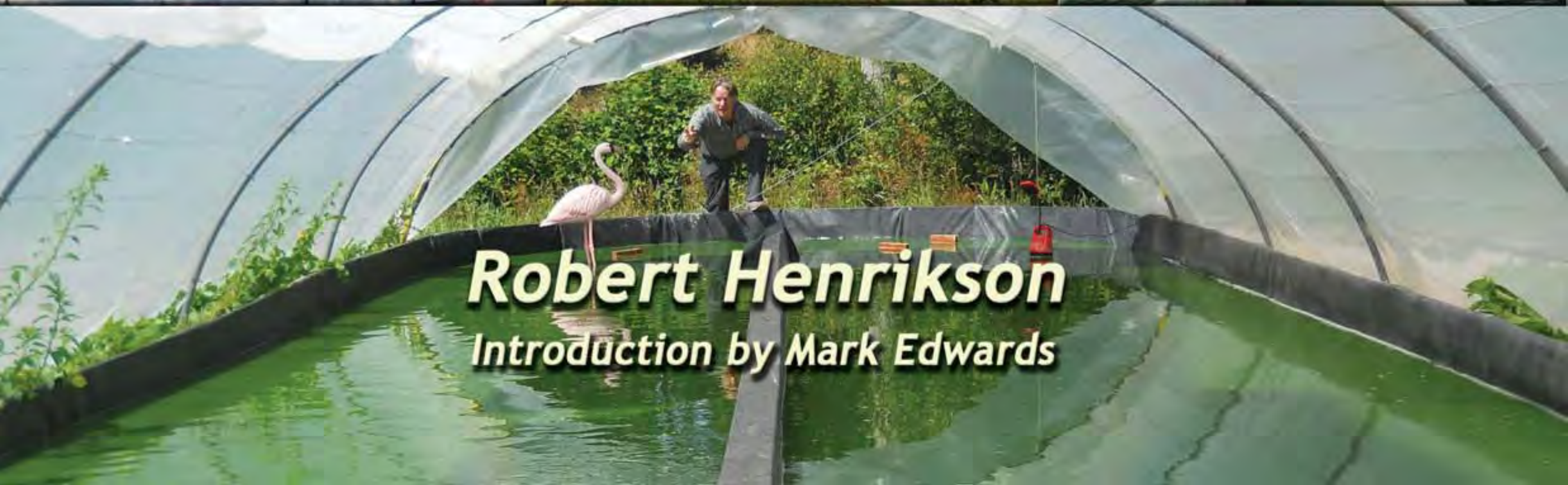
ALGAE MICROFARMS

for home, school, community and urban gardens, rooftop, mobile, and vertical farms and living buildings

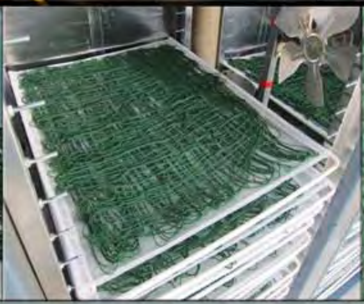


Robert Henrikson

Introduction by Mark Edwards

How algae microfarms can help transform our food culture by growing abundant healthy food in a very small area, extend the growing season, affordably and profitably.




Algae are 20 times more productive than conventional foods and are well known as nutrient dense superfoods with valuable health and medical benefits.

Over the past 30 years, large farms have grown algae for food, feed and fuels for thousands of useful products. Now an era of microfarms is emerging. Algae microfarms can empower people to grow healthy food in their own community for food security and self-sufficiency.

Robert Henrikson founded one of the world's first and largest algae farms 35 years ago. Now the time has come to introduce the algae microfarmers who are growing algae for healthy foods in their local communities.

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for home, school, community and urban gardens,
rooftop, mobile and vertical farms and living buildings

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ALGAE MICROFARMS

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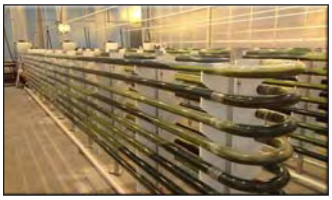

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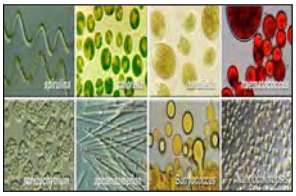


ALGAE REFERENCE GUIDE

Algae Microfarms

for home, school, community and urban gardens, rooftop, mobile and vertical farms and living buildings

Vision

How algae microfarms can help transform our food culture by growing abundant healthy food in a very small area and extend the growing season, affordably and profitably.

Algae are 20 times more productive than conventional food and are well known as nutrient dense superfoods with valuable health and medical benefits.

Over the past 30 years, large farms have grown algae for food, feed and fuel for thousands of useful products. Now an era of microfarms is emerging. Algae microfarms can empower people to grow healthy food in their own community for food security and self-sufficiency.

Inspiration

This book is dedicated to Dr. Ripley Fox and Larry Switzer

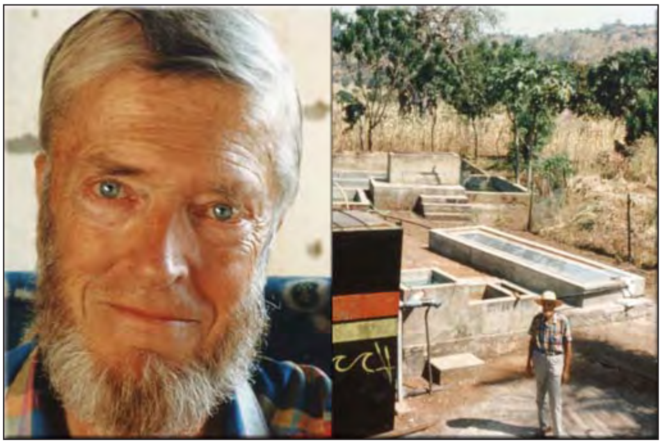


Photo: Robert Henrikson

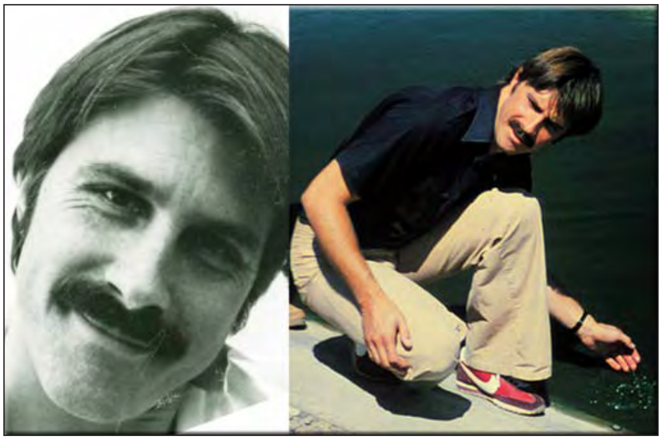


Photo: Dana Gluckstein

Ripley Fox

Ripley Fox was passionately devoted to innovative solutions to combat malnutrition in the developing world and a pioneer of village scale spirulina production since 1969. Ripley developed the integrated health and energy systems for village spirulina production.

First cultivation in India in 1973. First integrated village system in Wardha India in 1981. Integrated village system in Togo in 1983. Initiated humanitarian spirulina projects in Peru, Vietnam, Senegal, Madagascar, China and other countries.

Ripley authored *Spirulina Production & Potential* and numerous articles on spirulina. With his wife Denise Fox, Ripley inspired many humanitarian organizations working in the developing world, which led to the evolution of spirulina microfarms across France and Europe over the past decade.

Larry Switzer

Larry Switzer, a visionary bioneer and catalyst, founded Proteus Corporation in 1976 to develop spirulina blue-green algae as a world food resource. Proteus was funded by a group of California investors, committed to his spirulina vision.

Larry had been looking for new solutions and discovered microalgae was 20 times more productive as a protein source than any other food. It could be grown with unused land and water and it was possible to cultivate a pure culture on a large scale in many places the world.

Proteus Corporation with Dainippon Ink & Chemicals founded Earthrise Farms in 1981, which became the world's largest spirulina farm by the 1990s. In 1979 Larry launched the Earthrise® Spirulina product line which was eventually distributed in 30 countries around the world.

Imagine Our Algae Future

Mark Edwards

Algae are marvelous organisms that endow human societies with a broad spectrum of valuable solutions. Algae are overlooked because the cell size is tiny. 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 and will provide 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, malnutrition and poverty while regenerating polluted ecosystems. Microfarms will motivate people to innovate and overcome technology barriers.

We created Tiny Mighty Al 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 Al and shares how Al converted our CO2-rich atmosphere into sufficient oxygen to support life. Al saves our planet again by becoming the first food and feeding other creatures to grow and develop. Can Al save us again by sequestering CO2 and providing food, feed, fuel and medicine solutions? *You bet Al 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.
- Iron deficiency undermines the health of 40% of women in the developing world. Severe anemia kills 50,000 women a year during childbirth.

Algae provide a low fat, low calorie, nearly cholesterol-free source of protein. Algae such as spirulina contain up to 70% protein by dry weight – twice the protein of 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 proteins. 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 nutralence, 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.

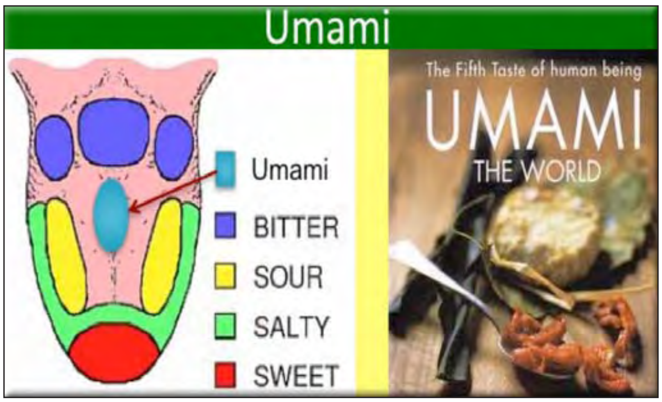
Algae provided a rich and nearly complete source of nutrition – a complex blend of nutrients that no other food source, plant or animal, could offer. Analogous to modern-day vitamin supplements, algae are a more robust, natural, and inclusive blend of healthful nutrition. Algae are a superior protein source, particularly the red, green and blue-green algae, up to 70% protein (dry weight), higher than soybean (36%) and corn (23%). Algae nutralence 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 functions in the body. Glutamate is the most abundant excitatory neurotransmitter in the vertebrate nervous system and regulates several brain functions. Its role in body and brain functions is so critical that the logical explanation for the umami taste bud 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 Foods

Today, most foods are produced using industrial agriculture that consumes massive amounts of natural resources and pollutes the environment. Algae food growers can use less 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. 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 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 Map for Food, Biofuels and Novel Solutions

Food	Biofuels	Novel Solutions
Primary • Protein • Lipids – oils • Carbohydrates • Nucleic acids **Secondary** • Flour • Meat enhancer • Ice cream • Milk substitute • Sugar substitute • Sea vegetables • Food ingredients • Emulsifiers and thickeners • Novel flavors and textures • Pigments • Health foods • Nutraceuticals • Omega 3s **Feed and fodder** • Pets, fish, fowl • Meat animals • Micronutrients • Medicines and vaccines	**Primary** • Gasoline • Clean diesel • Methanol/ethanol • JP-8 jet fuel **Secondary** • Aviation gasoline • Alcohols • Hydrogen • Asphalt • Plastics, biodegradable • Rubber substitute **Biofertilizers** • Organic N-P-K • Bioavailable target nutrients • Micronutrients • Plant hormones • Soil organics • Build soil structure • Improve porosity • Plant growth regulators • Natural pesticides • Natural herbicides	**Air** • Carbon sequestration • Carbon capture/recycle • Capture sulfur • Capture heavy metals **Water – clean** • Waste streams – municipal, industrial, farm, brine and ocean • Recover heavy metals **Cosmetics** • Moisturizers • Skin care **Local algae production** • Foreign aid • Disaster relief • Hunger and poverty **Medicines** • HIV / AIDS and SARS • Vaccines • Antibiotics /antiviral • Burns and bruises • Stomach remedies • Anti-cancer toxins • Pharmaceuticals • Advanced compounds

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.

Algae's Substantial Promise

Mark Edwards

Algae offer substantial solutions

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 were reserved for the Emperor of China in the 1100s. A few centuries later, another algae 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 biomass while cleaning air, water and soils.

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 people to grow their own food, cooking oil, animal feeds and medicines.

Novel Solutions

A current application for algae technologies focuses on carbon capture. Each ton of algae consumes two tons of CO2. Algae companies are eager to site production units near CO2 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.

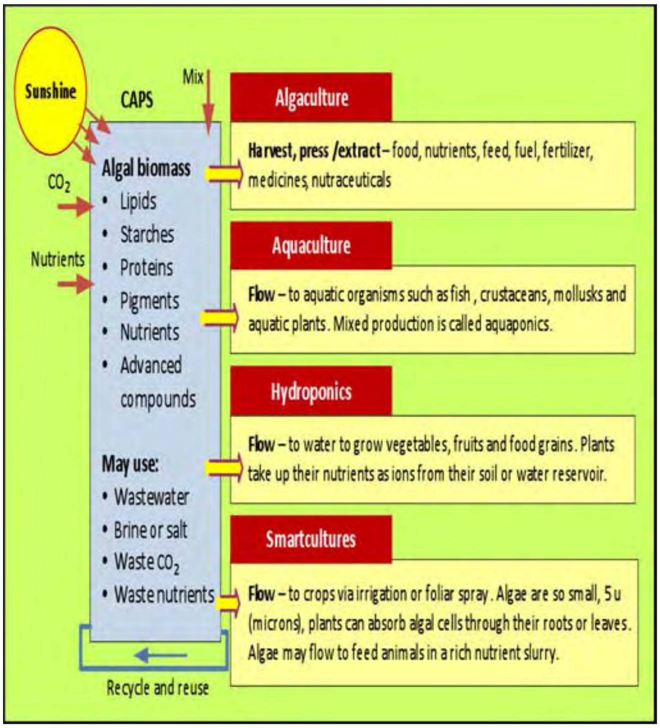
Manufacturers will use algae fibers to make fabrics for clothes, coverings, and carpets. Algae components will be manufactured into advanced materials such as composites to be fabricated into packaging, building materials and biodegradable products such as emollients and moisturizers.

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 will site their microfarm near waste streams and recover and repurpose nutrients in a rich algae biomass. They 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 more efficient use of fossil resources. Consumers will have choices for tastier foods that are two or three times higher in nutralence 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 social challenge focuses on unlocking algae's magnificent promises and making them our reality today.

Why algae microfarms are emerging today

Evolution of the algae industry

Over the past 40 years, global algae companies have produced high value food and feed products, supplements and nutraceuticals. More recently, well-funded ventures are attempting to develop commercial biofuels. These require huge investments to achieve necessary economies of scale. Large scale business models require algae experts and PhDs on location, with expensive staffing and sophisticated infrastructure.

More interest in smaller, scalable business models is emerging. Evolving from projects in developing world villages, algaepreneurs in France have been growing spirulina algae in small outdoor greenhouses. Along with outdoor pond systems, much algae R&D is focusing on bioreactors designed to grow more challenging algae under more controlled conditions.

Automated smart technology combined with modular growing systems may soon make it feasible to successfully deploy algae microfarms and photobioreactors anywhere in the world without on site expert personnel.

Algae are a productivity breakthrough

Historically, people harvested freshwater microscopic algae for food and biofertilizers near lakes and rivers around the world. Just in the past 40 years, with the commercialization of microalgae beginning in the 1970s, thousands of new algae-based products have emerged.

An algae production system can be an environmentally sound green food machine. Biomass can double every 2 to 5 days. With high protein algae like spirulina, this productivity breakthrough yields over 20 times more protein than soybeans on the same area, 40 times corn and 400 times beef. Other microalgae have even higher productivity.

The last 30 years progress in algae technology is remarkable. Successful algae cultivation requires a more ecological approach than industrial agriculture. As a living culture, if one factor changes in an algae system, the entire environment changes very quickly. Because algae grow so fast, the result can be seen in hours or days, not seasons or years like in conventional agriculture. Algae scientists balance system ecology to keep out weed algae and zooplankton algae eaters without using pesticides or herbicides. Algae cultivation is a new addition to ecological food production.

Some envision huge centralized algae farms producing food and energy on a vast scale. But others see networks of smaller farms.

Ecological communities can combine algae and aquaponics with organic gardens. Local food production avoids costs of transportation fuels and multi-level distribution along the value chain in the current food system. A higher portion of the value of locally grown food is returned to the grower, encouraging local food producers, creating greater income equality and local self-sufficiency for a more just and stable social fabric.

Microfarms for communities are coming

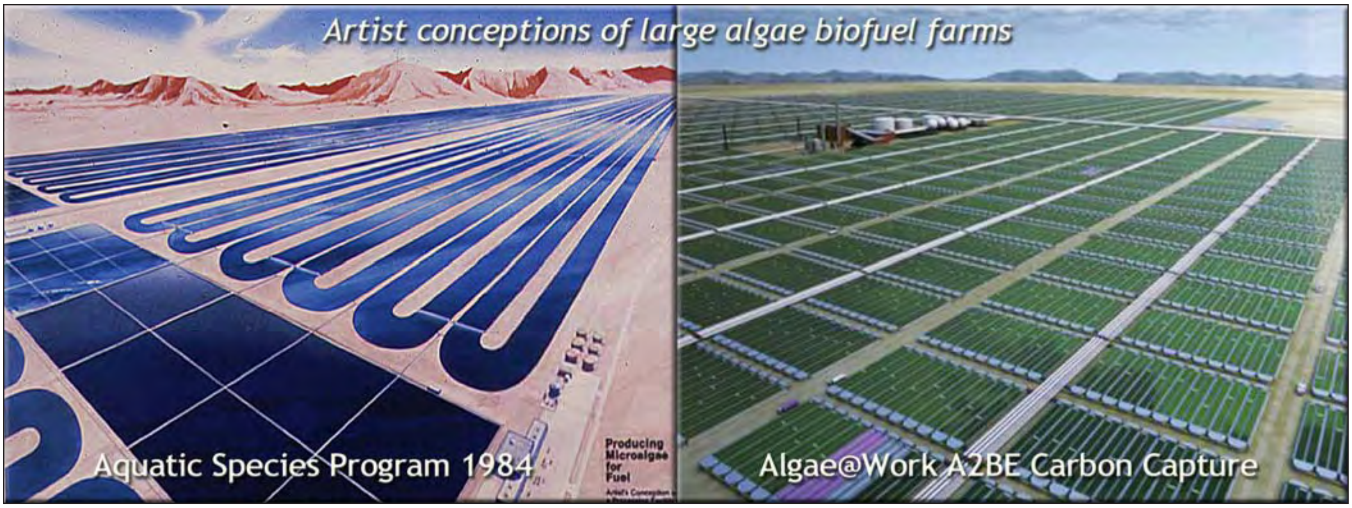
Many people have asked “How can I grow algae?” Gardeners, farmers and algaepreneurs want to grow algae without deep scientific expertise, experience and knowledge. In fact, small-scale algae farming has been tested for 30 years all over the world. Innovative, inexpensive and efficient small systems have been operating in villages in the developing world. In France, there are 110 algae microfarmers and a school curriculum for growing algae and these small growers are selling their own products directly in their local region.

Soon, remote sensors linked with cell phone apps may assist the basic functions of algae culture health monitoring and diagnosis. This will allow local algae growers to consult with remotely located algae experts on how to maintain a healthy algae culture in their small production systems.

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.

Going big - large scale algae cultivation is a big gamble

Algae farms for high value food and feed supplements, operating since the 1980s, such as Earthrise Nutritionals in California and Cyanotech in Hawaii, range up to 50 hectares in size. Today, algae biofuel ventures are looking to scale up from 100 to 1000 hectares to achieve the economies of scale to be worthwhile. Here are artist conceptions of outdoor algae biofuel farms.



Big algae production systems start small. Ideas migrate to lab research and then to demonstration systems. After success growing in small systems, companies scale up to larger production to achieve economies of scale.

If commercial algae production works, and the product finds a market, at some point, revenues will exceed break-even and variable costs, and over time, repay the original investment. For large ventures, with high investment and operating costs, what size will it take to make a profit?

One example is the Sapphire Energy Green Crude Farm in New Mexico, an Integrated Algal Bio-Refinery, funded with over $300 million in investments and loan guarantees. Building a prototype farm to demonstrate technology at this scale represents a substantial investment risk.

Beyond the uncertainties of developing novel algae systems, the high costs for lab, technical and operations staff represent high overhead. Some large algae ventures have succeeded, but many more have failed over the past 40 years.

Sapphire Farm in Columbia, New Mexico has 100 acres of growing ponds developed.

Staying small – the first microfarms are growing spirulina algae

Experimental Farm 1988, Togo

Maison de la Nutrition, Madagascar

Simplicity Farm Auroville India

Spirulina harvesting and drying process at Spiruline Saintonge in France.

Parallel to large scale commercial farms has been the evolution of village scale algae systems, primarily in the developing world. *Spirulina* has been most commonly adopted and there are now farms perhaps in as many as 40 countries.

With greater understanding of how to control and cultivate other high value algae, it is likely that other types of algae will become candidates for small-scale cultivation in the near future.

Why spirulina? It has these six advantages:

1. Traditionally consumed and proven safe.
2. Easy to grow.
3. Easy to harvest.
4. Major scientific evidence on health benefits.
5. Existing global market already established.
6. Low cost of entry for small scale production.

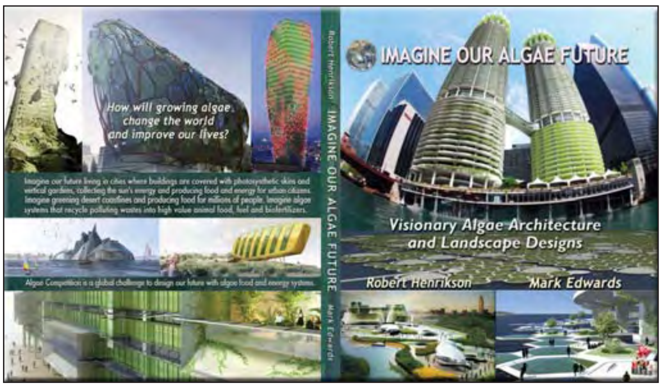
First Prize Winners in the International Algae Competition for algae production systems.

Greenhouse microfarm for temperate climates: Smart Microfarm near Olympia, Washington.

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

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. The 2011 International 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. The book, *Imagine Our Algae Future,* showcased 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, humans harvested algae like seaweed along the coastlines and near lakes and rivers; others harvested freshwater microscopic algae for food and biofertilizers. Just in the past 40 years, with the commercialization of microalgae beginning in the 1970s, thousands of new algae-based products have emerged.

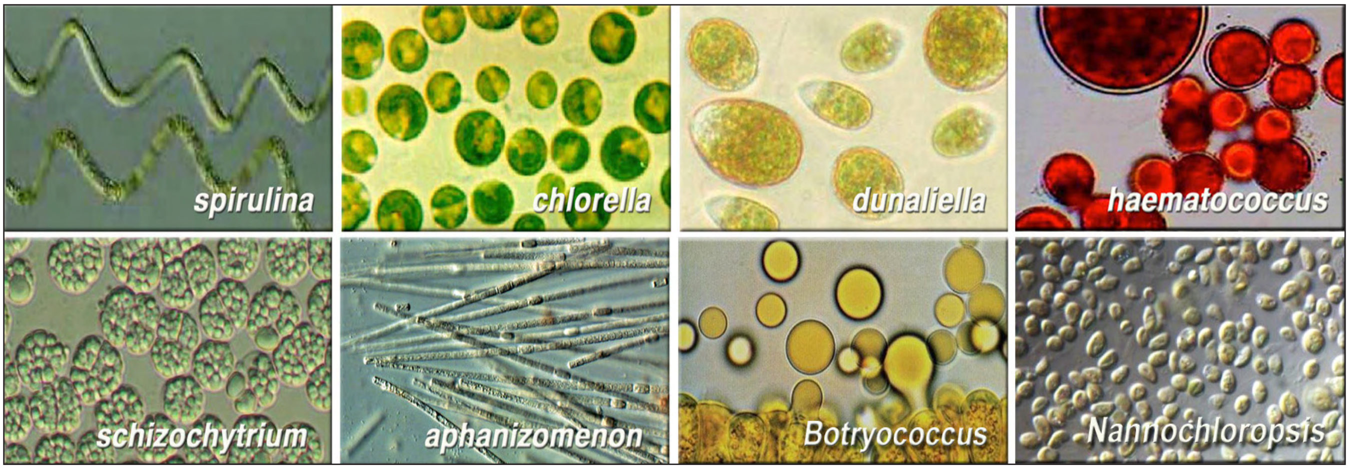
In the past five years, more than a billion dollars has flowed into algae biofuel development. Even though commercial biofuel from algae may be years away, this investment is creating innovations, making algae production more affordable, stimulating interest in growing algae for many products. Large 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. Algae offers a future beyond scarcity toward sustainability and abundance.

This new book, *Algae Microfarms,* introduces individuals and organizations growing algae on a small scale and making a difference today. Some of these small farms are humanitarian, some are commercial, some are both. Algae microfarms are producing heathy food and supplements and valuable products supporting the local economy.

Here is a look into our future of scalable microfarms for home, school and community gardens, urban and rooftop farms and even living buildings that are local, sustainable and profitable.

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 and 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 farms in the USA, China, India, Mexico, Myanmar and other countries, and many small village scale and microfarms in Europe, Africa and Asia.

Chlorella was the first microalgae to be commercially cultivated beginning in the 1970s and sold as a food supplement. Outdoor farms in Taiwan, Southern Japan and Indonesia produce much of the world supply. Chlorella is also grown commercially in closed indoor production systems.

Dunaliella thrives in water even saltier than the ocean in places like Australia and Israel. Too salty to be eaten as a whole food, its beta carotene is extracted as an oil or powder and sold as a food supplement, antioxidant and 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.

Botryococcus braunii is being commercialized for algae biofuel.

Nannochloropsis is being commercialized for biofuel and nutritional omega-3 oil.

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 every-day 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.

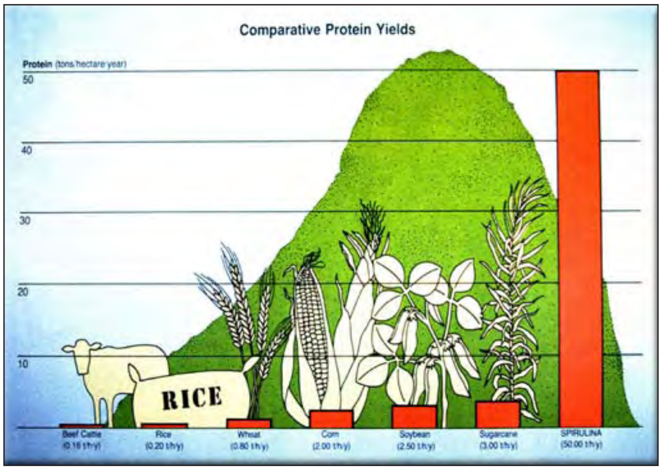
Algae as a food ingredient, source of natural pigments and colors, and DHA Oil from schizochytrium in infant formulas, prenatal supplements, food and beverage products.

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

Algae 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 Area Needed to Produce One Kilogram of Protein

	Sq. Meters	Quality
Spirulina[a] 65% protein	0.6	non-fertile
Soybeans[b] 34% protein	16	fertile
Corn[b] 9% protein	22	fertile
Grain-fed Feedlot Beef[b] 20% protein	190	fertile

a Y. Ota, Earthrise Farms, California 1995
b Leesley, et al. "A low energy method of manufacturing high-grade protein using spirulina," University of Texas, 1980. Pimentel, 1975, USDA

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.

Water Needed to Produce One Kilogram of Protein

	Liters	Quality
Spirulina[a] 65% protein	2100	brackish
Soybeans[b] 34% protein	9000	fresh
Corn[b] 9% protein	12500	fresh
Grain-fed Feedlot Beef[b] 20% protein	105000	fresh

a Y. Ota, Earthrise Farms, California 1995
b *Diet for a Small Planet*, 1982, pg. 76-77, Dr. David Pimentel, Cornell University, 1981.

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.

Energy Efficiency (Million Kjoules Per Kilogram of Product)

	Total Energy Output	Food + Residual Energy Output	Energy Output/ Input
Spirulina[a] 65% protein	3.8[b]	23	6.1
Soybeans[b] 34% protein	11.7	13.8	1.2
Corn[b] 9% protein	5.5	16.5	3.0
Grain-fed Feedlot Beef[b] 20% protein	456	16	.04

a Y.Ota, Earthrise Farms, California 1995
b Leesley, et al. "A low energy method of manufacturing high-grade protein using spirulina Universitiy" of Texas, 1980, Pimentel, 1975. USDA

Small algae farms in the developing world

Spirulina algae adopted in many countries

As a supplement, spirulina offers remarkable benefits for undernourished people, especially children, with a long historical record of safe use.

Taking just one to three grams per day, its rich beta-carotene can overcome eye problems caused by Vitamin A deficiency. Its digestible and very high 65% protein, B-vitamin complex, iron and trace minerals, improves a deficient diet and children's physical and cognitive development. One tablespoon a day can eliminate iron anemia, the most common mineral deficiency. It is the only food source, except mother's milk, with substantial GLA, an essential fatty acid that helps regulate the hormone system.

A growing body of research with undernourished people shows how spirulina restores beneficial intestinal flora and strengthens the immune system. Spirulina helped recovery of children from malnutrition related diseases in Mexico, Togo, Romania, China, Rwanda, Zaire, India, Ukraine and Belarus.

Recognizing this, over the past 30 years, charitable and humanitarian organizations have been leading the way to develop small scale systems.

Because spirulina can be cultivated in outdoor ponds with relatively modest investment, many initiatives have set up production using appropriate technology and available resources.

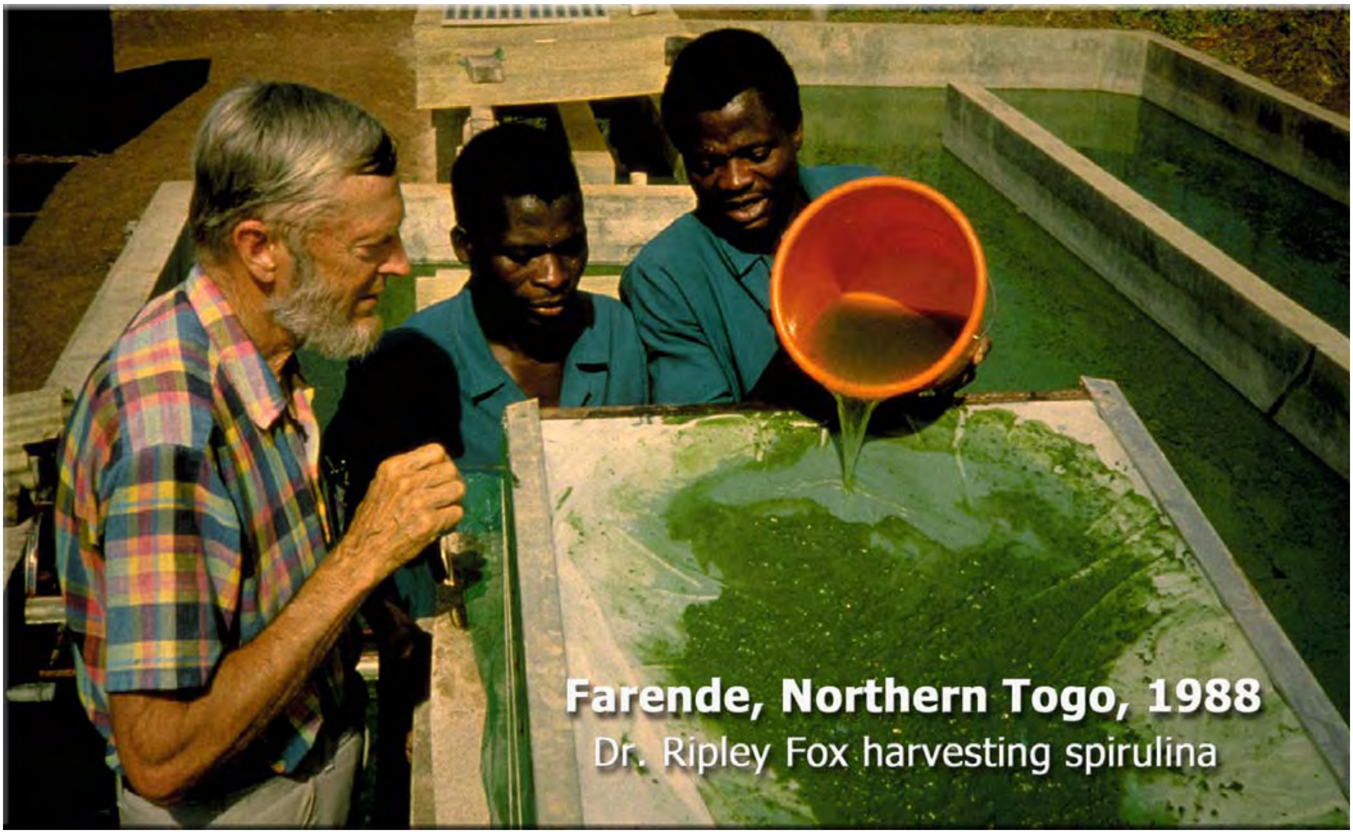
Over the past 30 years, numerous projects have been growing spirulina as a local food in Africa, Asia and South America. Here are stories of early pioneering projects, and some of the humanitarian and commercial farms around the world today.

Myanmar: Lake harvest has grown to 200 tons per year.

Thailand: Boonsom Farm has grown to 40,000m^2.

Ecuador: Andes Spirulina produces 36 tons per year.

Costa Rica: Spirulina Vera produces 3.5 tons per year.



Beginning of village scale technology

Parallel to the development of commercial production in the 1980s, Ripley and Denise Fox of France founded the non-profit Association Pour Combattre la Malnutrition par Algoculture (ACMA) to help fund the Integrated Health and Energy System, which recycled wastes already present in the villages for spirulina cultivation. They sponsored projects in India, Peru and Africa.

The Foxes grappled with the most fundamental problem: the lack of opportunity. Large commercial farms could produce spirulina, but if the hungriest people had no money to buy it, they would never get any. They must grow it themselves, but without the money to buy nutrients, how could a village project be self-sustaining?

