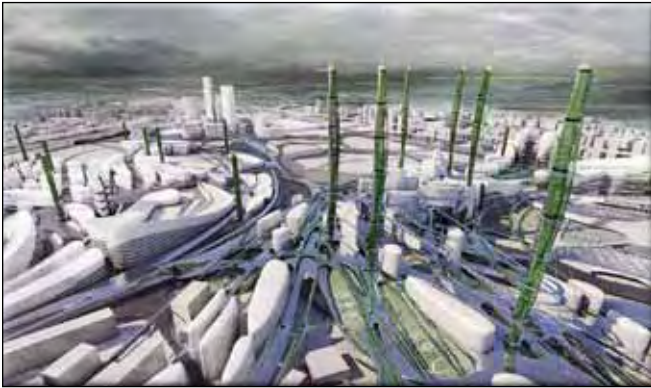


Varsity think tank in Oxbridge, England by Ivan Chang



# Algae Landscape Design and Architecture

## Redesigning urban master plans with algae production



### [Infra] Structural algae ecology for Taipei, Taiwan

This strategy is focused on minimizing the amount of newly built impervious surface by suggesting a porous intertwined network of transport infrastructure. Rain-water will be harvested through the porous urban fabric and recycled for horizontal and vertical farming. Algal photobioreactor towers will collect CO<sub>2</sub> from vehicles and buildings. Horizontal layers of hydroponics systems will provide food for the city.



### Urban algae culture in Shenzhen, China

*The Urban River from Waste to Source.* This is a proposed masterplan for an urban village of 20,000 people within the larger Shenzhen city of 14 million people. The proposal re-articulates the 'urban river', the historic landform of Shenzhen, as a decentralized waste water treatment network with sources of recycled water on a roofscape. This elevated urban river roofscape has modular algae units for waste treatment and fuel production, urban farming and community space.



### CO<sub>2</sub> eliminating floating park in Hong Kong

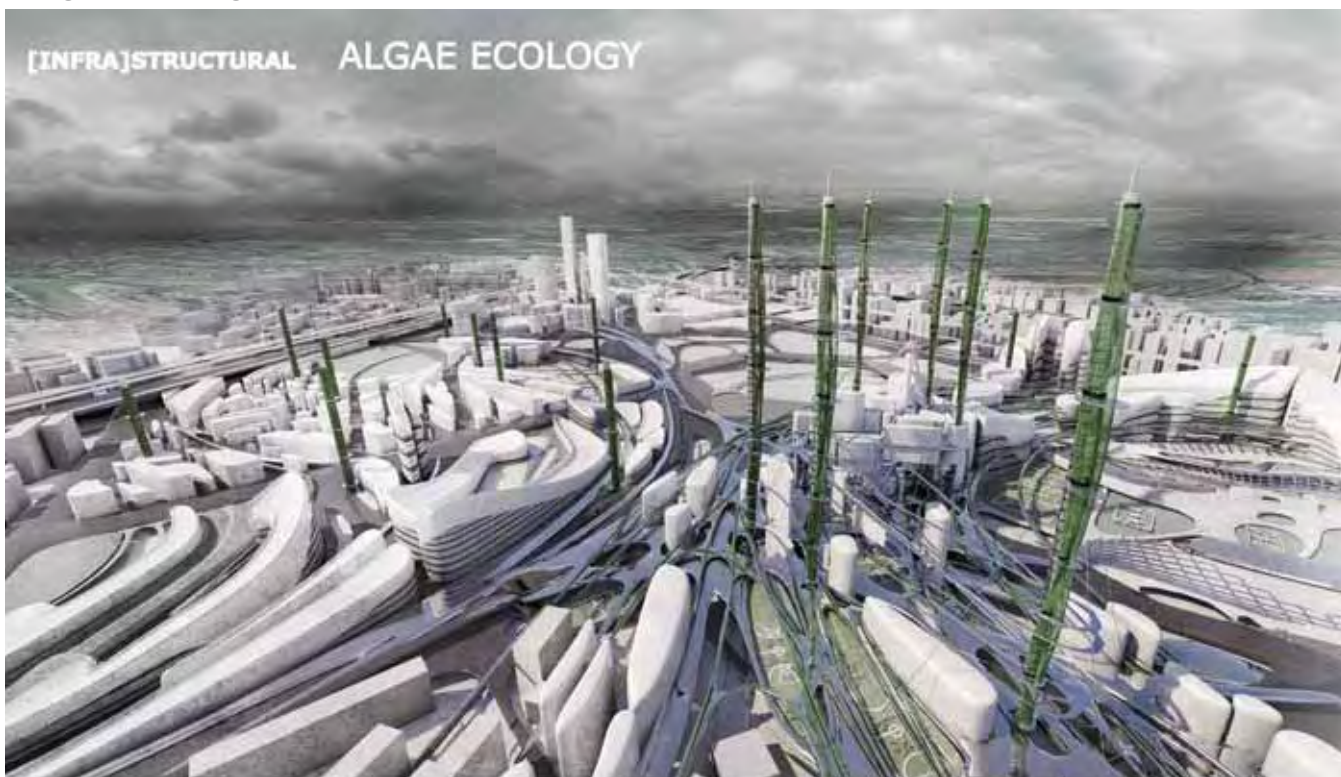
*Rule of Nature: Waste is Food.* This system uses algae to turn car exhaust (CO<sub>2</sub>) into power for the city. Three functional modules are the Algae Cell to turn CO<sub>2</sub> to H<sub>2</sub>+O<sub>2</sub>, the Fuel Cell to convert gases to electricity, and the Storage Cell for the city power grid. The site is a shore front expressway next to a dense urban residential development in Hong Kong. Car exhaust CO<sub>2</sub> is pumped to algae cell modules for hydrogen-producing marine algae to produce hydrogen and oxygen.



### 50 year master plan for Alameda Air Base

Decommissioned since the 1970s following the Vietnam era, the site is heavily polluted and mostly abandoned. The redevelopment of this site in Alameda on San Francisco Bay includes initial remediation of toxic land and water, habitat and wetlands restoration, infrastructure, tunnels and towers to sustain re-population and algae production for biofuel. Photobioreactors can be used to create covered spaces and lighted walkways when filled with bioluminescent algae.





## [INFRA]STRUCTURAL ALGAE ECOLOGY

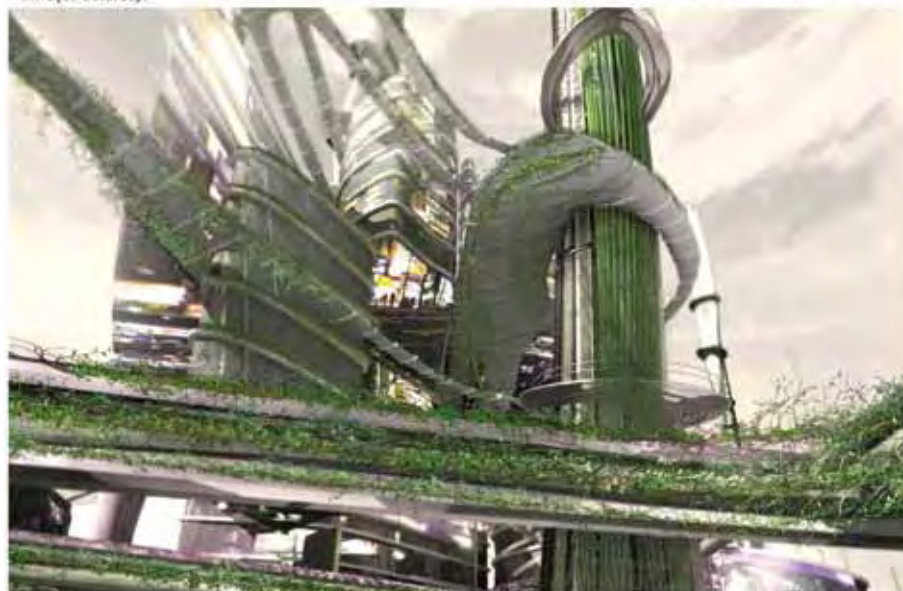
*[Infra]structural ecology* seeks to introduce a new urban strategy for Taipei, Taiwan by integrating vertical algae production systems. The chosen site is a large currently developing area north of Chiling river. There is an existing danger of high impervious surface ration in the city - this includes large concrete surfaces and built mass. The main urban strategy is focused on minimising the amount of newly built impervious surface by suggesting a porous intertwined network of transport infrastructure (hierarchised in areas for cars, mopeds and pedestrians), building services, buildings and urban farms. It establishes vertical and horizontal urban permeability on site, thus improving the pervious performance of roads and pavements. Inhabited spaces are formed within the voids created by merging multiple layers of city *infra(structures)*.

To maximise usable ground surface, innovative ways of farming and energy harvesting have been incorporated within the scheme. Longitudinal strips of hydroponics systems wrap around buildings and roads to provide food for the city. In addition, algae growing photobioreactor towers collect CO<sub>2</sub> from the dense transport network, which is then harvested for use back into the transport system. Rain water is allowed to penetrate through the layered porous urban fabric and is then used to supply nutrients to both systems. As a result, there is an established closed loop system that generates urban clusters and provides opportunities for growth.

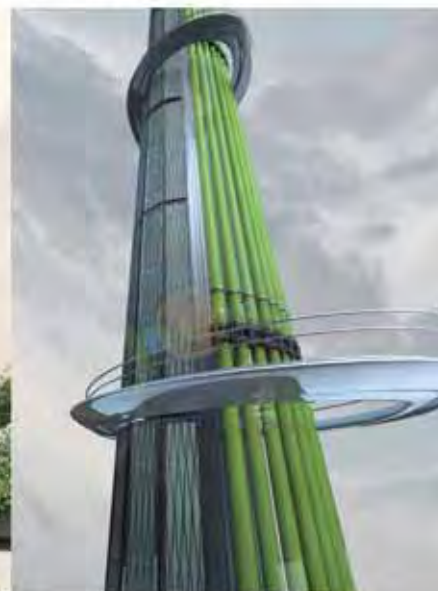
## URBAN POROSITY

## URBAN ECOLOGY

The project suggests possible scenarios for inhabitation of the vertical city - sport facilities, night markets and large public voids. Advertising signs and brand names begin to conceal the inhabited clusters, while an industrial like system of water pipes, bioreactors and hydroponics crawl through and around the city. There is no clear division between infrastructure and buildings, public and private space, suggesting that city circulation could in fact become occupied by urban growth. Thus, the scheme questions current urban planning strategies by inverting vertical and horizontal layers and blurring and unbalancing the boundaries of the city.



