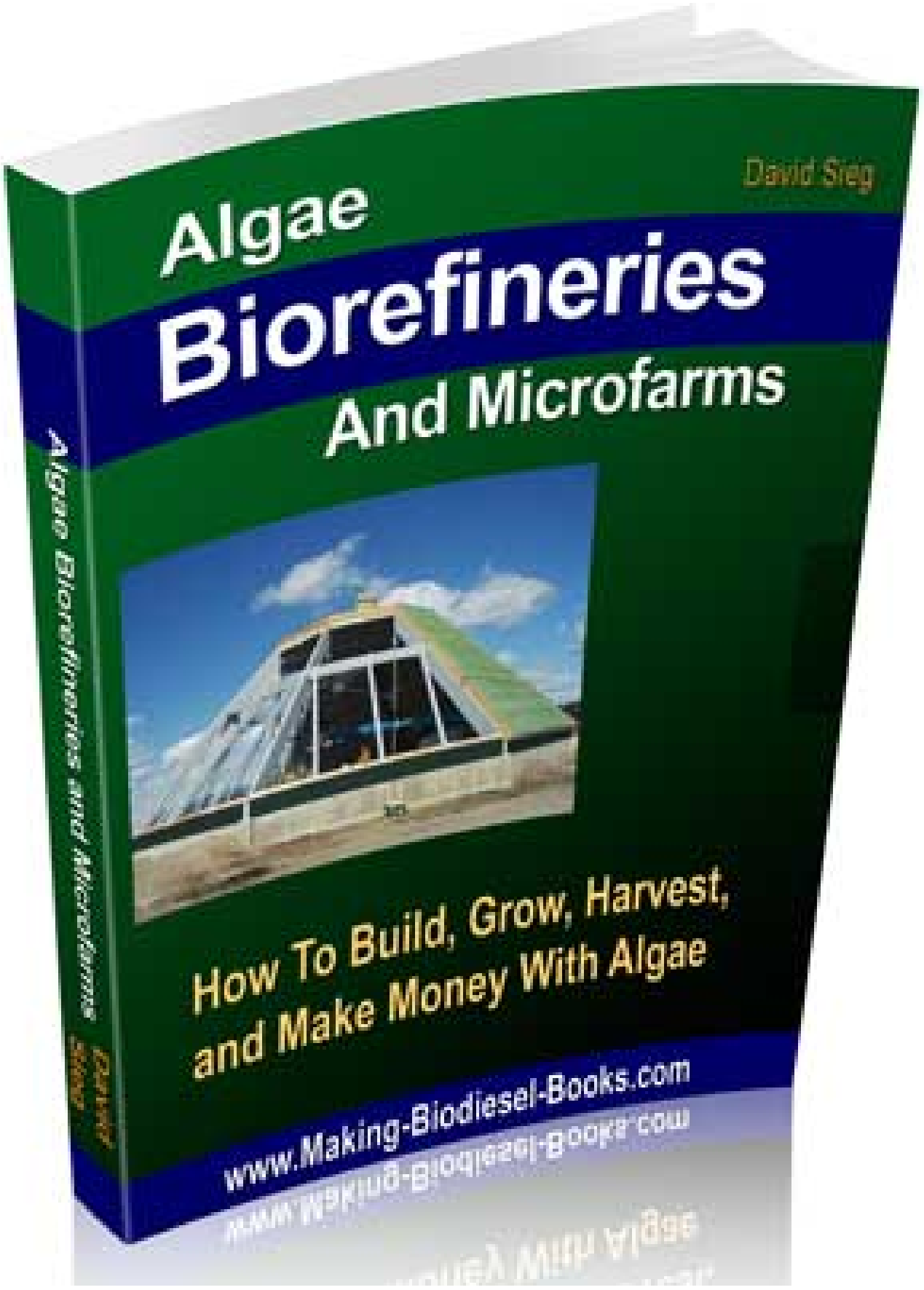
David Sieg
Algae
Biorefineries
And Microfarms
How To Build, Grow, Harvest, and Make Money With Algae
www.Making-Biodiesel-Books.com
Algae Biorefineries and Microfarms

Algae Bio Refineries and Micro-Farming

By David Sieg

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Short version: Keep this to yourself – otherwise I’ll have to unleash my lawyer (and man I hate paying that guy ☺)

Dedication:

To Lennon. For showing me the way back home.

Also to the Algae Entrepreneurs I've had the honor to meet and have nothing but the highest respect for. You risked everything while all others sat back and watched from safety; because you invested when others squandered; because you innovated while others were complacent; because you worked twice the hours, with 10 times the intensity than the overwhelming majority who prefer the 9 to 5 grind; because you've taken on infinitely more responsibility; because you get brusied, bloodied, knocked down and still get up every morning to play the game while the vast majority sit in the bleachers and boo the home team; because you paid the grossly disproportionate amount of taxes and act like Zeus carrying the rest of us on your shoulders; because you created, organized, and delivered the products, services, education, while the rest of us consume and humbly follow the trail you blazed into the algae wilderness.

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mailto:rex@process.co.za
http://www.process.co.za

Raouf Solaiman of Algae Venture Systems for the use of photographs.

Janet Leary for help with the manuscript, proofreading and advice.