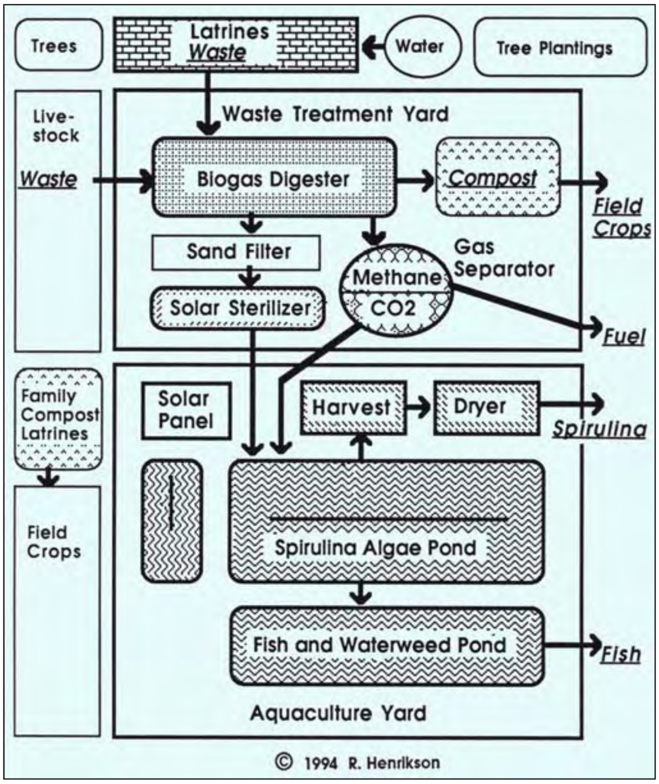
Villages have an abundance of human and animal wastes – a source of pollution and disease. Intestinal parasites, spread by contact with wastes, consume 30% of the food eaten by people. The first step in improving health and increasing effective food production is eliminating intestinal parasites through sanitation and waste treatment. Properly handled, wastes can be converted to energy, compost, clean nutrients and even food.

Denise and Ripley Fox, 1987.

“One recycles the wastes already present in the village.” This is the foundation of the Integrated Health and Energy System, described in his books, *Algoculture: Spirulina, Hope for a Hungry World*, and *Spirulina, Production and Potential* (1996).

Integrated Village System in Farende, Northern Togo

One experimental project was developed in a remote village in Northern Togo from 1984-1989. One 100m^2 pond could supplement the diet of 100 children a day. Solar panels powered pond paddlewheels. Spirulina rich pond water was poured through a screen, becoming a paste, which was solar dried and distributed at the health clinic.



Layout of Integrated Health and Energy System

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

The Foxes assisted Eglise Evangelique du Togo in building this experimental system, operated by two young village men. Also cooperating was the U.S. Peace Corps, teaching people about soil composting, vegetable gardening, conservation and growing trees. Sponsors were Dainippon Ink & Chemicals of Japan and Earthrise of California.

Modified versions were later adopted for projects in African countries, and small scale cultivation inspired a generation of French NGO workers who began the microfarm movement in France in 2001.

Undernourished children took spirulina as a daily supplement. One tablespoon a day mixed with water brought remarkable results. Children found the taste of this *"green medicine"* acceptable and within a week began to show signs of health improvement and gain weight.

Mothers from the surrounding countryside brought their children every week to participate in a clinical feeding study in 1989.

The health clinic nurse introduced children to spirulina.

Family scale cultivation in Tamil Nadu, Southern India

In India, a government sponsored project provided small backyard basins to women for family nutrition with the goal to develop into local village networks to combat Vitamin A and general immune deficiency conditions. In the 1990s, a joint effort by many government agencies covered all aspects of spirulina, from simple cultivation basins to large commercial farms.

Home cultivation and harvesting in a village in Tamil Nadu, India. *Photo: C.V. Seshadri.*

The *All India Coordinated Project on Algae* began in 1976 to harness algae as biofertilizer and to cultivate it for human nutrition and animal feed at both commercial and rural levels.

Original work began with *scenedesmus*, green algae, but later, spirulina was chosen because of its advantages. In 1991, the Indian government launched large scale nutritional studies. To demonstrate national interest, the Ministry of Health issued official standards for food grade spirulina.

As a result of these early efforts, there are numerous village projects across India today.

Reducing eye diseases

The world's largest spirulina nutrition program with 5,000 children was completed in 1992. Children near Madras consumed one gram a day for 150 days. This small amount provided the daily requirement of beta carotene (Vitamin A) which helps prevent blindness and eye disease. A symptom of Vitamin A deficiency, Bitot's spot, a scarring of the conjunctiva of the eye, decreased from 80% to 10%.

A spoonful of "Spiru-Om" noodles is given to a small child. *Photo: C.V. Seshadri.*

The government sponsored large scale nutrition studies and investigated therapeutic uses. Spirulina was given to children in extruded noodles, sweetened with sugar to preserve beta carotene. Called *"Spiru-Om,"* it was well accepted by the children. This project was sponsored by the Indian government and was led by Dr. C.V. Seshadri of the Murugappa Chettiar Research Center.

One goal of the program was to provide an alternative to Vitamin A therapy, requiring massive doses of imported Vitamin A every six months.

Dr. C.V. Seshadri, with Dr. Ripley Fox and Robert Henrikson, 1993.

Kanenbu Spirulina Ladies harvesting spirulina from Lake Boudou Andja, traditional drying in the sand.
Photos: Marzio Marzot from the FAO Report: The Future is an Ancient Lake, 2004.

Traditional spirulina production 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.

Techniques of harvesting and drying have been passed from mother to daughter for generations. Kanembu ladies scoop the wet algae in clay pots, drain the water through bags of cloth and spread out the algae a circular sand filter to dry in the sun. After about 20 minutes of drying, women cut the algae cakes into small squares for sale in the local market. *Dihé* is crumbled and mixed with a sauce of tomatoes and peppers, and poured over millet, beans, fish or meat.

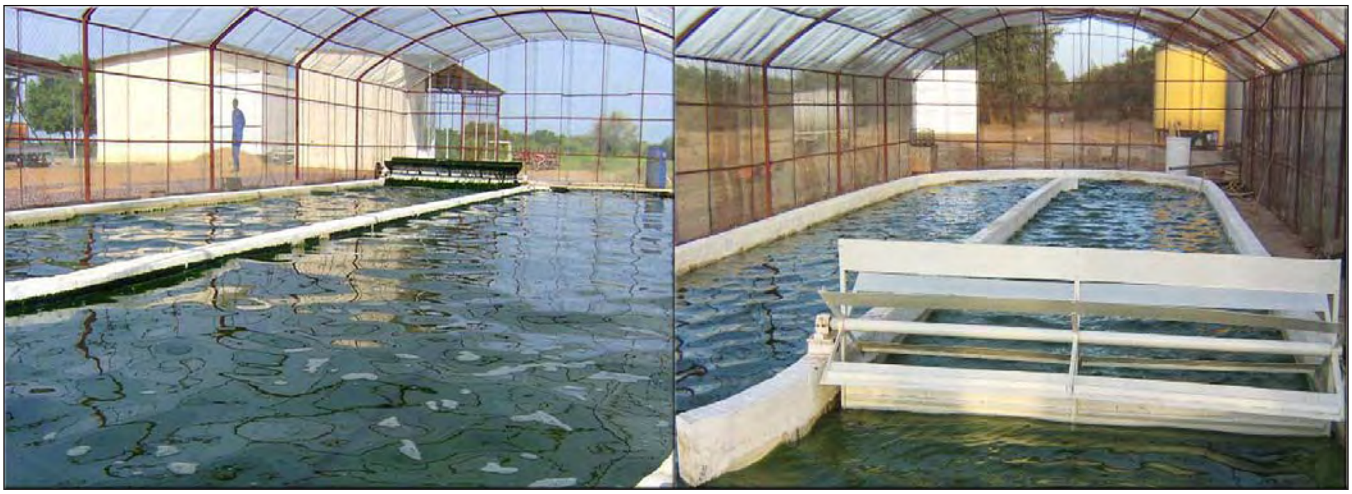
In 2004, the UN Food and Agriculture Organization (FAO) reported in the Kanem region of Chad, the local market price ranged from $.80 to $2 per kg –10 times less than in developed countries. Average consumption of *dihé* was as high as 50 grams per person per week. These ladies of Chad represent some of the highest volume and the lowest cost producers of *spirulina* in the world.

Selling dihé in the local market. Locals use dihé sauce poured over millet.
Photos: Marzio Marzot from the FAO Report: The Future is an Ancient Lake, 2004.

Evolution of spirulina production in Chad

Spirulina is skimmed from the lake and traditionally dried in sandy hollows.
The improved method: harvesting through fine cloths, extruding into noodles, solar drying and packaging.
By Mahamat Sorto, Food Technology Consultant FAO Chad, 2011.

Improvements in harvesting and good manufacturing practice 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 by 2010. The income of women has increased dramatically. This project was funded by the European Union and implemented by FAO.



Greenhouse production in Chad by Compagne Sucriére du Tchad, initiated in 2008 near Ndjamena.
Photos: Georges Bonnin.

Antenna Technologies in Africa and Asia

Antenna was established in Geneva in 1989 by Denis von der Weid, promoting spirulina against malnutrition with a mission to make algae more affordable.

Today, Antenna Foundation in Switzerland (antenna.ch) is engaged in research and dissemination of technologies appropriate to the needs of the poor in developing countries. Antenna France (antenna-france.org) and its local partners set up spirulina production programs in Africa and Asia.

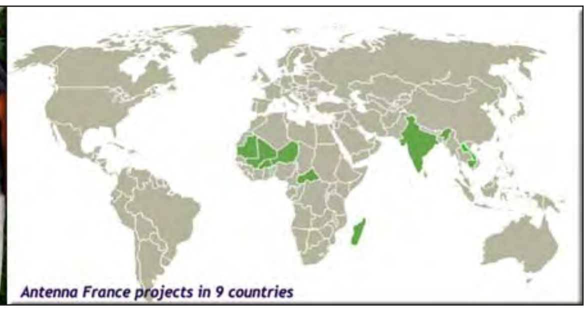
Over the past decade, many technical problems have been resolved and product quality, packaging and diversity have been improved. Challenges are to replace imported inputs with local products and use recycling systems for growth nutrients to reduce costs.

Establishing farms as businesses involves the engagement of local women, developing local distribution networks and educating people about nutritional benefits. The major challenge is to achieve financial sustainability.

Antenna estimates pond installation costs between $15 and $30 per square meter and a pond of 200 square meters will produce enough spirulina for 1200 children per year, and will support a sustainable food supply chain and local employment and income, especially for women.

Spirulina pond, Central African Republic. Photo: Antenna.

Production technology is simple, with pond stirring by wind or solar devices or by hand. Spirulina is harvested by filtering through cloths and can be solar dried for preservation or the wet paste can be mixed directly into the staple diet.



Today there are farms in Burkina Faso, Cambodia, Laos, Madagascar, Mali, Mauritania, Niger, Togo, Central African Republic and India, and eight of these farms are running by themselves.

Togo, Agou Nyogbo farm

This farm, about 150 km from the capital Lomé, was established in 2004. In 2012, the farm had 300m^2 of ponds. About 200kg per year has been distributed to mothers and children through the Research Center of Nutrition and other clinics.

In 2013 the farm is building another 500m^2 of ponds to meet the strong demand. The larger processing facility will include tableting machine and storage for food products enriched with spirulina. Channels for both humanitarian and commercial distribution and marketing are being expanded.

Objectives are expanding social distribution to provide dietary supplements to 3000 people each year, ensuring financial autonomy of the project within 2-3 years, creating 10 local jobs and developing a training center for community involvement and replication of the project.

(Photos: Antenna-France).

Madagascar farms and nutrition center

A local association founded by Antenna in 2005, created the Ibity farm, 20 km from Antsirabé, This 300m^2 farm was destroyed by a cyclone in 2011. Rebuilding in 2012, the objective is to reach 500kg annual production, benefiting 3500 children.

A second farm in Madray, 12 km from Antsirabé, was started in 2009, 250m^2 in size. Resuming after the cyclone, the current objective is to produce 300kg, with 100kg for humanitarian distribution. Two other farms have been established for humanitarian and commecrcial distribution.

In 2010, Antenna opened the Maison de la Nutrition in Antsirabé to distribute a daily balanced diet with added spirulina and educate mothers and children about balanced nutrition and elementary hygiene. Nearly 200 children were accommodated in 2011.

Daily meals at Maison de la Nutrition, Antsirabe, Madagascar. Photos: Antenna-France.

Cambodia, Siem Reap and Kandal farms

Antenna partnership farms near Angkor Wat and Phnom-Penh are run by local families growing mushrooms and vegetables. Spirulina has been approved by the Ministry of Health that allows spirulina sales and distrubution in Cambodia.

Beginning in 2011 in Siem Reap, 600m^2 of ponds, harvest and drying system are being constructed to produce 900kg spirulina products per year. Two-thirds of the production will be commercially marketed and one-third will be distributed through humanitarian organizations to 3000 children.

Food acceptability studies have been conducted with groups of children 2-6 years old. Initially, Cambodian children were confused by the dark green color, but then found spirulina had little taste when mixed in a dish. Spirulina was generally well accepted and the preferred food form was spirulina powder mixed in rice and vegetables. *(Photos: Antenna-France).*

Circular ponds with solar panels.

Fresh spirulina harvest.

Photos: Antenna-France.

Painting the solar dryer.

Spiruline du Burkina

Nayalgué farm in Koudougou

Burkina Faso has nine spirulina farms today (spirulineburkina.org).

The first farm was launched in Koudougou in 1999 under the auspices of the Catholic Organization for Development and Solidarity (OCADES). The three main objectives were 1) supply the diocese and other health centers in Burkina with spirulina against malnutrition, 2) sell a portion on the open market offering the public a food supplement at low cost, 3) create jobs at the farm.

The farm at Le Petite Seminaire expanded in stages to 900m^2 and has been self financing since 2000. Its chief objective remains giving the public access to spirulina at a minimum price and distributing the product among the most destitute. It received Health Ministry approval in 2005.

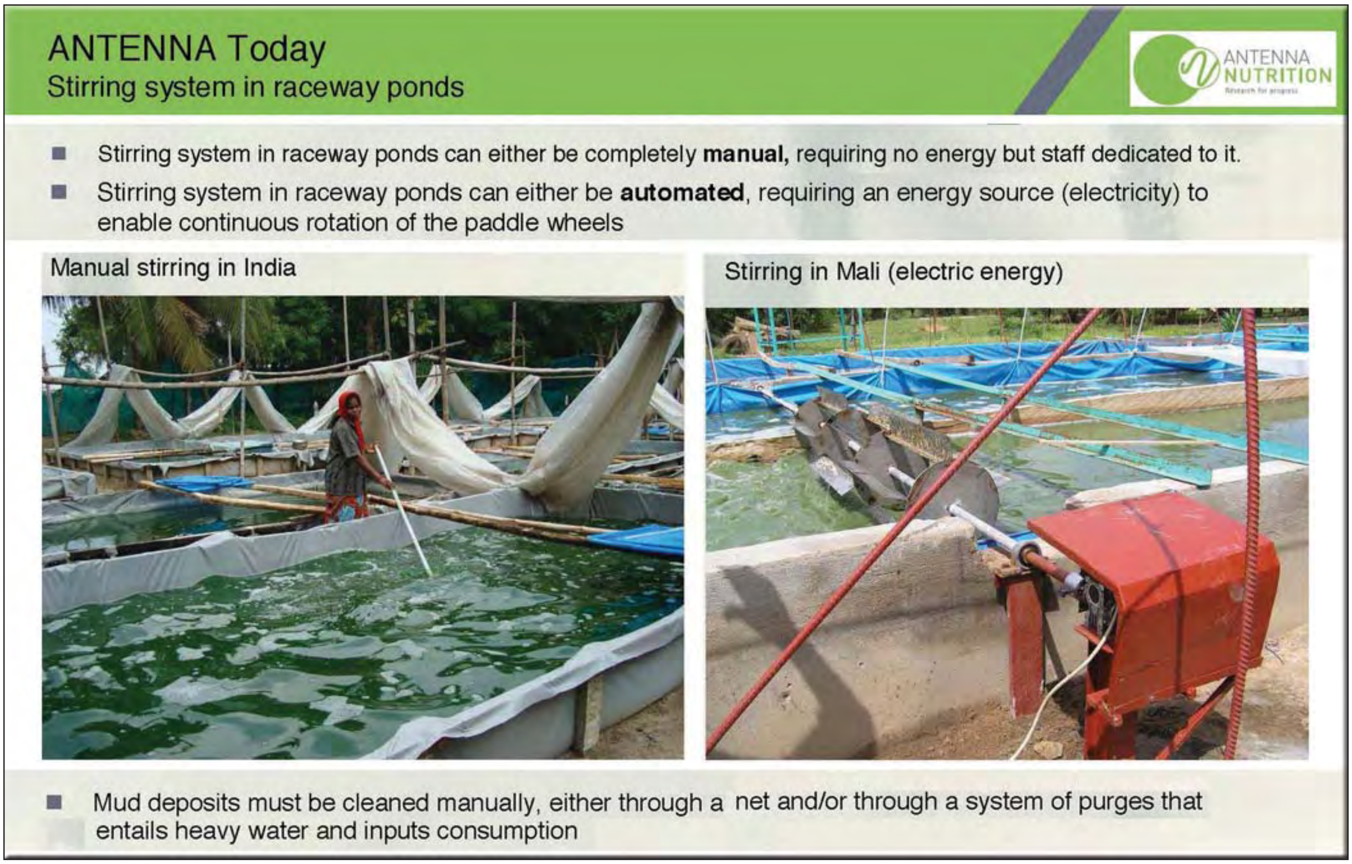
By 2001, success of spirulina, measured by improvement in public health, led to expanding existing farms and setting up new ones with the assistance of non-governmental organizations to meet growing demand in Burkina and in the neighboring countries.

Nayalgué farm in Koudougou. The Burkina Government became involved in a large project, the Nayalgué farm, in cooperation with the diocese of Koudougou and the French NGO TECHNAP. Nayalgué, means “that which expands”. This farm has 3600m^2 and a capacity of 8 tons annually.

This large farm oversupplied the local spirulina market, leading to export production to France. The present challenge is to increase exports to finance its humanitarian mission (45% is given or sold at humanitarian prices) and to be certified as fair-trade. Nayalgué claims to be a model farm in Africa as it is successful, locally managed, and easily visited by regional fact-finding missions.

Burkina Faso now has 9 farms or more, ranging from tiny 50m^2 pools to the 3600m^2 Nayalgué Farm. Most farms are members of a national spirulina association and use standardized packaging.

Antenna France has developed circular ponds to decrease costs. This project was awarded First Place Prize in the International Algae Competition for algae production.



ANTENNA Prospective

Circular tanks: General presentation

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

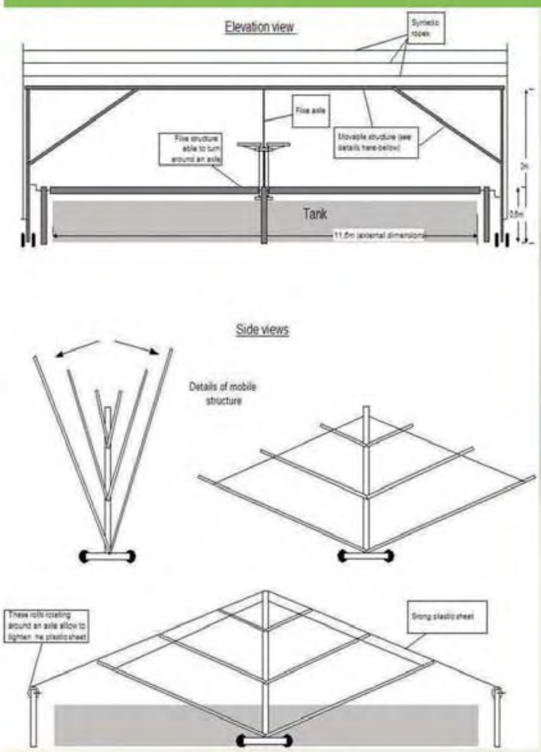
- ✓ Water stirring
- ✓ Continuous cleaning

Circular tank in Kenya

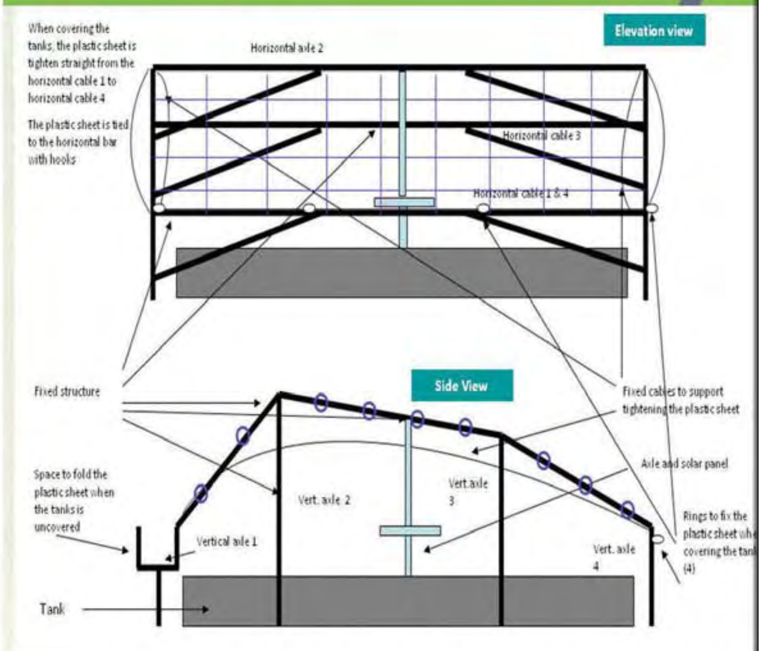
Circular tank in Kenya

Circular tank India

Circular Tanks Covering / proposal 1



Circular Tanks Covering / proposal 2



2 persons can cover the tank in one move, each one being located on each side of the tank. Thanks to the hooks slipping on the horizontal bar, the plastic sheet can be unfolded and tightened along the horizontal axles

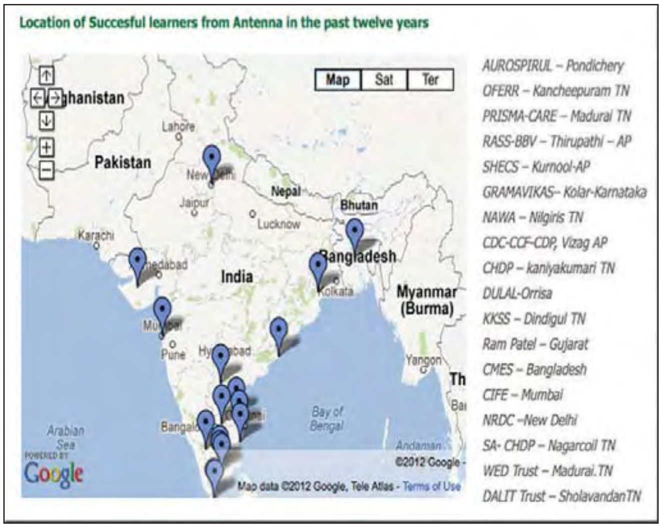
NB: 12meters long horizontal cables can be supported with squares or rigid beams

NB2: to avoid water ponds following heavy rains, the plastic sheet is very tightened thanks to a grid of horizontal cables (in blue)

Antenna Nutritech spirulina ponds, nutritional products and social programs for children.
Photos: Antenna Nutritech (antennaindia.org).

Antenna Nutritech Foundation in Madurai, India

This social enterprise is devoted to providing everybody the necessary micronutrients for daily needs through fortified spirulina products. The first farm was launched in 1995 with one small basin. Technical support from Antenna Switzerland helped to enlarge the farm.



Over the years, Antenna has trained people from non-governmental organizations (NGOs) to grow spirulina in small farms all over India and Bangladesh. To increase the number of people consuming spirulina, a marketing division developed new products.

Today Antenna Nutritech Foundation is integrated from production to product and reaches consumers through a strong network of NGO distributors.

Spirulina Tuttipakkam near Pondicherry was begun in 2007 as a collaboration between Volontariat of India (volontariat-inde.org) and Codégaz, linked to Gaz de France. The algae is grown in 4 tanks with an area of 250 m^2. Production is 25 to 30 kg per month and it has 4 basins in greenhouses. Half is distributed to humanitarian associations, half is sold for economic self-sufficiency.

Green Tongue Candies were a finalist in the Algae Competition for food development.

Spirulina-
GREEN TONGUE CANDIES

To combat
Child Malnutrition
with

- Affordable
- Acceptable
- Stable

Spirulina Product

INGREDIENTS

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

Steps in Green Tongue candy making

1. Syrup of Refined sugar and Liquid Glucose is prepared at130°C
2. Cool down to 70-60°C
3. Spirulina Powder is Mixed with syrup
4. The Mix mass is made in to candies
5. Candies are Cooled to normal temperature and packed

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

Production of Spirulina & Green Tongue Candies

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 5th candy is absolutely free to SHG member who is promoting candies to poor rural children

Spirulina GREEN TONGUE Candies

- **Affordable**
- **Most suitable to children**
- **1/3rd 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.

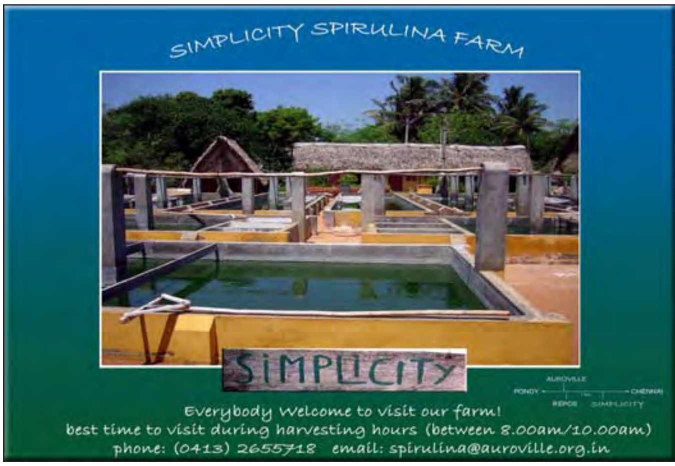
Simplicity Farm in Auroville, India

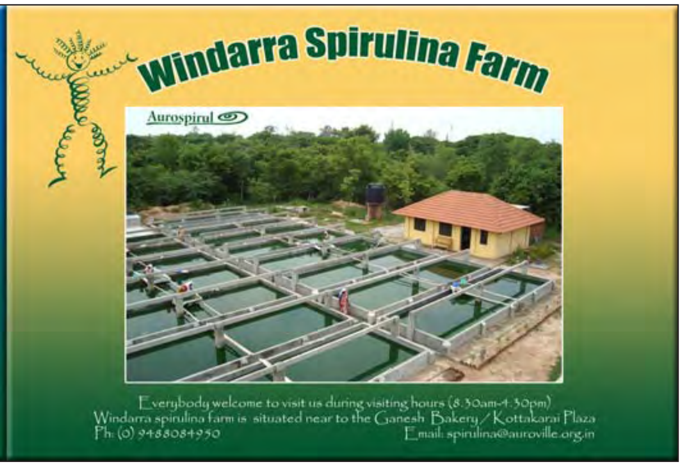
Since 1997,Simplicity Farm has been growing spirulina for Auroville and for sale outside. It produces high quality spirulina, grown by simple eco-friendly methods made possible by the highly alkaline pH level of the spirulina culture, without the use of herbicides or pesticides or other materials harmful to the environment. Spirulina is sun-dried, which gives it a special energy and a wonderful taste.

In the 1970s, Aurovilians Bob and Deborah Lawlor started a small algae farm in Auroville's Success Community with a mixture of green algae, mostly *chlorella* and *scenedesmus*. Jim De Vries was experimenting with chlorella farming at La Ferme around 1978, pumping water with *chlorella* onto the rooftops of the buildings around the ponds.

In the beginning of the 1990s, Bonaventura Chanson founded Simplicity with the vision of starting a spirulina farm and introduced spirulina to the community. After Bonaventura's passing, Aurovilian Hendrik van Poederooijen (from the Netherlands) who presently runs the farm, decided with Tejas Joseph to start the project with a loan given to the project by the Auroville Health Centre.

1970s farm in Auroville • 1998 Hendrik's first harvest.





In 2008 the foundation stone was laid for the new Simplicity Spirulina Farm at Windarra community in Auroville's Green Belt. Aurospirul has established itself as a well-known brand of spirulina.

Today Hendrik is producing at two locations in Auroville 1) Simplicity Spirulina Farm (near the beach) and since 2008 at Windarra spirulina farm (a few km more in the center of Auroville). Together they produce around 4 tons a year, mostly sold within the Indian domestic market.

Spirulina powder can be added to fruit or vegetable juices or dishes - tasty in soups, salads, pasta, or mixed with yogurt. Spirulina Crunchy is a snack or a seasoning for dishes, bread or salads. For fresh lemon juice, add a teaspoon of spirulina. Capsules and tablets are convenient any time.

Algaepreneurs and the microfarm movement in France

Since the 1980s, French charitable and non-governmental organizations have been building and operating small spirulina algae systems in Africa and Asia using appropriate technology and developing simple and effective growing and processing systems. Upon returning to France, some technicians who became expert in local spirulina cultivation began small scale production at home.

Philippe Calamand, Ripley Fox and Denis von der Weid view La Capitelle greenhouse, 2002.

Spiruline La Capitelle, first microfarm in France

After several years working at spirulina farms around the world, Philippe Calamand built two greenhouses at his homestead in the South of France. Since 2001, with 300m^2 pond area, his ponds have produced 300 kg over 5 summer months.

Each year, local demand for Spiruline La Capitelle (spirulinelacapitelle.com) noodles has exceeded capacity. A new business model emerged for growing spirulina in microfarms and selling to the local community in the developed world.

La Capitelle process: harvest algae • fresh paste • extrude noodles • solar dehydration • package product.

Symposium of the Fédération des Spiruliniers de France in Motz France was held in November 2012.

In 1996, Ripley Fox published *"Spirulina: Production & Potential"* which included sections on costs and materials for family scale farms and a technical manual for growing spirulina.

In 2002, Jean-Paul Jourdan published *"Cultivez Votre Spiruline" (Grow Your Own Spirulina)*. In 2009, Gilles Planchon published *"La Spiruline Pour Tous" ("Spirulina for Everybody")* an easy-to-read manual (in French) for growing spirulina.

A spirulina school was established at the CFPPA Center in Hyères in 2005 and Jean-Paul Jourdan became a professor of spirulina culture, engaging more people to join this community, and training entrepreneurs to grow their own algae business.

As the numbers of microfarmers grew, by 2008 the Fédération des Spiruliniers was organized as an association with 80 members to agree on good business practices and quality control guidelines.

In 2011, work began on a Federation Charter, with quality control standards and good manufacturing practices. A goal is to coordinate food standards with government agencies on regulatory issues.

Currently, a big effort is underway to use biomass fermentation to generate methane gas ("methanation") to heat spirulina pond water. This will extend the growing season and help spirulina farms in Northern France compete with those in the warmer South of France. This technology is profitable because the government pays a premium for electrical generation provided the heat byproduct is used for profitable purposes. The methanation investment should be recouped before current government regulations expire.

Today French microfarmers sell all the spirulina they produce, supplying about 10% of the estimated French market demand.

By 2010, 100 microfarmers were operating from the Mediterranean in the south to Normandy in the north, from the Pyrenees to the Alps. By 2011, the microfarm movement had spread to Spain.

Based on current trends, by 2015, 500 algae microfarmers are projected for France.

Today Spiruline La Capitelle has the same size greenhouses as in 2002. Philippe Calamand sells out the entire production every year. He sells direct off the farm, on the internet, and drives his horse carriage to set up at the local farmers market. Price direct to the consumer is 150€ for 1 kg dried spirulina. La Capitelle product mix is about 80% dry, 20% fresh.

Value proposition for local algae production

Although small-scale production may cost more than large producers who enjoy economies of scale, when microfarmers sell product direct to the customer they capture full retail value chain.

Going Direct: Big producers get only 10% of the retail price selling bulk spirulina in quantity to manufacturers. They may capture 35% of the retail price when they tablet, bottle, label, package and market branded finished products and sell through the typical wholesale and retail distribution system that takes 65% of retail value. When microfarmers sell direct to local customers, they can capture 100% of the retail value.

Going Fresh: Small producers sell fresh harvest algae locally. Fresh can be kept refrigerated for only 3 days, guaranteeing frequent rebuys. Frozen can be kept much longer. Fresh spirulina is not easily commoditized by large distant producers.

View of the Spiru-vie greenhouses in Ganges, South of France.

Robert Henrikson with Emmanuel Gorodetzky at his Spiru-Vie farm in Ganges. Spirulina growing pond inside a greenhouse. Display of packaged Spiru-Vie products.

Boris Atlan operates a small farm high in the mountains above LaSalle.

The greenhouses are set up in old vineyard terraces in the hillside.

An organic integrated algae microfarm in Normandy

An experimental integrated spirulina microfarm in the far north of France, 3 km from the Normandy Coast, Eco-Domaine Ferme de Bouquetot, has four 50m² algae ponds.

These ponds are covered, insulated and heated to retain warmth to extend the short growing season. An experimental biogas digester converts local farm waste into biogas for heating ponds and digested organic nutrients for feeding algae in one of the ponds.

Ferme de Bouquetot, Normandy.

Gilles Planchon cleaning a 50m² spirulina pond.