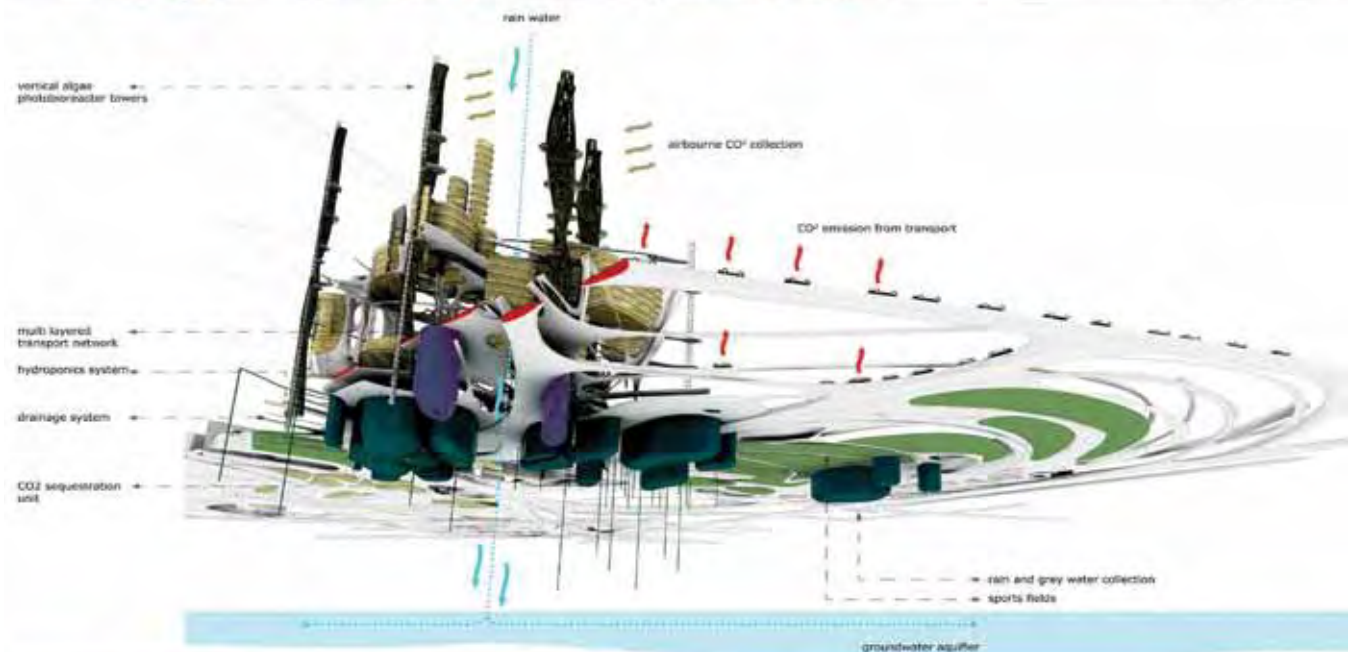
Algae landscape integrated within transport infrastructure networks



Detail perspective of a bioreactor tower

## [Infra]Structural algae ecology for Taipei, Taiwan





Flow diagram describing algae and water agricultural systems

by Aleksandrina Rizova & Richard Beckett



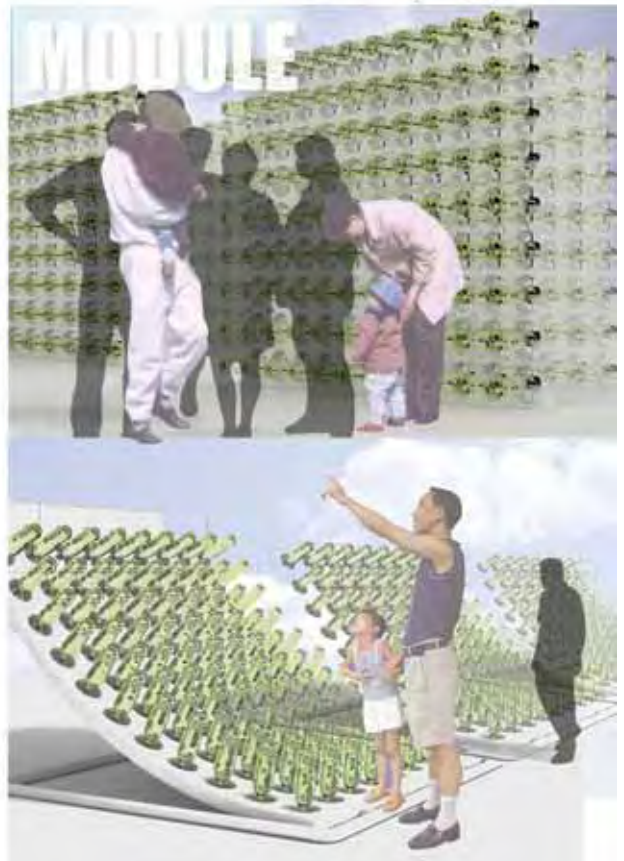
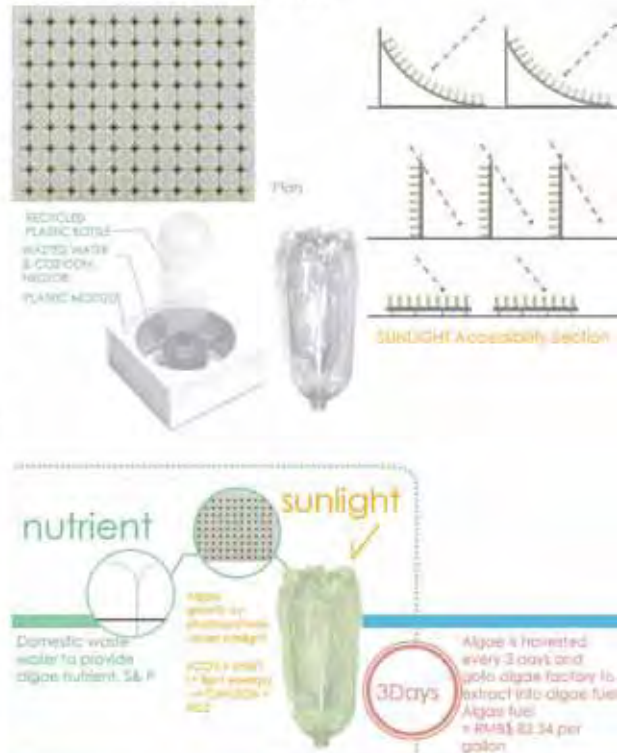


Urban algae culture in Gangxiacun, Shenzhen, China





## ALGAE PRODUCTION



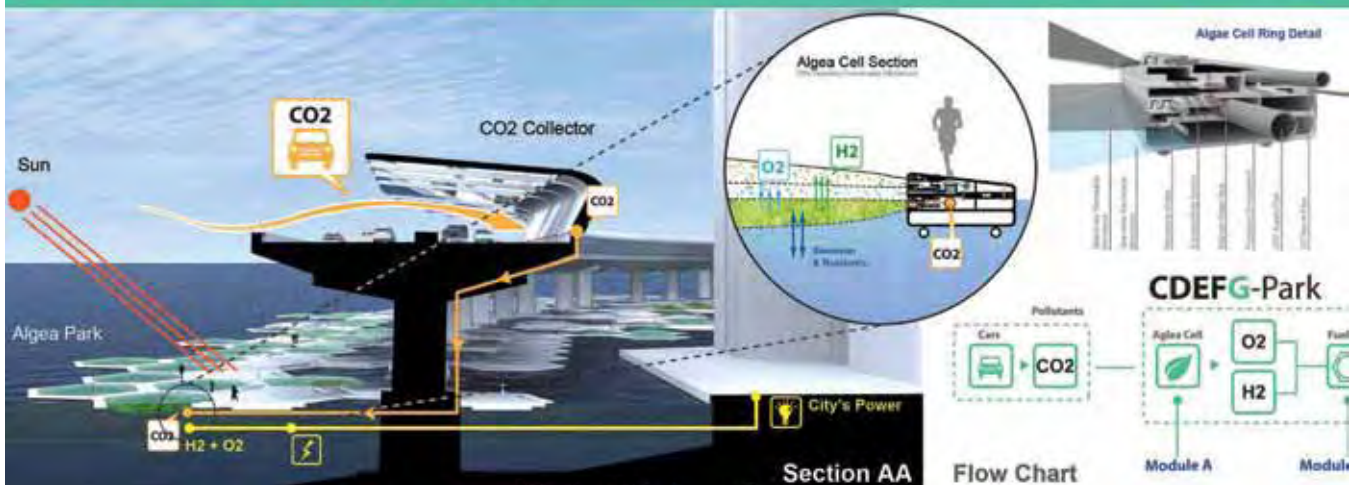
by Kady, Wong Hoi Kei & Kate, Lau Hoi Ying & Perry Li



Track 1 Algae Landscape Design



Car Exhaust to City's Power



Carbon dioxide eliminating floating green park in Hong Kong



# CDEFG-Park

CarbonDioxide-Eliminating Floating Green Park



Unpleasant Space to Public Green Park

## Design Philosophy

### The Rule of Nature: WASTE IS FOOD.

Simple but conscious designs to create not just an urban green extension, but a sustainable system utilizing algae to turn car exhaust (CO<sub>2</sub>) into power for the city, with fresh water as a by-product to support park vegetations. The three functional modules: Algae Cell to turn CO<sub>2</sub> to H<sub>2</sub>+O<sub>2</sub>, the Fuel Cell then convert them to electricity, stored in the Storage Cell for city's use, redefining unpleasant space below express way to a floating dual function green interface.

morsus-frog Hydroryza aristata

## Design Inspiration

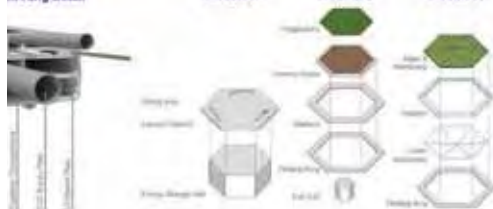


## Before

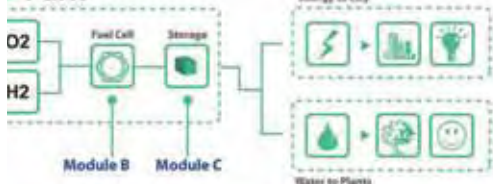


[ Module C ]  
Storage + Platform

## Ring Detail



## i-Park



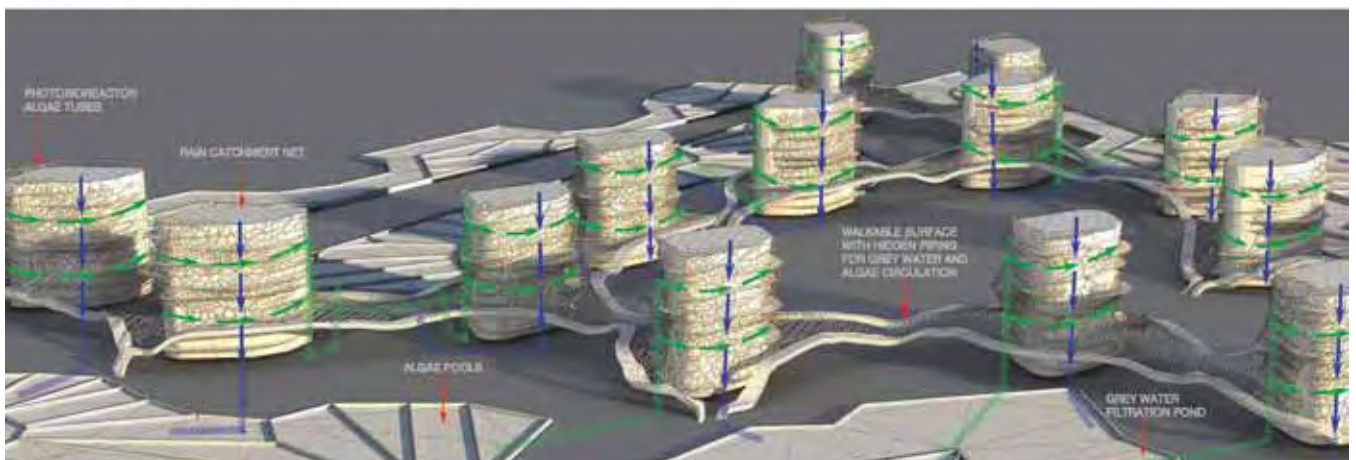
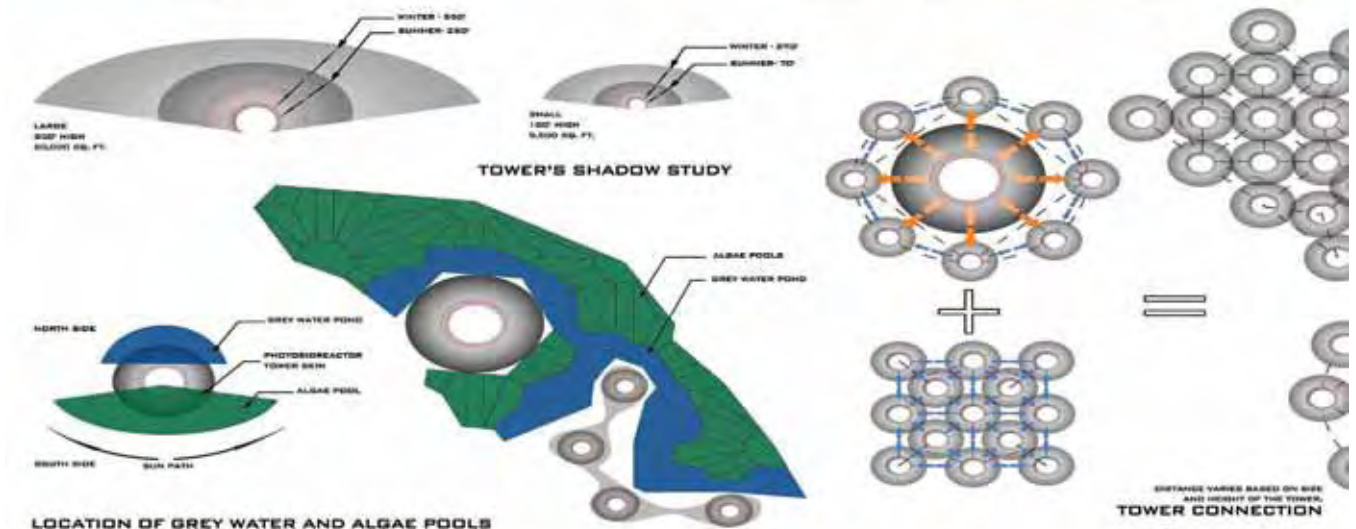
H<sub>2</sub> O<sub>2</sub> producing Micro Algae: Chlamydomonas Species