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

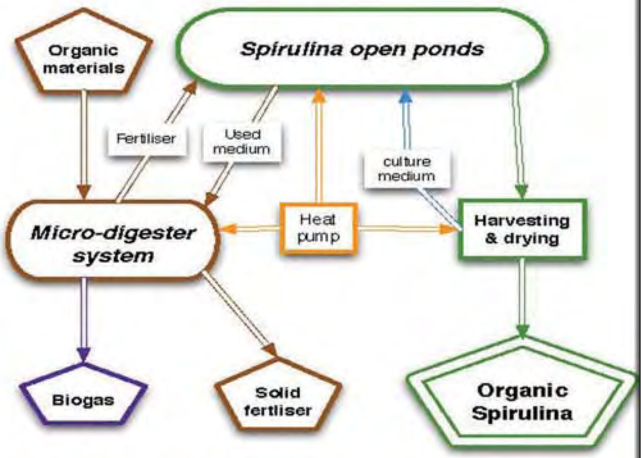


Figure 2: Heat use in a micro-farm

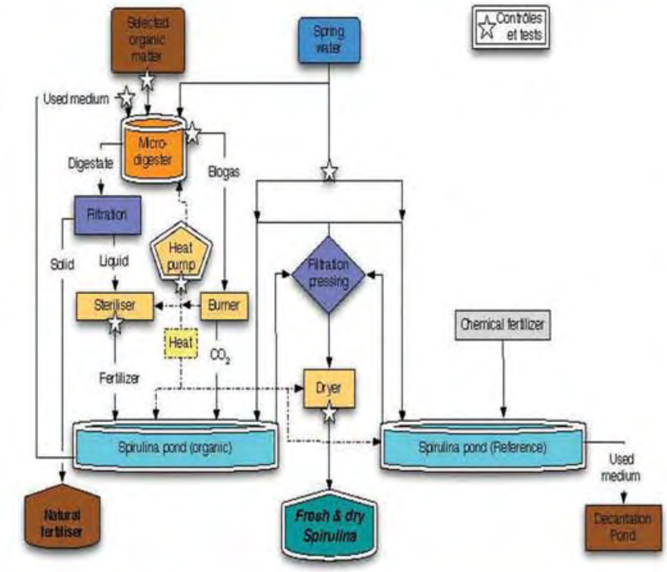


Figure 3: Experimental set-up

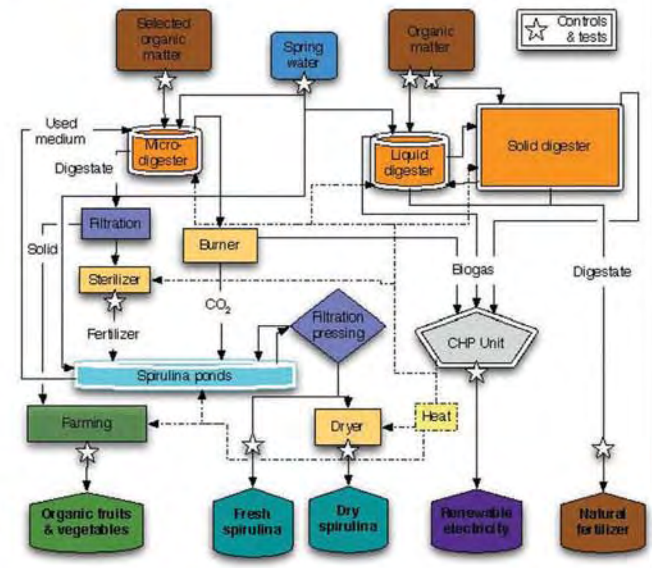
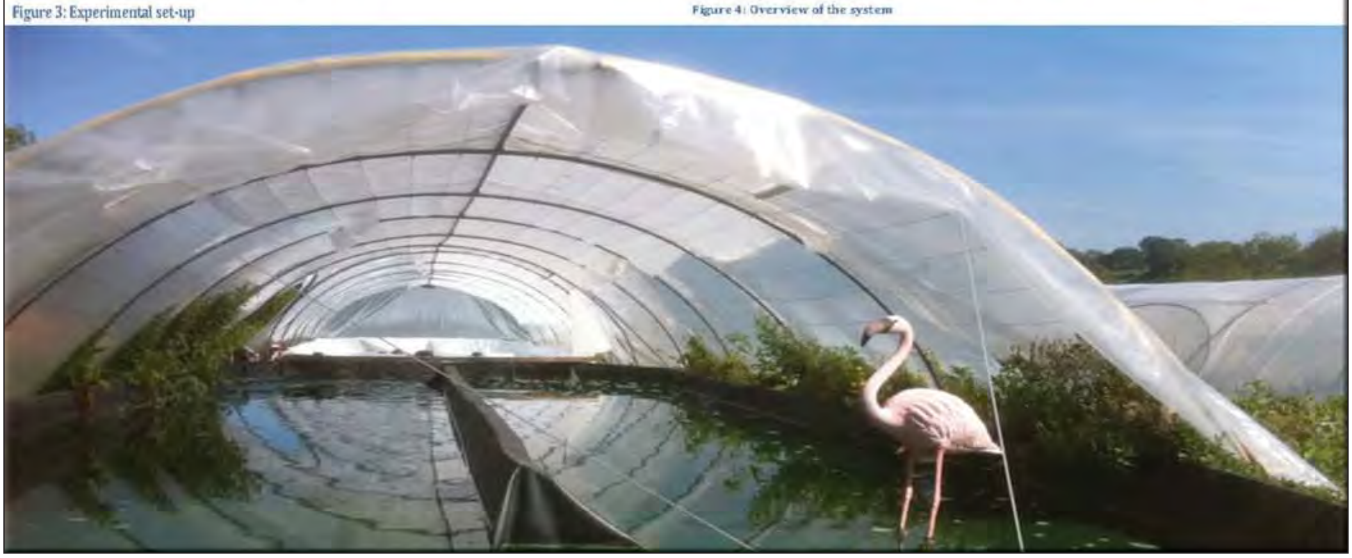


Figure 4: Overview of the system

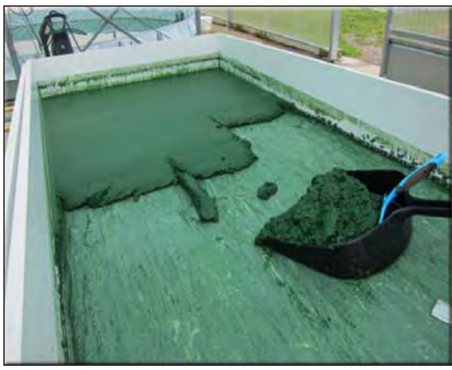


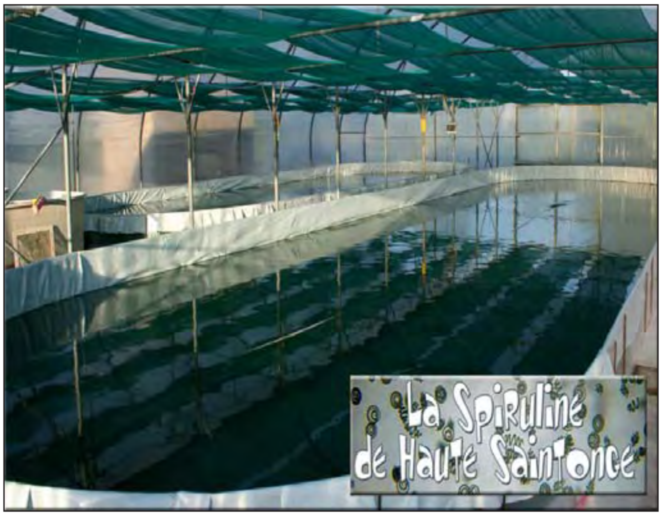
Jean-Michel Tyrel & Nathalie de Poix

La Spiruline de Haute Saintonge was founded by Nathalie de Poix and Jean-Michel Tyrel de Poix. Two bi-tunnel greenhouses (300m^2 and 800m^2) are covered in double skin. One houses two ponds of 100m^2 and the other two ponds of 300m^2. These pools 20m x 40m x 5m and 8m have circular ends. The depths of culture are kept at 15cm to 30cm.

In each basin, agitation is performed with a pump. Carbon is provided in the form of CO2. Pumps are stopped at night and spirulina is harvested early in the morning. A submersible pump sends it through a 150 micron filter and then a fabric mesh of 30 microns.

The harvested dough patty, 50cm diameter and 8 cm thick, is subjected to pressure of 100 to 300kg for one hour reducing water content by about 60%.





Spirulina paste is extruded into 1.4 mm diameter spaghettis. Two cross layers on 50x70cm shelves are dried in a cabinet equipped with a powerful fan and industrial dehumidifier. Drying occurs in 4 to 6 hours at less than 35°C.

Currently, productivity is about 700g of dried spirulina per m^2/year. The cultivation equipment and environment monitoring are rapidly evolving.

Feeding Koi Carp and Goldfish

Jean Michel has been a commercial fish farmer for over 20 years, raising koi carp and goldfish and selling directly through the internet to individuals to decorate garden ponds. For two years he has experimented with spirulina to improve larval survival. For adult fish, spirulina flakes are suitable for goldfish,and for farmed fish it is added to fish flour.

Extruding spaghetti noodles, laying noodles on drying shelves, the dried product.

Spirulina can mix with all kinds of foods. Scatter on vegetables, salads, soups, fish, mashed potatoes, meat. Sprinkle on toast, a slice of butter or cheese in all kinds of sandwiches. Add to fruit juice which for additional vitamin C. Mix with yogurt, cottage cheese, applesauce, cereals, sauces, dressings.

Bernhard Rampelt, an Austrian, founded Spiruline Solaire in 2008 in Alpes-de-Haute-Provence, a mountainous region close to the Italian border. At 1100 meter elevation, it gets cold in the winter. He described the site as having “little water, no electric power, and a lot of sunshine - the perfect place to prove spirulina can be grown anywhere”.

The first attempt to cover pools with a standard greenhouse failed. At high altitude, temperature loss at night was too high. Bernhard then covered pools with a second layer inside the greenhouse, raising average water temperature higher than farms at sea-level. In summer, this inner translucent insulation is movable to prevent overheating.

This heat regulated greenhouse significantly extends the production season, even without heating. A small heat pump would allow production in winter. Four solar panels move automatically following the sun and feed two independent stirring systems: one directly connected to panels, another through batteries for occasional stirring at night. The pools are circulated by helical impeller.

The farm was built with recycled material whenever possible. Most mechanical parts are made from old bicycles, the vacuum-press uses old gas-tanks, an old caravan became the drying-room and most parts of the structure are recycled from old doors, panels, tables, clothes and anything else.

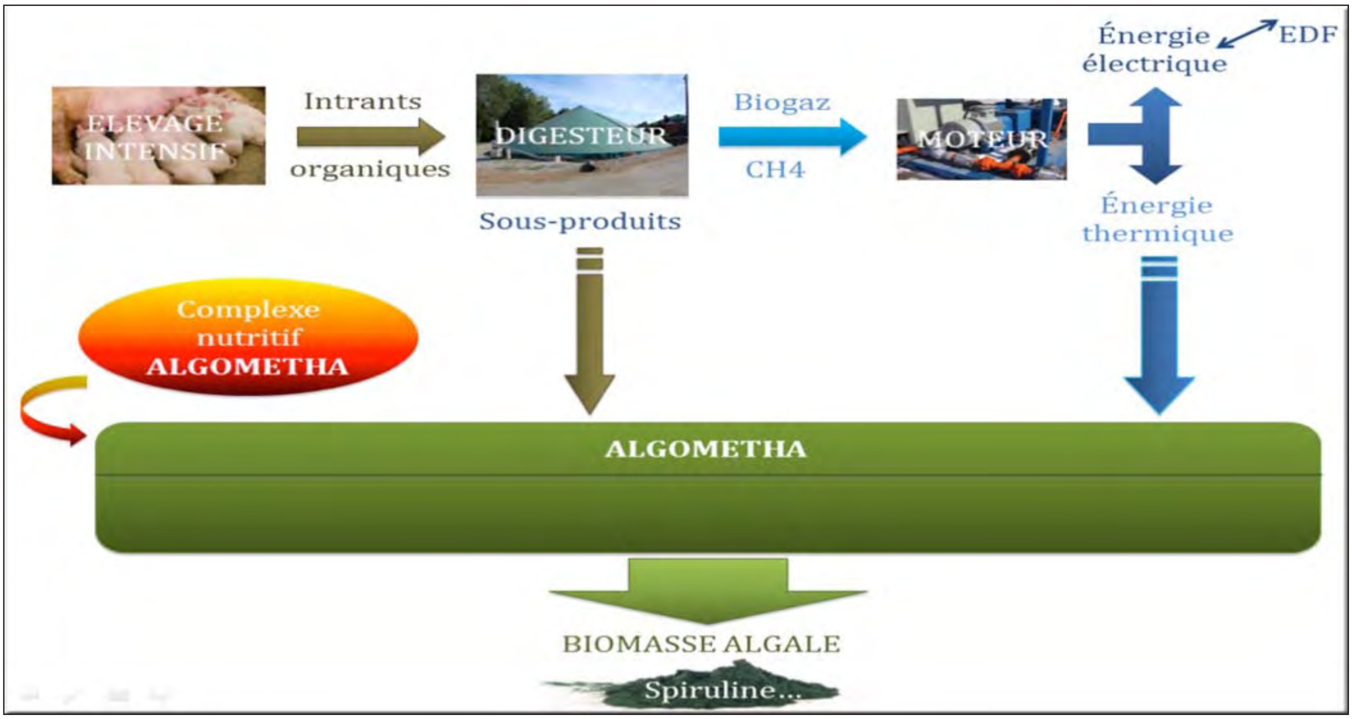
Many projects are yet to be developed such as energy storage in form of pressurized air, CO_2-production by composting grass, and also fertilization by urine to complete independence.


Alps in May


Dryer

Algae Green Value has developed the *Algometha process* (see chart below) for year round production of spirulina in colder climates such as in Brittany France.

Georges Bonnin, Scientific Director, writes "the purpose is to utilize waste heat from cogeneration engines running on biogas from farm wastes to heat the greenhouses under which Spirulina is cultivated. There are two 250m^2 ponds. We are getting by now 10 g/m^2/d as an average, and we can maintain the temperature between 28°C and 37°C even during winter."



Peter Schilling, founder and builder of his spirulina farm in the Canary Island writes:

"The farm is at my home. Because of this I am able to supervise the culture all the time. My home is not connected to the grid. All electricity is generated by my solar panels and one wind turbine.

The water is produced by reverse osmosis from seawater by a local provider. The water is almost free of minerals and impurity. For this reason my medium is long lasting and I do not have problems with salinization.

For fertilization, I use CO2 from bottles only and not the widely used bicarbonate. The medium is always recycled completely. Therefore I use a specially designed recycling station.

All components used for the production process have been selected in order to be inert and FDA conforming. Stainless steel is widely used.

Agitation is provided by paddlewheels with following properties: full stainless steel construction, brush- and gearless direct drive, controlled by microcontroller. The advantages are: potent

The 3m² culture tank. Growing up a volume of culture in one section, then the full tank.

Two 65m² spirulina ponds

agitation with low power consumption, maintenance free.

I have four culture tanks: One with 3m², one with 38m² and two with 65m². In use is just one of the big tanks. The annual production is about 100kg.

Drying is below 40°C by a thermodynamic process. The process is hermetically isolated. That makes it possible to use inert gas to prevent oxidation. The final product is sealed under inert gas in barrier filmed bags. The price is 150€/kg. I sell only to end consumers and get important feedback.

My personal claim is to cultivate spirulina with best properties. Therefore I designed and built in my workshop all the necessary special technology.

In addition to this high tech I develop low tech solutions, too. At the Agadez colloquium in 2006 I did a workshop to demonstrate the basics how to build an effective paddlewheel. For some french farmers I have built paddlewheels applying the principle demonstrated in Agadez."

Spaghetti extruder and dryer

Spirulina Atlaua in Uzes, South of France, is located near the famous Pont du Gard, the ancient aqueduct bridge built by the Romans to carry water from the spring at Uzes to the colony at Nimes.

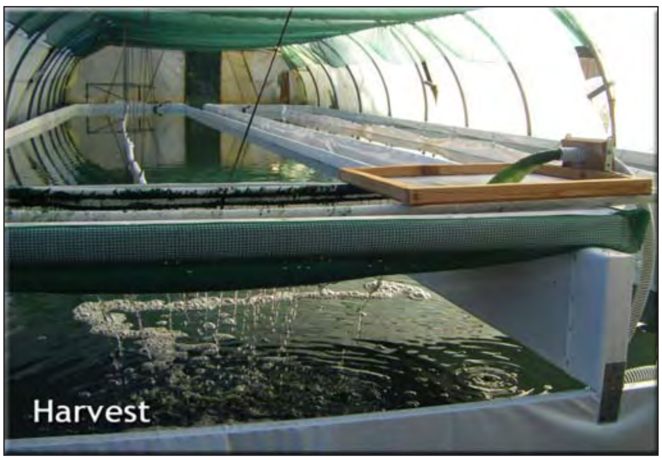
Interview with Thomas Mauvezin

"My name is Thomas Mauvezin and I grow spirulina in a craft way in south of France since 2008. Back from a trip in India, I was interested by learning how to grow spirulina. I went to see a friend called Sebastien Herraiz in his farm in south west of France and he gave me advice and a spirulina strain from Peru.

With the help of Ripley Fox's books, JP Jourdan's manual and Gilles Planchon and Charito Fuentes's book, I started a very small family growing of spirulina ($1m^2$, then $5m^2$). I was eating only fresh spirulina. In 2009, I built a tunnel greenhouse, $230m^2$ of pools, a small laboratory and a solar dryer. In 2010, I start the production. My intention was to produce a good spirulina in a human-size farm.

A harvest day starts early in the morning (around 6 am). Spirulina is filtered and pressed. Then to dry

it, I lay spirulina rods (spaghetti) on a perforated tray. Rods are obtained by extrusion of 1mm diameter. Drying time is around 5 hours and the temperature is less than 40°C. Then I break the rods into smaller pieces.



I produce around 180kg of dry spirulina during one harvest season (May to October). 80% of the production is directly sold to the consumer (farmers markets, mail-order and farm sales) and 20% to health food and running shops.

I think spirulina is a fantastic food for its incomparable nutritional and agronomic qualities (every week people tell me the benefits of eating spirulina) and there are so many things to improve and to discover about spirulina growing techniques.

In 2010, I joined the French spirulina growers federation (Fédération Spiruliniers de France). This federation's intention is among other things to promote the French small spirulina farms model, to permit a knowledge sharing between growers and to help the development of spirulina. In 2013, there are around 85 members.

I think the French mall spirulina farms model is a very interesting way. It permits to grow spirulina in human-size farms for a local consumption."

Harvest press

Drying screen

Dehydrator

Dry noodles

Algae products from microfarms

In'spir
Naturopathic condiment
Developed in Drome
in Provence area, France.

To get a better Health

In'spir is a set of three symphonys.

Symphony 1 : spirulina plus pumkin seeds* and sun flower seeds*
Symphony 2 : spirulina,hemp seeds * plus aromatic plants * from Drome.
Symphony 3 : spirulina, barm*, hemp seed*, gomasio* 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 ?

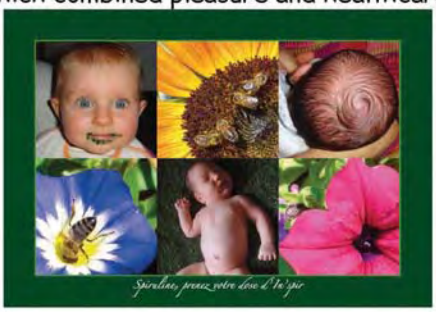
Spirulina is a « super power food» which should be worlwide eaten. In'spir is developed to extend Spirulina among people, beause Humanity have to connect with Spirulina.

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.
Gomasio is salted and grilled sesame.
Barm is one another microorganism which contains protein and B vitamines .
Aromatic and medical plants from our montains in Drôme give an excellent taste and make disgestion easier.


spirulina ponds.


Spirulina harvesting.

Ins'pisr is produced in "les jardins Coquet", in a micro-spirulina farm in Drôme in the south est of France since 2005. These products have been engineered by Cédric Coquet (master in biological agriculture), in close connection with nutritionnists and naturopathe.

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

Few photos,
Cause we don't
like spirulina,

We love
Spirulina

Algae products from microfarms

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.

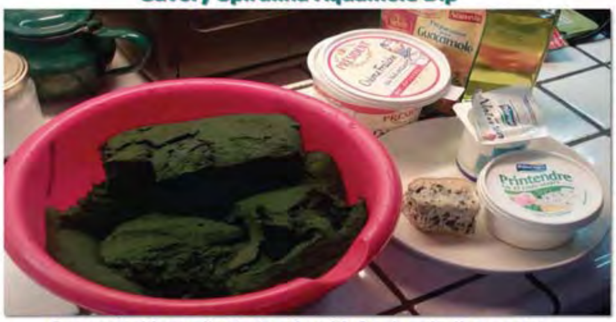
Spirulina Algae grown at Spiru-Vie Farm in Ganges, France

Robert Henrikson 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

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)

Sweet Spirulina Fruit Dip

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

Savory Spirulina Aquamole Dip

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.

Growing algae at home and in community

Over the past 30 years, many people have asked they can grow algae themselves in their own back yard. One of the most common requests has been *"How can I grow my own algae?"*

The good news is small scale algae farming has been tested for 30 years all over the world, and models are being introduced as effective algae growing systems for gardeners, farmers and algaepreneurs who want to grow algae but don't have years of scientific experience and knowledge.

Algae microfarming is a perfect fit for the growing Do-It-Yourself movement and the trend growing food and herbs indoors, in the backyard, in greenhouses, in empty lots in urban and community gardens and in green rooftop farms.

A few entrepreneurial growers have emerged, mostly below the public radar in countries like France, growing spirulina algae in outdoor covered greenhouses because of its relative ease of cultivation.

Parallel to open pond systems has been research and development on small enclosed, high-tech bioreactors designed to grow algae under more controlled conditions.

Indoor aquariums, deck modules and backyard micropond in Point Richmond, California.

Grow Your Own Spirulina introduced by Jean Paul Jourdan

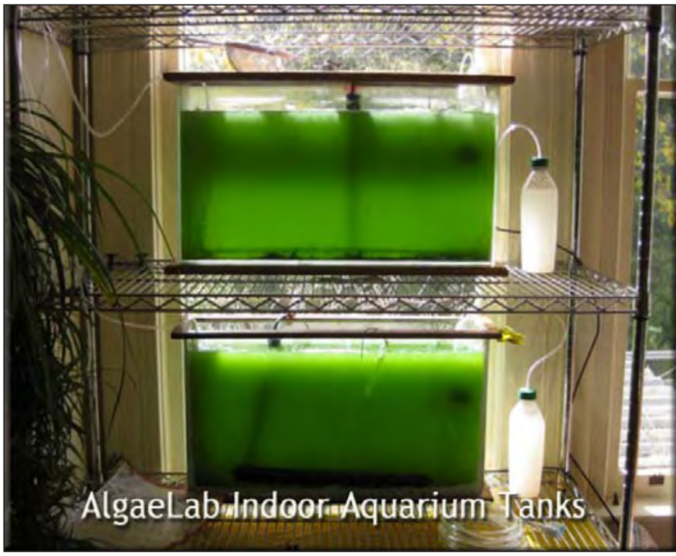
For many years, Jean Paul Jourdan developed algae projects in Europe and Africa. In his popular practical manual published in 2002, *Grow Your Own Spirulina (Cultivez Votre Spiruline,)* he describes how to cultivate algae on a family scale.

Since 2002 Jean Paul has edited a monthly newsletter *Petites Nouvelles de la Spiruline.* From 2004-2008 he was professor of spirulina culture at the CFPPA Center in Hyères, engaging many of the future producers from southern France to as far north as Brittany, Savoie and Alsace. He is a consultant to the Fédération des Spiruliniers.

When he moved to more northern France in recent years, Jean Paul developed an insulated growing tank in his backyard to keep algae culture warm and grow all throughout the year, even in winter.

At his algae microfarm in Mailet France in 2002, Jean-Paul demonstrated how he grows, harvests and dries spirulina.

Algae Lab aquarium kits and webinars



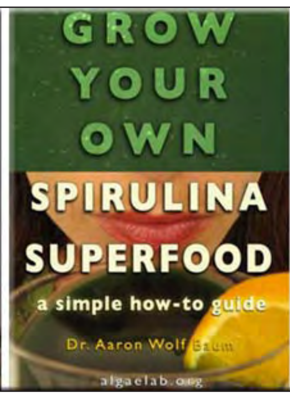
AlgaeLab offers growing kits and trainings

In Oakland California, Aaron Wolf Braun founded AlgaeLab (algaelab.org) in 2008, first rehabbing a 20’ shipping container for a portable laboratory and community algae lab.

For several years he has led Home Grow Algae Workshops explaining how a personal algae photobioreactor in one sunny window can provide enough to significantly supplement the diet of one person every day.

Participants who complete the workshop take home an aquarium growing kit and all the supplies needed to grow at home. The workshop supplies a 10 gallon home-grow kit which includes tank, heater, air pump, air diffuser, air tubing, valves, starter and make-up nutrient powder mix, pH testing, harvesting tube, harvesting cloth, clips, plug timer, and 1 liter live spirulina.

The AlgaeLab.org online store offers supplies needed to grow at home and the website has pictures of the cultivation and harvest processes.



Aaron Wolf Baum in a workshop. His new book Grow Your Own Spirulina Superfood. AlgaeLab growing kit.

Spirulina Viva in Mexico

Spirulina Viva workshop. Family microfarm package with solar system, enough for family of 4-5 people.

Francisco Portillo Rangel founded Spirulina Viva (spirulinaviva.org) in the town of Xilitla in the state of San Luis Potosi, in the center of the country, 220 km north of the capital. Part of their mission is to promote improved nutrition in highly marginalized communities around Xilitla through the installation of spirulina ponds.

With three years experience cultivating spirulina Spirulina Viva authored an 18 page practical manual so anyone can start growing at home. It organizes training workshops for growing spirulina in various places of the country, they sell a kit and have posted two videos online.

Spirulina Viva offers several size packages of growing systems. The larger family microfarm can be installed easily in a sunny area 1.5m^2 in a garden or on a roof.

This complete growing system comes with a liter bottle of Spirulina seed culture, short video on home spirulina production and the assembly, growing tank assembly kit, harvest screen, water pump, solar panel and cookbook with recipes, and all you need to grow spirulina: thermometer, pH strips, supplies, the 18 page manual and support via telephone and email.

The Spirulina Garden™

The Spirulina Garden in the foothills of California's Sierra Nevada Mountains near Yosemite.

Ron Henson grows Spirulina over the summer months at his Spirulina garden near Yosemite in the foothills of California's Sierra Nevada Mountains. The system is simple, based on decades of experience building commercial algae farms.

The greenhouse keeps the ponds from freezing in winter months. Spirulina overwinters and comes back fresh as the weather warms. In late spring the greenhouse is easily removed allowing full sunlight. Pure mountain spring water and brilliant mountain sunshine help create high quality fresh spirulina.

Ron provides plenty of fresh spirulina to family and friends. He has used The Spirulina Garden™ to demonstrate commercial feasibility for fresh frozen USDA Organic certifiable Spirulina.

Ron Henson worked with Robert Henrikson since the 1970s developing commercial and village level Spirulina farming. Since then Ron has worked to develop algae projects for food, feed, pharmaceuticals and fuel in over nine countries around the globe.

Ron says: "No food is more densely packed with vibrant life than fresh Spirulina. If you already use algae in dry form, try fresh raw Spirulina to experience the difference. Dried algae are heated to temperatures above 160°F. Think cooked raisins versus fresh grapes. The Spirulina Garden™ grows living Spirulina blue-green algae, fresh chilled or fresh-frozen, never heated, full of life!"

Fresh spirulina smoothie drink.

Ron Henson at The Spirulina Garden.

Fresh frozen sealed pouch.

Smart Microfarms is developing a variety of scalable systems

Indoor Aquariums

Outdoor Deck Growing Modules

In Point Richmond, California, by San Francisco Bay, Robert Henrikson, CEO of Smart Microfarms, developed a series of small, scalable algae growing platforms.

Robert was a founder of Earthrise, the first USA spirulina farm, which became the world's largest commercial farm in the 1980s, still producing today as Earthrise Nutritionals in Imperial Valley California. By the 1990s, Earthrise distributed spirulina and green superfood products in over 30 countries. Having pioneered big commercial farms 35 years ago, the time has arrived for small scalable algae systems.

In-Store Display in Berkeley California

Smart Microfarms is currently testing, growing and harvesting spirulina on a small scale, producing fresh, frozen and dehydrated products for family and local consumption as a daily nutritious food supplement.

The easiest systems are indoor aquariums, using standard or custom fish aquarium tanks, with air bubblers and heaters and lights on timers. Where possible, aquariums should be placed near sunny windows to gather available sunlight. If not enough natural light is available, like the in-store display shown for a Berkeley store, LED lights or grow lights can keep the culture growing.

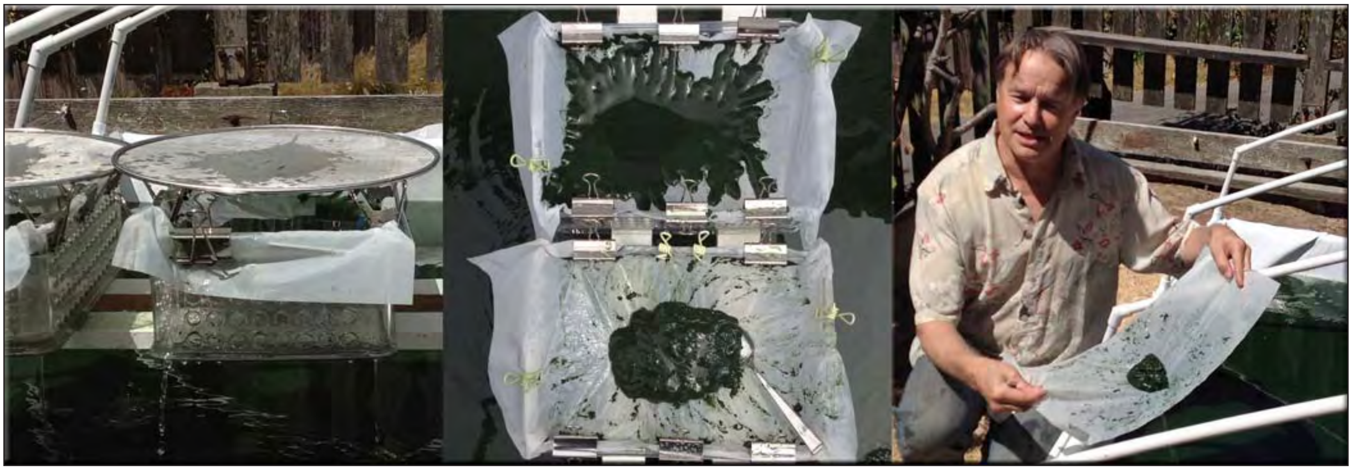
These small indoor systems are built with locally available supplies and are the easiest systems to maintain stable and growing algae cultures.

Smart Microfarms has also installed simple modular growing systems for cultivation outdoors on porch deck or backyard. These are designed for scale up to larger sizes. The materials cost range from a few hundred dollars for small systems to thousands of dollars for scaled-up larger ponds inside greenhouses.

Moving outdoors presents increasing degrees of difficulty and challenges to maintain a stable, healthy and growing algae culture. Seasonality, weather changes, storms, cold, rain, wind and dust can rapidly destabilize outdoor algae cultures and impair production.

Backyard Smart Microfarm

This backyard 4'x 8' microfarm was installed in August 2012 in Point Richmond California. Simple aquarium bubblers circulate the pond water. Aquarium heaters and the plastic removable greenhouse cover keep the algae pond water warm enough for growing spirulina even during the cooler, rainier months of the year including November through February.



Harvesting wet spirulina paste from a backyard micropond.

Blending fresh harvested paste into a fruit smoothie.

Fresh harvested algae food and drinks

Growing at home, algae can be eaten fresh, frozen or dried in a food dehydrator. Fresh harvested spirulina is a thick paste like yogurt, dough or tofu depending on how much water is removed. Best of all, unlike dried powder, fresh has almost no taste at all, and can be mixed into juice for a fresh green drink without changing the juice flavor!

A tasty way to consume freshly harvested paste is in recipes for dips and spreads, a very popular way in France. See *"How to eat fresh spirulina algae in Aquamole dips"* blending fresh spirulina with yogurt, cream cheese, herbs and guacamole spices for a savory green dip for crackers, chips and bread.

Making frozen heart shaped cubes with fresh harvest.

Drying spirulina noodles in a home food dehydrator.

Smart Microfarm testbed, Olympia Washington

The first Pacific Northwest spirulina microfarm is located in Oakville, near Olympia Washington. This eco-region has a temperate rainforest climate with warm sunny summers and wet cloudy winters.

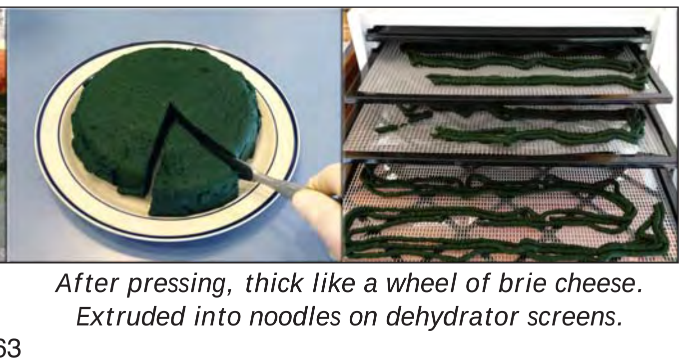
Beginning in April 2013, the first smart micro-ponds were installed inside a larger vegetable greenhouse at a farm near Olympia Washington. This demonstration microfarm is equipped with web camera and smart monitoring system.

Two spirulina ponds, 4'x 55', 20m^2 each, have insulating foam panels below and retractable cover above, all within the larger greenhouse. This microfarm was designed to keep algae cultures warm and extend the growing season beyond the summer months. As one of the northern most spirulina farms in operation today, this farm will demonstrate the capability of algae microfarms in cooler climates.

These spirulina ponds are harvested several times a week during the growing season, and the fresh harvest is transformed into three products - fresh spirulina paste, frozen cubes, and dehydrated noodles and granules.

This testbed will help develop metrics for microfarm operations and productivity especially for temperate climates. It will test practical, affordable and replicable systems for growing algae for local food and high value products in urban, community, rooftop, mobile and vertical gardens to demonstrate how microfarms can transform any small food growing area into higher income generating food products.

Harvesting spirulina through a fine microscreen.
Algae paste collected on the harvest screen.



After pressing, thick like a wheel of brie cheese.
Extruded into noodles on dehydrator screens.

Smart Microfarm systems and services

Algae growing ponds have retractable and removable greenhouse covers. In cooler seasons, ponds are covered at night to retain warmth. In summertime, covers are completely removed.

Smart Microfarms offers complete, modular algae microfarm components shipped to any location in North America to be assembled under the supervision of construction specialists. The client can have installed an algae microfarm that is profitable, reliable and environmentally sustainable.

The entire design, procurement, shipment, installation, start-up, training and ongoing monitoring can be managed under the quality control of Smart Microfarms. The company provides professional consulting services, ranging from preliminary site assessment through system design, delivery, installation, supervision, start-up and long term technical support. Other services include feasibility studies, commercial and technical analysis, business planning for prospective enterprises and evaluation of existing facilities.

Experience and specialization in scalable algae microfarms means Smart Microfarms can help terrestrial, hydroponic and aquaponic greenhouse farms diversify their income stream with high-value algae food products.

Intriguing the next generation of microfarmers: Haakan Kenney.

Tour group from Seattle, Bellingham and British Columbia in July 2013.

Web-based monitoring of Smart Microfarms and photobioreactors

Until now, successful algae cultivation and systems operation required trained and experienced algae experts and PhDs on location. This knowledge level requires sophisticated, expensive staffing and infrastructure.

Automated smart technology combined with modular growing systems will make it feasible to deploy algae cultivation systems, microfarms and photobioreactors, anywhere in the world without on site expert personnel.

Remote monitoring would allow a single laboratory to support a large number of deployed units. The large user database feeds grower experience into the algae operating system that provides the knowledge base for an advanced learning system that offers process automation and an expert system that provides grower guidance.

Currently under development and real time testing at Smart Microfarms, Olympia Washington, is an evolving remote monitoring and control system for algae culture maintenance. Periodically during the day, key measurements such as water temperature, pH, culture density, nutrient additions and harvest data are sent to a remote technician who guides the local operator in effective pond management to prevent crashes and maintain optimum algae productivity.

Smart Microfarm technology will empower people globally to grow healthy food and co-products for the needs of family and community locally using predominately sustainable and affordable inputs.

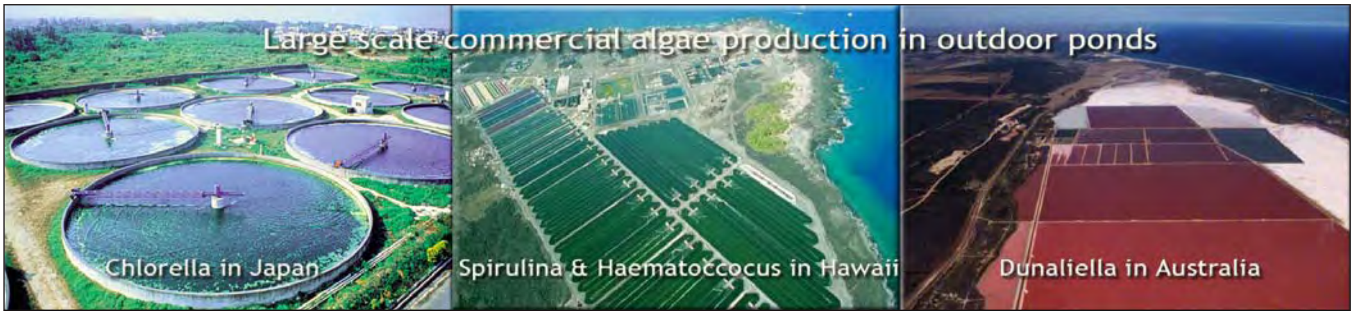
Flexible microcrop platforms produce food and valuable co-products locally mimicking nature as they grow algae and other microorganisms integrating light and intelligent technology. These adaptable platforms transform solar energy, CO_2 and nutrients to products that support health and vitality of people, animals, and plants.

Smart monitoring by laptop or smart phone from any location using an interactive webcam.

Microfarms and bioreactors in modular systems

Comparing ponds and photobioreactors

Algae are grown in ponds, greenhouses, photo bioreactors, fermenters and hybrid systems combining bioreactors and ponds. As new technologies arrive, algae microfarming will be less costly, easier and more accessible for more people. Some algae like dunaliella are grown in deep saline ponds with little mixing. Algae like spirulina are grown in shallow raceway ponds mixed with a paddlewheel or compressed air that keeps the culture moving around the raceway. This turbulence moves algae cells to the surface where they absorb sunlight. Algae biomass is harvested by microscreen, filter, centrifuge or flocculation.



Raceways scale to any size and have the advantage of simple, low cost construction and maintenance. Most algae production today is in open raceways because ponds are cheap to build and operate. Ponds are more productive in tropical, subtropical and temperate areas with warm temperatures, low rainfall and little cloud cover.

Disadvantages of ponds are lower productivity from lack of temperature control and high water evaporation which increases retained salts over time and impacts culture stability. It is hard to control algae predators such as amoeba, ciliates, bacteria, rotifers, viruses, fungi, and zooplankton that can decimate algae biomass within hours. Open ponds are vulnerable to contamination from dust, wind borne organisms, insects, and birds.

Commercial algae producers have strategies to minimize contamination by opportunistic weed algae in open ponds. Producers grow *spirulina* at high bicarbonate concentrations with high pH and *dunaliella* in high saline water to discourage competing species. To limit contamination, producers grow *chlorella* in batches in increasing volumes, until harvesting the entire amount, purging ponds and then restarting from pure laboratory cultures.

Photobioreactor tubes, flat plates or bags are more capital intensive than outdoor ponds, and have been primarily used for higher value algae products. Advantages are growing in cold weather and low light by adding heat and light. Closed systems offer tighter control of contamination from unwanted algae, zooplankton predators, dust and debris. Disadvantages, apart from cost, include overheating in hot climates and the need for cooling, and high cleaning maintenance from fouling.

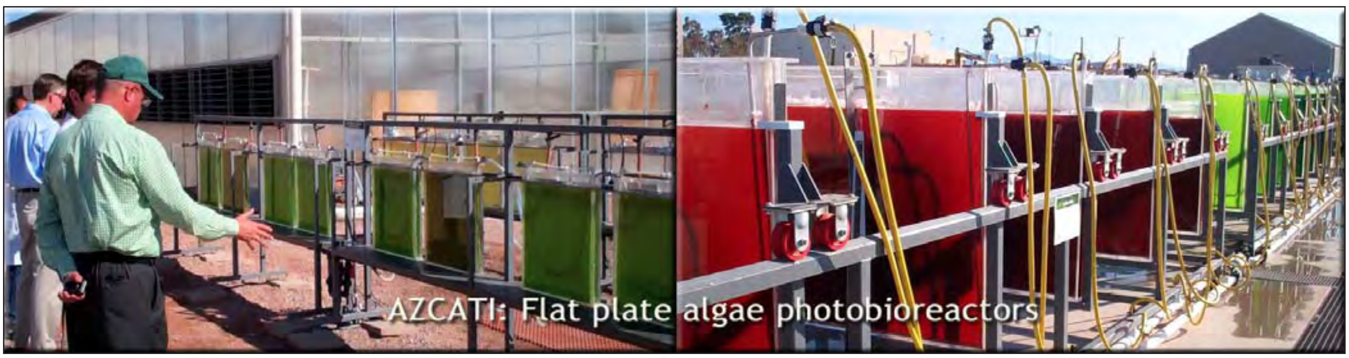
For all these considerations, new research centers and algae incubators have been testing various pond and photobioreactor systems on a small scale to compare results and develop smarter automation systems.

Arizona Center for Algae Technology and Innovation (*azcati.com*)

One of the most impressive research centers is located at Arizona State University Polytechnic Campus in Mesa Arizona. The AZCATI testbed features raceway ponds and column and flat plate photobioreactors and other novel systems built by NanoVoltaics, an engineering service provider to the cleantech sector. AZCATI serves as a hub for research, testing and commercialization of algae-products, including biofuels, pharmaceuticals, nutraceuticals and other algae biomass products.

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. Ponds and photobioreactors like these will move into future landscapes, living buildings and into communities for local food and energy.



Algae PARC in Wageningen, Netherlands

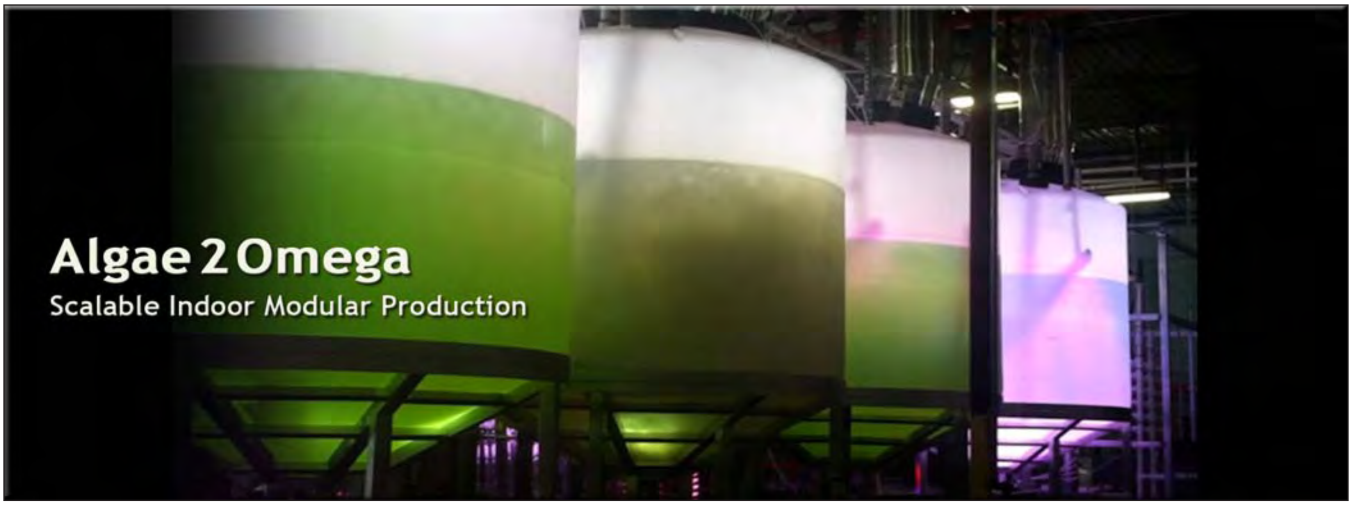
The goal of Algae Production And Research Centre (algaeparc.com) is to develop knowledge, technology and process strategies for sustainable production of microalgae as feedstock for fuel, chemicals, food and feed at industrial scale.

AlgaePARC pilot plant claims to be the first research center in the world that allows comparison of different outdoor photobioreactor designs. The pilot facility comprises four large (24 m^2) and three small (2.4 m^2) photobioreactors. The systems will be run in parallel and compare technical, economic and sustainability performance. Results will be used to build up knowledge required for commercial production of microalgae.

The photobioreactors were chosen based on state-of-the-art technology and will allow AlgaePARC to study and overcome critical aspects for the successful operation and scale-up of photobioreactors, such as challenges of mass transfer, light supply and photosynthetic efficiency.

Given their unequalled growing rate among photosynthetic organisms, algae hold great promise for the cost efficient large scale production of biofuels, bulk and commodity chemicals and fine chemicals.

Raceway pond | Horizontal tubular reactor | Vertical stacked tubular reactor | Flat panels



Algae2Omega (algae2omega.com) is growing algae Inside warehouses in Florida. Light is brought inside 3000 gallon tanks using three methods: solartubes bring light from the roof to the surface, solar collectors send light through fiber optic inside the culture, and artificial lighting with LEDs.

Algae to Omega Holdings, Inc. produces, markets and distributes algae derived products. The company utilizes environmentally clean technologies, coupled with innovative production methods and proprietary technologies to cultivate and harvest algae biomass to supply organic raw materials for the functional foods, nutraceutical, animal feed and personal care markets.

The initial focus is to produce and sell high demand nutraceutical products such as astaxanthin and Omega 3 oil for human and animal nutrition and raw materials for the beauty and personal care industries.

Algae to Omega has developed a proprietary, state of the art closed looped production system, which combines unique technology for cultivating algae in a controlled environment and proprietary methodologies for separation and extraction of Omega 3 oil, astaxanthin and other high valued nutrients.

This is designed as a scalable modular production system that is low-cost, energy efficient and environmentally sound, and claims to generate faster algae growth rates versus less efficient open pond and non-continuous closed-loop systems.

Algae2Omega whole cell extraction technology utilizes a unique blend of oils, food grade acids and low heat during the extraction process and bypasses certain energy intensive steps and reduces production costs.

Typically most companies utilize supercritical CO_2 extraction, which exposes heat-sensitive oils to temperatures as high as 400°F or hexane, which is carcinogenic and has to be removed from the end product. Whole cell extraction technology is a chemical free process, which replaces harsh solvents and high heat while preserving the bioavailability of the products.

LGem (lgem.nl) is growing *nannochloropsis* for omega-3 in Den Haag, the Netherlands. Inside large high-tech warm greenhouses widely used for growing crops in the Netherlands, sunlight illuminates the algae cultures during sunny days and can be supplemented with artificial lighting during cloudy days and off season shorter days.

LGem is the first Dutch company to use closed photobioreactors to produce microalgae on a commercial scale. Since 2007 freeze-dried algae *nannochloropsis* powder has been produced and sold as a food supplement. The process has been steadily improved, resulting in a stable and robust production platform. In 2009, GF Piping Systems joined the development team and the tubular bioreactor evolved into a well designed system with lower operating costs.

The easy-to-operate GemTube system makes it possible to produce algae at lower cost. It uses a patented technology with waves combined with high velocity air stream that resembles the surf in the ocean (Wavywind™).

The bubbles accompanying the waves (Bubble-brush™) keep the wall clear of fouling, which is an important feature. The ground breaking Wavywind technology allows a stream of air to travel twice the velocity of culture fluid. The fast air stream creates eddies on the surface and a unique stirring effect that gives the desired light-dark cycle, under 1 Hertz.

The GemTube consists of a circulation tank, a centrifugal liquid pump, a linear air-pump a pH/temperature probe and a switch cabinet.

LGem claims these advantages of tubular bioreactors:

- It is a closed system for a high hygienic level and biomass product quality;
- Effective illumination for higher yield of biomass compared to open ponds;
- Ideal for research and development;
- Lower operating costs, reduced carbon footprint;
- Proven commercial value on an economic scale;
- Relatively easy to scale to large farms.

Brad Reeves stands next to a 120-liter bag of Haematococcus algae in "the green stage. The algae turn red as they produce astaxanthin as a defense mechanism against the stress of intense sunlight. Photos: Eileen Chao.

Maui Tropical Algae Farm is growing *haematococcus pluvialis* in Kihei, Hawaii on a 21 acre facility in the Kihei Tech Park. Initially, their algae nursery was cultivated in geo-domes used by the former Bio Real, Inc. subsidiary of Fuji Chemical, but Maui Tropical Algae Farm has since found a safer, more cost-effective, environmentally friendly way to grow algae with little or no waste.

Instead of growing algae in domes, which are hard to clean and susceptible to contamination, they have solved this problem by usingg polypropylene bags that are 60-120 liters in volume for both the red and green stages of astaxanthin development.

The bags are recyclable and allow the farm to experiment without the risk of losing an entire batch while enabling them to produce higher levels of astaxanthin content both indoors and outdoors in the perfect Maui, Hawaii environment.

The use of bags vs. geo-domes furthermore enables the algae to receive care and control of the ph, nutrients, carbon dioxide, and sunlight/photon levels, all elements of the valuable commercial products that develop from the *haematococcus* over a 30-day growth cycle.

Chief Executive Manager Brad Reeves has created the first carbon neutral, petroleum free algae farm that utilizes off-grid solar power and carbon dioxide that is generated on site from local Maui grown sugar cane for the production of astaxanthin. By using renewable energy technologies, the farm has been able to cut energy costs and energy consumption by 95 percent.

Future plans to harness algae for spirulina production are in the works along with a full scale community garden, commerical farm stand, and an educational research lab for conducting experiments by the University of Hawaii, Maui Community College and other interns, commerical investors and scientists wanting to learn about sustainable farming.

The old acrylic domes used by Fuji Chemical are no longer in use. Photo: Eileen Chao.

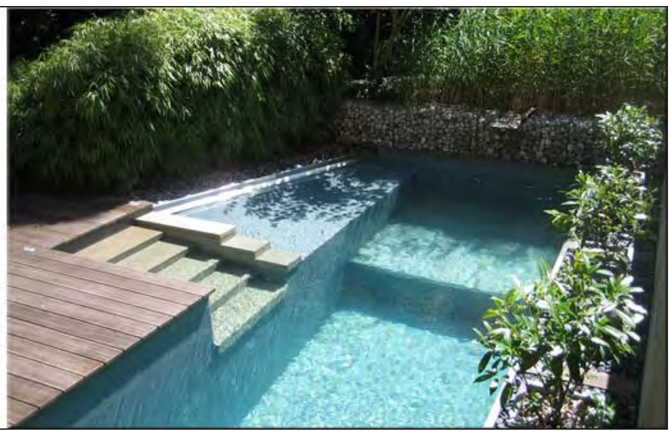
Biopools were developed by Koen Vanhoutte (www.waterarchitect.be). They represent a big advance over chemically treated pools, and are now being installed in Belgium and other European countries.

Chlorine based treatment is potent and reliable but there are the unpleasant smells and irritations. It is also scientifically proven to be dangerous to your and your children's health. There are two safe alternatives to chlorine based systems.

Natural swimming pools use water plants, functional animals and photosynthetic microalgae to clean the water as the water flows through the 'plant-filter'. The filter is carefully designed to contain a balanced diversity of minerals, plants, algae and animals. This composed jungle will naturally evolve. It becomes more efficient with every passing season.

Biopools use a natural oxygen system based on eco-chemistry. Eco-chemistry uses only elements that occur in safe natural environments. You can swim comfortably with open eyes under water. Eco-chemistry is stable so you do not have to monitor or adjust pH or anything else. One annual checkup suffices. Lush and flowering vegetation can be integrated into the pool design by adding separate plant-ponds. Bio-pools use only 25% of the energy of a traditional pool.

The diversity of functional microalgae is important. These are introduced as stabilized polycultures. They come in both liquid and solid form for easy use. Outside the natural swimming pool, they can be used to treat fish-ponds, aquaculture farms, polluted rivers and water bodies and even sewage treatment plants. They will significantly aid and enhance existing processes.



Biopools designed by Koen Vanhoutte, De WaterArchitect. Photos: Hilde Verbeke.



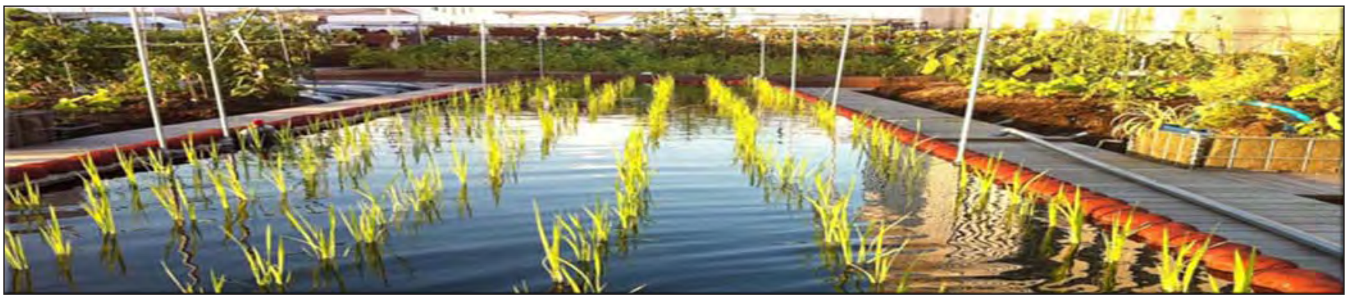

Algae microfarms and aquaponic gardens for green rooftops?

Urban and community gardens are a rapidly emerging movement for local food production in urban and suburban communities in empty lots and rooftops. Because algae is so productive in a small area, algae growing systems are ideal for urban gardens for growing food. Our cities, industrial and commercial zones have vast areas of flat rooftops with day long sunshine. Algae microfarm greenhouses could enhance the productivity and income potential of rooftop gardens.

The Gotham Greens commercial roof farm on the new Whole Foods Market in Brooklyn New York is another example of the trend toward green roofs and rooftop gardens.

Uncommon Ground rooftop garden in Chicago.

Brooklyn Grange Rooftop Farm in New York.



Rice Paddy City Farm in Tokyo.


Inside Urban Farmers rooftop greenhouse and Urban Farmers first commercial-scale farm on a Basel rooftop. Courtesy of Urban Farmers Ltd. (urbanfarmers.com)

Urban Farmers was launched in 2011 with the goal of developing large-scale commercial aquaponic rooftop farms. Beginning with the shipping container farm (below), next was building a 2700 square foor greehouse farm on a rooftop in Basel Switzerland. They were selling fresh produce to local restaurants by January 2013. Rooftops offer large, unexploited spaces within any city.

Modular algae microfarms for shipping container gardens?

Shipping containers have been redesigned for modular housing, offices and health clinics. Now they are being transformed into container gardens with controlled environmental systems. With a shipping container and a greenhouse on the roof or sides, a tiny urban farm can be placed anywhere for create local, sustainable, fresh food that also tastes better.

Containers have advantages. They are available, inexpensive and durable, uniform in dimension, easy to insulate, and stackable, easy to transport and set up. Each build-out is a repeatable process, which leads to efficiencies and economies of scale. Here are examples of container gardens:

Urban Farmers fish and vegetable box combines aquaponics with hydroponics. A mutual support system uses microbe-powered biological filters to convert fish wastes into fertilizers that plants need to grow in a hydroponic greenhouse.

The UF box warmth promotes vegetable growth and keeps the fish comfortable below. The lower level has a fish tank with two filter systems, recycling all water, with water added only to make up for evaporation. This small-scale production unit that can be placed in backyards or on parking lots. Production is 60 kg fish and 120 kg vegetables.

The ArkFab (arklab.org) is a vertical farm for mushroom cultivation. A repurposed shipping container has an estimated lifetime of 10 years, provides easier installation and relocation and allows stacking to use up valuable real-estate. The shipping industry moves containers around the globe, so containerized systems can be quickly transported to post-disaster recovery areas.

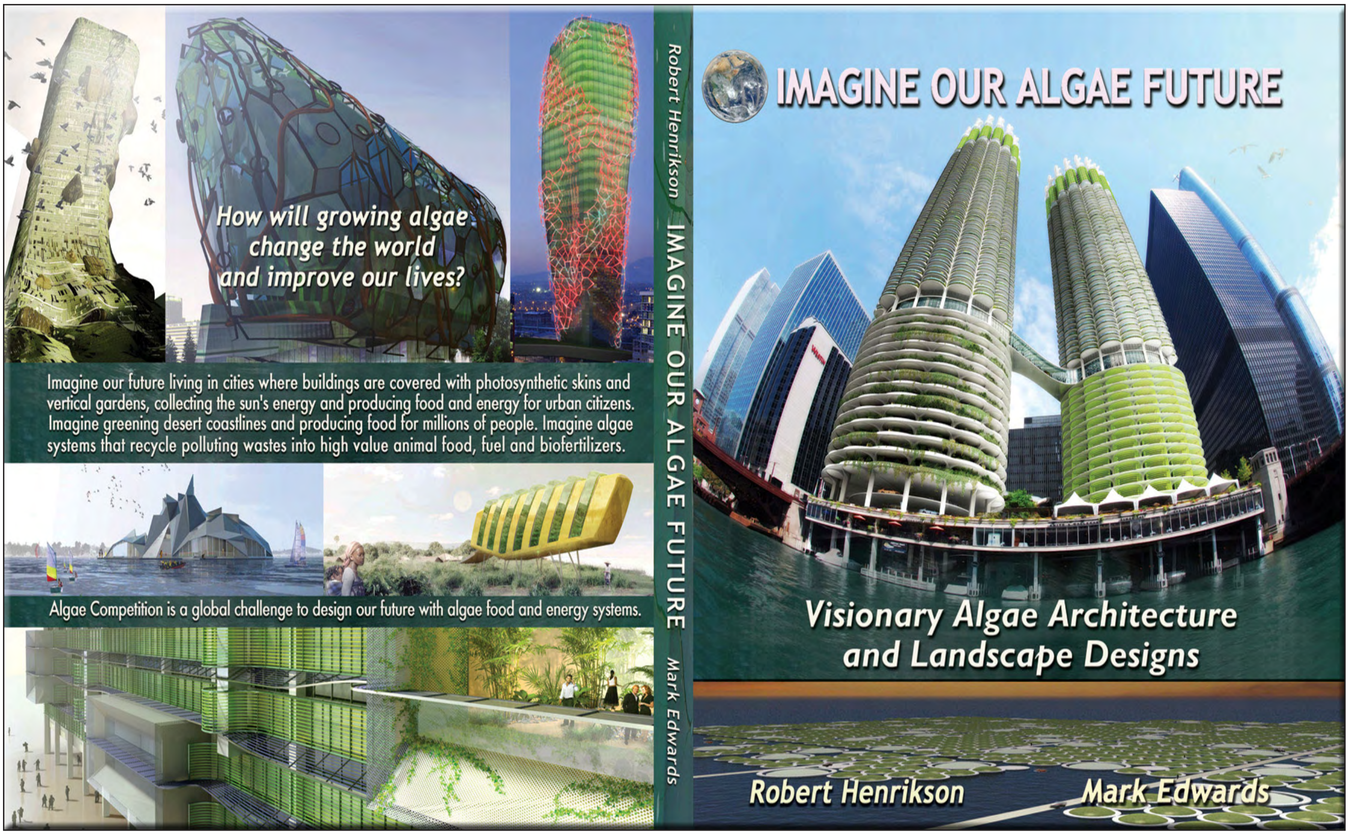
Future visions of living algae systems in daily life

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.

The International Algae Competition is a global challenge to design our future with algae food and energy systems. Participants from 40 countries around the world submitted 140 projects for algae architecture and landscapes, cultivation systems and food. Let's look into our future and see how some of these algae systems from the Algae Competition could move into landscapes, living buildings with green photosynthetic membranes, and eco-communities producing local food and energy.

These complex algae systems requiring automated technology combined with modular growing systems may make it feasible to deploy microfarms and photobioreactors anywhere in the world without onsite expert algae technicians.

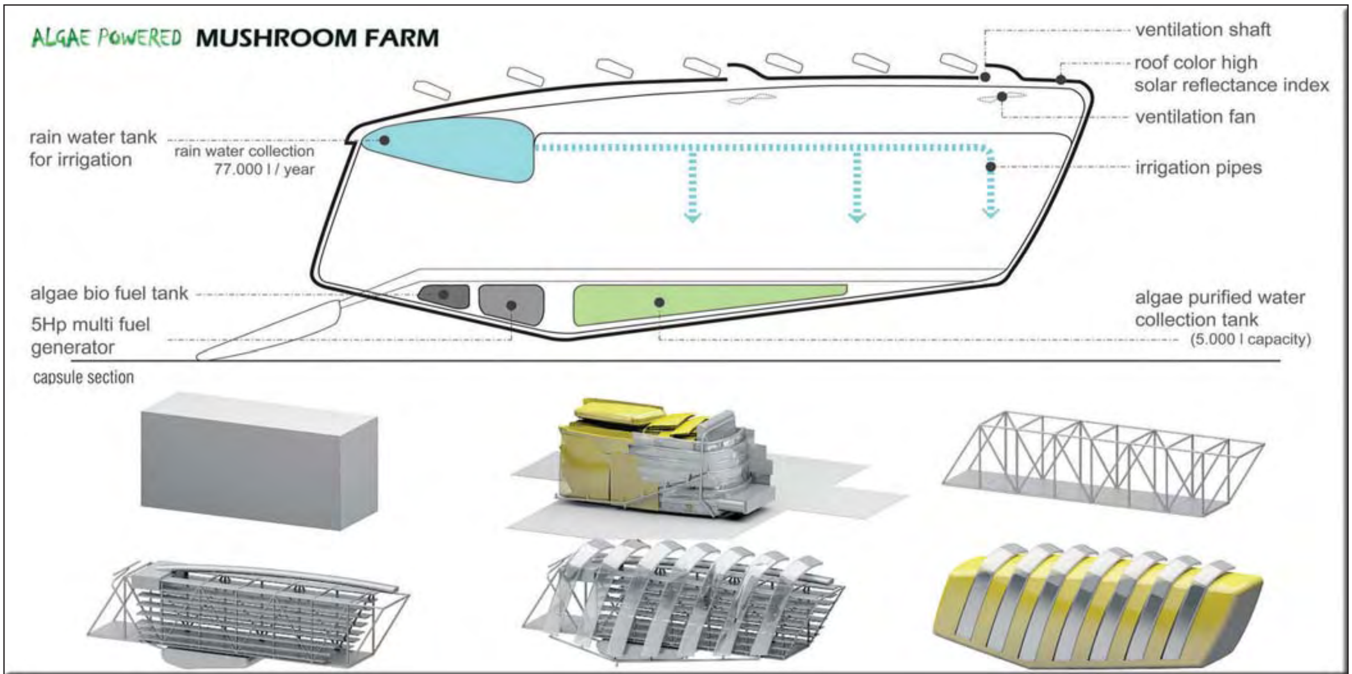
Here are some future visions from the International Algae Competition incorporating algae systems in building design and microfarms in eco-communities of the future:

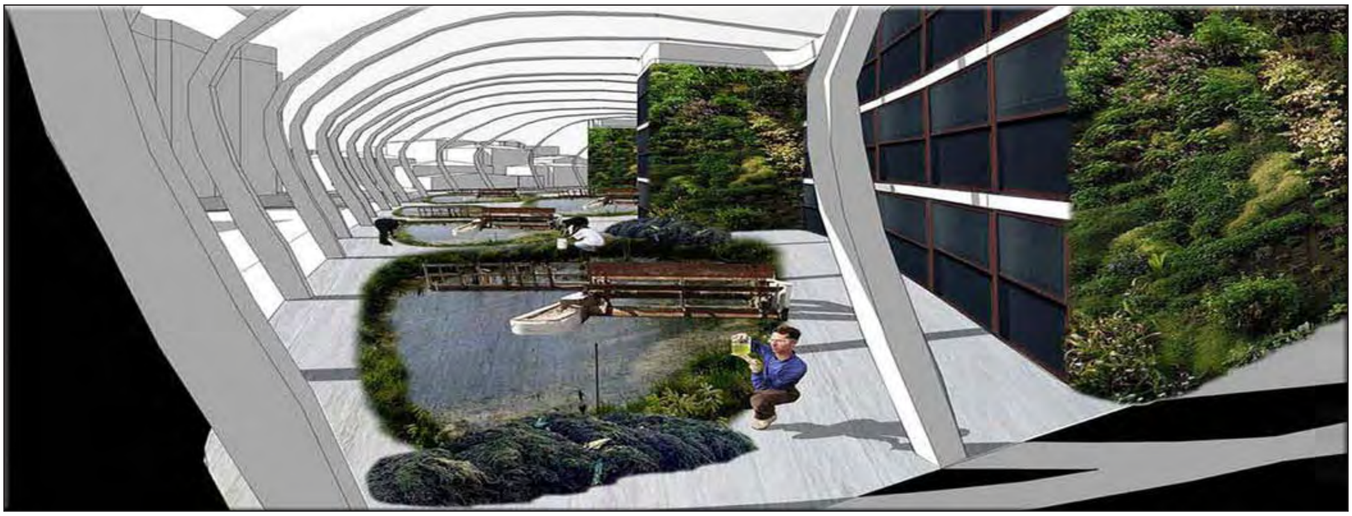


"Imagine Our Algae Future" reviews algae production, products and potential today and showcases the amazing visions of our future from the Algae Competition.

Future visions from the International Algae Competition

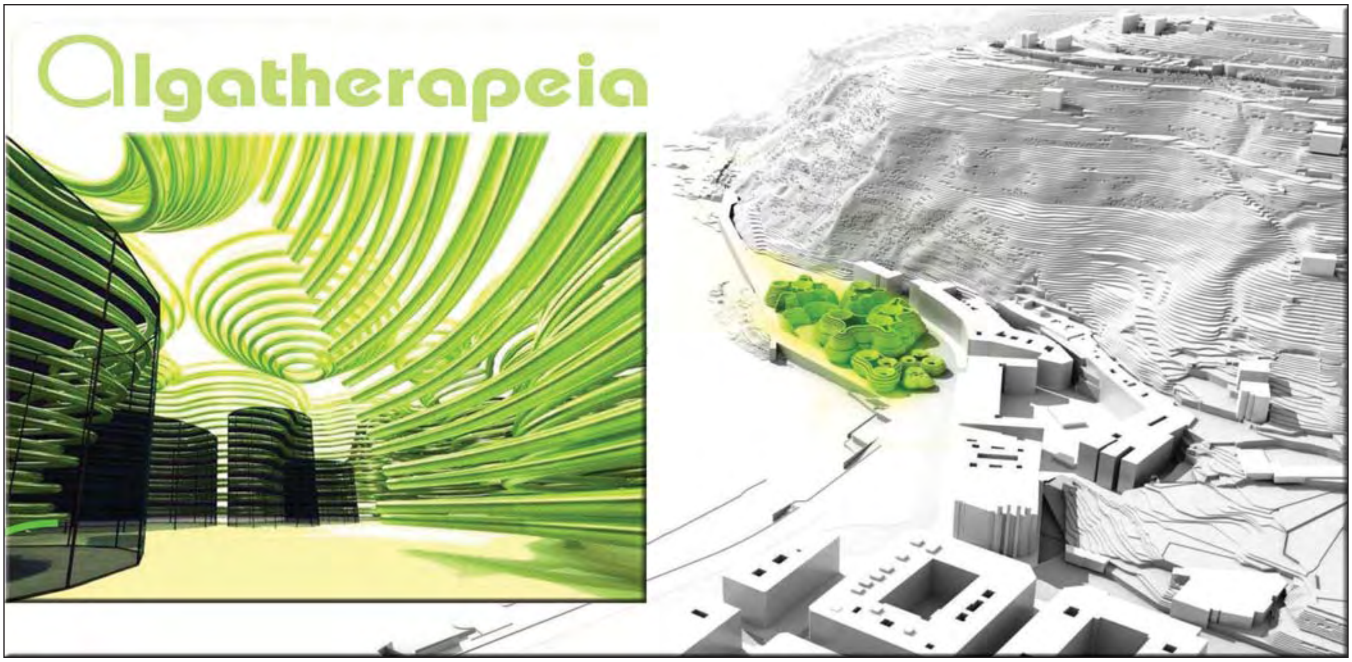
Algae Powered Mushroom Farm was voted the Appreciation Prize by participants in the International Algae Competition. It can be placed anywhere in the world to support micro-economic development in poverty stricken regions. The farm will grow mushrooms because of easy cultivation and high yield. Algae 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. *(Designed by 10 Design Group, Ted Givins: tgivens@10design.co).*

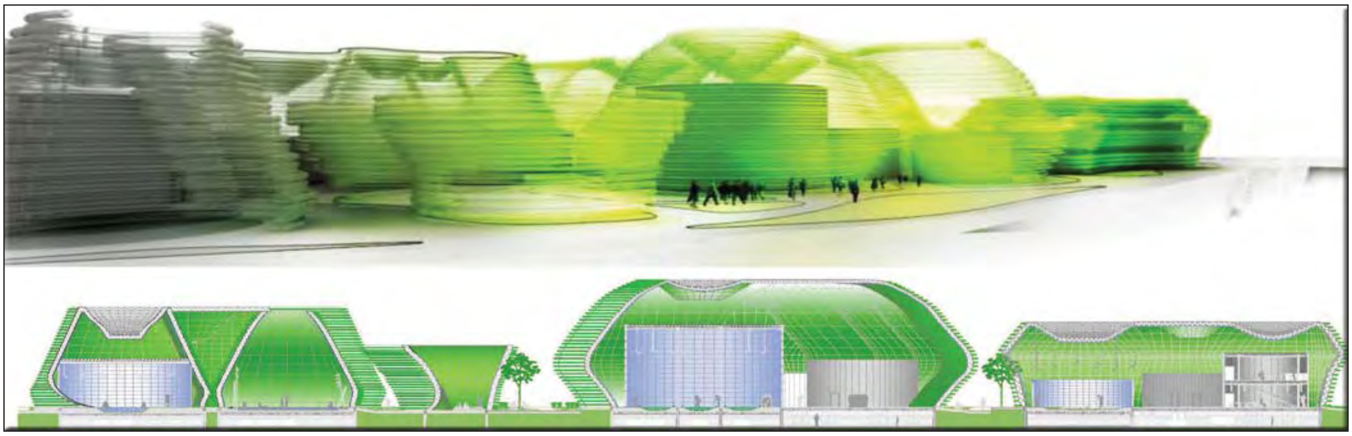




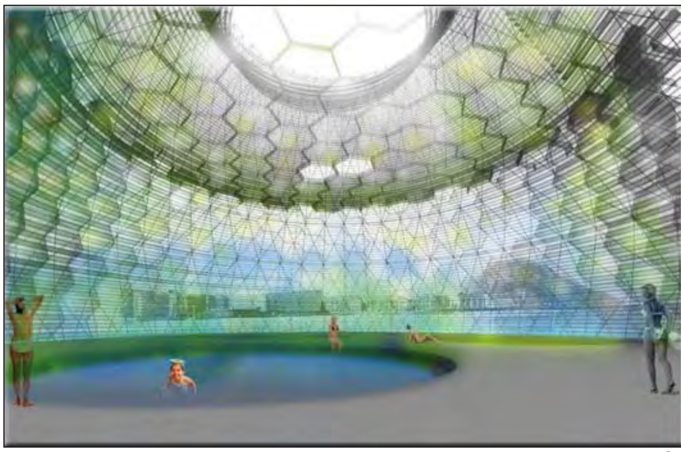
Urban Algae Bio-Fuel Production and Eco-Community in Kosovo. Designed for central Prishtina, with seven floors for residential space, each with a green garden. The community has a roof garden to grow produce, market, cinema and restaurant. The eco-community building is linked to the algae building with a glass roof to produce bio-fuel, food and compost.