Noise Barrier with CO<sub>2</sub> Collecting Louvers

by Adrian Yee Cheung Lo



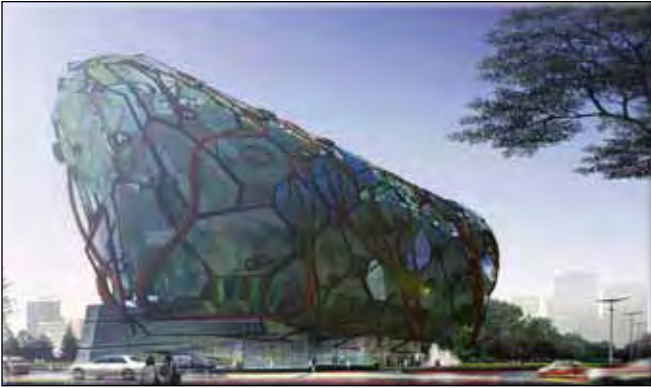


Algal Urbanism: 50 year master plan for Alameda Air Base by Olga Kozachek, E. Avera, A. Galo



# Algae Landscape Design and Architecture

## Designing living buildings with photosynthetic architecture



### Persatuan Arkitek Malaysia Centre in Malaysia

As a living entity, this building becomes the breathable Malaysian Institute of Architects. The outer skin is a glass shell reinforced with octagonal frames and perforated with controllable openings. Modular bioreactor panels are placed at openings along the inner facade. Algae is contained in continuous loop tubes which are self-perpetuating and require minimal maintenance. Building components biomimic the stem-leaf mechanism of a tree, mimicing being in the shade of a tree.



### BioOctonic utility towers in Zagreb, Croatia

Designed for any city, these vertical farming towers are designed for production of biofuel and city air recuperation, to be placed on existing petrol stations. First façade layer of the tower is an outer skin layer which is a tubular system for the growth of algae. Design specifications of the BioOctonic Tower are: location- any urban area in the world; stories above ground- 30 floors; stories below ground- 3 floors; structure- reinforced and pre-stressed concrete.



### A self sustaining tower for London

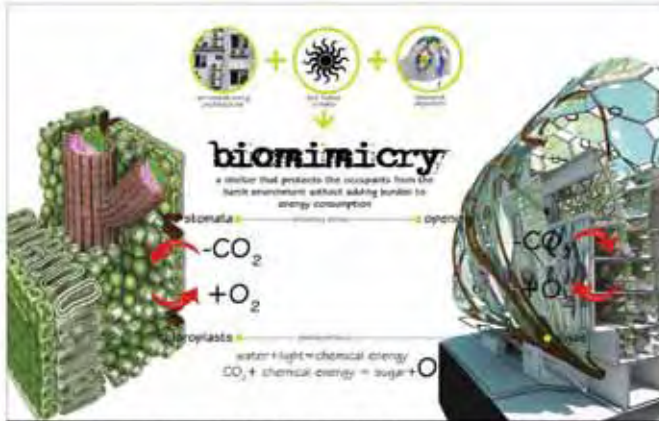
*Ecologies of (Bio) Diversity.* The building is a living ecology. Algal 'fields' covering the facade absorb CO<sub>2</sub> and can be harvested for bio methane for renewable energy for the tower and surrounding structures. The waste biomass through anaerobic digestion feeds the building skin. Waste water from the building is sent through the algae, cleaning it for re-use. Surplus heat from the digestion and the tube beneath can be circulated through the tower in winter.



### Thames pilotage station, Millwall Dock in London

This algae biofueled Thames River pilotage station can handle 12 launch boats along its floating jetty with marine algae biofuel stations, floating boat-like architecture with bioreactor panel wall, algae cuisine dining area, courtyard, garden, pool and accommodations. Algae is processed through the three towers which are like funnels on a ship. Fuel mixing, drying and oil extraction happen within the towers and fuel is stored in collapsible bladders for use at the pump station.

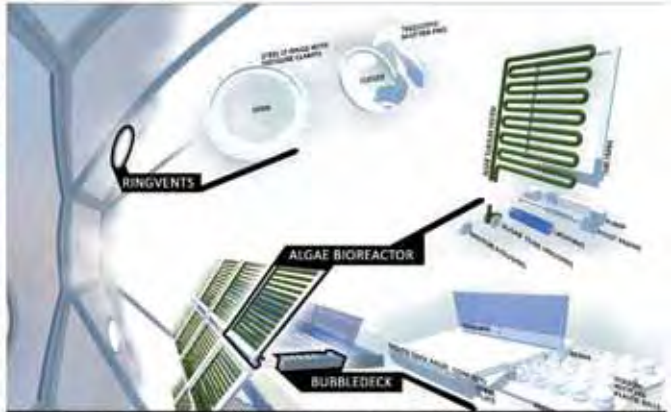




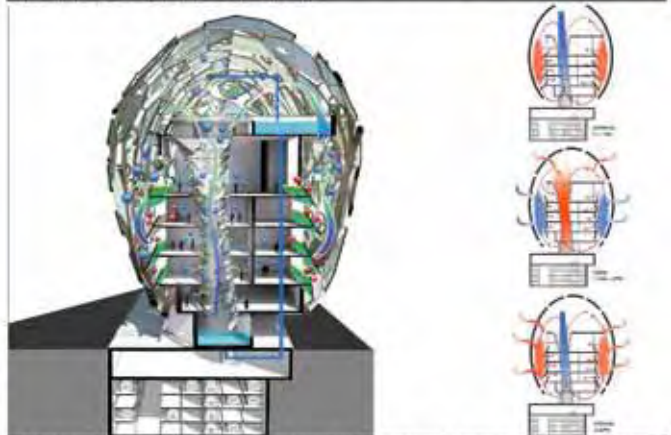
The new PAM Centre minimizes solar thermal absorption by implementing vernacular solutions through plant system adaptation where it becomes a **BIOMIMICRY** of the tropical stomatal mechanism which has passive cooling properties further enhanced by recent advances in bioscience that allowed the use of **ALGAE** as a bio-reactor which substantially increases the efficiency of the cooling effect.



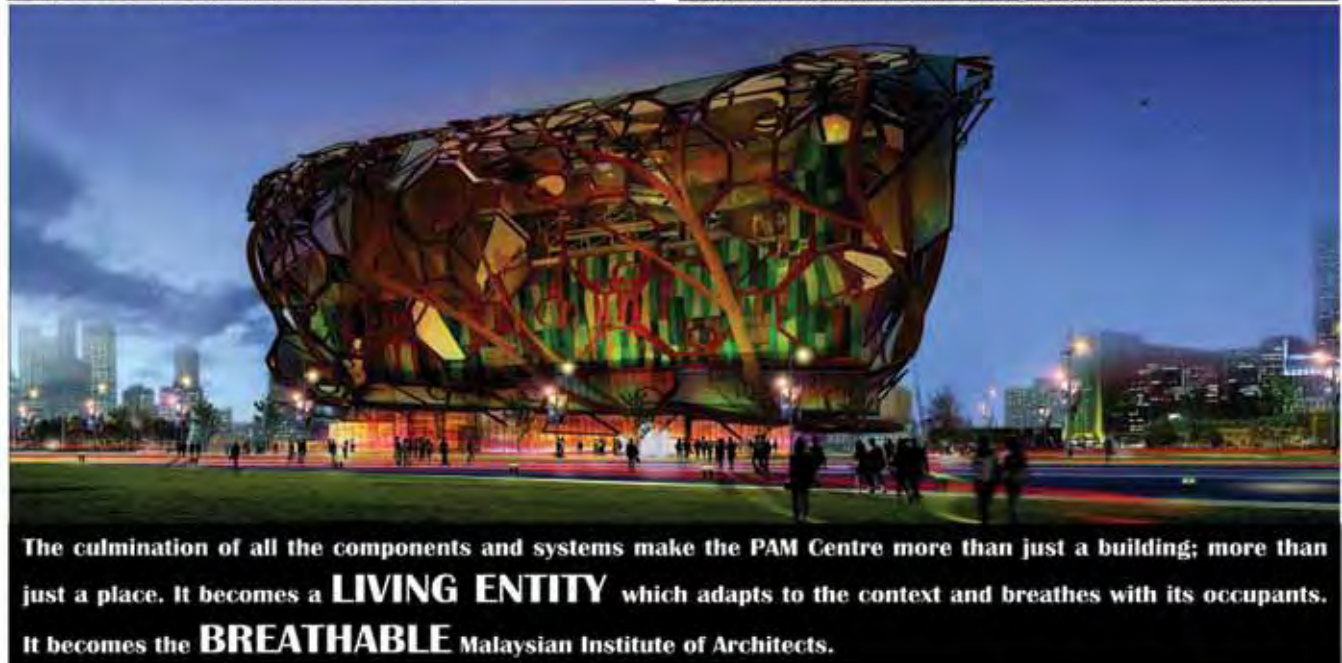
Proposed building floor plans encourage no least use of mechanical air conditioning system, addressing to the issue where the Malaysian conventional architecture is not responding to the context. They are more air-conditioning boxes of no architectural value where the building itself should pioneer **SUSTAINABLE ARCHITECTURE** through implementation of the **GREEN BUILDING INDEX (GBI)** and demonstration of a responsive eco-regional architecture which conform to the government's maxim of 'Leadership through Example'. It is a vision to evoke a bolder Malaysian mindset.



**ALGAE IN TUBULAR BIO-REACTOR PANELS** on the building skin serves the dual function of absorbing solar radiation while simultaneously oxygenating the microclimate through photosynthesis improves work productivity by reducing fatigue. The facade morphosize when certain conditions are met to optimize internal airflow and heat dissipation via **RINGVENT** openings which mimics the stomata of a leaf structure that regulating the building's 'breathability'.



Main air oxygenation flow path and as it diffuses throughout the day through use of openings & thermal effects. PAM Centre has a second skin with perforations mimicking the **STOMA** of the leaf. In addition to being able to direct airflow, these perforations also allows the building to perspire and consequently reduce heat.



The culmination of all the components and systems make the PAM Centre more than just a building; more than just a place. It becomes a **LIVING ENTITY** which adapts to the context and breathes with its occupants. It becomes the **BREATHABLE** Malaysian Institute of Architects.

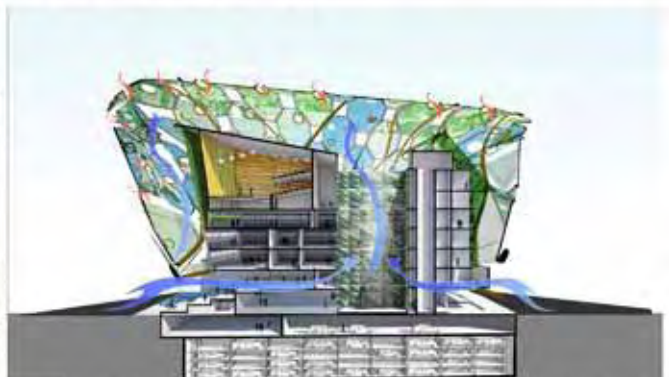




The PAM Centre is a bold statement towards **SUSTAINABLE LIVING**. The porous outer skin is an integral component challenging the norms of conventional design. The periodically transforming algae façade renders the building dynamic and sensitive to the environment. The approach is carried internally through the unorthodox openness of the spaces to create strong ties with our Malaysian lifestyle.



The core building form is carefully studied and moulded to take advantage of prevailing wind. It is introduced into an inner air cycle to reduce Volatile Organic Compounds (VOC) in the air. Airflow is then controlled thermally through the **ALGAE BIO-REACTOR PANELS** and **VAPOUR ATRIUM**.