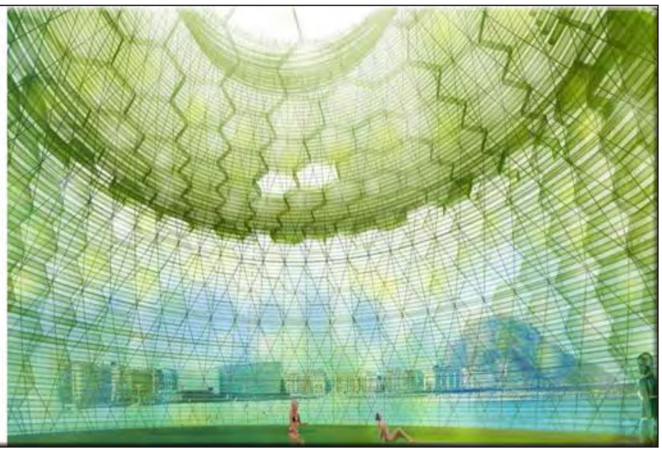
"In the last ten years Prishtina has seen a building boom, but there are close to zero eco-communities in the city. We have found a perfect site in the central city and designed an eco-community to encourage Europe's youngest country with the youngest population to turn to a sustainable way of living." *(Designed by Arben Jashari & Diana Jashari: benarchi1@hotmail.co.uk)*.



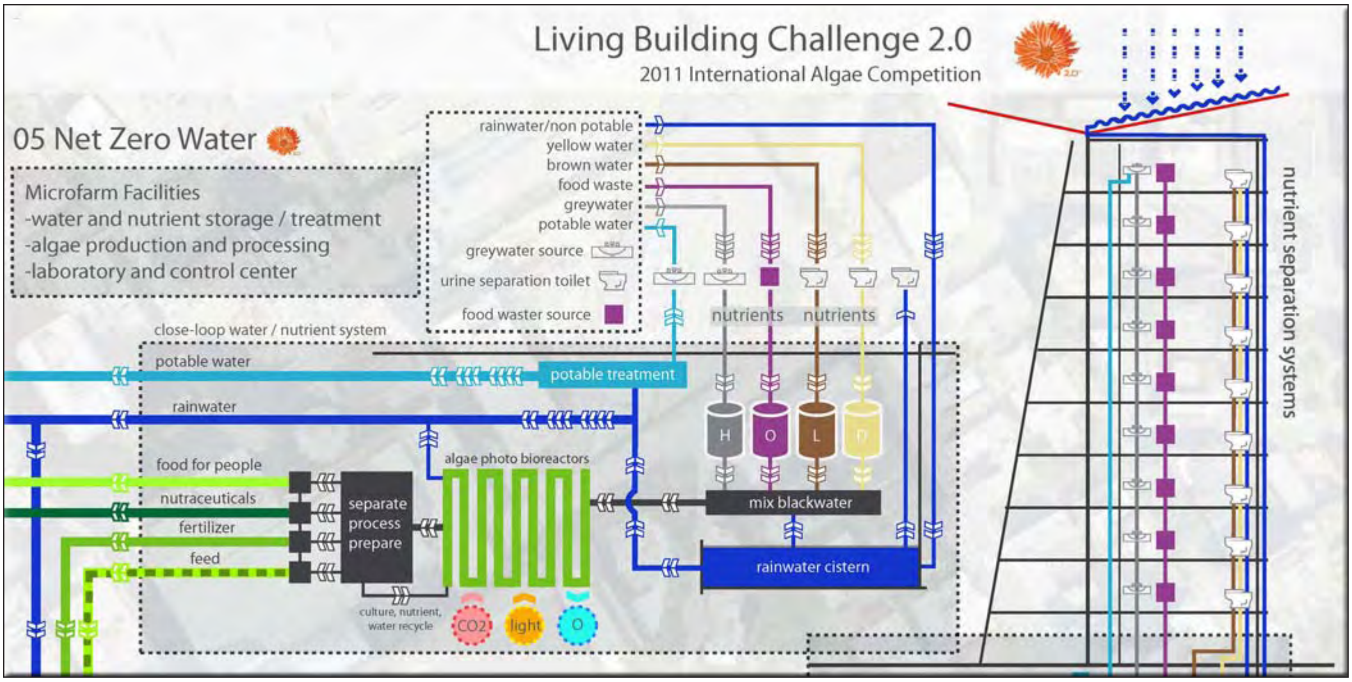


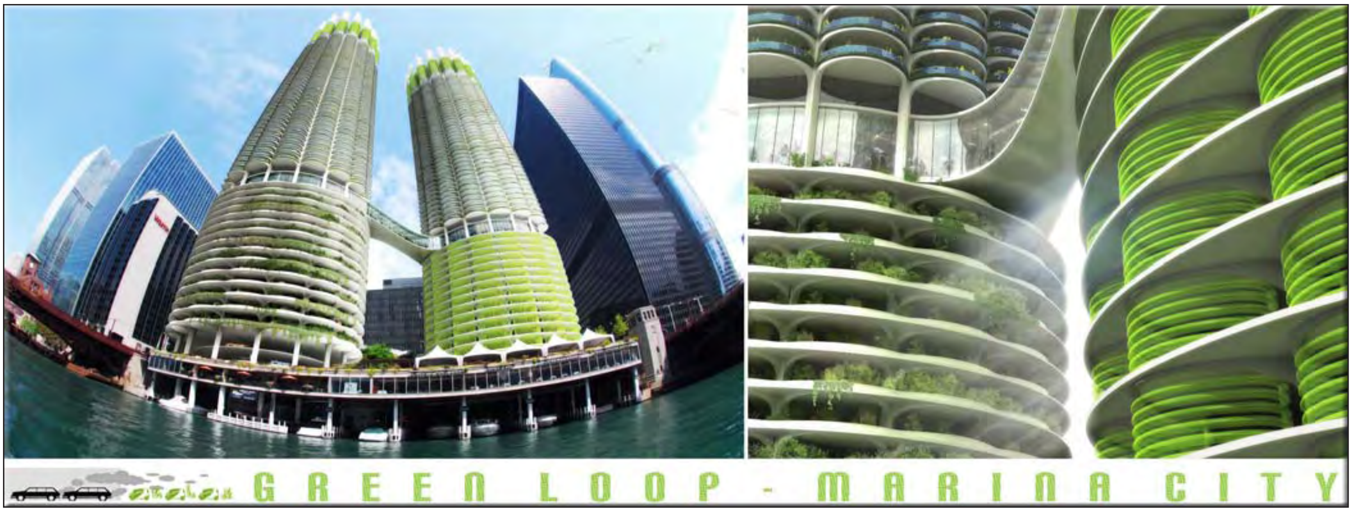
Alga Therapeia Center, San Sebastian, Spain. A design for a research center of marine algae typical of the Basque coast for medicinal, food and industrial applications. A photobioreactor skin generates the necessary energy for all building operations: therapy baths, solarium, kitchens, classrooms and research laboratory. *(Designed by Judit Aragonés: judit@estudiodinamik.com)*.



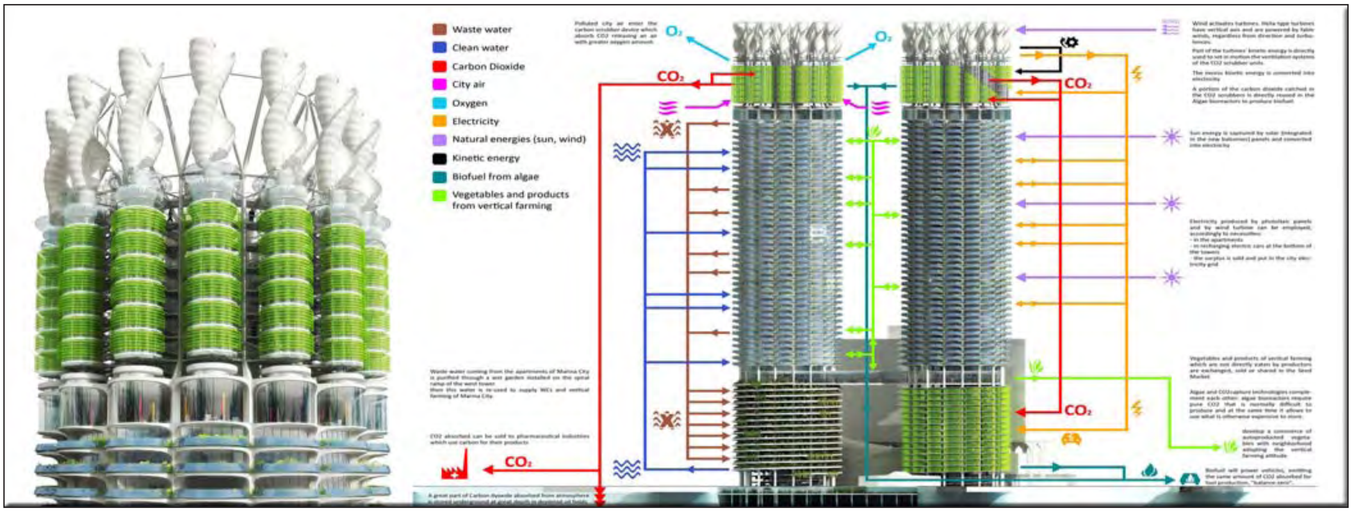


Eco Laboratory: Algae Microfarm Center, Seattle. This design is the heart of the community: a living building with algaculture, hydroponics, aquaculture, aeroponics, aquaponics and farming. Includes rooftop garden, algae bioreactors, farmers market, community gardens, orchards and greenhouses. *(Designed by Mark Buehrer: mark@2020engineering.com)*.



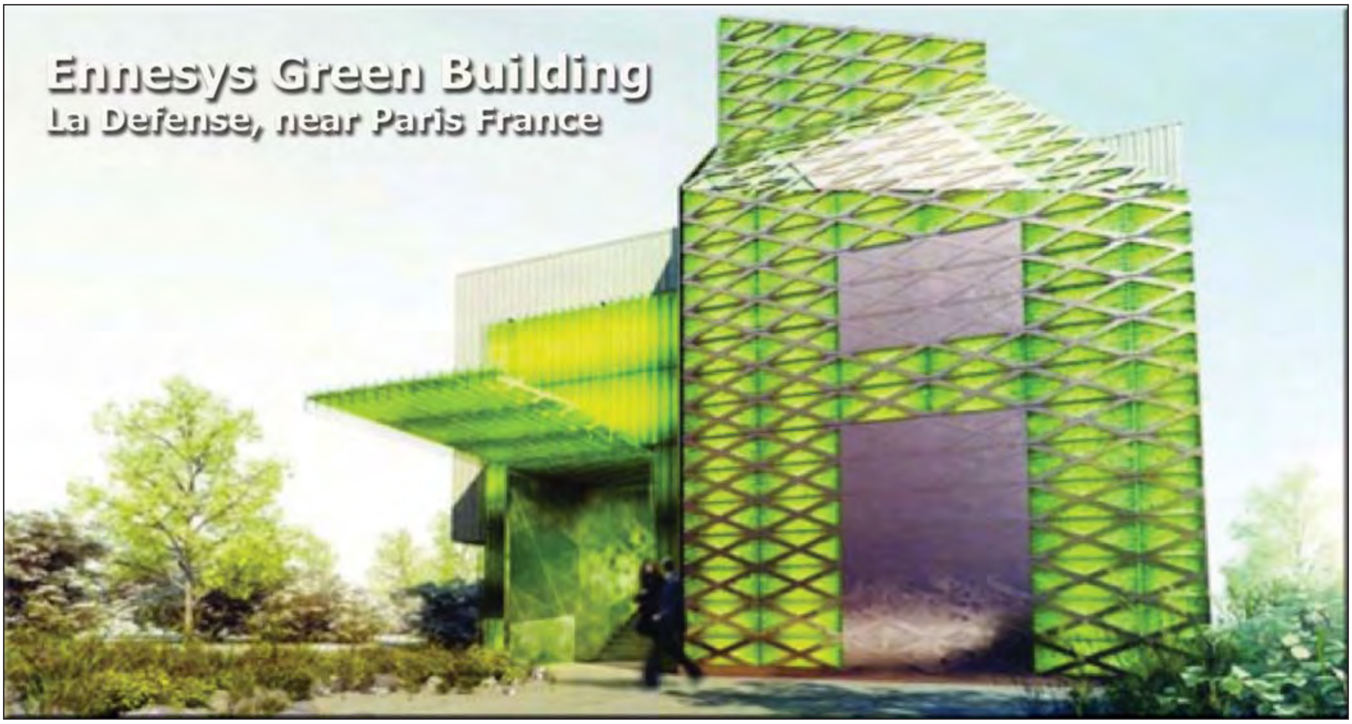


Green Loop: Marina City Global Algae Retrofitting, Chicago is a proposal for one of the most innovative buildings in the Loop of Chicago: Marina City Towers. This algae strategy represents a new model in urban areas. Re-visioning an iconic building from the past century fossil fuel economy. This is an environmental vision committed to the Chicago Climate Action Plan. *(Designed by Influx-Studio, Mario Caceres, Christian Canonico. contact@influx-studio.com).*



Algae Architecture - Future fantasies or just around the corner?

Some have dismissed the integration of algae growing systems into building architecture as impractical or just speculation. Yet, the first living algae buildings are here now.

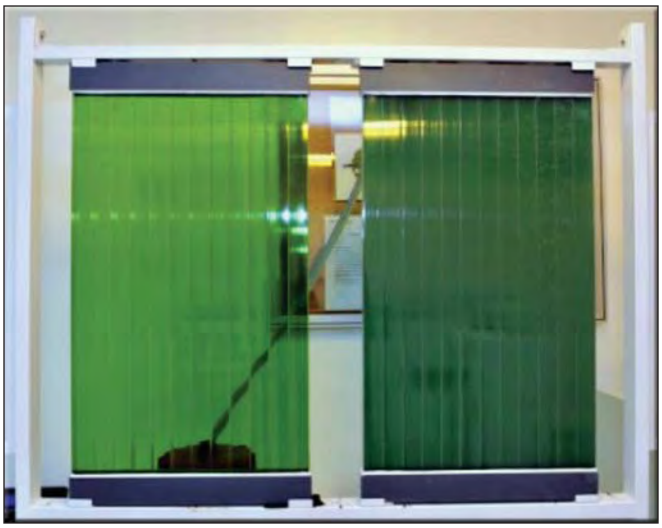


Green Building in La Defense near Paris

Ennesys has launched a 'truly green' building in La Defense near Paris. The concept is to turn buildings into energy production using light, CO_2 and wastewater to grow algae.

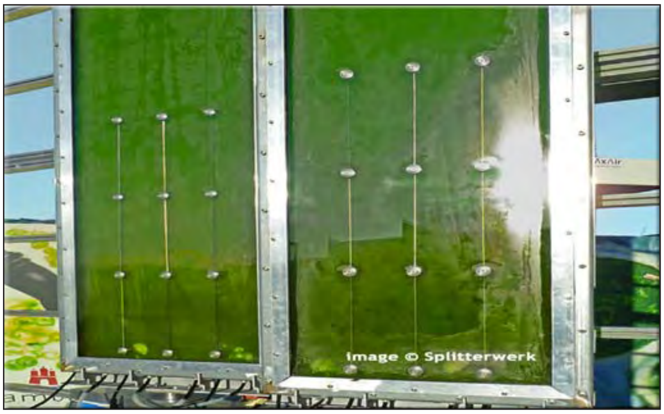
Ennesys, a Paris energy systems company, is partnering with Origin Oil, a US company, on this new urban algae demonstration project, harvesting energy from algae in wastewater from the building and filtering the water for use as graywater.

The flat-paneled algae harvesters mounted verticaly on the building facade act as insulation, keeping out summer heat and winter cold. Algae is harvested using Origin Oils' harvest appliance, processed into biomass and used to run building systems. Filtered water can be used as graywater to flush toilets.



A zero-energy house uses the world's first bio-adaptive façade with living microalgae to provide shade and generate renewable energy. The five story BIQ apartment building was installed in March 2013 in Hamburg Germany as part of the International Building Exhibition.

On the two south facing sides, algae in the bio-reactor glass panels of the facade grow in the bright sunlight and provide internal shading to keep the building cooler during warmer days. These bio-reactors also capture solar thermal heat and produce biomass that can be harvested - both clean sources of renewable energy to help power the building and its 15 apartments.



Prototype algae panels.

BIQ House under construction.

This ambitious project choose as the test site a city known for its long winters, but if it can operate in Hamburg, it can be done anywhere. The BIQ house will allow scientists, engineers and builders to assess the potential of the system as a green alternative providing dynamic solar shading and sustainable, renewable energy.

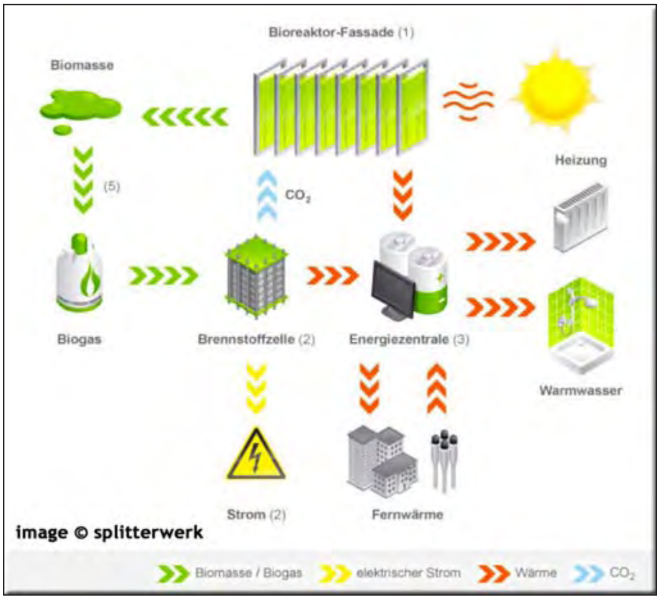


Diagram of energy flow and operating system.

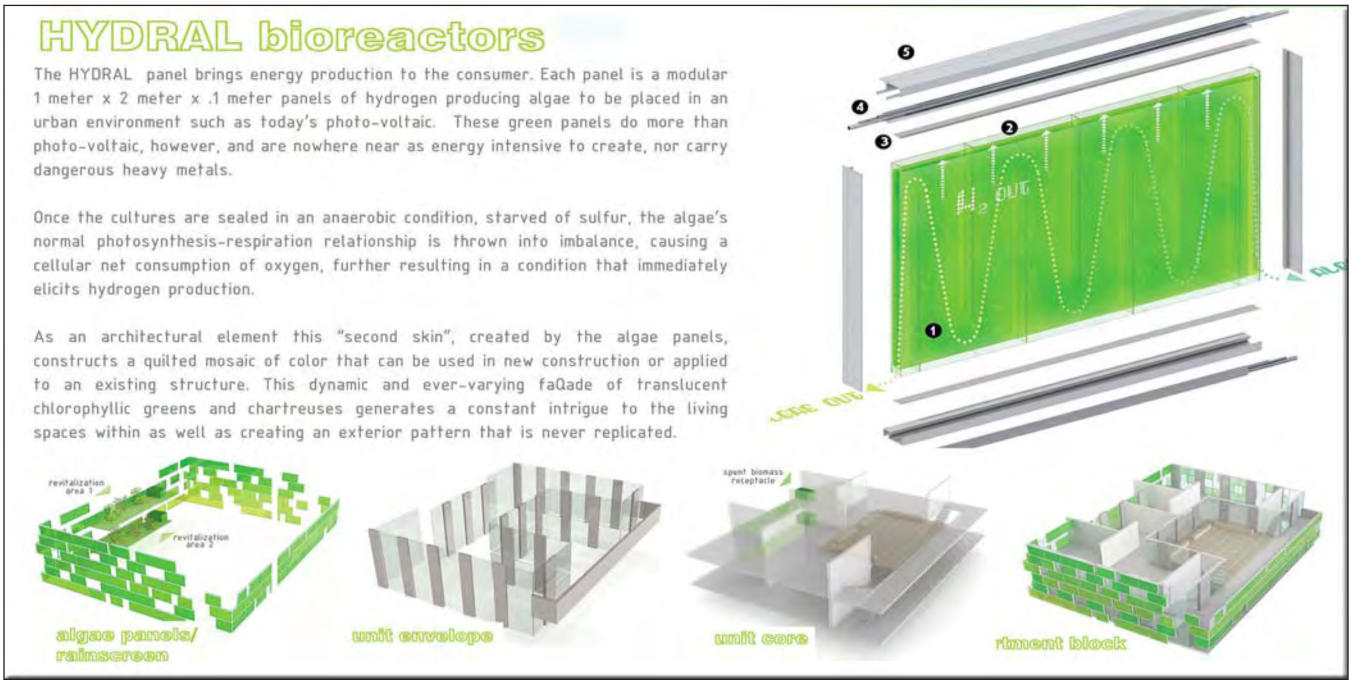
Photos: Martin Kunze, Johannes Arlt, Martin Kunze.

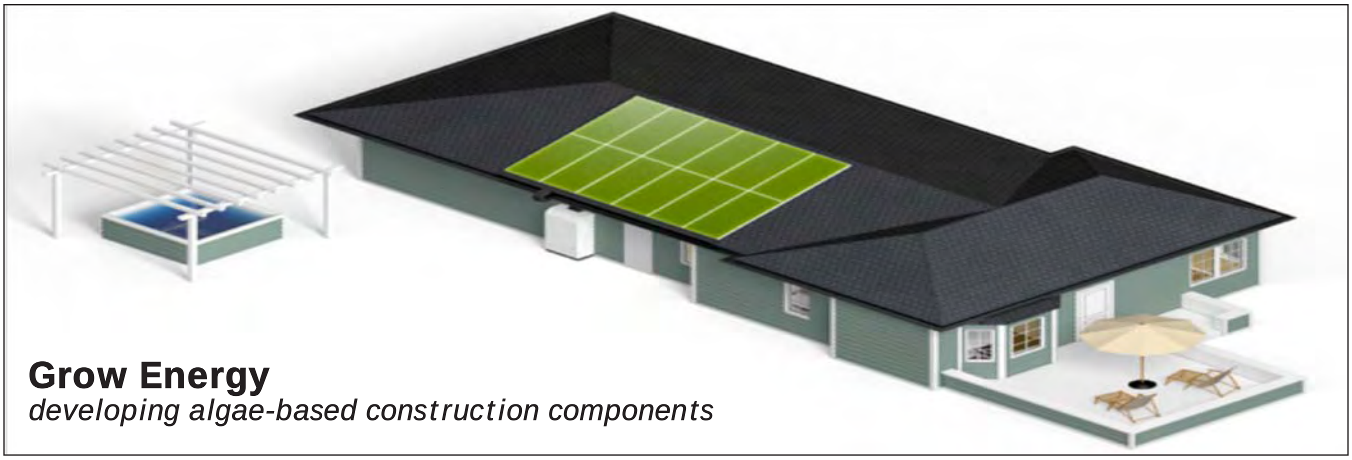
Hydral Housing units with modular hydrogen producing panels.

Modular panels of hydrogen producing algae can be placed like photovoltaics. Only 35% of the building's envelope need to be algae panels to create a self-sufficient units.

This second skin of algae panels constructs a quilted mosaic of color. Housing units create fresh water and reduce carbon emissions, without requiring occupants to change acquired energy-consuming habits.

(Designed by Thomas Kosbau. thomas@oredesign.org)





Grow Energy

developing algae-based construction components

Grow Energy's Verde panels will be mounted like solar panels for residential heat and electricity. Developing a new generation of energy-producing components. Grow Energy, of San Diego, California, plans to create clean electricity with algae for residential and commercial structures.

Their first system, called Verde, is technology designed for individual homes. According to the company, Verde employs a clean combustion process to burn algal biomass to create electricity and heat energy, which can significantly offset a property's utility expenses.

Verde photobioreactors are algae panels that mount onto a building's roof or envelope and grow algae by using recycled elements and nutrients in a closed-loop process. Grow Energy plans to introduce Verde to the homeowner market in 2015.

The company's second construction component system in development is called Hydral, which grows genetically modified algae in architectural or utility bioreactors, using an enhanced strain that produces hydrogen gas, instead of oxygen, in its natural photosynthetic process.

The hydrogen gas is channeled into fuel cells and electricity/thermal heat is generated, while the spent algal biomass is recycled as a rich fertilizer. Hydral doubles as a water supply system, connecting to a building's plumbing to cleanse wastewater, and the fuel cell process generates drinking water.

Hydral is currently being designed for high-rise structures, large-scale properties and communities. Grow Energy sees Hydral as an architectural style for next-generation renewable living, and is developing the system with Thomas Kosbau, the CEO of Ore Design + Technology.

Hydral is scheduled to be available to property developers in late 2015 and to individual properties and experimental utility-scale systems for powering communities and cities by 2020.

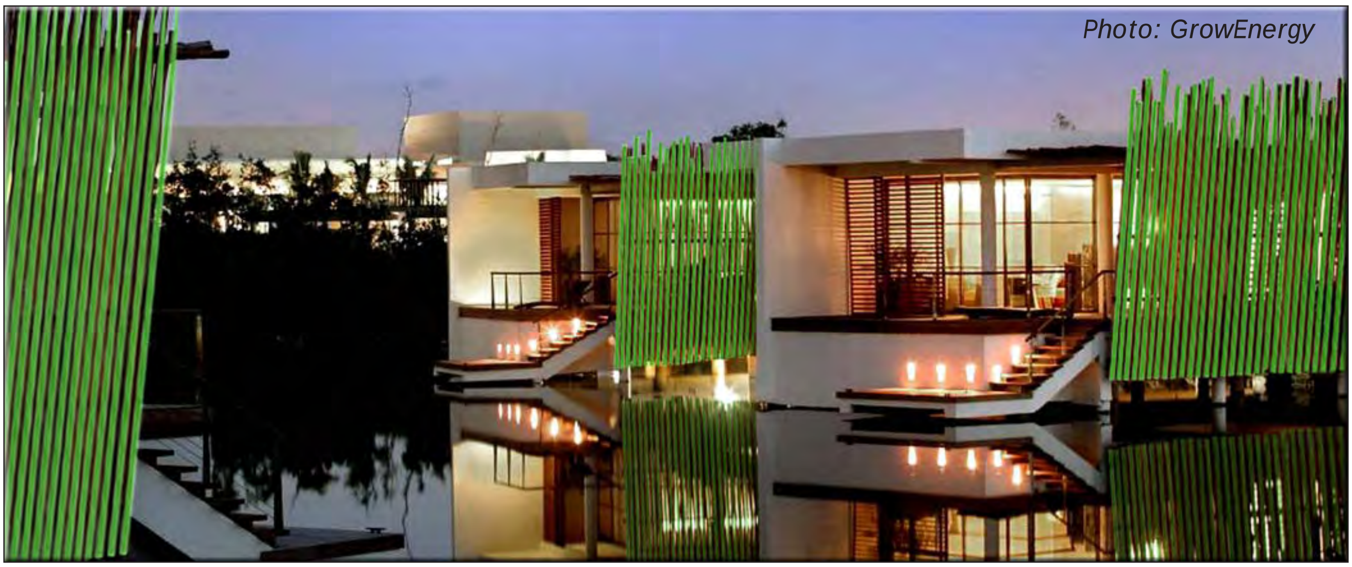


Photo: GrowEnergy

Algae Production, Products & Potential Today

Quick review of the past 40 years and current status

Macroalgae (seaweed or marine algae) have been harvested for centuries in Asia and Europe for a variety of foods, feeds, food ingredients and fertilizers. Microalgae (microscopic algae) havebeen commercially produced for only the past 40 years. There are thousands of products in everyday life we consume that contain microalgae: nutraceuticals, food supplements, food ingredients, specialty food oils, feed supplements, feeds, cosmeceuticals. Microalgae is being used for biofertilizers and in waste treatment.

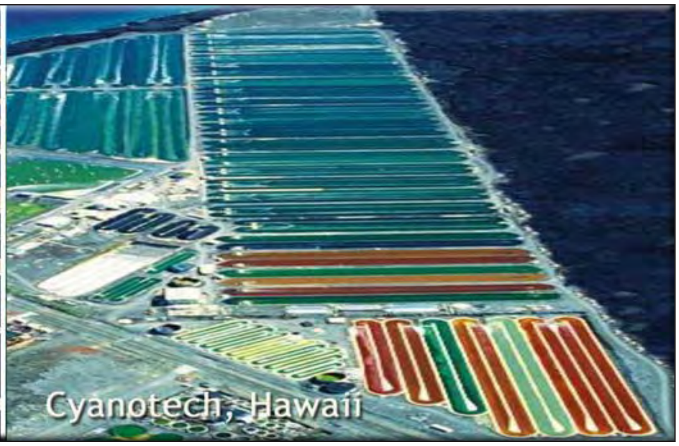
In the past decade, huge investments have flowed into microalgae to develop algae biofuels. Commercialization of cost competitive algae biofuel, and the very large scale it requires, still seems to be years in the future. Yet many higher value products on the way to biofuel, such as specialty oils, fine chemicals and bioplastics will arrive first. For perspective, here's a brief review of the past 40 years of algae production and processing methods and products:

- Outdoor ponds for food, feed and nutraceuticals
- Big 4: *spirulina, chlorella, dunaliella, haematoccocus*
- Photobioreactors for high value products
- Industrial fermentation for fuel, feed and food oils
- Seaweed and marine algae industry
- Natural algae biofertilizers
- Aquaculture and animal feed supplements
- Algae for biofuel, bioplastics and fine chemicals
- Algae wastewater treatment systems

Microfarms: Raceways, PhotoBioreactors, Bags, Plates and Tubes

Algae Production Systems Today

Outdoor pond production for nutraceuticals, food, feed and fuel



Commercial algae production is estimated at 10,000 tons or more per year with 98% 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, with typical water depth of 15 to 25 centimeters.

Earthrise Nutritionals in California, USA was established in 1981 and ultimately expanded to cover 108 acres. Owned by Dainippon Ink & Chemicals of Japan, by the mid 1990s 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 fish food supplements.

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

Boonsom Farm near Chiang Mai in Thailand, has produced *spirulina* value-added 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 is the world's largest *spirulina* grower, producing an estimated 50% of the world's output for domestic and export markets. There are numerous growers across Southern China and Hainan Island and as far north as Inner Mongolia.

Production in outdoor ponds is active in many other countries today including Taiwan, Australia, Vietnam, Israel, Bangladesh, Philippines, Cuba, Chile, Costa Rica, Martinique, Peru, Ecuador, Brazil, Spain, Portugal, Morocco and France.

Outdoor Pond Production Systems
The big 4: spirulina, chlorella, dunaliella and haematococcus

Chlorella vulgaris for food supplements

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

Many farms developed circular ponds rather than raceway ponds. *Chlorella* grows in more normal pH water than *spirulina*. 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, *spirulin*a has become more widely grown around the world.

For the past 30 years, thousands of tons of *chlorella* have been sold each year 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, requiring 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, antioxidant and as a color for aquaculture feeds.

Haematococcus pluvialis for astaxanthin

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

Other blue-green algae food supplements

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

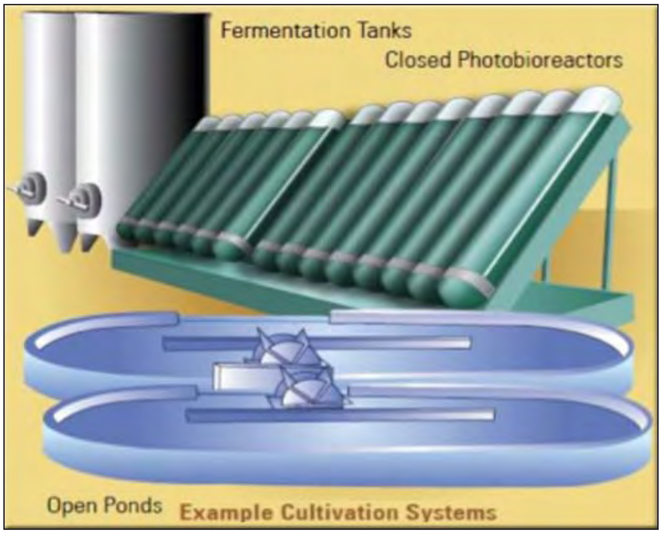
Photobioreactors and Closed Systems
for high value nutraceutical and chemical products

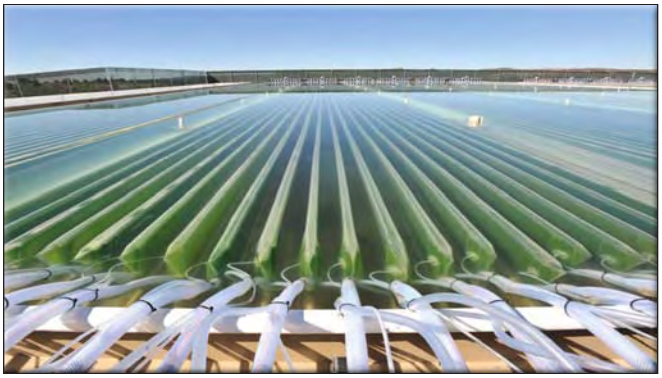
Photobioreactor and tube systems

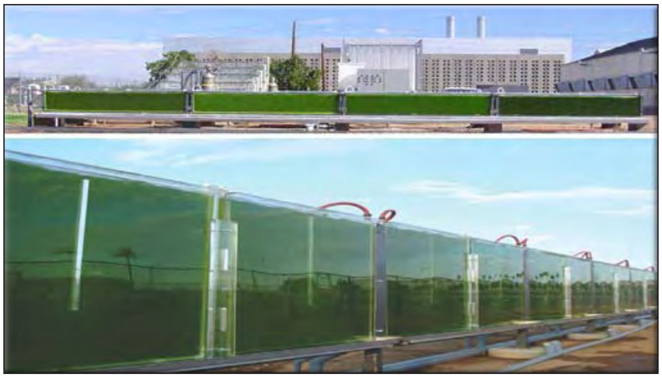
Many algae are subject to contamination by competing algae and other microorganisms. Maintaining a pure culture outdoors can be challenging.

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

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







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

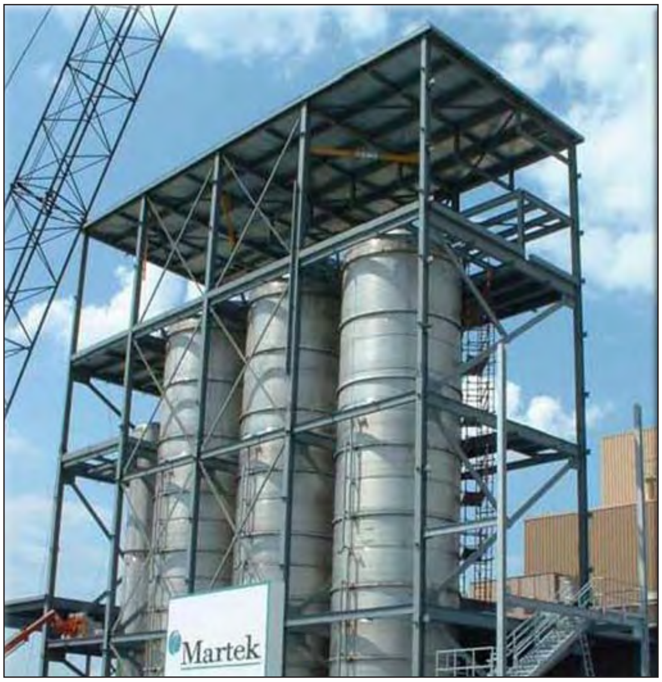
Growing haematococcus for astaxanthin at the large photobioreactor complex at Kibbutz Kentura, Israel.

Industrial Fermentation Systems
Producing algae oils for food, feed and fuel

Fermentation systems

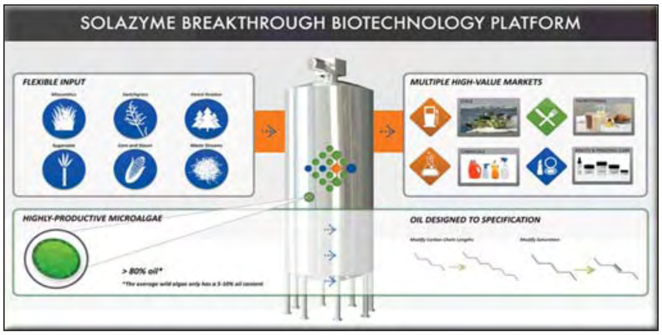
Fermentation is used to grow bacteria like yeast. Rather than using photosynthesis through sunlight or artificial light, an autotropic process, fermentation is a heterotropic process, which grows by obtaining carbon through organic compounds.

Companies like DSM/Martek and Solazyme use fermentation to grow algae. Their feedstocks include sugar and cellulosics. Industrial fermentation is decades-old established technology, and this has enabled algae fermentation companies to rapidly commercialize without the risks of outdoor cultivation or novel photobioreactor technology.



Martek Biosciences was a pioneer in using fermentation technology to grow algae and 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 *crypthecodinium,* 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.

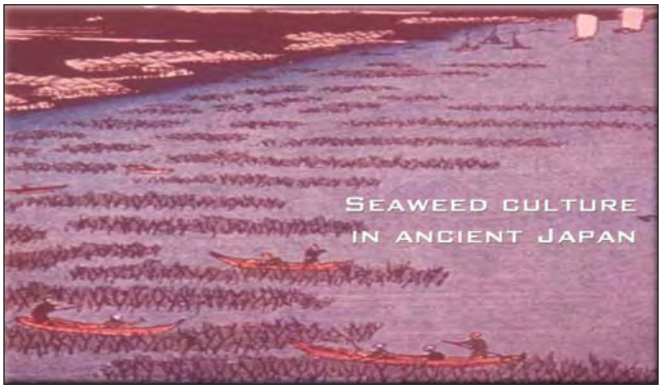


Solazyme has developed an industrial biotechnology platform that harnesses the prolific oil-producing ability of microalgae, using industrial fermentation equipment to efficiently scale and accelerate microalgae's natural oil production time to just a few days.

This platform is feedstock flexible and can use a variety of plant-based sugars, such as sugarcane-based sucrose, corn-based dextrose, and sugar from other biomass sources including cellulosics. 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.

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 impact 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 a broad group of algae that share a number of characteristics. They photosynthesize and provide oxygen. Seaweeds 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 microalgae from unicellular phytoplankton to macroalgae like giant kelp, *macrocystis pyrifera*, largest of all algae, growing up to 50 meters long.


Nori *(porphyra)* cultivation

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. The largest group of organisms cultivated 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.

For centuries, around 500 seaweeds have been used, directly or indirectly, for human food and medicine and as extracted phycocolloids, the gelling, thickening, emulsifying, binding and stabilizing agents known as carrageennans, agars and alginates.

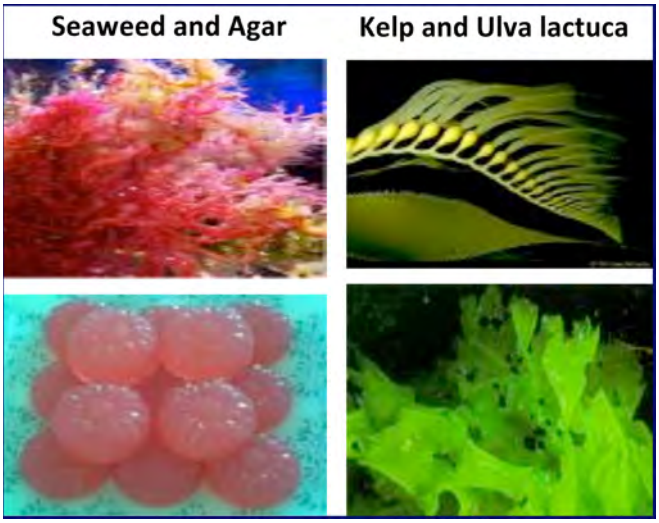
Use of sea vegetables for human consumption is growing. Already well known as nori wrapping for sushi and floating pieces in soups, seaweeds are becoming popular in salads and garnishes. Extracts are widely used in cosmetics and skin care creams because they help soft and healthy skin. Seaweeds are used 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 integration 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 moisturizing treatment of skin, 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, 100 BCE. The classic red color of Roman tunics came from pigments extracted from the lichen *urchilles*. Roman women valued the plant and used it as a 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 creating a skin tightening effect.

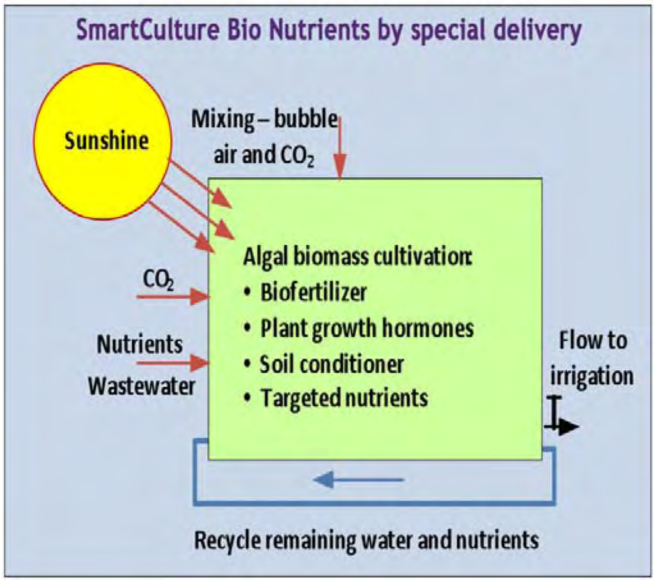
Organic algae cosmetics provide advanced compounds that smooth, protect, heal and promote skin regeneration. Algae produce a wide range of valuable antioxidants in a spectrum of anti-aging formulations. As advanced cosmeceutical compounds are discovered in algae, growers can produce them quickly and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

Algae Natural Biofertilizers
SmartCultures for crops and restoring soil fertility

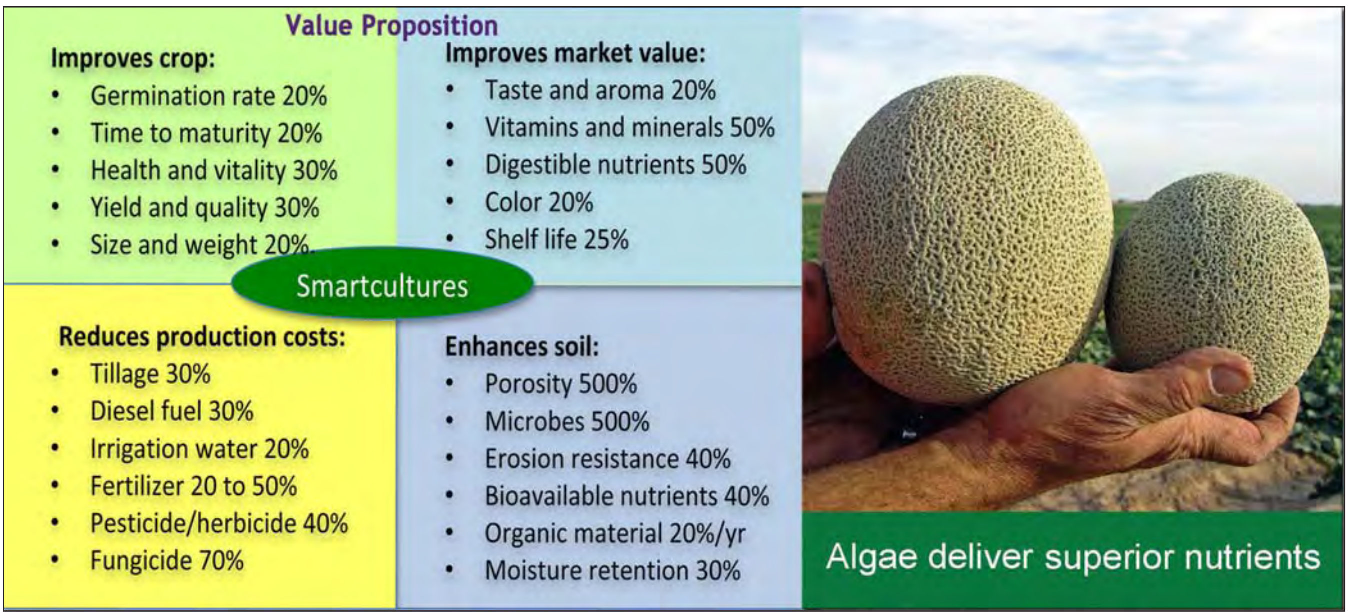
Algal biofertilizers or inoculants are a low cost, effective, environment-friendly and renewable source of plant nutrients that supplement and may even replace chemical fertilizers. Microalgae live in symbiosis with lichens and mosses and make up cryptogamic crusts, which are major sources of biologically 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 and 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 from 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 an 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 producing healthier crops. In taste tests with melons, consumers preferred those grown with natural algae biofertilizers.



Aquaculture and Animal Feed Industry
Growing algae to feed fish, shrimp, mollusks, animals and pets

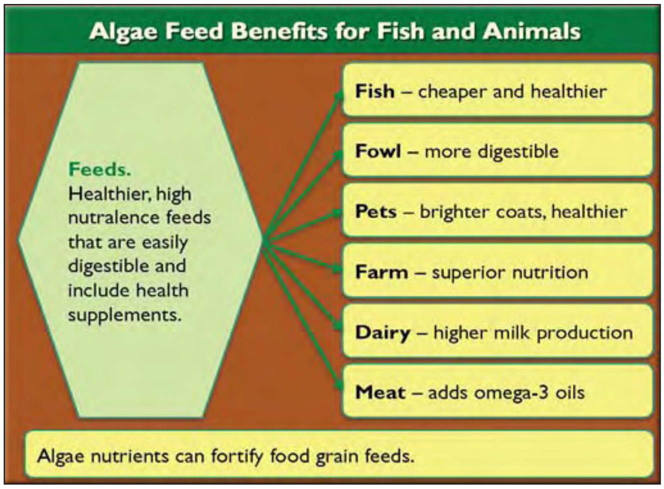
About one-third of all cultivated algae is used in aquaculture to feed mollusks such as oysters, scallops, clams and mussels, and shellfish like abalone. Algae are used to feed zooplankton which feed a wide variety of shellfish and finfish. Many aquaculture farms grow algae next to fish ponds and feed 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. Yet the cost of fish meal to feed farmed fish continues to rise and fish farmers are motivated to replace fish meal with algae meal as algae costs fall.

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

For more than thirty years, algae like *spirulina* have been widely used in aquarium, tropical and ornamental food formulas. Algae offer a broad 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* to improve their health and color. Canary, finch, parrot, lovebird and other bird breeders use algae supplements to enhance color, growth and fertility. Algae feed increases survival rates and the 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 while improving disease resistance.

Algae in aquarium tropical fish foods, flakes and pellets.

Spirulina algae in ornamental pond fish feeds for health 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 have been built on 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 pressure and heat over 400 million years. Therefore, anything made from fossil fuels can also be made from algae. Algae biofuel production is sustainable and occurs in weeks rather than eons.

US Navy successfully tests algae biofuel

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.

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.

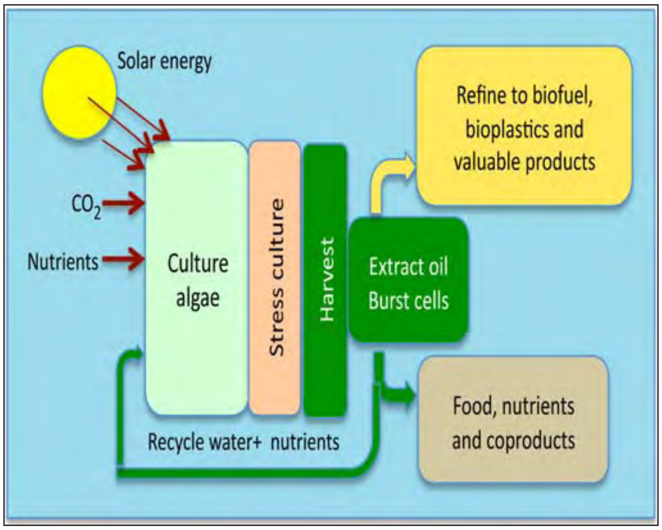
• Recycle CO2, reducing the carbon load while burning clean, with no black soot particulates.

Algaeus-
algae powered car


Sapphire Energy Green Crude Farm in New Mexico 100 acres of ponds

How are algae biofuels made?

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.



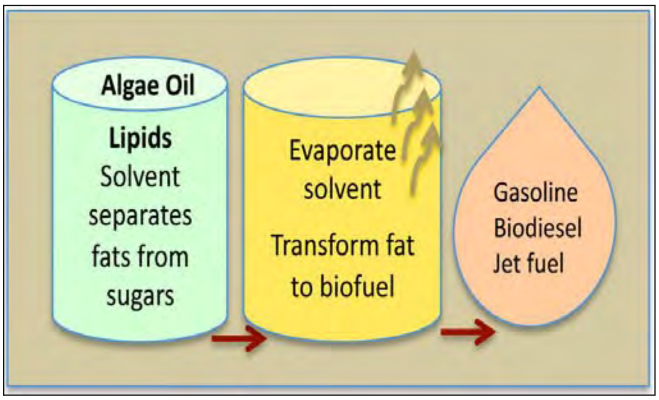
Harvested algae biomass undergoes lysis, which bursts the cells and enables the oils to float to the surface. Lysis may occur with solvents such as hexane, or enzymes, electrical, mechanical pressure or lasers. Carbon dioxide acts as the supercritical fluid when pressurized and heated to change its composition from gas to liquid. Supercritical CO2, mixed with the algae, extracts nearly 100% of the oil, but is more costly than other methods.

Producers refine algae oil to make biofuel, bioplastics or fine green chemicals. Oil refining uses transesterification on the fatty acid chains. 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.

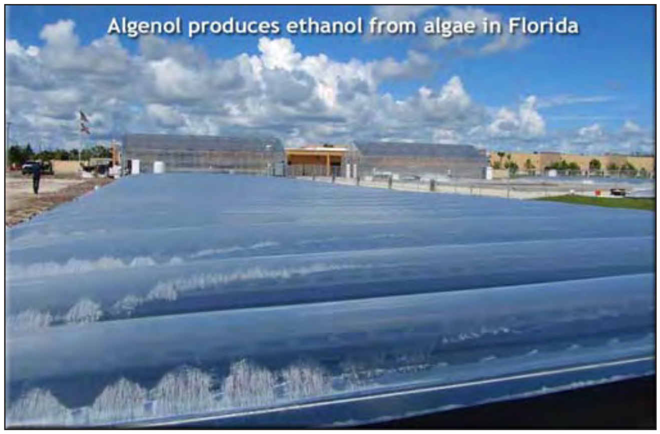

Algae sweating oil droplets

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. The oil rises to the top of the water column where a skimmer removes the oil. The algae oil can then be refined.

The residual biomass, mostly protein and carbohydrates, can 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 most powerful benefits from biofuel production is the R&D discoveries that will benefit all algae producers.



Other fuel sources from algae are being developed. Rather than algae to biodiesel, Algenol in Florida is growing algae for ethanol using long tubular bioreactors. Other researchers and companies are experimenting with hydrogen producing algae for hydrogen as fuel source.


Algenol produces ethanol from algae in Florida

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. Questions persist such as: What algae species: blue green, green or marine algae? What production method: ponds, photobioreactors, fermentation? What nutrient sources: water quality, waste streams, recovered industrial CO2? What process method: harvesting, lysing, chemical, sweating, flocculation, evaporation? What end product: biodiesel, ethanol, butanol, hydrogen? Which will become successful paths to commercialization?

Companies continue to invest millions trying to develop algae biofuels, but scaling up from the laboratory is more complex than expected. Total scale for biofuel cultivation will require hundreds or 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 algae 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, creative resources are developing algae innovations that will benefit us all.

How algae production costs will come down

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! Can they deliver cost competitive algae biofuels within this decade?

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

• Algae ventures with deep financial backing from multinational oil firms, government and capital markets, and with technology that works, will be prepared to stay the course.

• Many companies are already repositioning their business models to develop more valuable and 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.

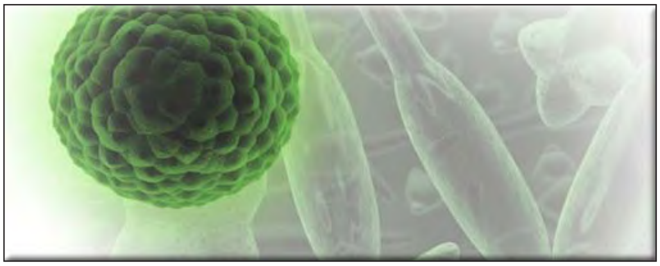
• Some big corporate partners will bail. The executive decision will boil down to: "had a good look, but now we are moving on to more immediately profitable opportunities."

• 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 will intensify 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. 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. Recycle waste CO2 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. Start with the end product and work backwards. Determine 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 CO2 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

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. They remove and recover nitrogen and phosphorus while producing algae biomass, which can be used as biofuel feedstock or agricultural fertilizer, all while improving water quality.

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, removing 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 CO2 from power plants or other sources to fertilize the algae for optimal productivity and for removing nitrogen and phosphorus nutrients efficiently, - key issues for sustainable wastewater treatment.

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

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.

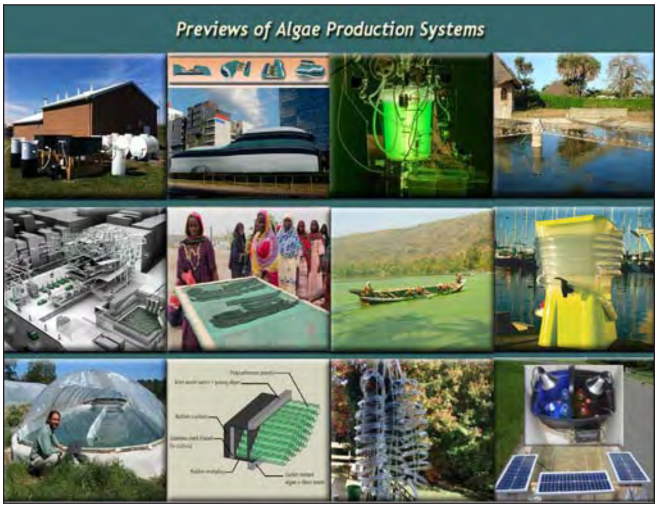
International Algae Competition Tracks
Algae Landscape Design, Production Systems and Food Development

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

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 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 CO2, 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

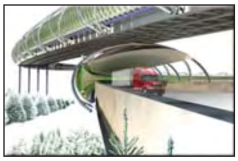
Algae powered mushroom farm in Congo, Africa *by 10 Design Group, Ted Givins.*

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.*

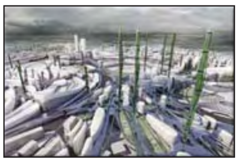
Ecologies of (Bio)Diversity: A self sustaining tower for London *by David Edwards.*

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

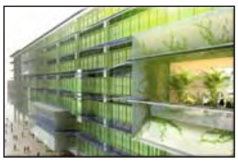


Green Miles. I-40 near Knoxville, Tennessee *by Kathryn Hier.*

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

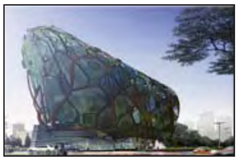


[Infra]Structural algae ecology for Taipei, Taiwan *by Aleksandrina Rizova & Richard Beckett.*



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.*

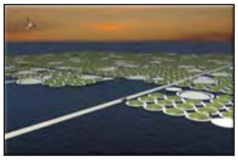


Persatuan Arkitek Malaysia (PAM) Centre in Malaysia *by Chew Teik Hee.*

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

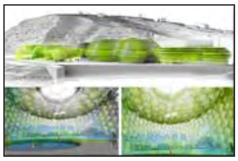
Eco-Pod: modular algae bioreactor in Boston *by Squared Design Lab: & Höweler+Yoon Architecture.*

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

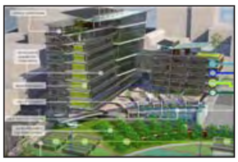


Production landscape for warm coastal areas of the world *by Ho Wing Ho.*

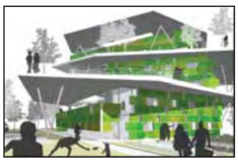
Algaegarden celebrates the beauty and potential of algae *by Heather Ring, B. Parker, S. Fredericks.*



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



Eco-Laboratory: Algae microfarm 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.*

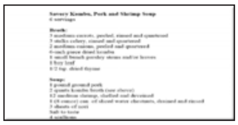
In'Spir- naturopathic condimen from Provence, France *by Cédric Coquet.*

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

Korean style algae 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.*

Dulse cashew granola *by Jessi Apfe.*

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

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

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

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

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.*

Grow Your Own Spirulina

Teaching Manual by Jean-Paul Jourdan

This is the condensed version of the teaching manual *"Grow Your Own Spirulina"* authored by Jean-Paul Jourdan, written in French and distributed by Antenna Technology.

"The purpose of this little manual is to bring my field experience on small scale spirulina production to those who would need it.

To make the presentation shorter, easier and more accurate, I decided not to avoid using technical terms: in case some would confuse you, look for an explanation in a chemistry college handbook.

What is called *"spirulina"* here actually has the scientific name *"Arthrospira platensis"*, a cyanobacteria. But the common name *"spirulina"* is universally used. This is not a general book on spirulina. Excellent ones are available:"

"Spirulina World Food", by Robert Henrikson, U.S.A. (2010).

"Spirulina, Production & Potential", by Ripley D. Fox, Editions Edisud, France (1996).

"Spirulina platensis (Arthrospira): Physiology, Cell-biology and Biotechnology", edited by A. Vonshak, published by Taylor & Francis (1997).

Jean-Paul Jourdan spent more than 12 years working on the development of low-cost techniques of spirulina production.

After a career in the chemical industry, Jean-Paul Jourdan devoted his retirement time in the south of France, with the goal to participate in making spirulina available to the children in developing countries. He worked with Ripley Fox and Francisco Ayala, became a member of Technap, and collaborated closely with Antenna Technologies and several other NGOs working on spirulina.

Since 2002 Jean Paul has edited a monthly newsletter called *Petites Nouvelles de la Spiruline*. From 2004-2008 he was professor of spirulina culture at the CFPPA Center in Hyères, engaging many producers from southern France to as far north as Brittany, Savoie and Alsace. He is a consultant to the Fédération des Spiruliniers de France.

When he moved to more northern France in recent years, he developed an insulated growing tank in his backyard to keep algae culture warm and grow all throughout the year, even in winter.

	GROW YOUR OWN SPIRULINA
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A2	Measuring Salinity of the culture medium
A3	Measuring Alkalinity of the culture medium
A4	Measuring the pH
A5	Comparing spirulina samples
A6	Harvesting and drying spirulina

Climatic Factors

Temperature is the most important climatic factor influencing the rate of growth of spirulina.

Below 20°C, growth is practically nil, but spirulina does not die. Optimum temperature for growth is 35°C, but above 38°C spirulina is in danger.

Growth only takes place in light (photosynthesis), but illumination 24 hours a day is not recommended. During dark periods, chemical reactions take place within spirulina, like synthesis of proteins and respiration.

Respiration decreases the mass of spirulina ("biomass"); its rate is much greater at high temperature, so cool nights are better on that account, but in the morning beware that spirulina cannot stand a strong light when cold (below 15°C).

Light is an important factor but full sunlight may not be best for illumination: 30% of full sun light is actually better, except that more may be required to quickly heat up the culture in the morning.

Individual spirulina filaments are destroyed by prolonged strong illumination ("photolysis"), therefore it is necessary to agitate the culture in order to minimize the time they are exposed to full sunlight.

Rain is beneficial to compensate for evaporation, but it must not be allowed to cause overflowing of the culture pond. Wind is beneficial for agitating and aerating the culture, but it may bring dirt into it.

Artificial light and heating may be used to grow spirulina, although they are not economical. Fluorescent tubes and halogen lamps are both convenient. Lamps can illuminate and heat the culture simultaneously.

Ponds

Spirulina thrives in alkaline, brackish water. Any watertight, open container can be used to grow spirulina, provided it will resist corrosion and be non-toxic. Its shape is immaterial, although sharp angles should be avoided to facilitate agitation and cleaning. Its depth is usually 40 cm (twice the depth of the culture itself). It can be as small as $1 m^2$ but 5, 20 or $100 m^2$ are more economical. Dimensions are only limited by the necessity of accessing for agitation and cleaning. The bottom should have a slight slope and a recess to facilitate cleaning and emptying. Two ponds are better than just one, for practical reasons.

The most economical ponds are made of food grade UV resistant plastic film of 0.5 mm thickness or more with sides supported by bricks or a wooden structure or metal tubes. If termites are present, a layer of dry ash plus a layer of sand should be placed under the film to protect it, and of course wood should not be used.

Concrete ponds are a good, durable solution where experienced labor is available. Before starting the culture, the cement should be cured and whitewashed.

A greenhouse over the ponds offers many advantages, provided it can be aerated and shaded. Covering the ponds is necessary in many instances.

Agitation can be manual, with a broom, once every two hours. If electricity is available, aquarium pumps are practical to agitate the surface of the culture (one watt/m^2 is enough). "Raceway" ponds agitated by paddlewheels are standard in the industry, but somewhat outside the scope of this manual.

Culture Medium

Spirulina can live in a wide range of water chemistry; the following is an example:

mg/l	Typical Spirulina Water Analysis
2800	Carbonates
720	Bicarbonates
614	Nitrate
80	Phosphate
350	Sulfate
3030	Chloride
4380	Sodium
642	Potassium
10	Magnesium
10	Calcium
0.8	Iron
12847	Total Dissolved Solids
1010 g/l	Density @ 20°C
0.105 N	Alkalinity *(moles strong base/liter)*
10.4	pH @ 20°C

In addition, the solution contains traces of all micronutrients necessary to support plant life. Such solution can be obtained by dissolving various combinations of chemicals; here is one example convenient for many typical soft waters:

	Spirulina Culture Medium
g/l	**Fertilizer (grams per liter)**
5	Sodium carbonate (soda ash)
5	Sodium chloride (salt)
2	Potassium nitrate
1	Sodium bicarbonate (baking soda)
1	Potassium sulfate crystallized
0.02	Urea
0.1	Monoammonium phosphate crystallized
0.2	Magnesium sulfate crystallized
0.02	Lime
0.005	Ferrous sulfate

The water should be clean or filtered to avoid foreign algae. Potable water is convenient. Water often contains enough calcium, but if it is too hard it will cause mud that is more a nuisance than a real problem. Brackish water may be advantageous but should be analyzed for its contents or tested. Seawater can be used under some very special conditions, outside the scope of this manual.

The culture medium is used to start new cultures. The make- up medium should best be as follows: carbonate is replaced by bicarbonate (8 g/l in total), urea is up to 0.07 g/l, and nitrate can be omitted.

Certain ions can be present in concentrations limited only by the total dissolved solids which should not be much over 25 g/l; these are: sulfate, chloride, nitrate, and sodium. Sodium or potassium nitrate can replace urea, the advantage being a large stock of nitrogen; urea is more efficient to supply nitrogen but is highly toxic for spirulina at too high concentration. Spirulina can grow on either nitrate or urea alone, but using both together is advantageous.

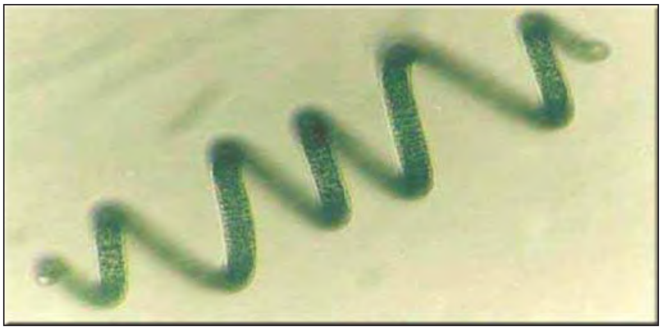
Phosphate, magnesium and calcium cannot be increased much without precipitating magnesium or calcium phosphate, possibly leading to imbalances in the solution.

Potassium can be increased, provided it does not become more than five times the sodium concentration. This makes it possible to use potash extracted from wood ash to replace sodium carbonate/bicarbonate should these not be available (let the potash solution absorb CO_2 from the air until pH has come down to 10.5 before using it).

If fertilizer grade chemicals are used, they should be of the "soluble" or "crystallized" type, not of the "slow release", granulated type. Micronutrients traces contained in the water and in the chemicals are sufficient to support the initial growth.

In case of necessity ("survival" type situations), nitrogen, phosphate, sulfate, sodium, potassium and magnesium can all be brought by urine (from persons or animals in good health, not consuming drugs) at 5 ml/l and iron by a saturated solution of iron in vinegar (use about 0.1 ml/l).

Solutions of iron should preferably be introduced very slowly with agitation into the medium. Dripping is best.



Seeding

Choose a spirulina strain containing a high proportion of coiled filaments (less than 25 % straight filaments, and if available 0 %), easy to harvest, and with at least 1 % of gamma-linolenic acid (GLA) based on dry weight.

Concentrated spirulina seed culture can be obtained either from the floating layer of an unagitated culture, or by rediluting a freshly filtered biomass (beware of lumps). A concentration of up to 3 g spirulina (dry) per liter is permissible if storage and transportation last less than a week's time, provided the seed culture is aerated at least two times a day. If aeration is continuous, the concentration may be up to 10 g/l (weights of spirulina always refer to contained dry matter).

It is advisable to maintain the growing culture at a fairly high concentration in spirulina after each dilution with culture medium, about 0.3 g/l: the "Secchi disk" reading (see Appendix 1) should not be above 5 cm, i.e. the color of the culture should stay clearly green (otherwise shading is mandatory). The rate of growth is about 30%/day when light and temperature are adequate and the make-up culture medium is based on bicarbonate (without carbonate).

As growth is proportional to the area of the culture exposed to light, it is recommended to maximize this area (i.e. use the minimum feasible depth during the expanding area period, generally 5 to 10 cm).

When the final area and depth (10 to 20 cm) are reached in the pond, let the spirulina concentration rise to about 0.5 g/l (Secchi disk at about 2 cm) before harvesting.

Harvesting

When spirulina is in good condition, separating it from the water is an easy operation, but when it gets too old and “sticky” harvesting may become a nightmare.

The best time for harvesting is early morning for various reasons: the cool temperature makes the work easier, more sunshine hours will be available to dry the product, the % proteins in the spirulina is highest in the morning. There are basically two steps in harvesting:

1. Filtration to obtain a “biomass” containing about 10% dry matter (1 liter = 100 g dry) and 50 % residual culture medium,

2. Removal of the residual culture medium to obtain fresh spirulina biomass, ready to be consumed or dried, containing about 20% dry matter and practically no culture medium.

Filtration is simply accomplished by passing the culture through a fine weave cloth, using gravity as the driving force. Synthetic fiber cloth (especially polyamide or polyester) with a mesh size of about 30 to 50 microns is the preferred filtering medium. Supporting the filtration cloth by a net will accelerate somewhat the filtration and protect the cloth against rupturing, but a simple bag made from the cloth works well also. The filter can be installed above the pond to directly recycle the filtrate.

The culture to be harvested should be passed through a sieve (mesh size about 200 μ) to remove foreign matter such as insects, larvae, leaves and lumps of polysaccharide or mud.