The PAM Centre goes back to basics by capturing the essence of the plant system and translating it into building mechanisms which allows the building to essentially be a living organism. This bio-mimicry is seen through use of **ALGAE AND FERNS** at the building skin which allows **PHOTOSYNTHESIZING**, external mechanical pores which mimic transpiration and a vapour atrium which is the counterpart of the plant's xylem. Thus the building breathes and transforms to maintain equilibrium of comfort levels. An iconic outer skin acts as a building sheath and is used to improve and direct air flow within the building to promote **VENTILATION AND AIRFLOW**. The airflow also circulates oxygen enriched air from the bio-reactors to work spaces, thereby bettering the work environment increasing work efficiency.

by Chew Teik Hee





# biooctanic

## ISSUE

We are already witnesses to some facts, which are occurring in our time:

1. Some states are giving more subsidies for crop production which are essential to bio-fuel production, than they are subsidizing farming, crop production and growing edible plants. There are many appeals from United Nations which are pointing out the problem of food shortages and food production for poor countries. In addition, the EU is also conditioning their members to use 5-10% of bio-fuel in transportation. So, the thing that is really happening is that more and more of agricultural areas are used for crop production for bio-fuels instead of using those areas to grow - food.
2. Environmental pollution is a global issue, and because of it, urban areas are being deprived of clean air. Greenhouse gases and reduction of green, public spaces in cities, due to constant expansion and of building areas, are drastically reducing the quality of life in urban areas, and in fact, they are becoming hazardous.

The issue is, are we able to improve our life conditions with application of contemporary technologies refined in new ideas.

Production of bio-fuels is certainly one of the options, but it has its drawbacks, which can't be ignored. The task of replacing all conventional fossil fuels, used in transportation with bio-fuels would require vast agricultural areas to grow required amounts of plants and its crops to create enough bio-fuel.

In relation to this issue we considered scientific facts, results, studies and calculations in creation of an architectural respond.

## OUR SOLUTION

Our solution is creation of utility towers used for production of bio fuel and city air recuperation. The idea is to place these towers on positions of existing petrol stations in cities.

## TYPOLGY AND ADVANTAGES

One of the important aspect of this, vertical farming, is the choice of plants which would be grown and processed in these towers.

Our research led us to the conclusion that algae and bamboo would give best production results; max. amount of bio-fuels per unit of surface (or spatial unit), also considering other factors, like cost of technologies required for cultivation and processing, growth rate, annual input-to-yield ratio, etc.

Because of the high cellulose content of bamboo, large amounts of bio-ethanol (substitution for petroleum-derived gasoline) can be produced from it, and processing algae give large amounts of algal oil, the key ingredient to create biodiesel (substitution for conventional, petroleum-derived diesel). Apart from that, these plants aren't soil-dependant, which means that they can be grown in pools of water (process called hydroponics).

Algae cultivation is possible in closed, water-filled glass tubes (photo-bio-reactors). These tubular panel systems require minimum space, in combination with optimal illumination enabling maximum floor and height area usage.

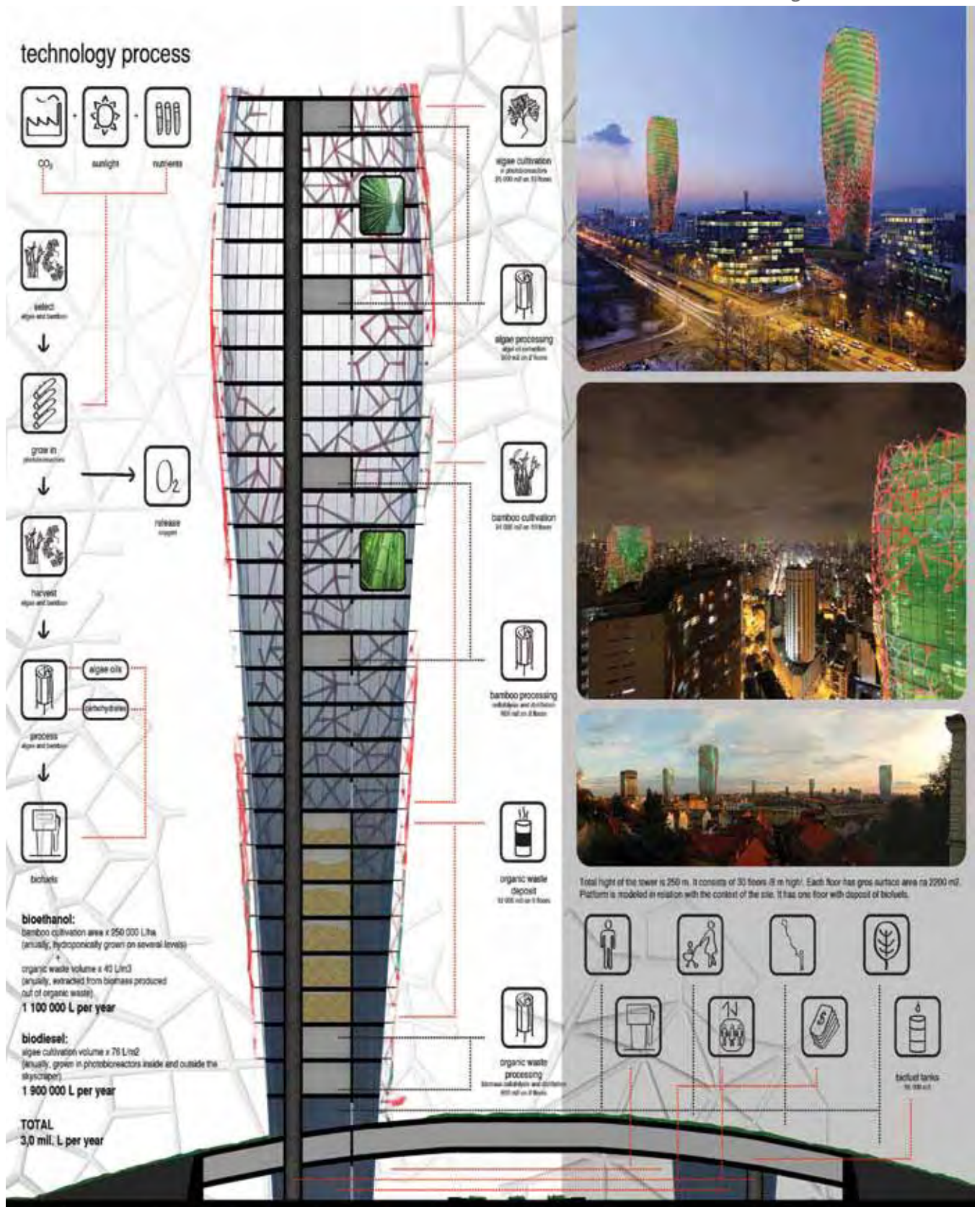
Another important source of feedstock for bio-ethanol is organic waste, which is at first, converted to cellulosic biomass, and then it can be used to produce bio-ethanol. Organic waste from all over the town could be deposited in these towers, also reducing the amount of garbage needed to be deposited on garbage dumps.

Distribution area is realized beneath the platform in which pipe systems of produced bio-fuels and oxygen are spread. This platform serves also as a green, public space and bridge, spanned over both sides of the road.

In combination with the form of the tower and the platform beneath, the outer skin layer of the tower is presented with a symbolic eco parasitic tubular system for growth of algae.

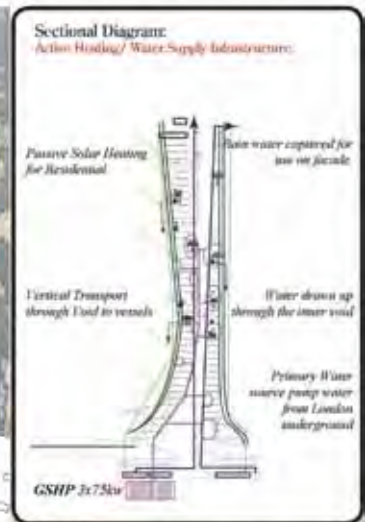
BioOctonic utility towers in Zagreb, Croatia






by UPI-2M: A. Plestina, I. Zmisa, S. Marenic, M. Nikic & M. Gornik







**Layering of Building Primary Elements.**



**The Outer Skin:**  
The outer skin consists of three surface layers in single physical order that acts as the weather shield and seals the building. The skin frame first supports the gable skin and attaches to the primary support structure. The gable skin also is a freestanding system. This layer acts as a moisture-impervious membrane to keep the interior dry and secure, and provides a barrier to the attachment of the vines.



**Variable Lattice Framework.**  
The internal skin of the tower encloses the hollow ground. The diagonal members form the frame's support system and extending one or two levels into floor plates and attached to ground. The three slabs and junctions to support the outer building skin.



**Floor Plates & Covers**  
The floor plates support the lattice floor which are the primary structural frame for the structure. The Vastu connect the floor and provide lateral support, giving movement flexibility to the floor plates allowing the slabs to be supported in a stable way. These slabs are the main element to be centrally located or could be the center and outside of the structural space.







by David Edwards



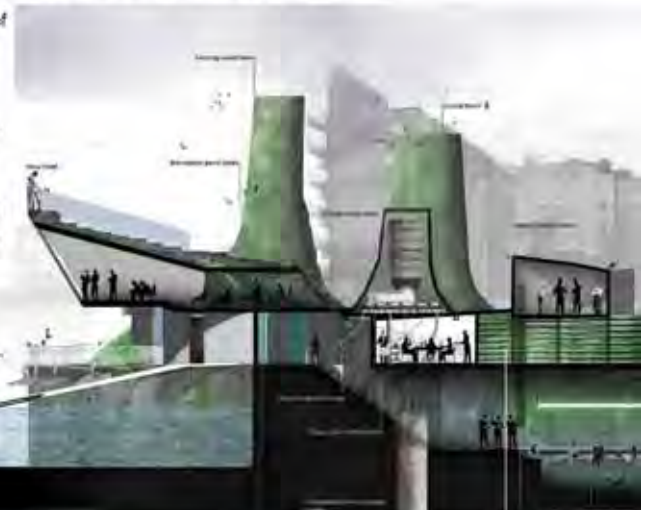
## Algae Bio-fuelled Thames Pilotage Station, Millwall Dock, London

This architectural algae concept is designed around the Worshipful Company of River Pilots with 12 specialist river pilots from PLA pilotage department intending for them to be self-reliant, sustainable

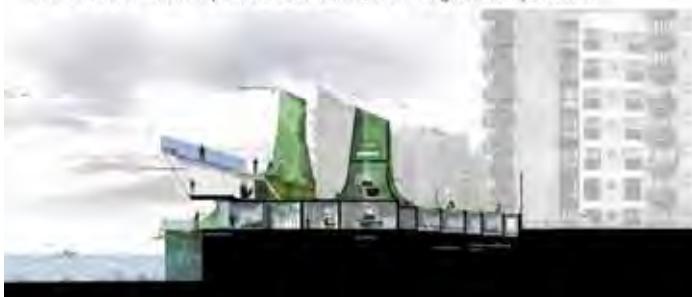


Situated along the bank of the river Thames this architecture promotes the use of greener energy and algae biofuel technology. 12 specialist PLA river pilots live in harmony amongst this living metabolism, enhancing the growth of algae and like a monks in a monastery produce their own brand of algae bio-diesel to be consumed by their own launch boats and visiting vessels.

A series of nutrient mist showers encourages algae growth along the bank and the ceremonial act of gathering is partaken by the pilots at specific tidal intervals. Algae is then processed through the building and its towers; mixing, drying and oil extraction happen with the funnel towers and oil is sent to collapsible storage bladders until ready for use at the marine pump station. Visitors are attracted to a green layered roof landscape formed by the stepped bio-reactor panels, deliberately directed toward sunlight for maximum exposure. As the density increases the shades of green become darker and opaque. The community can roam this algae roof garden and admire the viewpoints upon the three towers, which are like funnels on a ship, giving the building its industrial identity. At night this building still comes to life. The pilots are on duty 24 hours and surrounded by fascinating illuminations of algae which sends off a glowing emerald aura to its environment.



This innovative, contemporary station accommodates cabin rooms, a control tower operations room taking advantage of modern technologies and utilising panoramic views overlooking the river, ready room, wet room, communal areas, courtyard and roof garden, algae cuisine kitchen and dining area, a jetty with marine biofuel pumps, a pool and debating chamber; all vital organs for the Guild of River Pilots to function in synchronisation with nature and algae biofuel production.



Algae biofuelled Thames pilotage station, Millwall Dock in London by Isla Marshall



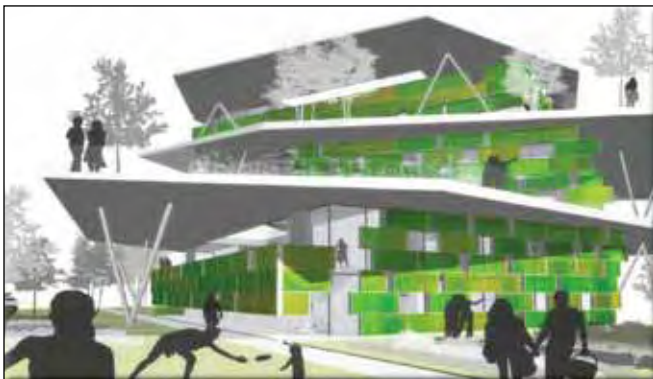
## Algae Landscape Design and Architecture

### Retrofitting and modularizing buildings with algae architecture



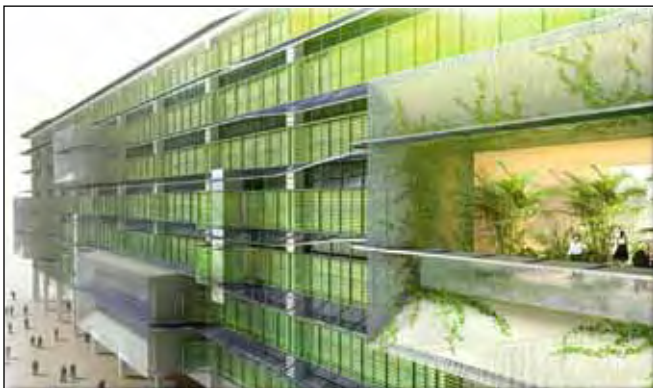
#### Eco-Pod: modular algae bioreactor in Boston

Eco-Pod is a temporary vertical algae bioreactor and public commons built with custom prefab modules. The pods serve as biofuel sources and as micro-incubators for R&D programs. As an open and reconfigurable structure, the voids between pods form a network of vertical public parks and botanical gardens housing unique plant species. An on-site robotic armature, powered by algae biofuel, will reconfigure the modules to maximize algae growth and accommodate changing needs.



#### Hydral housing with hydrogen producing panels

Hydrogen has long been viewed as a fuel source for a carbon emission free future. Modular panels of hydrogen producing algae can be placed like photovoltaics. This second skin of algae panels constructs a quilted mosaic of color. This photosynthetic city of modular housing units creates fresh water and reduces carbon emissions, without requiring occupants to change energy-consuming habits. The entire complex is sustained as a closed system.



#### Retrofit GSA Federal Building in Los Angeles

*Process Zero: Retrofit Resolution.* The goal is to design a zero environmental footprint and energy self-sufficiency using Living Building Challenge 2.0 guidelines. Photovoltaic and solar thermal panels cover the roof, tracing the sun through the day. Thin film PV shading devices line the windows, reduce glare and reflect light deeper into the interior. A modular system of algae tubes wrap the building and absorb the sun's radiation, produce lipids for fuel, and shade interior office spaces.



#### Marina City global algae retrofitting in Chicago

Algae proposal for one of the most innovative buildings in the Loop of Chicago: Marina City Towers. Aligned with the 2008 Chicago Climate Action Plan, the goal is to showcase algae with green technologies, clean polluted air, reuse water, and produce energy and food. The key issue is how to anticipate algae's green future in the core of the major cities, transforming existing buildings, where most people live and where CO<sub>2</sub> emissions are highest.



# ECO-POD

PRE-CYCLED MODULAR ALGAE BIOREACTOR



Taking advantage of stalled construction sites created by the nation's economic downturn, Eco-Pod is a proposal to immediately stimulate the economy, and the ecology, of urban cores. Eco-Pod (Generation 1.0) is a temporary vertical algae bioreactor and new public commons, built with custom prefabricated modules. The pods will serve as biofuel sources and as micro-incubators for flexible research and development programs. As an open and reconfigurable structure, the voids between pods form a network of vertical public parks/ botanical gardens housing unique plant species - a new uncommon for the commons.

Microalgae is one of the most promising biofuel crops of today, yielding over thirty times more energy per acre than any other fuel crop. Unlike other crops, algae can grow vertically and on non-arable land, is biodegradable, and may be the only viable method by which we can produce enough automotive fuel to replace the world's current diesel usage. Algae farming uses sugar and cellulose to create biofuels and simultaneously helps reduce carbon dioxide emissions, since it replaces CO<sub>2</sub> with oxygen during photosynthesis. While the bioreactor process is currently in an experimental phase, recent advances in single step algae oil extraction and low energy, high efficiency LEDs make the algae bioreactor an extremely promising prospect on the renewable energy technology horizon.

In addition to being an active bioreactor and local source of renewable energy, the Eco-Pod is also a research incubator in which scientists can test algae species and methods of fuel extraction, including new techniques of using low energy LED lighting for regulating the algae growth cycles.

The central location of the Eco-Pod and the public and visible nature of the research, allows the public to experience the algae growth and energy production processes. As a productive botanical garden, it also functions as a pilot project, a public information center, and a catalyst for ecological awareness.

An on-site robotic armature (powered by the algae biofuel) is designed to reconfigure the modules to maximize algae growth conditions and to accommodate evolving spatial and programmatic conditions in real-time. The reconfigurable modular units allow the structure to transform to meet changing programmatic and economic needs, while the continuous construction on the site will broadcast a subtle semaphore of constructional activity and economic recovery. This is anticipatory architecture, capable of generating a new micro-urbanism that is local, agile, and carbon net positive.

This proposal envisions the immediate deployment of a "crane ready" modular temporary structure to house experimental and research based programs. Once funding is in place for the original architectural proposal, the modules can be easily disassembled and redistributed to other empty sites, testing new proposals, and developing initiatives with other communities. Designed with flexibility and re-configurability in mind, the modularity of the units anticipates future deployments on other sites. An instant architecture, designed with an intention towards its afterlife, this is a pre-cycled architecture.

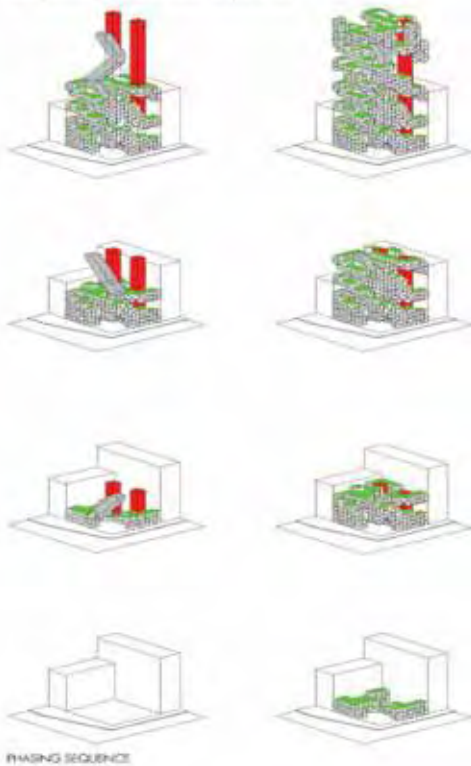
In our ongoing, synergistic scenario, the growth of the algae propels, and is propelled by, technologically-enabled developments that literally and metaphorically "grow the economy."

## Eco-Pod: Precycled modular algae bioreactor in Boston





URBAN DEPLOYMENT CASE STUDY: BOSTON, MA



by Squared Design Lab and & Höweler+Yoon Architecture



## A Hydrogen Future

Hydrogen has long been viewed as a fuel source that could be the answer to a carbon-emission free future. Unfortunately Hydrogen en masse was not, until now, a naturally created element on our planet.

As this new technology's dawn approaches, it is important to design ways to capitalize on its immediate benefits. We see this not simply as a revolution in ecological fuel sources, but as a revolution in the structure of our fuel supply system. When fuel is no longer an ecologically harmful process to create, it no longer needs to be produced in remote locations that cause further pollution and energy expenditure in transportation.

## HYDRAL 1

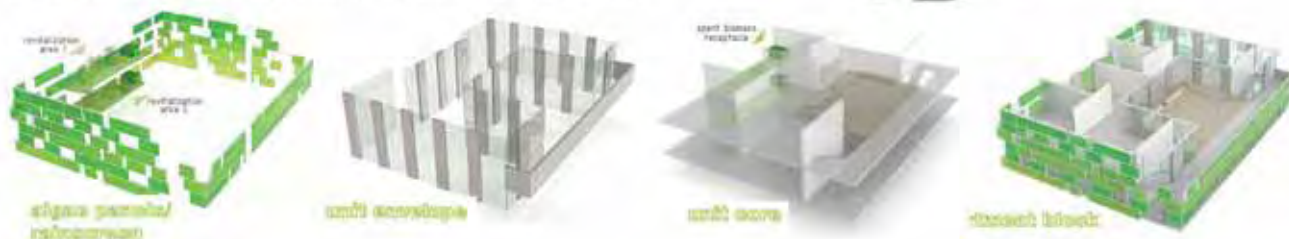


## HYDRAL bioreactors

The HYDRAL panel brings energy production to the consumer. Each panel is a modular 1 meter x 2 meter x 1 meter panels of hydrogen producing algae to be placed in an urban environment such as today's photo-voltaic. These green panels do more than photo-voltaic, however, and are nowhere near as energy intensive to create, nor carry dangerous heavy metals.

Once the cultures are sealed in an anaerobic condition, starved of sulfur, the algae's normal photosynthesis-respiration relationship is thrown into imbalance, causing a cellular net consumption of oxygen, further resulting in a condition that immediately elicits hydrogen production.

As an architectural element this "second skin", created by the algae panels, constructs a quilted mosaic of color that can be used in new construction or applied to an existing structure. This dynamic and ever-varying faade of translucent chlorophyllic greens and chartreuses generates a constant intrigue to the living spaces within as well as creating an exterior pattern that is never replicated.



Hydral housing units with modular hydrogen producing panels





The revolution of these buildings is that they give back more than they take. This Photosynthetic City creates fresh water and reduces carbon emissions, without requiring the inhabitant to change their energy-consuming habits. The entire complex is sustained as a closed system. The water created from the Hydrogen fuel cell is delivered to each residential unit as well as the public drinking fountains. Waste water is filtered and treated by on site living machines. The resulting grey-water is used for irrigation and flushing toilets. The spent algal biomass from the HYDRAL panels is excellent compost for the private and community food producing gardens throughout the site. Seasonal crops can be eaten directly, donated to local shelters, or sold at the local farmers' market.