When spirulina floats, which is the normal case without agitation, it is efficient to scoop out the “cream”, using a straight edge pail. Harvesting the floating layer (generally richer in spiralled spirulina) will tend to increase the % straight spirulina in the culture. Straight spirulina is more difficult to harvest. So actually it is not recommended to harvest the floating layer when both straight and spiralled spirulina are present.

Filtration is accelerated by gently moving or scraping the filter cloth. When most of the water has filtered through, the biomass will agglomerate into a ball, leaving the cloth clean. This desirable condition happens mostly when the biomass is richer in spiralled forms and the culture medium is clean. Otherwise it may be necessary to scrape it out from the cloth.

The final dewatering is accomplished by pressing the biomass enclosed in a piece of filtration cloth plus a strong cotton cloth, either by hand or in any kind of press. The simplest is to apply pressure (0.15 kg/cm^2 is enough) by putting a heavy stone on the bag containing the biomass. The “juice” that is expelled comes out first colorless, later it turns green and the operation must then be discontinued otherwise too much product will be lost. For the usual thickness of cake (about one inch after pressing), the pressing time is about 15 minutes. Practically all the interstitial water (culture medium) is removed, and some rinsing may be effected by the internal juices from ruptured cells. The pH of the well pressed biomass is near 7 (neutrality).

This pressing operation effects a more efficient separation of the residual culture medium than washing the biomass with its weight of water on the filter. Washing with fresh water may cause rupture of the cell wall of the spirulina due to osmotic shock, leading to loss of valuable products; it may also introduce germs contained in the wash water. Washed biomass is a lot more prone to fermentation than pressed biomass. Pressed biomass contains twice as much dry matter as unpressed biomass, which reduces the drying time.

When the biomass is too “sticky”, for instance 100 % straight filaments, it may not be possible to dewater it: in such case, it must be washed.



Harvested spirulina roll on screen • Pressing to remove water • Extruding noodles into a dehydrator

Feeding the culture

The nutrients extracted from the culture medium by the harvested biomass should be replaced to maintain the fertility of the culture medium.

The main nutrient is carbon, which is spontaneously absorbed by the culture from the air, as carbon dioxide (CO_2), whenever the pH of the medium is above 10. However the air contains so little CO_2 that this absorption is a slow process, corresponding to a maximum productivity of 4 g spirulina/day/m^2. This maximum rate is reached at or above pH = 10.5.

Extra CO_2 can be introduced to increase the productivity, either pure CO_2 gas (from fermentation or from a cylinder). The gas is bubbled into the medium, under a piece of floating plastic film (about 4 % of the area of the pond).

Another popular, although usually costly, means of feeding carbon is bicarbonate. Adding bicarbonate is an easy and efficient way of reducing the pH, but it increases the salinity; to maintain the salinity, it is mandatory to drain part of the culture medium from time to time and replace it by new medium rich in bicarbonate. Disposal of the drained medium may be an environmental problem and the cost of the chemicals consumed may be uneconomical.

The amount of gas or bicarbonate to be fed is adjusted to control pH at around 10.4. PH lower than 10.2 may cause an overproduction of undesirable, but not dangerous, exopolysacharide (EPS). A good practical dose of carbon feed is the equivalent of 40 % of the spirulina produced (i.e. about 0.8 kg of CO_2 per kg of dry spirulina harvested).

Apart from carbon, spirulina requires the usual major biological nutrients: N, P, K, S, Mg, Ca, Fe, plus a number of micronutrients. In many cases, the micronutrients and the calcium need not be fed to the culture, being supplied as natural impurities contained in the make-up water and the chemicals used as food for the spirulina. In some locations, the water contains a large excess of calcium, magnesium or iron that may become a nuisance by producing abundant mud.

The major nutrients can be supplied in various ways, preferably in a soluble form, but even insoluble materials will slowly be dissolved as the corresponding ions are consumed by spirulina in the medium. Availability, quality and cost are the main criterion for selecting the sources of nutrients, but their content in valuable micronutrients may also affect the choice.

If fertilizer grade chemicals are used, they should be of the "soluble" or "crystallized" type, not of the "slow release", granulated type. Beware of the contents in "heavy metals" (mercury, cadmium, lead and antimony), as spirulina readily absorbs these and strict specifications must be met.

Natural nitrate from Chile, where available, is a good source of nitrogen, not only on the basis of its low cost but also because it contains many valuable nutrients apart from nitrogen. But very generally the cheapest source of nitrogen is urea. Urea, made up of ammonia and CO_2, is an excellent nutrient for spirulina but its concentration in the medium must be kept low (below about 60 mg/liter.

Excess urea is converted either to nitrates or to ammonia in the medium. A faint smell of ammonia is a sign that there is an excess of nitrogen, not necessarily harmful; a strong odor however indicates an overdose.

Fertilizers other than urea can be fed every month or so, but urea (or urine) has to be fed daily, based on the average production expected.

	Spirulina Makeup Medium
	Nutrient formula per kg of harvested spirulina dry product:
300 g	Urea
50 g	Monoammonium phosphate
	(concentrated pure phosphoric acid may replace the phosphate)
30 g	Potassium sulfate
	(40 g if no potassium nitrate is used)
30 g	Magnesium Sulfate
10 g	Lime
2.5 g	Iron Sulfate
	(iron sulfate for lawns is not suitable) (iron can be supplied by a saturated solution of iron in vinegar (use about 100 ml/kg) plus some lemon juice).
5 ml	Micronutrients solution *(optional)*

Taking care of the culture

Apart from harvesting and feeding, a spirulina culture requires some attention in order to be kept in good condition. Agitation is a requisite. Continuous agitation however is not required.

One third of full sun will saturate the photosynthetic capacity of spirulina, but shading is not required except to reduce the consumption of water (evaporation) or the temperature (< 38°C) or the pH (< 11.3). The temperature will practically never be too high, but the pH may soon become too high if insufficient carbon is supplied.

The depth of culture must be kept between 10 and 20 cm. Evaporation must be compensated for by adding water. Rains must be compensated for either by evaporation or by draining part of the medium (in the latter case, add the chemicals corresponding to the volume of medium drained).

Accumulation of mud may cause some to float due to anaerobic fermentation gases, and this will disturb the harvesting process. Therefore it is recommended to agitate the mud layer with a broom from time to time. If too much mud accumulates at the bottom of the pond, it can be removed by pumping or siphoning (preferably while the spirulina is floating, in order to reduce the loss). Add new culture medium to replace the volume removed. Of course another way to remove the mud is to provisionally transfer the culture into another pond and clean the bottom.

In large industrial spirulina farms, continuous monitoring of the elements contained in the culture medium makes the exact make-up of individual micronutrient possible. But this is too costly for small-scale operators, who then have to rely on renewing the culture medium or on the addition of minor amounts of a concentrated solution of micronutrients as mentioned above.

Excessive production of exopolysaccharide (EPS) by the spirulina or its too slow biodegradation will cause "stickiness" of the biomass and/or a flocculation of spirulina into undesirable aggregates. To control this, maintain higher pH, nitrogen and iron contents in the culture medium. The pH should be above 10, preferably above 10.3. Partial or total renewal of the culture medium helps remedy the "stickiness" of the biomass.

Excessive turbidity of the filtrate may be reduced by slowing down the growth of spirulina and/or maintaining agitation during the night. This applies to the organic mud and EPS also. The culture is an ecosystem inside which various microorganisms (useful bacteria and zooplankton) live in symbiosis, resulting in a continuous, but slow, cleaning effect of the medium. If pollutants are produced more rapidly than this biological cleansing system can absorb, renewal of the medium will be necessary to keep it clean. Slowing down the growth may be obtained by shading or by reducing the rate of harvesting.

When stressed by a pH or salinity sudden variation, for instance by a heavy rain (more than 10% of the culture volume), spirulina may sink to the bottom of the pond, where they will be in danger of dying from suffocation. To facilitate recovery, agitate the bottom often to give them more chance to disentangle from the mud.

The culture may become colonized by predators living on spirulina, like larvae of mosquitoes and ephydra flies, or amoebas. In our experience these invaders cause no other trouble than reducing the productivity. Often they can be controlled by increased salinity, pH or temperature, or they disappear by themselves after a few weeks.

If the concentration of spirulina is too low, the culture may be invaded by chlorella (a unicellular, edible alga). Fortunately, chlorella pass through the filter during harvesting: so you can harvest all the spirulina, recover the wet biomass, wash it with some new culture medium and use it to restart a new tank; The contaminated medium can either be discarded or sterilized. The same procedure should be applicable to diatoms.

Toxic algae like anabaena and microcystis do not grow in a well tended spirulina culture, but for safety's sake it is recommended to have the culture checked by a microscopic examination at least once a year.

A culture of young artemias can be used to check the absence of toxic algae: boil a little of the spirulina culture to be checked (10 % of the artemias culture) during one minute, cool it and mix it with the artemias culture: observe the small animals; if they retain their vitality for at least 6 hours, there is no toxic algae. Artemias eggs are sold by aquarium stores.

Usual pathogenic bacteria do not survive the high pH (> 9.7) of a spirulina culture; however a microbiological assay of the product should be made also at least once a year. Contaminations most generally occur during or after harvesting.

The color of the culture should be deep green. If it turns yellowish, this may be due to either a lack of nitrogen or an excess of light (photolysis) or of ammonia (excess of urea). In the latter two cases recovery is generally possible within two weeks while resting the culture under shading.

Storing the product

There is no question that freshly harvested pressed biomass is superior to any other form of spirulina. However it will not keep more than a few days in the refrigerator, and no more than a few hours at room temperature.

Adding 10 % salt is a way to extend these keeping times up to several months, but the appearance and taste of the product change: the blue pigment (phycocyanin) is liberated, the product becomes fluid and the taste is somewhat like anchovy's paste.

Quick freezing is a convenient way to keep fresh spirulina for a long time.

Drying is the only commercial way to store and distribute spirulina. If suitably packaged under vacuum in aluminized heat sealed plastic bags, dry spirulina is considered good for consumption up to five years. But drying is an expensive process and it generally conveys the product a different and possibly unpleasant taste and odor, especially if the product is spray dried at high temperature as is the case in large-scale plants.

Drying

The industrial type of spirulina dryer is the spray dryer which flash dries fine droplets at very high temperature and yields an extremely fine powder of low apparent density. This type is outside the reach of artisan producers. So is freeze-drying, the best way of drying but far too expensive and complicated.

Sun drying is the most popular among small producers, but requires a few precautions. Direct sun drying must be very quick, otherwise the chlorophyll will be destroyed and the dry product will appear bluish.

Whatever the source of heat, the biomass to be dried must be thin enough to dry before it starts fermenting. Basically two types of shapes are used: thin layers of rather fluid biomass laid on a plastic film, and rods ("spaghetti") laid on a perforated tray. In the former case the air flows horizontally over the film, while in the latter one it flows either horizontally or vertically through the tray. The rod shape is theoretically better as evaporation can take place all around; rods are obtained by extrusion to a diameter of 1 to 2 mm. But rods must be sturdy enough to maintain their shape, so this type of drying is restricted to biomass that can be dewatered by pressing into a firm paste.

Warm, dry air passed over or through the biomass to be dried must have a high velocity at the beginning of the drying process. Later on in the process the velocity of the air is less important than its dryness (therefore it is usual to end up with air heated at 65°C). Total duration should not exceed a few hours, preferably 2 hours.

During the drying process and afterwards the product must be protected against contaminations from dust and insects and should not be touched by hands.

Drying temperature should be limited to 68°C, and drying time to 7 hours. Incipient fermentation during drying can be detected by smelling during the drying process as well as afterwards. However it is customary that a rather strong smell evolves from the biomass at the beginning of the drying.

The dry chips or rods are converted to powder by grinding in order to increase their apparent density. The best storage is in heat sealed, aluminized plastic bags.

Consumption

Persons who cannot stand the taste and odor of spirulina most probably were exposed to low quality product. Good quality fresh spirulina is so bland it can replace butter on toasts and can enrich almost any dish; cold drinks can be prepared by mixing it with fruit juices. Fresh spirulina paste is easily mixed, diluted, extruded.

There are literally thousands of possible recipes making use of spirulina either fresh, frozen or dry, raw or cooked. Above 70°C the gorgeous green color often turns brown in the presence of water. So you can choose your preferred color for soups and sauces.

Appendices

A1) MEASURING THE CONCENTRATION IN SPIRULINA WITH THE SECCHI DISK

The "Secchi disk" is a self-made instrument: a piece of white plastic fixed at the tip of a graduated rod. Dip it vertically into the spirulina culture until you just cannot see the white piece; the reading in centimeters gives an approximate value of the concentration. If the medium itself (the filtrate) is turbid, use the appropriate curve, after measuring the turbidity of the filtrate using a black Secchi disk, expressed in cm in the same way as the concentration.

As the reading depends on the eye of the operator, every one should make his own graph, based on absolute measurements of the concentration (by filtering a given amount, drying in the oven and weighing). The reading also depends on the shape of the filaments.

The following graphs were established by the author for the Lonar (coiled) and for the Paracas (loosely coiled, almost straight) strains. They can be used as approximations.

A2) MEASURING THE SALINITY OF THE CULTURE MEDIUM

Use a densitometer calibrated for densities above 1.

Temperature correction: D = DT + 0.000325 x (T - 20)

Where D = density at 20 °C, DT = density at T °C, expressed in kg/liter

Salinity SAL is calculated from D by the formulas:

If D > 1.0155, SAL = 1275 x (D - 1) - 0.75, g/liter

Otherwise, SAL = 1087 x (D-0.998)

A3) MEASURING THE ALCALINITY OF THE MEDIUM (ALCALIMETRY)

Titrate the medium using normal hydrochloric acid (concentrated acid diluted 10 times with water). Use pH 4 as the end point. Alkalinity (moles of strong base/liter) is the ratio of the volume of acid used to the volume of the sample of medium.

A4) MEASURING THE PH

The pH meter should be calibrated at from time to time. If standard calibration solutions are not available, self-made solutions can be made for calibration as follows (pH at 25°C):

pH 11.6: 10.6 g sodium carbonate per liter water (freshly made solution or flask kept closed).

pH 9.9: 5.5 g sodium bicarbonate + 1.4 g caustic soda per liter water, or: 4.2 g sodium bicarbonate + 5.3 g sodium carbonate per liter water; maintain in contact with the atmosphere and make up for evaporated water.

pH 7: 5.8 g monoammonium phosphate + 11 g sodium bicarbonate per liter of water; maintain in a closed bottle.

pH 2.8: standard vinegar (6 % acetic acid, density 1.01).Temperature correction on pH: pH at 25°C = pH at T°C + 0.00625 x (T - 25).

A5) COMPARING SPIRULINA SAMPLES

Protein, iron, gamma-linolenic acid, heavy metals contents and the microbiological analysis can only be performed by a competent laboratory, but a few homemade tests can give an idea of the quality of a spirulina sample by comparing with a reference product.

Examination of color, odor and taste may reveal significant differences between samples. The green color should tend more towards the blue than the yellow.

The "pH test" reveals the degree of removal of the culture medium from the biomass. On fresh spirulina simply measure the pH: if near 7, the biomass is pure. For dry spirulina powder, mix a 4 % suspension in water and measure the pH: the initial pH should be near 7 (for many commercial products it is near 9 or even 10), and after 12 hours it usually falls down to well below 6. For biomasses that were washed with acidified water, the initial pH may be acidic (< 7).

To assay the blue pigment phycocyanin content proceed as for the pH test on dry samples, mixing several times the suspension. After 12 hours, take a one drop sample of the decanted solution and put it on a filter paper (for instance the "Mellita" filter paper for coffee making) maintained horizontal. The amount of blue color in the stain is proportional to the concentration of phycocyanin in the sample. Some spirulina samples require to be heated to 70°C before the test for the blue pigment to be fully released into the solution.

To assay the carotenoids content, mix the dry powdered sample with twice its weight of acetone (or of 90 % ethanol) in a closed flask, wait 15 minutes, and put one drop of the decanted solution on filter paper. The intensity of the brown-yellow color of the stain is proportional to the concentration of carotenoids (and hence of beta-carotene) in the sample. Old samples stored without precautions contain practically no carotenoids.

A6) HARVESTING AND DRYING SPIRULINA

Filtration is done on a 30 µ mesh cloth. When most of the water has filtered through, the biomass will agglomerate into a "ball" under motion of the filtering cloth, leaving the cloth clean (this desirable condition happens when the biomass is richer in spiral forms and the culture medium is clean). At this stage the biomass contains 10% dry matter and it has a soft consistency; it will not stick to plastic materials but glide on it.

Final dewatering of the biomass is accomplished by pressing the biomass enclosed in a piece of filtration cloth, either by hand or in any kind of press. The simplest is to apply pressure (0.15 kg/cm^2 is enough) by putting a heavy stone on the bag containing the biomass. The "juice" that is expelled comes out clear and colorless, and the operation must then be discontinued when no more liquid drops out. For the usual thickness of cake (about one inch after pressing), the pressing time is about 15 minutes. Practically all the interstitial water (culture medium) is removed. The pH of the pressed biomass is near 8 and may even be brought below due to breakage of some spirulina cells, but it is not advisable to bring it too low.

This pressing operation effects a more efficient separation of the residual culture medium than washing the biomass. Washing with fresh water may cause rupture of the cell wall of the spirulina due to osmotic shock, leading to loss of valuable products; it may also introduce germs contained in the wash water.

Pressed biomass contains twice as much dry matter as unpressed biomass, which reduces the drying time. It has a firm consistency (can be cut by a knife like cheese). It can be eaten as is.

The biomass to be dried must be thin enough to dry before it starts fermenting. It is extruded into fine rods ("spaghetti") of a diameter of 1 to 2 mm onto a plastic perforated tray (or nylon mosquito net). The rods must be sturdy enough to maintain their shape, so this type of drying is restricted to biomass that can be dewatered by pressing into a firm consistency.

In India the "indiappam makker" kitchen instrument can be used for extruding (the wooden type is preferred to the aluminum one).

During the drying process as well as afterwards the product must be protected against contaminations from dust and insects and should not be touched by hands.

Drying temperature should be limited to 68°C, and drying time to 7 hours. With good ventilation and low charge (1 kg fresh rods/m^2 of tray) the drying time may be reduced to 2 hours. The final % water should be less than 9. The dry product detaches itself easily from the tray.

Incipient fermentation during drying can be detected by smelling during the drying process as well as afterwards. The dry rods are usually converted to powder by grinding in order to increase their apparent density. The best storage is under vacuum in heat sealed, aluminized plastic bags.

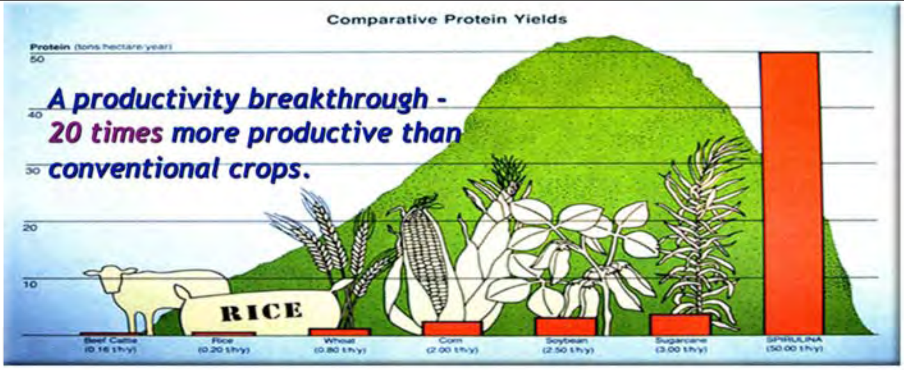
At his spirulina greenhouse at Le Castanet in the South of France in 2002, Jean-Paul Jourdan demonstrated how he grows, harvests and dries spirulina, producing a tasty food product.

In his manual "Cultivez Votre Spiruline", he describes how to cultivate spirulina on a family scale.


SMART MICROFARMS
Algae Evolution from Large Farms to Microfarms
by Robert Henrikson
SmartMicrofarms.com
AlgaeCompetition.com
AlgaeAlliance.com
SpirulinaSource.com
SMART MICROFARMS
PO Box 71024, Richmond CA 94807 USA
roberthe@sonic.net • 808.264.8184
Earthrise, California
Cyanotech, Hawaii
Sekong, Laos (photo by Antenna)
Chad farm (photo by Georges Bonin)
Antenna, Kenya
Normandy, France
Smart Microfarm Testbed • Olympia Washington


Algae Evolution from Large Farms to Microfarms
Overview
Brief history of microalgae production over 40 years
Development of small farms in developing world
Microfarms and the new algae entrepreneurs
Algae microfarms empower people to grow high value healthy food locally

Why Algae?



Produced by commercial farms for over 30 years around the world

Proven market value as nutritional superfood for over 30 years

Nutrient dense phytonutrients offer valuable medical benefits

Just Close Your Eyes And Chew

By Eric Perlman

Dr. William J. Oswald and Fran Ong

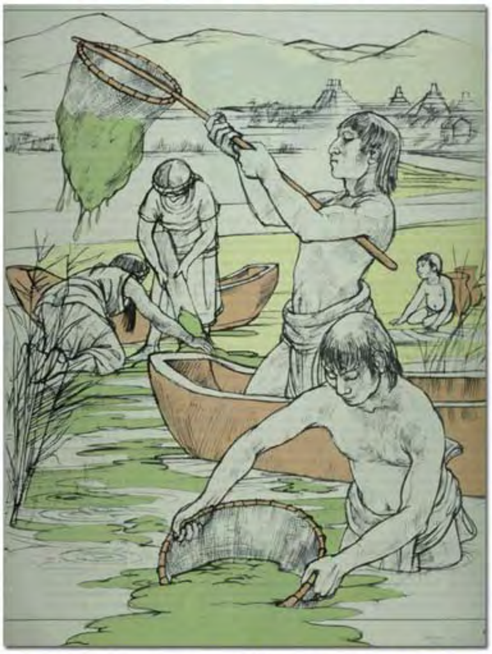
"Algae can grow faster, produce more food, and purify more body wastes for recirculation than any other biological organism."

SMART MICROFARMS **BRIEF HISTORY**

Microscopic algae was introduced as a *'Food of the Future'* 35 years ago.

San Francisco Examiner article about algae in 1977

Rediscovery of microalgae harvest by traditional people



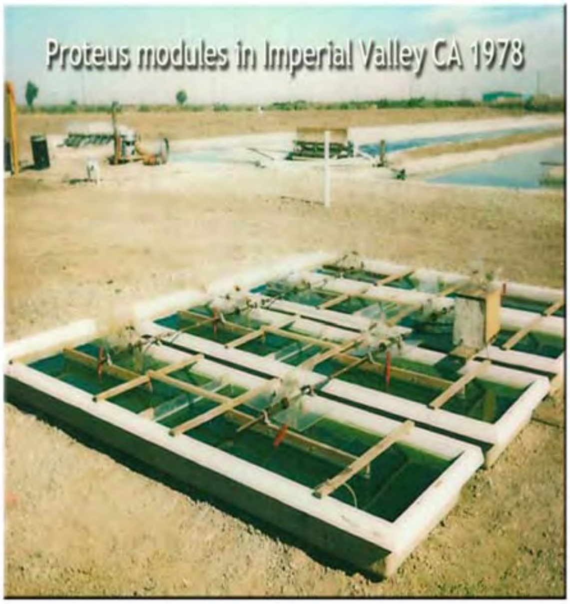
Aztec harvest in Mexico in 1500s

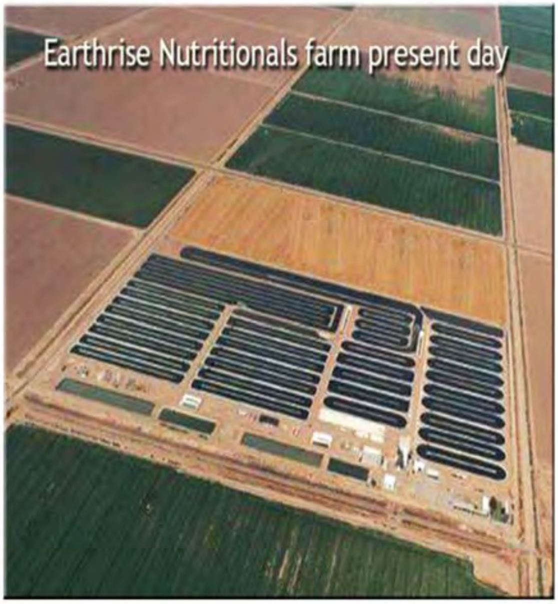
Kanembu spirulina ladies of Chad today

The first major *spirulina* algae producer was Sosa Texcoco in Mexico in the 1970s.

Growing in alkaline soda lake near Mexico City. Closed in mid 1990s.

In California, the first *spirulina* algae farm began in 1977





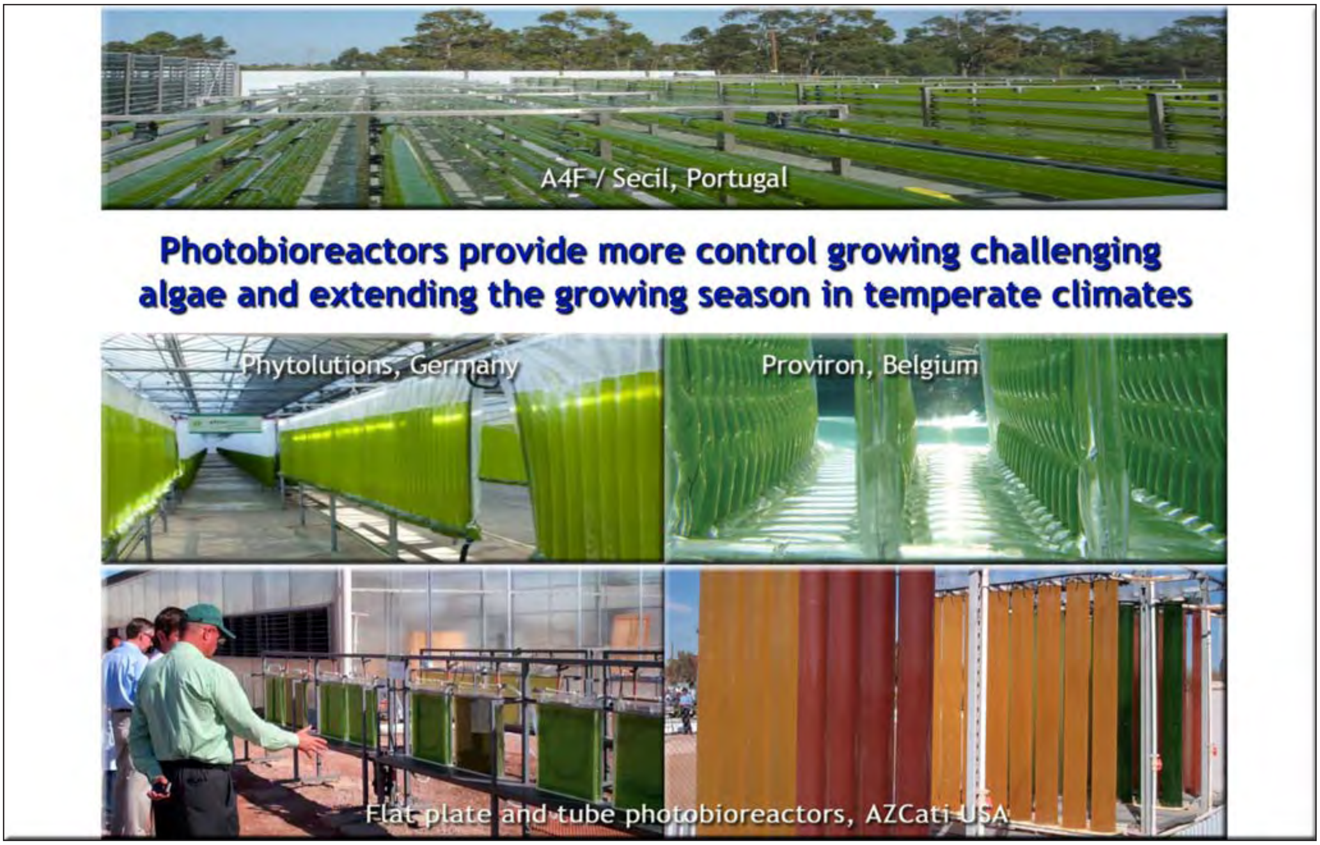
These small growing modules helped launch Earthrise Nutritionals *spirulina* farm in Imperial Valley, California

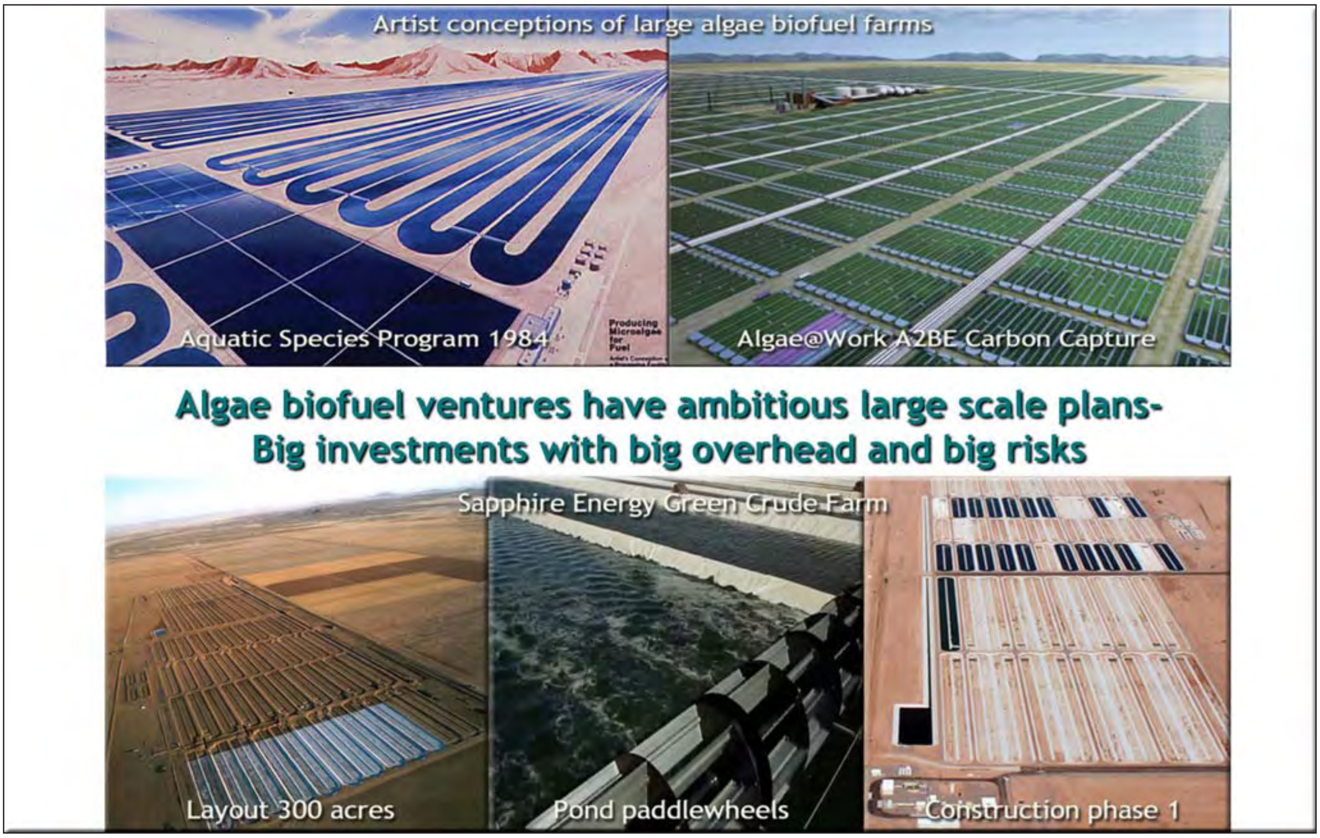
Cyanotech in Hawaii began growing *spirulina* In Hawaii in the 1980s and added *haematoccocus* for astaxanthin in the 1990s

In the past 30 years, large commercial microalgae farms have produced food and feed supplements for global markets

Spirulina
Chlorella
Dunaliella
Haematoccocus

For over 20 years, using industrial fermentation, Martek Biosciences has produced the DHA rich algae *schizochytrium* for food and feed products


A4F / Secil, Portugal
Photobioreactors provide more control growing challenging algae and extending the growing season in temperate climates
Phytolutions, Germany
Proviron, Belgium
Flat plate and tube photobioreactors, AZCati USA


Artist conceptions of large algae biofuel farms
Aquatic Species Program 1984
Algae@Work A2BE Carbon Capture
Algae biofuel ventures have ambitious large scale plans- Big investments with big overhead and big risks
Sapphire Energy Green Crude Farm
Layout 300 acres
Pond paddlewheels
Construction phase 1

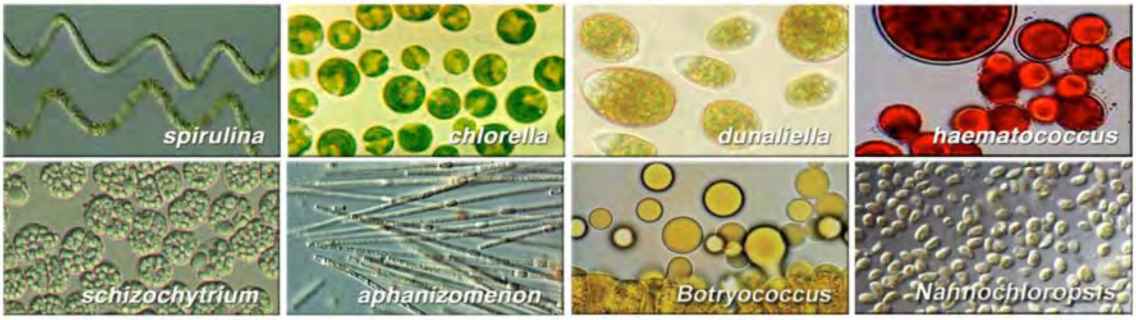
Most people have no idea how many food, feed and household products contain micro and macro algae

SMALL SCALE SYSTEMS

Parallel to large commercial farms has been the evolution of village systems in the developing world and recently algae microfarms in the developed world

First Prize winners in the International Algae Competition: Antenna France circular pond and Eco-Domaine organic microfarm in Normandy France.