## HYDRAL 2



by Thomas Kosbau



## PROCESS ZERO: RETROFIT RESOLUTION



### DIAGRAMS - SECOND MEMBRANE - ENERGY PRODUCTION SYSTEMS

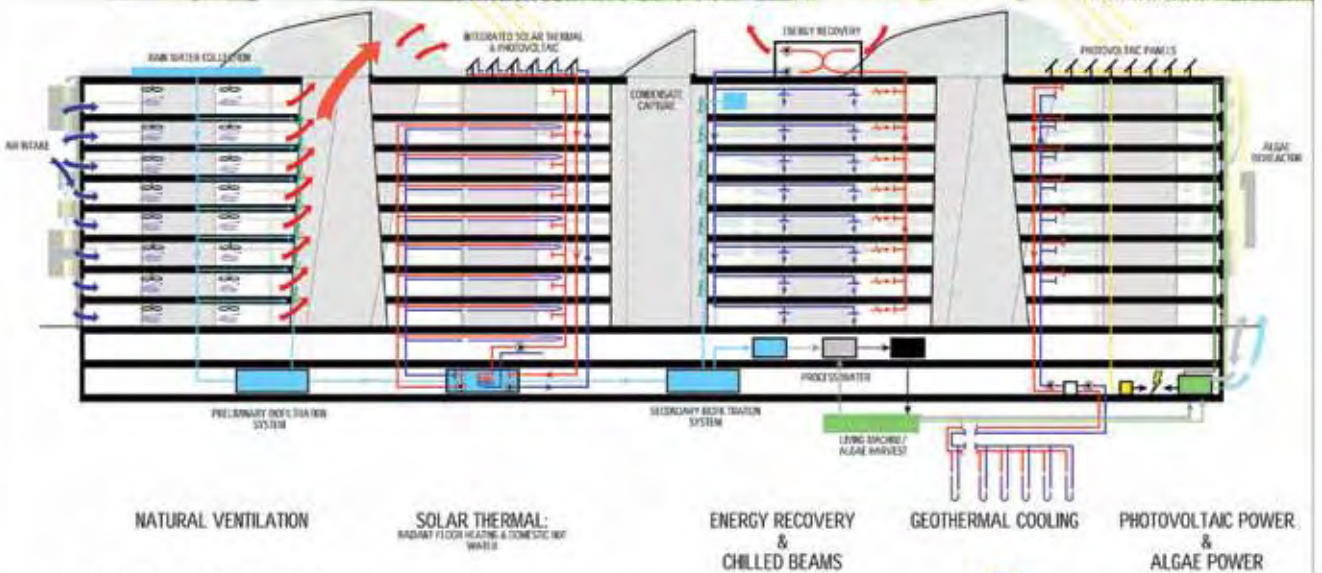


## O4 ENVELOPE SYSTEMS

### Process Zero: Retrofit Resolution. GSA Federal Building in Los Angeles



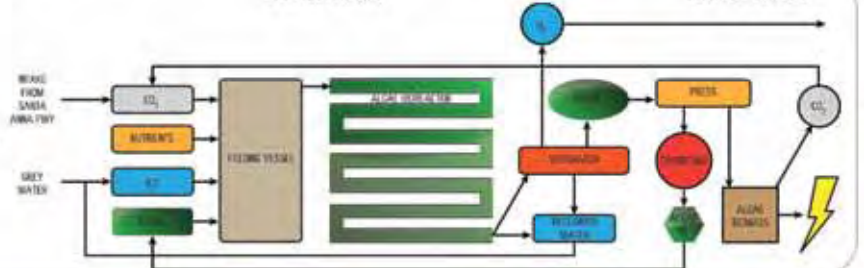
To create replicable solutions for existing buildings, it is necessary to develop a **PROCESS** that identifies key problems and integrative design **RESOLUTIONS**. Existing buildings come with a multitude of both permanent and adjustable conditions; it is the design team's responsibility to **RETROFIT** fixed components and create flexibility for a **ZERO Environmental Footprint Building**.



#### DIAGRAMS - ALGAE BIOREACTOR SYSTEM

Renewable energy systems, including a thin film photovoltaic façade system, rooftop photovoltaics, integrated solar thermal panels, and an innovative algae system produce 14 kBTU/SF-year. This collection of renewable energy systems offset the energy consumption of the building and achieve the goal of a net zero design.

IMAGE & ILLUSTRATION SOURCE: ADAPTED FROM ELIAS, 2012. CREDIT: OFFICE OF ALGAE BIOPRODUCTS. <http://www.algaebioproducts.com/algaebioproducts/>



#### 09 RENEWABLE ENERGY

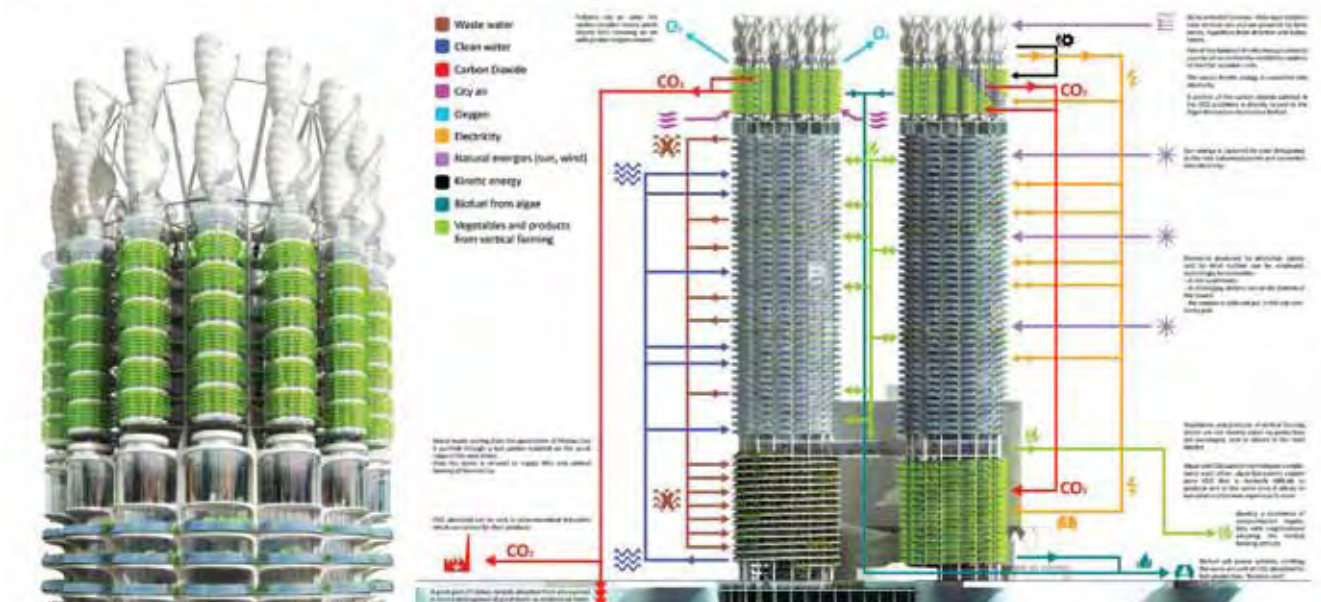
by HOK/Vanderweil, Sean Quinn Lead Architect



TRACK 1 : ALGAE LANDSCAPE DESIGN



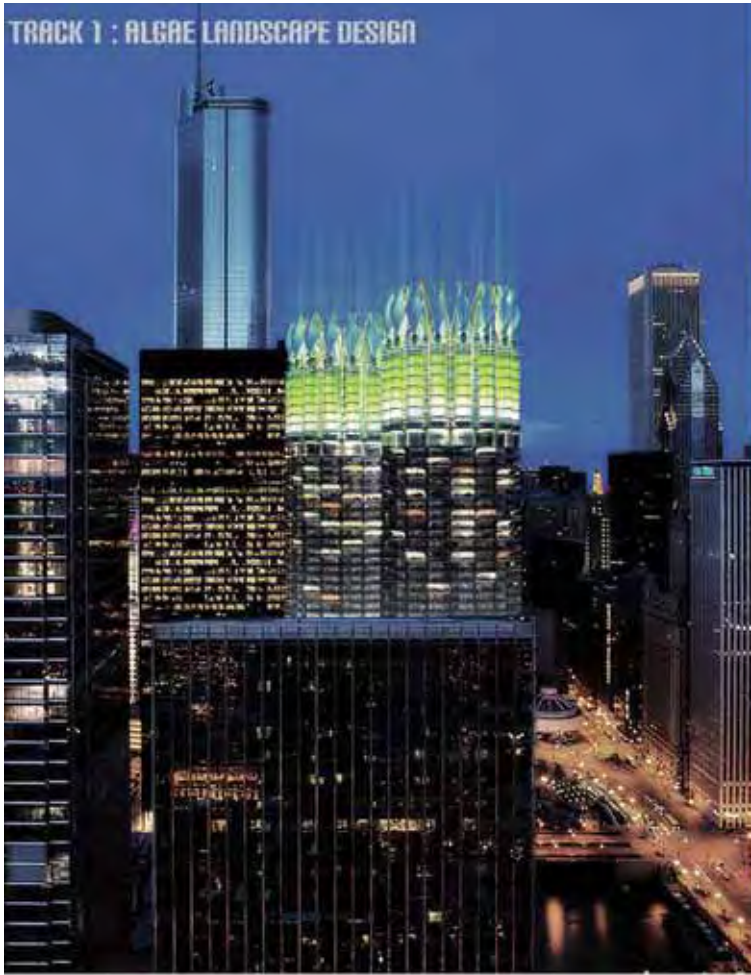
GREEN LOOP - MARINA CITY



Green Loop: Marina City global algae retrofitting in Chicago



## TRACK 1 : ALGAE LANDSCAPE DESIGN

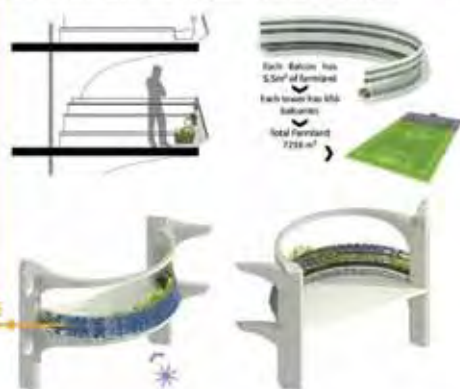


## GLOBAL ALGAE RETROFITTING - CHICAGO



### Vertical Farming

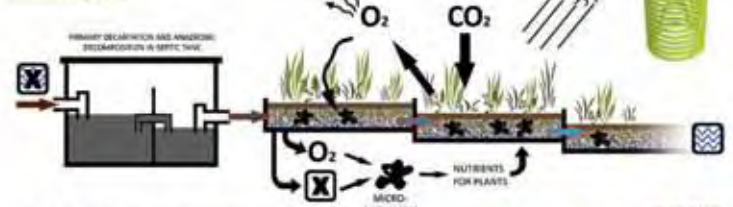
Characteristics building balconies will be multifunctional with spatial shaped elements able and both a space for growing plants and vegetables, and a support for production panels. The vertical farming is a solution to reduce extensive plantations and cost (income but also pollution for transport. This will also enhance the community life, with inclusion of products, useful, vitamins. We consider the creation of a public area, the 100% & 100% BALCONY - this is a bridge between the two towers but also among people.



### Phytoremediation garden

This characteristic canopy of Marina City towers give us possibilities for new uses, different from the main use parking function typical of the urban society. In the same tower we propose the installation of a garden for natural purification of water coming of Marina City inhabitants. The slight slope of the ramp is optimal for providing a slow flow of water through natural soil and plant roots.

### Ecosystem garden



One loop of wetpark - a loop connected to the water loop of the parking area



by Influx\_Studio/ Aétrangère, Mario Caceres, Christian Canonico. Images by Inimagenable.







# International Algae Competition

## Algae Food Development and Recipes



Here are some delicious new algae food products and recipes from around the world entered in the International Algae Competition

*Algae Competition asked: What will be the next algae foods and recipes and future uses of algae as food and feed ingredients that will transform our health?*



Dances With Algae- marine algae foods by Lynn Cornish, S. Hubley, R. Nickerson, J, Todd.



H'ors d'oeuvres d'algues - Oz style in Australia by Pia Winberg and Friday.



Aquamole fresh spirulina dip in Laroque, France by Denise Fox.



In'Spir- naturopathic condiments from Provence, France by Cédric Coquet.



Spirulina tofu in Singapore by Sun-Up Bean Food PTE LTD.



Biosphere instant soup concept: algae, inside an alginate sphere by Lucie Bolzec.



Korean style algae pancake by JiSun Lee.



Spirulina Green Tongue Candies in India by Duraikkannan Selvendran, Antenna.



Spirulina tacos al pastor by Spencer Drew.



# H'ORS D'OEUVRES D'ALGUES – Oz style

Track 3 Food Development – user: pia # 3112

Entry to the 2011 International Algae Competition:

Pia Winberg and Friday, Australia.



## the geek & the chef! Development of our invention



Pia Winberg is a Swedish born marine scientist undertaking research on seaweeds at the University in Wollongong in NSW, Australia. Her key focus is the development of sustainable primary production industries in the oceans to address global issues of food security and nutritional deficiencies.



Friday is a native Torres Strait Islander, Australia. Friday is a fully trained ala carte chef and is well recognised in the local region for exceptional culinary skills. Friday has worked at many reputable restaurants such as Manor House, Turtles Restaurant, Stevenson house, Zippo's, Al Pavilion on the Park Friday was part of the Master chef Hans Zuercher team that has prepared food for Prince Charles. Locally, Friday has prepared menus for the Judicial Commission of NSW who have highly commended Friday's skills.

In 2008, Friday & Pia cooked up a storm for the Seaweeds Australia research and industry network.

Friday blew everyone away with his novel use of seaweeds in a five course meal.



In 2011 we got together again challenged by the announcement of the International Algae Competition

Our vision was to serve an *h'ors d'oeuvre* suite of seaweed delights to show the world that healthy and sustainable .... seaweed is sexy

## Our seaweed selection – an international selection of red, green and brown seaweeds



### • Wild Ozzie (Australian) *Porphyra*

Wild Australian *Porphyra* will be difficult to source, even in Australia, but an equivalent can be easily sourced using your local species of Nori or easily bought in Asian stores and supermarkets that supply ingredients for sushi rolls.



### • Ozzie *Ulva*

Again the Australian variety will be difficult to source internationally, and this one is a special cultivar from our work. However your local clean rocky shores will provide your local *Ulva* species or some select shops and Maine Sea Coast Vegetables (U.S.) will supply dried *Ulva* or *aonori*.



### • *Chondrus crispus* (Hana Tsunomata™)

*Chondrus crispus*, a classic in the northern hemisphere and not native in Australia. Luckily there are commercial suppliers for *Chondrus*, and the famous tricolor variants are available from Acadian Sea Plants in Canada.



### • *Ascophyllum nodosum*

We don't have this one in Australia either, but it is one of the largest global trade commodities and we sourced a food grade powder from Canada at Acadian SeaPlants, but the northern hemisphere folk won't have trouble sourcing it from abundant shores.

## making Sea Twists®

Dry 150g fresh cultivated (or wild) *Ulva* at 70°C



Grind to green powder



Weigh up to 30g of dry powder for each kg of flour



Add egg whites to well developed yeast mixed with lukewarm water, salt, sugar and olive oil



Add to flour



Knead to a firm dough in extra flour and allow dough to rise covered for 1.5 hours (we tried four concentrations here)



Roll out dough to 2mm



Slice into 1cm strips

Let cool on tray until crisp and VOILA!



Twist and place on baking paper on tray, baste with water and sprinkle generously with coarse sea salt. Bake on tray in 175 °C oven for up to 20 minutes until crisp, but NOT too brown. The sticks should still be green.



## making Ginger Nori Delight®

Rehydrate nori in water and chop ginger



Add all ingredients Together; bring to boil in pot and simmer for 1 hour.

Cool enough to pure with electric blender and chill.



Serve with Sea Twists & VOILA!



## making Crispy Chondrus®

Dried *Chondrus crispus* or Hana Tsunomata™



Reconstitute *Chondrus* in water and drain



Serve with the three colours together & VOILA!



Dip *Chondrus* pieces into tempura batter and deep fry directly in hot oil until crisp. Drain and cool immediately.



Beat egg lightly and mix in the blend of dry ingredients, adding cold mineral water as needed to make a thin, smooth batter. We tried three mixes to get the perfect one.



## In'spir

Naturopathic condiment  
Developed in Drome  
in Provence area, France.



### To get a better Health

In'spir is a set of three symphonies.

Symphony 1 : spirulina plus pumpkin seeds\* and sun flower seeds\*

Symphony 2 : spirulina, hemp seeds\* plus aromatic plants\* from Drome.

Symphony 3 : spirulina, hemp\*, hemp seed\*, gomaseo\* plus aromatic plants\* from Drome.  
\*components from organic agriculture.

You will enjoy these symphonies engineered for you.  
Mixture of specific components for a superpower food.



Symphony 1

Symphony 2

Symphony 3

### Why did we develop In'spir ?

Spirulina is a « super power food » which should be worldwide eaten. In'spir is developed to extend Spirulina among people, because Humanity have to connect with Spirulina.

In'spir is easy to eat and you can use it as a condiment in your main dishes and salads.

In'spir is like a modern « fast food », well balanced, which gives you micro nutriments. In addition with olive oil, you can spread over bread. You get a complete meal in less than 5 minutes.

In'spir will feed you with a well balanced food and you will not get fat.

**In'spir is a gastronomic meal  
which combined pleasure and healthcare.**



**In'spir,  
Healthy food  
Allied with pleasure for taste buds.**

Each symphony contains 30 % of spirulina.  
Seeds are selected for their high content of fatty acids.  
Hemp seed contains omega 3, which is one of the few elements not included in spirulina.  
Gomaseo is salted and grilled season.  
Barn is one another microorganism which contains protein and B vitamins.  
Aromatic and medical plants from our mountains in Drome give an excellent taste and make digestion easier.



spirulina ponds.



Spirulina harvesting.

In'spir is produced in "les jardins Coquet", in a micro-spirulina farm in Drome in the south east of France since 2005. These products have been engineered by Cédric Coquet (master in biological agriculture), in close connection with nutritionists and naturopaths.

Spirulina is produced in ponds (500m²) in our own family farm away from any pollution, in the french south east mountains.



Few photos,  
Cause we don't  
like spirulina,

**We love  
Spirulina**





# BIOSPHERE



«Biosphere» is a soup concept based on algae and vegetables. The dehydrated ingredients, which correspond to an individual portion, are encapsulated in a transparent sphere made with alginate film. This agro-based material, made from red algae extracts, is eatable and it liquefy under hot water. Thus, the consumer just have to boil some water and to pour it on a Biosphere, and he instantaneously gets a rehydrated soup, very tasty and full of essential and beneficial nutrients.

Between naturality and technology, this product suggest a new way to eat algae, without hiding them. The consumer is

aware of eating algae and he knows all the inferred benefits, but contrary to most of the other products about algae, Biosphere gives to the consumer a moment of pleasure, a tastes discovery and also a spectacular instant at the transformation of the sphere.

As earth citizen, we all have the responsibility to find new ways to feed our planet in the future. With this aim in view, I really invested myself in this project. I wanted to exploit algae as much as possible. With Biosphere, I reach my goal because algae is present both in the content and in the container.



Algae, vegetables, herbs and seasoning



## Bretonne recipe

Ulva sp.  
Himantophyllum elongata  
Leeks  
Carrots  
Red cabbages  
Nutmeg  
Tarragon  
French sea salt



## Provençale recipe

Palmaria palmata  
Porphyra  
Eggplants  
Tomatoes  
Red and yellow peppers  
Black pepper  
Oregano  
Garlic



## Japonaise recipe

Laminaria saccharina  
Undaria pinnatifida  
Bamboo shoots  
Beetroot  
Black mushrooms  
Ginger  
Lemongrass



Sample of soldered alginate film—

## Components

Alginate (21%)  
Glycerol (1.33%)  
Starch (7.87%)  
Water (92.86%)







## Spirulina- GREEN TONGUE CANDIES

### INGREDIENTS

- Spirulina Powder
- Refined sugar
- Liquid Glucose
- Flavor Essence



### Green Tongue Candy Launch Program



Free candies being Distributed



A child with candy on her tongue



Awareness to School girls



Drama group demonstrates the benefits to children

Spirulina Product	Rate To NGOs By ANF (in INR)	Rate to SHGs By NGOs (in INR)	Rate to the End users (in INR)
GREEN TONGUE Candy	0.70	0.80	1.00

**Special Note: [Feed Your Child free]**

Every 5<sup>th</sup> candy is absolutely free to SHG member who is promoting candies to poor rural children

### Vision



To combat  
Child Malnutrition  
with

- Affordable
- Acceptable
- Stable

Spirulina Product

### Steps in Green Tongue candy making

Syrup of Refined sugar and Liquid Glucose is prepared at 130°C

Cool down to 70-80°C

Spirulina Powder is Mixed with syrup

The Mix mass is made in to candies

Candies are Cooled to normal temperature and packed

### Production of Spirulina & Green Tongue Candies



### Spirulina GREEN TONGUE Candies

- **Affordable**
- **Most suitable to children**
- **1/3<sup>rd</sup> price to market price (INR 1.00/3.00)**
- **Offers 30% margin to SHGs and NGOs**
- **30% margins looks after the need of Promoting SHG (Self Help Group) Women and NGOs.**







## Dances with Algae

Lynn Cornish  
Scott Hubley  
Romelda Nickerson  
Josie Todd

Dances with Algae

There is compelling evidence to suggest that algae should become a part of the global nutritional diet



## Here is an example of some items on a typical menu at the fictional 'Algalicious Café and Restaurant'



Hana-Tsunomata™

### Cultivated Sea Vegetable Bouquet

The clean and pure, strikingly beautiful fronds and vivid colors of pink, green and yellow Hana-Tsunomata™ stand out from other sea vegetables. Popular in Japan for 20 years, healthy Hana-Tsunomata™ sea vegetables can be found in various applications, from dry packaged foods to exclusive restaurants. They are especially prominent in ready-to-eat fresh "bento" (seaweed) salads sold in convenience food outlets throughout the country.

Acadian Seaplants

- Simply rehydrate and add your favourite dressing, or mix fronds into other salads -



### Emi-Tsunomata™ Caper Stir-fry



In this recipe we added only a tablespoon of Emi-Tsunomata™ early in the cooking and finished the dish adding most of the algal ingredient near the end. This provided some textural differences and a more tender mouthfeel, compatible with the crunchiness of the other vegetables.

### Hana-Tsunomata™ and Kombu-banded Seafood Cakes



### Emi-Tsunomata™ Algee-licious Popcorn

Plain popcorn is already a nutritious snackfood, but by adding a seaweed ingredient, both flavour and nutrition are enhanced.

This seaweed-based topping is packed with essential nutrients and antioxidants. Emi-Tsunomata™ is available from Acadian Seaplants Limited ([www.acadianseaplants.com](http://www.acadianseaplants.com))







### Fresh harvested spirulina paste – direct from the grower

- looks like thick green yogurt or bread dough
- has no taste, can add to smoothies or use in recipes
- about 80% moisture – if refrigerated it's good for 3-4 days



Emmanuel Gorodetzky and Denise Fox. Preparation of fresh spirulina paste.

### Savory Spirulina Aquamole Dip



**Suggested ingredients to mix with fresh spirulina paste:**  
yogurt, sour cream, blue cheese and cheese with herbs, olive oil, and guacamole spices (chili, cumin, basil, coriander)

### Savory Spirulina Aquamole Dip



### Spirulina Algae grown at Spiru-Vie Farm in Ganges, France



Robert Henriksen with Emmanuel Gorodetzky, owner. Spirulina greenhouse pond. Spiru-Vie products.



### Two Recipes for Fresh Spirulina Aquamole Dip



1. Denise Fox prepares savory guacamole style dip
2. Taromé Gorodetzky prepares sweet fruit style dip

### Sweet Spirulina Fruit Dip



**Suggested ingredients to mix with fresh spirulina paste:**  
Fresh fruit cut up into small pieces, yogurt and honey.

### Fresh Spirulina Aquamole Dip



Served at the meeting of the Federation des Spiruliniers, hosted by Ripley and Denise Fox, June 26, 2011 in Laroque, France.

Aquamole fresh spirulina dip in Laroque France by Denise Fox



FOOD RECIPE PREPARED BY:

SUN-UP BEAN FOOD MFG PTE LTD

COUNTRY: SINGAPORE

SINGAPORE DATE: 08 OCT 2011

SINGAPORE TIME 23:00PM



## Spirulina Tofu



**BY 2045 Earth population will likely have swelled from 7 to 9 billion people.**



ADJUSTING OUR DIETS

To fill all the 7 to 9 billion peoples stomachs in 30 years time , one of the solution is to adjust our diets accordingly.



**Less meat can mean more food. Soybeans provide up to 15 times more protein per acre than land set aside for meat production, according to the National Soybean research Laboratory**



**INCREASED RESEARCH**

Do you know....

To fill all 7 to 9 billion peoples stomachs, we need to increase research.

FOOD FOR THE NEXT GENERATION...



**RECIPE**



**INGREDIENT:**

- 1 Packet 300gm Silken Tofu
- ¼ tsp spirulina powder
- Soya sauce as topping(optional)

**PREPARATION TOOLS:-**

- Juice Grinder
- Bowl
- Baking mould ( OVEN SAFE )
- Plastic Knife
- Spoon
- Steam cooker

**RECIPE**



**Methods**

STEP 1: Cut the tofu into small cubes.