Of the microalgae being commercially grown today, *spirulina* is the most often adopted for microfarms

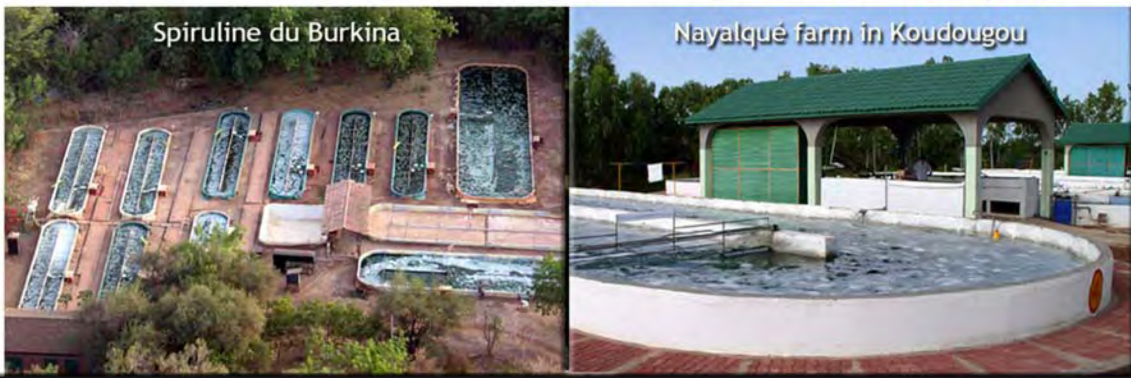


Spirulina has 6 advantages:

1. *Historically consumed safe nutritious food*
2. *Can successfully grow outdoors in ponds*
3. *Easy to harvest with microscreens*
4. *40 years published scientific medical research*
5. *Existing global market already developed*
6. *Lower cost of entry for small scale production*

Small farms in the developing world

Over the past 30 years small scale projects in Africa, Asia and South America have been growing spirulina for food for local people




Antenna farms in Africa and India against malnutrition
Antenna Nutritech Foundation, Madurai, South India
Since 1989, Antenna Switzerland and Antenna France have set up spirulina programs. Today there are farms in Burkina Faso, Cambodia, Central African Republic, Laos, Madagascar, Mali, Mauritania, Niger and India. Eight farms are running by themselves.
ANTENNA GREEN TONGUE
For healthy and active children
› Spirulina candy


Antenna farms with both humanitarian and commercial components
Cambodia
Togo
Madagascar

Growing spirulina for Auroville since 1997. Now producing 4000 kg per year at two farms and selling in Auroville and the domestic market.

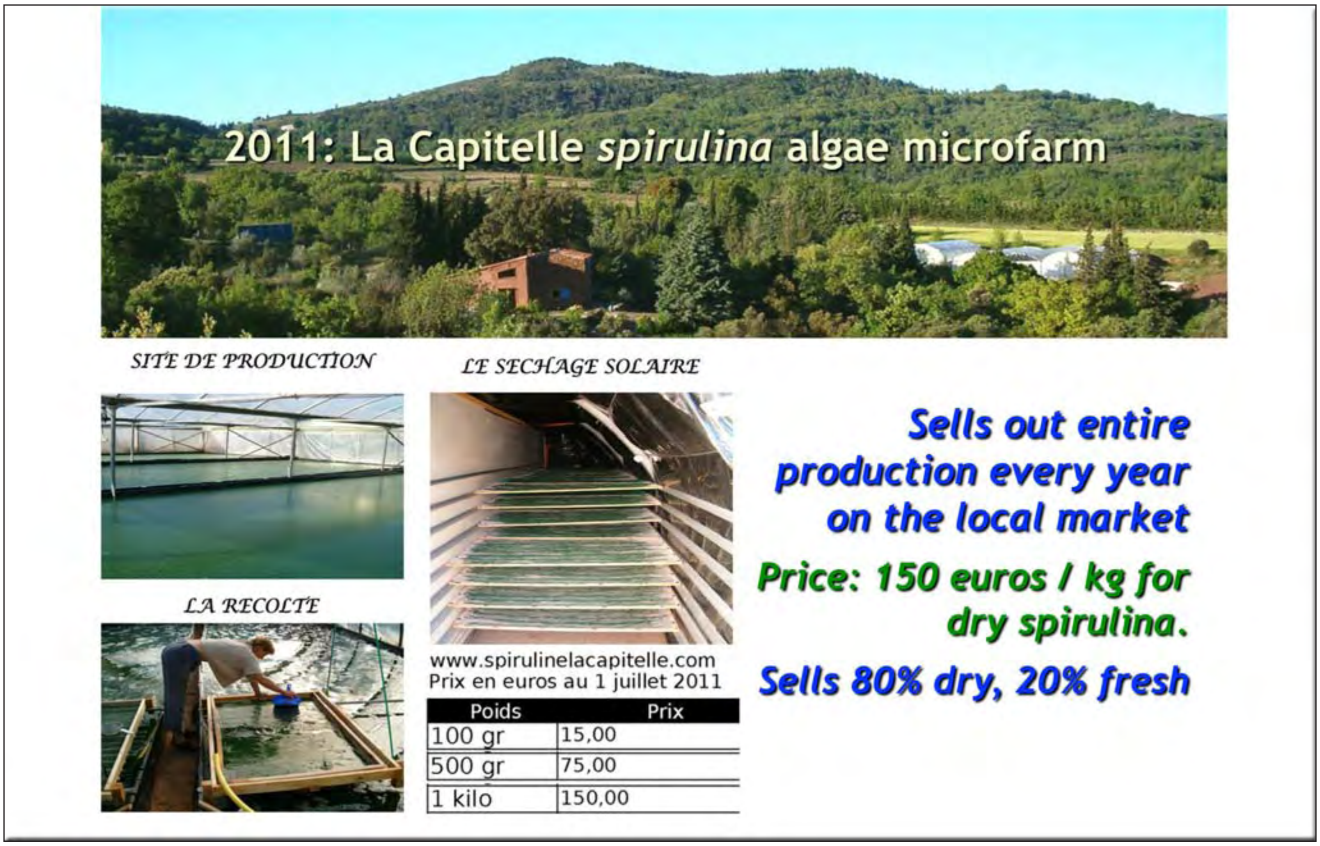
Algaepreneurs and the microfarm movement in France

French NGOs developed small scale *spirulina* systems in Africa and India. Upon returning, NGO technicians started small scale production in France.

In 2002, La Capitelle greenhouses produce over 300 kg in 5 summer months, selling everything direct to local customers. New business model emerges.

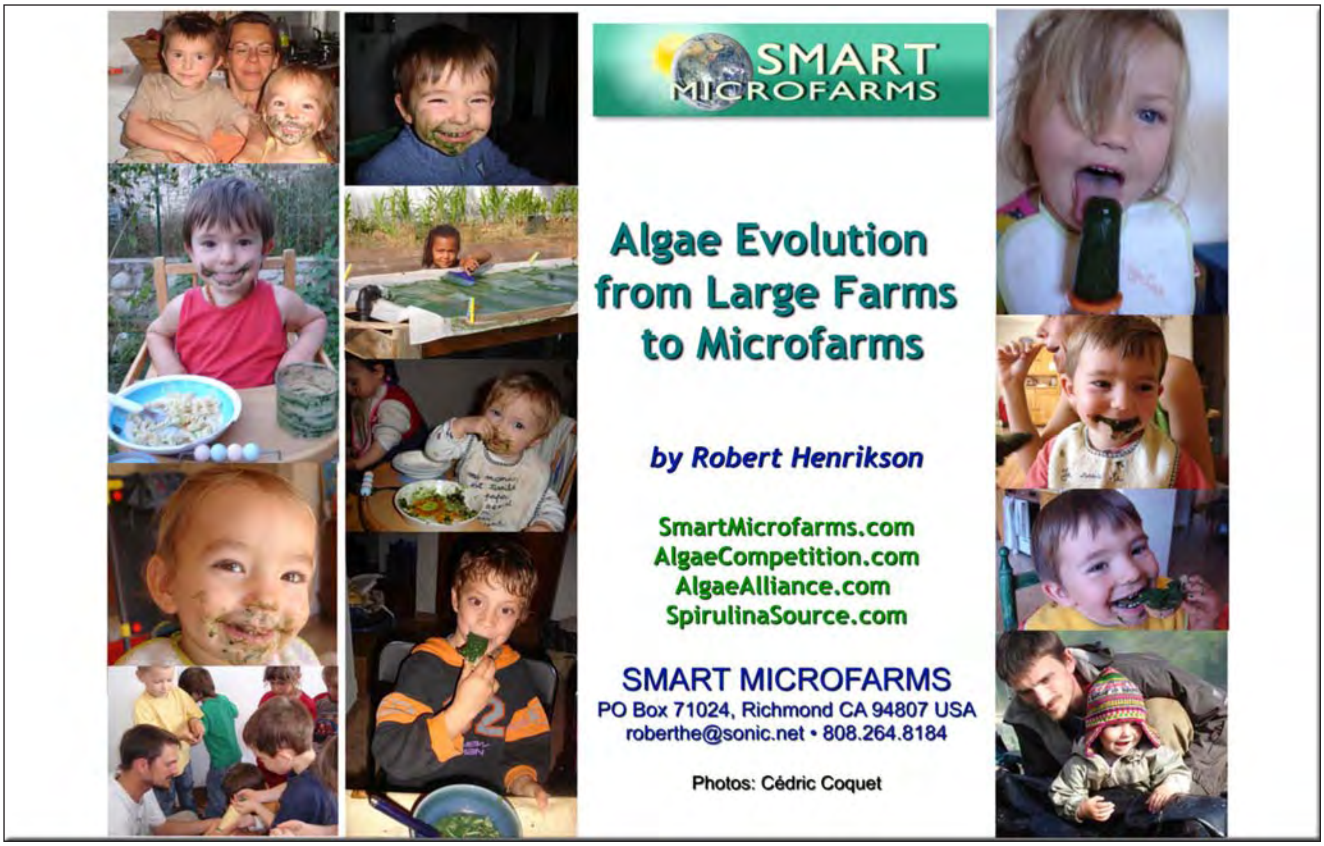

Viva La France!
2001: 1 spirulina microfarm
2012: 110 spirulina microfarms
In 2012, French microfarmers sold all they produced, supplying 10% of estimated French market demand
FEDERATION DES SPIRULINIERS DE FRANCE


French spirulina algae microfarmers
SPIRU-VIE
Ganges, South of France
Emmanuel Gorodetsky
Spiruline Solaire
high in the Alps
BernhardRampelt
Eco-Domaine in Normandy
Laurent Lecesve
SPIRULINA
in the Canary Islands
Peter Schilling


2011: La Capitelle spirulina algae microfarm
SITE DE PRODUCTION
LE SECHAGE SOLAIRE
LA RECOLTE
Sells out entire production every year on the local market
Price: 150 euros / kg for dry spirulina.
Sells 80% dry, 20% fresh
www.spirulinelacapitelle.com
Prix en euros au 1 juillet 2011
Poids Prix
100 gr 15,00
500 gr 75,00
1 kilo 150,00


Scaling up algae microfarms in greenhouses
Insulated greenhouse ponds to extend the growing season in northern climates
Smart Microfarm Testbed • Olympia Washington


Algae microfarms for urban farms and green rooftops?
Terrestrial, hydroponic and aquaponic greenhouse farms can now enhance their income stream with high-value algae food products.
New Whole Foods Market
Commercial Roof Farm
Brooklyn New York
Uncommon Ground Chicago
Urban Farmers Rooftop Basel
Brooklyn Grange Rooftop Farm
Rice Paddy City Farm Tokyo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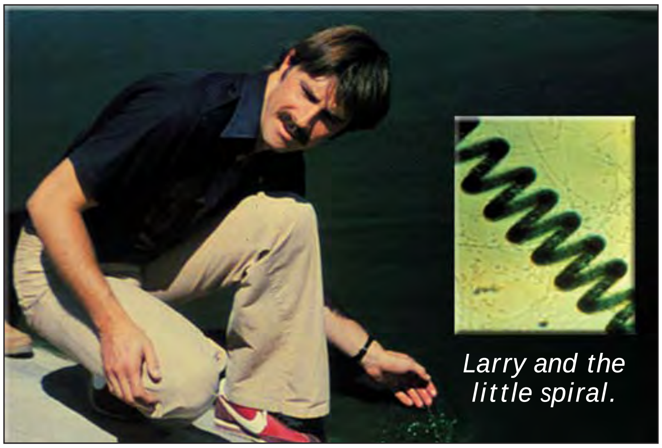
Photos: Cédric Coquet

Personal journey from small to large to small again

(adapted from Spirulina World Food by Robert Henrikson)

Over 37 years ago, Larry Switzer, a visionary bioneer and catalyst, founded Proteus Corp. in 1976 to develop spirulina algae as a world food resource. Proteus was funded by private California investors, committed to the vision. Joined by Robert Henrikson, this team began early cultivation.



Larry and the little spiral.

Larry had been looking for new solutions. He discovered microalgae was 20 times more productive as a protein source than any other food and could be grown with unused land and water. It was possible to cultivate on a large scale in many places worldwide. Spirulina was a safe food, consumed for hundreds of years by traditional peoples, and showed nutritional and therapeutic health benefits. If this blue-green algae were cultivated and consumed by millions of people, it would benefit the world's children and our planet's future.

However, it hadn't been done yet! No one had successfully cultivated spirulina on a large scale, produced it as a safe food, and convinced anyone they should eat algae! If it was an idea whose time had come, it was, nonetheless, a daunting task.

First farm site in Imperial Valley CA 1977.

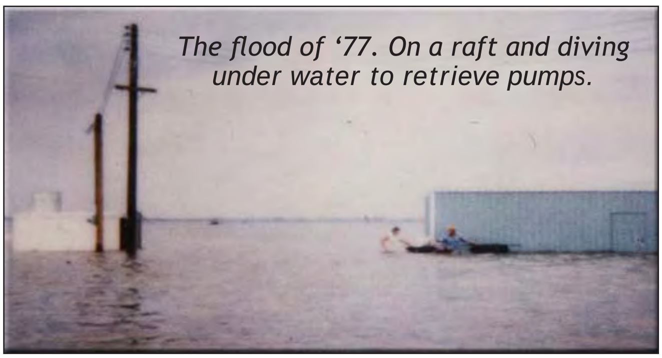
After building a prototype system in Concord, Larry and Robert left the comforts of Berkeley for California's hot Imperial Valley in early 1977. We were joined by Dr. Alan Jassby, who helped design the early systems and cultivation programs.

Growing spirulina culture in small pools.

Robert with the first paddlewheel pond.

For three years this small entrepreneurial team sweated in the desert to build a successful farm model. Just about everything that could go wrong, did, and every problem had to be overcome.

In August 1977, our first farm was wiped out by Hurricane Doreen! This August storm caused a one in a hundred year flood, and our little farm was in the middle of ten square miles under 4 feet of water!



The flood of '77. On a raft and diving under water to retrieve pumps.

Building the second pilot farm

We asked our investors for more funding, relocated, and started a second farm. Ron Henson showed up to help with construction. Ron eventually became Operations Manager of Earthrise Farms, and later Sales Manager for Earthrise Nutritionals.

Robert Henrikson, Ron Henson, Bruce Carlson, Larry Switzer.

Larry checks out fresh harvest.

We developed larger growing ponds, tested harvesting and drying, and felt confident that we could build a commercial farm. Then we began looking for new funding, several million dollars. To interest investors, we now had to prove we could actually sell algae to someone. We began importing spirulina, and formed a partnership with a Japanese company that had begun growing in Thailand.

Robert eats fresh spirulina harvest.

First farm site in Imperial Valley CA 1980.

Large production pond.

Fortunately we were not alone. Other algae bioneers emerged around the world.

A new planetary idea often incarnates through many messengers. This was true with spirulina. While Earthrise was underway in California, other companies began cultivation around the world. Hubert Durand-Chastel, now a Senator of France, encouraged a Mexican company to set up a farm in Lake Texcoco in the 1970s.

Israeli, Indian and European scientists began cultivation research. Others developed village and appropriate technology farms, notably Dr. Ripley D. Fox of France, and Dr. C.V. Sesahdri of India. Other bioneers emerged in their respective countries.

In 1980 in Thailand, a Japanese company, Dainippon Ink & Chemicals (DIC), built one of the first farms. This global company with a commitment to developing microalgae for food, biochemicals and pharmaceuticals, was led by visionaries who were fascinated with its potential. DIC Presidents, Shigekuni Kawamura and Takemitsu Takahashi, were long time spirulina sponsors, and funded development. Heading up the program was Hidenori Shimamatsu of DIC Bio Division.

Introducing algae to the natural food market

In 1978, we chose Earthrise as our trademark and symbol. Apollo astronauts witnessed the first Rising of the Earth from the moon's surface in 1969. This powerful image represents our awakening to the miracle of our living planet. We rediscovered that blue-green algae, the original photosynthetic life form, offers health benefits to ourselves, our society and our planet today. We dedicated these gifts to a new awareness of our Earth Rising.

Earthrise® Trademark and tablets 1979.

New Age Earthrise® Spirulina ad 1980.

Larry and Robert at Health Food Trade Show 1979.

We established Earthrise as a sales company directed by Robert Bellows and Terry Cohen of Boulder, Colorado. Earthrise® Spirulina began appearing in natural food stores in 1979, gaining popularity fast.

In 1981, *National Enquirer* pronounced spirulina a magic diet pill. Demand exploded overnight. Diet pill companies jumped on the bandwagon, and sold spirulina diet pills that didn't even contain any. There wasn't much real spirulina around.

The diet boom faded by 1983, but the market began to grow again by 1987. More people experienced health benefits from spirulina. Published scientific research documented its therapeutic benefits.

Earthrise Berkeley Team, 1981.

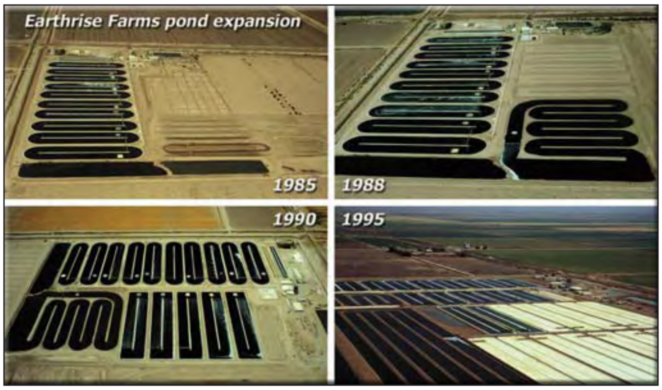
Natural Food Trade Show Team 1984.

First US Production: Earthrise Farms

We built a relationship with Dainippon Ink & Chemicals (DIC), and imported from their farm in Thailand for Earthrise. This unusual partnership between California entrepreneurs and Japanese corporate intrapreneurs blossomed. We shared a common vision of spirulina's coming impact on the world economy. Together we founded Earthrise Farms in 1982 the first US spirulina production farm.

Bellows, Henrikson, Ota, Yamada, Carlson, Shimamatsu, Jassby, Sonnenville.

Earthrise® Spirulina ad 1984.



Earthrise Farms expansion over the years.

Earthrise Farms on 108 acres in 1996.

In following years, as funding was needed for expansion, Earthrise Farms became a subsidiary of DIC. Under the leadership of Yoshimichi Ota, the farm expanded in size and quality assurance. Dr. Amha Belay from Ethiopia, land of spirulina lakes, became Senior VP, responsible for cultivation, and research. Juan Chavez, VP and Production Manager, expanded production to 500 tons a year by 1996.

Juan Chavez, Yoshimichi Ota, Dr. Amha Belay.

Earthrise® Spirulina products go global

As President since 1981, I sold the Earthrise sales company to DIC in 1988 to begin a dynamic new growth phase. With new financial resources, we rapidly expanded. Through the 1990s, Earthrise Company developed health food supplement products for distributors around the world.

By 1996, Earthrise® trademark products were sold in 40 countries, making it the world's best selling spirulina at that time.

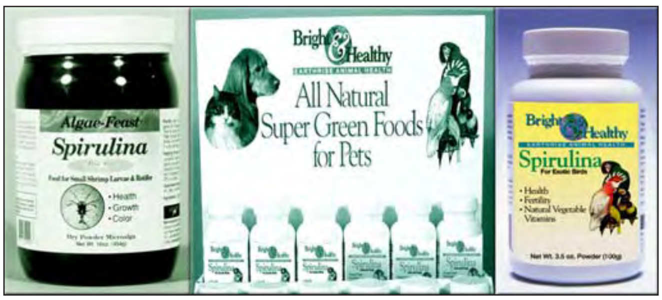
Earthrise® Spirulina ad 1997.

Earthrise developed an extensive line of food supplements for the US market of about 10,000 natural and health food stores and other outlets.

Robert Henrikson demos a green smoothie.

Earthrise® USA product line, 1996.

Earthrise® tablets sold by Unibond in China, 1996.



Earthrise® pet food, fish and bird supplements.

Visit to a village farm in Togo, 1988

Earthrise sponsored algae humanitarian projects in the 1980s and 1990s. One of these was the integrated health and energy system in a remote village in Northern Togo. Dr. Fox developed an experimental system using appropriate technology to convert village waste through biogas digestion into biogas and nutrients for growing spirulina.

Ripley and Denise Fox with local spirulina farm team, Farende, Togo 1988.

I visited the Togo project in 1988, and experienced first hand how small algae farms could play an important role in benefiting a local community.

The people of Farende Togo, 1988.
Photocollage: Robert Henrikson.

Children of Chernobyl, 1995

Earthrise and DIC donated spirulina to hospitals in the Ukraine and Belarus. Doctors reported giving children 5 grams of spirulina per day reduced urine radioactivity by 50% in 20 days and concluded spirulina decreased radiation dose load from contaminated food and was advisable to treat people with radiation sickness.

In 1995, I visited hospitals and met with doctors and children in Ukraine, imagining how much better it would be if this region had its own algae production.

DM 4,-
öS 28,-
SFR 4,-

bulletin

Der Informationsdienst für gesundheitsbewußte Menschen 11/97

Erfolge mit Mikroalgen in der Naturheilpraxis

Spirulina in der Therapie

VON SABINE GERICKE

Spirulina ist eine winzige, spiralförmige Alge, reich an Proteinen, essentiellen Aminosäuren, Vitaminen, Mineralstoffen und essentiellen Fettsäuren wie der Gamma-Linolensäure. Sie wird kommerziell hergestellt und auf der ganzen Welt als Nahrungsergänzung im Gesundheitshandel vertrieben. Bis vor Senkung des Cholesterinspiegels und Einflüssen auf das Krebsgeschehen bis hin zur Stimulation des Immunsystems, Vermehrung der Lactobazilli im Darm, verminderter Toxizität von Schwermetallen und Medikamenten in den Nieren, bis zum Schutz vor Strahlung reicht.

Krankenschwester mit einem der jungen Strahlenopfer in Weißrußland, welche an einer Spirulina-Therapie teilnahmen.

zum Beispiel der Schwangerschaft und größerem beruflichem oder privatem Streß, bietet sich Spirulina aus verschiedenen Gründen als Ergänzung der Nahrung an. Welche einzelnen Bestandteile im synergetischen Zusammenspiel hierbei eine Rolle spielen, lesen Sie bitte in den folgenden Abschnitten. ►

Franz Nacke und Robert Henrikson in der Kinderklinik in Kiew.

IN DIESER AUSGABE

Report on the use of spirulina for treating radiation sickness in the Ukraine, 1995.

First microfarm in France, 2002

At a conference in Mialet in the South of France in 2002, Jean-Paul Jourdan demonstrated growing spirulina in his personal greenhouse on his farmstead. Then the group moved to the new La Capitelle spirulina microfarm, established in 2001 by Philippe and Estelle Calamand.

La Capitelle was the first commercial spirulina microfarm in France. Philippe showed how he grew, harvested and processed spirulina on a small scale making his own products that he sold directly in his local community.

Philippe Calamand, Ripley Fox, Denis von der Weid view La Capitelle spirulina microfarm, 2002.

Mialet, France 2002. Ripley Fox, Robert Henrikson, Jean-Paul Jourdan, Philippe Calamand, Hubert Durand-Chastel, Hendrik van Poederooijen.

Algae Tourism in Thailand, 2010

Boonsom Spirulina Farm near Chiang Mai is now the largest in Thailand, with 40,000 square meters of growing pond area, and is ISO 22000 Certified. The pioneering founders are Professors Jiamjit and Somchye Boonsom.

Beyond making Green Diamond natural food supplements, Boonsom has an inviting and innovative program with a spirulina health spa, offering spirulina waffles, ice cream, beer and facial masks. Boonsom Farm represents an excellent business model showing the benefits of algae tourism.

Over 20 years, family owned Boonsom Farm has grown from a small farm to a medium size farm.

Touring microfarms in France, 2011

By 2011, an estimated 100 small spirulina producers stretched from Southern France to as far north as Normandy. A school at the CFPPA Center in Hyères was training more spirulina growers each year, In 2010, growers established the Fédération des Spiruliniers de France with 80 members. I was overdue to visit some of these French microfarmers.

Ripley and Denise Fox hosted a meeting of the Fédération des Spiruliniers in Laroque in June 2011.

I toured Spiru-Vie and Ferme de la Borie in the South of France. Met with members of the Spirulina Federation and learned of their progress, challenges and prospects. Then moved to Normandy to visit Laurent Lecesve and his Eco-Domaine ferme de Bouquetot, an experimental farm with a biogas plant to produce organic nutrients for growing spirulina.

Laurent Lecesve, Gilles Planchon, Jean-Paul Jourdan and Robert Henrikson with the Eco Domaine team in Normandy, July 2011.

Evolution of Smart Microfarms

It was time to introduce algae microfarming to North America. In 2011-12, I built home and backyard units in Point Richmond by San Francisco Bay, and in 2013, a spirulina microfarm testbed near Olympia Washington. Based on learning through my personal journey, these systems were designed as evolving replicable systems for growing algae in temperate climates along with smart technology so local growers benefit from assistance from remote experts.

Smart Microfarms provides professional consulting services, ranging from preliminary site assessment through system design, delivery, installation, supervision, start-up and long term technical support.

References and Author Biographies

Contact information




Small Farms in the Developing World

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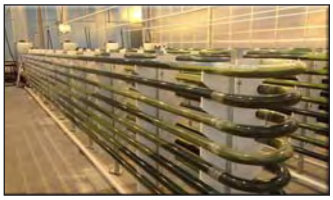


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072. Brad Reeves. brad@mauitropicalalgaefarm.com
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086. Thomas Kosbau. thomas@oredesign.org
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087. John Walsh. john@growenergy.org

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Algae Resources

Algae Associations

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www.algalbiomass.org.

National Algae Association.
www.nationalalgaeassociation.com.

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www.eaba-association.eu.

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www.psaalgae.org.

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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 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.

CPPC Algae and Cyanobacteria Culture Collection Links. www.phycol.ca/links. This is an extensive list of algae collections in countries around the world.

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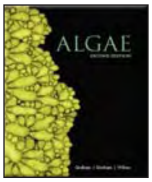

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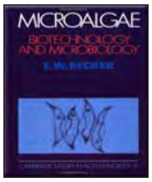

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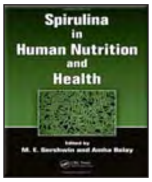

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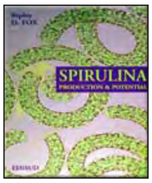

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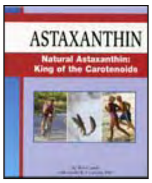

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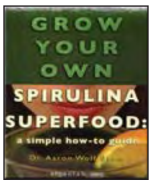

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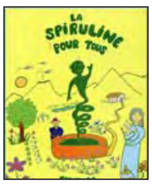

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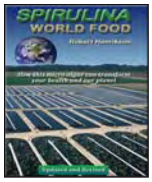

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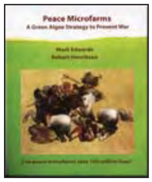

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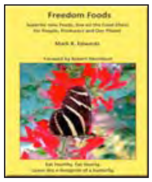

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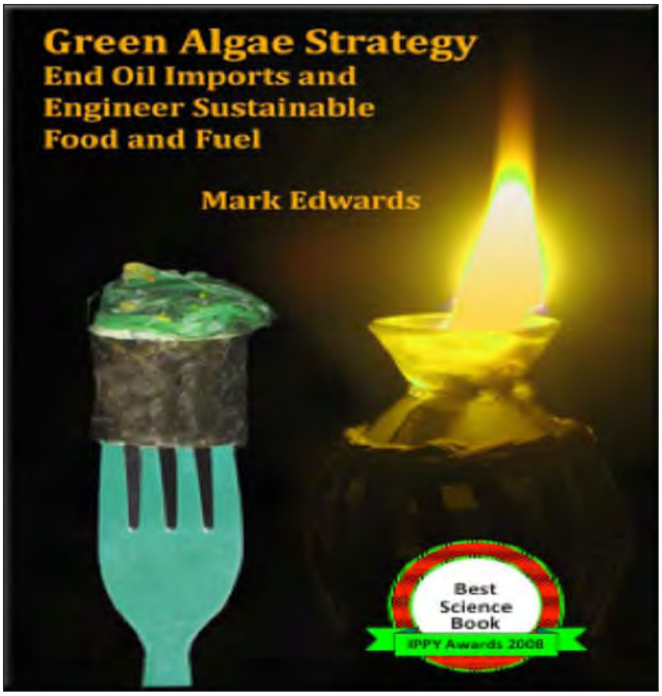
About the Authors

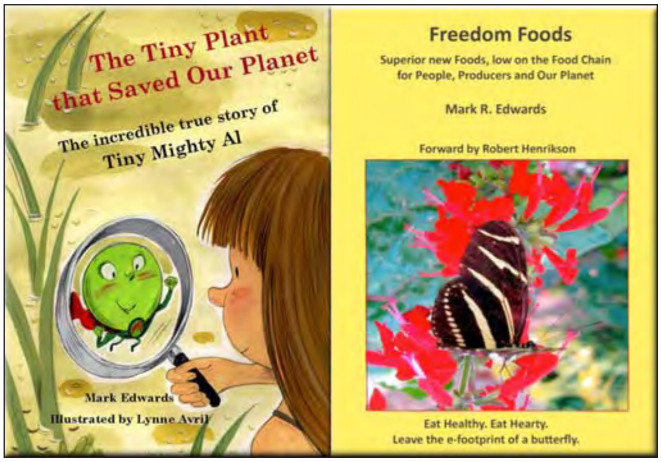
Mark Edwards focuses his energy on one goal, enabling people globally to grow algae locally for the needs of their family and community. AlgaeCompetition.com creates a global collaboratory of Green Masterminds (growers) that moves towards the goal of democratizing food and energy security.



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 scare 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 best seller, 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, *Algae 101*, 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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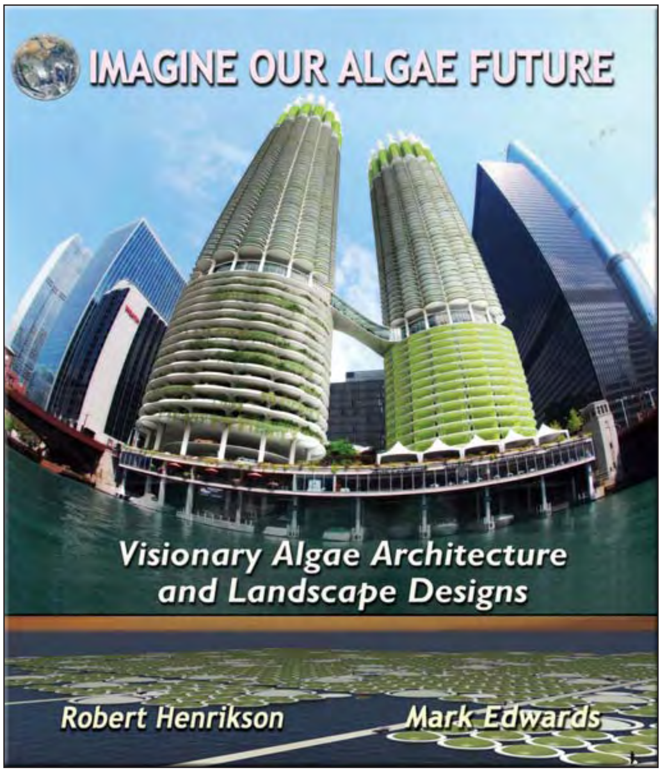
About the Authors

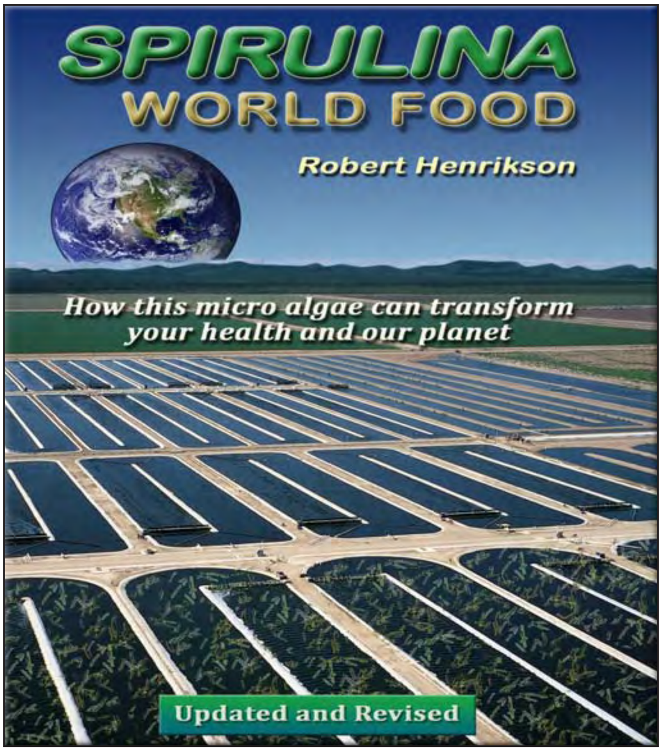
Robert Henrikson has been a green business entrepreneur for over 35 years in sustainable development business models for algae, bamboo and natural resources. Robert is the coauthor of the book *Bamboo Architecture in Competition and Exhibition* (2011) based on the International Bamboo Building Design Competition. He is coauthor of *Imagine our Algae Future* (2012) based on the visionary architecture and landscape designs of the International Algae Competition.



Robert is an Algae Alliance consultant on business development, strategic planning, sales and marketing, advising companies and investors in algae ventures (AlgaeAlliance.com), and founder of Smart Microfarms (SmartMicrofarms.com) for scalable algae microfarms.

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).

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).



Robert is a photographer (Panmagic.com) and documentary filmmaker, and produced the DVD series *Folding Time and Space at Burning Man* (Folding-Time.com). Co-owner of Hana Gardenland, botanical paradise retreat in Hana Maui (HanaPalmsRetreat.com) and co-owner of Wild Thyme Farm, sustainable forestry and permaculture farming (WildThymeFarm.com).

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Spherical collage from a Google® search of images of microscopic algae and cyanobacteria.