STEP 2: Switch on the Juice Grinder and put tofu in it and let the juice grinder grind the tofu into paste.

STEP 3: Pour half the white tofu paste into the mould. Pour the ¼ tsp spirulina powder into the balance white tofu paste and blend it well.

STEP 4: Pour out the spirulina tofu paste in the same mould beside the white tofu paste.

STEP 5: Add 50ml of water in steam cooker and place the mould in steam cooker and steam for 10 mins.





## Korean Style Algae Pancake

## Korean Style Algae Pancake

### Ingredients

- All purpose wheat flour
- Egg
- Onion
- Green Onion
- Chinese Chive (It is not necessary.)
- Seafood (shrimp, squid, oyster) or Meat (Pork, Beef)
- Salt & Pepper
- Water
- Olive oil in pan
- Soy sauce, Red pepper powder, Vinegar (These are for sauce.)

- **Direction for Korean Style Pancake**

1. Take out the squid and seafood(or meat) from the freezer, and unfreeze them.
2. Cut the seafood(or meat. If you use a pork, you should cut smaller than bite-sized because of cook time.) and vegetable (Onion, Chive, Algae) into bite-sized pieces.



- Put flour, egg, salt & pepper, water, seafood, and algae into a bowl.
- Mix well until do not see powder.



5. Hit frying pan with olive oil(or vegetable oil)
6. Fry until crispy



## SPIRULINA TACOS AL PASTOR

Green Tacos al Pastor, a delicious Mexican flavor with a **twist**.

## TACOS AL PASTOR



The music in *House*, Stephen's heart is a laboratory, not a living, an various experiments with process and form. *House* is dominated by music. The songs are usually songs with a philosophy, which is think about and learned in the lyrics. This method of creating music is identical to that used for the aforementioned work (however, brought to Pindali, Pindali is Lebanese immigrants in the 1970s). The technique was copied by the Phoenician society (Lebanese immigrants), who established a new form. The musical stand for a form of justice and justice in Pindali with vertical lines of people with something in their mind, wood-burned heart. This song makes two dozen letters in letters, a person with the alphabet, or more as part of a text, a person, a person. Here are the first music, music, music, music, music, music.

## INGREDIENTS

- [illegible]



### DIRECTIONS

- Many of the people who are asked about the use and value of the following information:
- 1) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.
  - 2) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.
  - 3) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.
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  - 6) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.
  - 7) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.
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  - 9) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.
  - 10) It is a good idea to have a good idea of the value of the information that is being collected, and to have a good idea of the value of the information that is being collected.









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## Special Thanks to Jurors and Sponsors

### Algae Competition Jurors

International Algae Competition assembled distinguished jurors from diverse backgrounds to evaluate entries in the three tracks of the competition: landscape designs, production systems and food development. There were two rounds of jurying. In the first round, evaluating groups of the 140 entries in three tracks, the combined scores of jurors determined 40 finalists. In the second round, jurors ranked the finalists, and the combined scores determined the award winners.

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### Algae Competition Sponsors



**AlgaeAlliance.com** members Robert Henrikson and Mark Edwards are the creators and developers of the Algae Competition to expand and share a vision for algae in our future and create an open source algae community and collaboratory. [www.algaealliance.com](http://www.algaealliance.com).



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**AlgaeIndustryMagazine.com** is the online trade publication addressing the growth and development of the algae biofuels and co-products industry: • its influential personalities • developing technologies • evolving businesses • breakthrough products • important news. [www.algaeindustrymagazine.com](http://www.algaeindustrymagazine.com).

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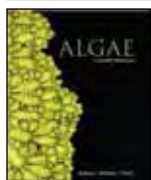
## Algae bookshelf



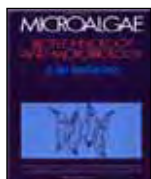
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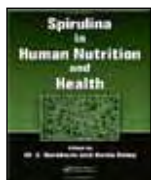
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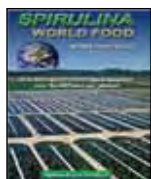
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## Algae resources

### Algae Associations

**Algal Biomass Organization.**  
www.algalbiomass.org.

**National Algae Association.**  
www.nationalalgaeassociation.com.

**European Algae Biomass Association (EABA).**  
www.eaba-association.eu.

**Phycological Society of America.**  
www.psaalgae.org.

**International Phycological Society**  
www.intphycsoc.org.

**British Phycological Society**  
www.brphycsoc.org.

**International Society for Applied Phycology**  
www.appliedphycologysoc.org.

**Australasian Society for Phycology**  
www.aspab.org.

**International Seaweed Association**  
www.isaseaweed.org.

**Northeast Algal Society**  
www.e-neas.org.

### Algae Culture Collections

**USA: University of Texas Culture Collection of Algae,**  
www.utex.org.

Approximately 3,000 different strains of living algae, representing most major algal taxa. Cultures in the collection are used for research, teaching, biotechnology development, and various other projects throughout the world. UTEX supports this community of users through the provision of algal cultures along with a variety of other goods and services.

**Canada: Canadian Phycological Culture Center (CPCC).** www.phycol.ca.

As Canada's national service collection of freshwater algae and cyanobacteria, about 50% of the strains are native to Canada and about 80% are unique to the CPCC. Approximately 400 strains of primarily freshwater algae and cyanobacteria along with strains of marine microalgae and Lemna spp. are maintained. CPCC provides high-quality cultures and culture medium along with training workshops in aseptic technique and culture maintenance.

**CPCC Algae and Cyanobacteria Culture Collection Links.** www.phycol.ca/links.

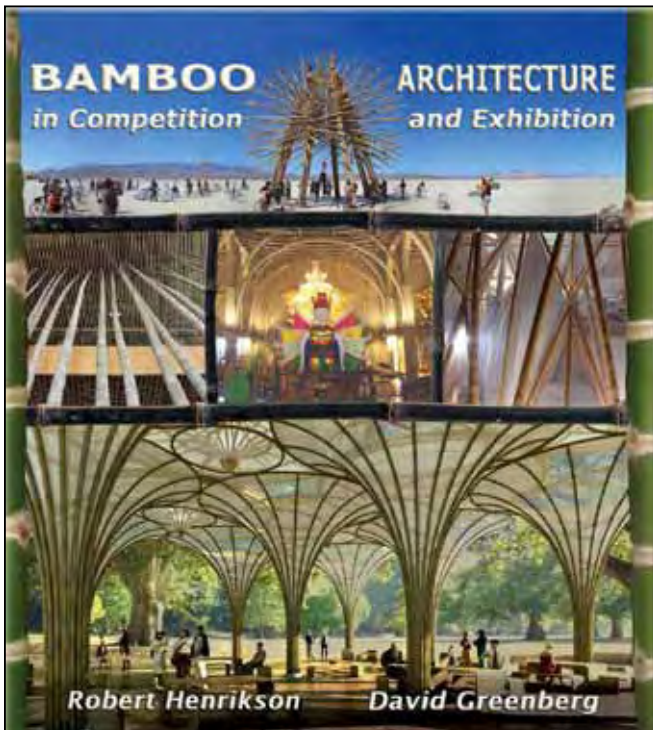
This is an extensive list of algae culture collections in countries around the world.



## About the Authors



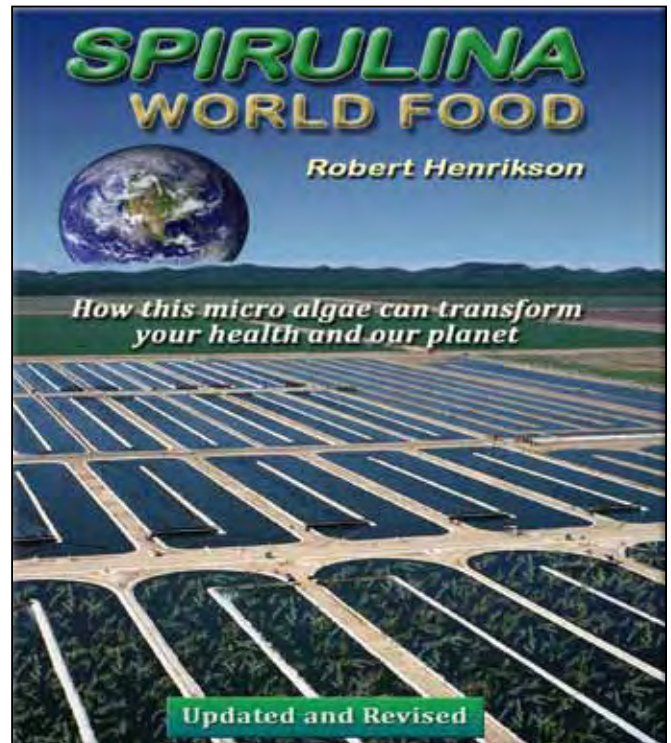
**Robert Henrikson** has been a green business entrepreneur for over 30 years in sustainable development business models for algae, bamboo and natural resources. Robert was the creator and director of the International Bamboo Building Design Competition ([BambooCompetition.com](http://BambooCompetition.com)), and the former CEO of a leading company building certified, code-approved bamboo buildings. Robert is the co-author of the book *Bamboo Architecture in Competition and Exhibition* based on the International Bamboo Building Design Competition.



Robert is an Algae Alliance consultant on business development, strategic planning, branding, sales and marketing, advising companies and investors in algae ventures ([AlgaeAlliance.com](http://AlgaeAlliance.com)).

Robert was a founder of Earthrise Farms and for 20 years, was President of Earthrise, pioneer in algae. He developed Earthrise® brand products in the USA and 30 countries. Authored the book *Spirulina World Food* in 2010, previously *Earth Food Spirulina*, translated into 6 international editions ([SpirulinaSource.com](http://SpirulinaSource.com)).

Robert has written numerous articles and produced many videos on algae over the past 30 years, and currently contributes articles to *Algae Industry Magazine* and speaks at algae conferences. In 2011 he launched the International Algae Competition: A Global Challenge to Design Visionary Algae Food and Energy Systems ([AlgaeCompetition.com](http://AlgaeCompetition.com)).



Robert is a photographer ([Panmagic.com](http://Panmagic.com)) and documentary filmmaker, and produced the DVD series *Folding Time and Space at Burning Man* ([Folding-Time.com](http://Folding-Time.com)). Co-Owner of Hana Gardenland, a botanical paradise retreat in Hana Maui, with vacation retreats and eco-tourism ([HanaPalmsRetreat.com](http://HanaPalmsRetreat.com)). Co-Owner of Wild Thyme Farm, a sustainable forestry and permaculture farming eco-community ([WildThymeFarm.com](http://WildThymeFarm.com)).

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**Mark Edwards** focuses his energy on one goal, enabling people globally to grow algae locally for the needs of their family and community. AlgaeCompetition.com creates a global collaboratory of Green Masterminds (growers) that moves towards the goal of democratizing food and energy security.

Mark speaks, consults and writes about algae's promise to solve critical challenges for human societies. He serves on numerous algae boards and provides coaching to assist algae start-ups move toward success.

Mark pursues abundance, a novel growing system to create food security while consuming no or minimal fossil resources. His *Freedom Foods* give consumers choice to make healthy dietary choices with better nutrition and taste with less pollution and waste.

*Abundance* enables growers to use plentiful resources rather than consuming increasingly scarce and expensive fossil resources. His innovations in algae fertilizers and growth hormones, described in *Smartcultures*, enable growers to grow superior produce while leaving every field or garden better than they found it.



Mark's nine books in the award winning *Green Algae Strategy Series* focuses on sustainable and affordable food and energy, (SAFE) production. His books are used in colleges, universities and institutes in over 26 countries in diverse disciplines.

*Green Algae Strategy*, an Amazon algae bestseller, won the 2009 Gold Medal for Best Science Book. *Abundance* won the 2011 Best Environmental Book and *Tiny Mighty Al* won the 2011 Nautilus Silver Medal for Best Children's Book.

NASA selected his research to design the astronaut habitat for the 100-Year Starship Symposium in 2011. His blog, *Algae101*, is among the most visited algae blogs. Mark graduated from the U.S. Naval Academy in engineering, oceanography and meteorology. He holds an MBA and PhD in marketing and consumer behavior and has taught strategic marketing and sustainability at Arizona State University for over 35 years.

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