Lastly, my wife Tram and my son Lennon. As I've said before, a simple thank you seems so inadequate.

TABLE OF CONTENTS

Chapter 6: Production

- Building production scale PBR's
  - Vendors
  - Prices
- Building production scale open ponds
  - Vendors
  - Prices
- Production scale harvesting systems
- Production scale oil extraction
- Production scale ethanol processing

Chapter 7: Co products

- Co products depending on algae strain
- Algae Biofuel products
- Algae co-products
- Where to sell co products

Chapter 8: New Technologies

- Offshore Micro Algae Farming
- No land required
- Production Yields
- Environmental Impacts
- Genetic Modification of Algae Species:
- Carbon reuse or carbon sequestration of industrial
- emissions using micro-algae:

Chapter 9: Algae Micro Farming Products

- Animal Feed
- Fish Feed
- Aquaponics
- Bio fertilizers
- Biofuels
- Bio plastics
- Bioconcrete
- Waste water treatment
- Cosmetics
- Nutraceuticals
- Pharmaceuticals
- Biodegrable lubricants

This Table of contents is no means complete at this point in time. Existing TOC only indicates publisher approved topics. More will be added to the book before publication.

Introduction

> **To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science.**
>
> **Albert Einstein**

Let's call a spade, a spade and quit beating around the bush. This book is radical and it expresses radical thoughts as well as proposes radical solutions. If out of the box thinking offends you, ask for a refund.

Our current food/energy/health care/pharmaceutical paradigm no longer works in the USA, or in many other places in the world.

Make no mistake if current trends continue, these models will collapse. They're unsustainable. They can't continue in their present form. It's no longer a question of "if" but a question of "when." Things have got to change.

You know it, and I know it. Or at least you feel it deep down in your bones, or you wouldn't be reading this book, or searching for alternatives.

It is no longer a question of making small changes here and there to alter the course of a river so it doesn't flood. A tsunami of change is upon us, whether we like it or not. We will change our current mode of thinking of just about everything or that tidal wave will sweep us, as a species, out to sea. Mother Nature has done it before.

But let's get one thing clear from the beginning. I'm not a part of the "End-of-the-world" crowd. Just the opposite. I'm hoping for a new beginning, with new ideas, and new thinking. I'm optimistic. It could also be a time of growth and great change...for the better.

Being a realist doesn't necessarily mean you're a pessimist.

Maybe because of my background, or my experiences, or the influences in my life, I firmly believe small scale production of algae and/or the creation of biorefineries can go a long way to solving the food/energy/health care crisis I referred to in the beginning of this introduction. In truth I think it can solve a lot more than that.

For most of my life I've heard the laughter in the background each time I've brought the subject up, or uttered those words. Many times I've endured the rolling of the eyes and/or the far-away look of disbelief and boredom. You will too if you bring this conversation up in "polite conversation."

But the truth is, at this moment all those systems discussed above could collapse and be no more, and I would still have (healthy) organic food to eat, fuel to heat my home, organic feed for my animals, organic fertilizer for my garden, health food supplements for any inadequacies in my diet, and many other things besides. But the basics of a simple life are covered.

Call me nuts, but I bet I'm better prepared and (will be) better off than you are when the shit finally hits the fan.

The true sign of intelligence is not knowledge but imagination.

Albert Einstein

I may not be living on Park Avenue but I won't be starving to death in the gutter, either.

I dare you to name any other single organism that can do so much, with so little, so quickly, with so few inputs, or so cheaply.

Large scale algal production is not currently sustainable because algae production does not require large scale. It is at its most efficient in a small scale setting.

While what is needed isn't more research, or more dollars, but grass roots support, and a million strong army of home cultivators, creating their own units and solving their own food/fuel/heath care problems.

The major advantage of algal production systems is the ability to grow anywhere at any scale. A large network of small scale biorefineries will out compete large scale infrastructure because unlike large scale farms microfarms can be built with low capital, modular scalability, at the point of consumption for direct access to free waste nutrients from the human user and the fuel conversion and combustion gases.

This means less need for the transport of water, nutrients, co2, and end products. This means all these problems can be solved, and used, locally. That means the time/money necessary will be kept local, and spent locally as well.

Any private sector efforts to grow algae on a large scale will have be incentivised by the value of food trade algae biomass and omega three oils that sell for much more than $4/gal.

The only way for an algae production company to gain a foothold in the future is to offer domestic

and mobile scale systems that produce a wide array of essential products from a wide array of domestic waste materials, while offering a wide variety of essential life products in return.

This way a distribution infrastructure isn't needed except to transport excess biomass and by products to the existing local processing centers.

You can never solve a problem on the level on which it was created.

Albert Einstein

Coal plants, concrete manufacturers, nuclear plants, waste to energy landfills, oil refiners and rigs, can all be used to grow algae. Anywhere there is some form of waste there is a need for algae. Anywhere there is a conversion process taking place there is waste. There is no end to the application niches for algae to fill.

Sustain-ability and economic viability are NOT the same thing. This is a common mistake and should not go unchallenged. As Ryan Davis points out, scale-driven thermodynamics are used in most reports to define "sustain ability" in a precise way that is only loosely tied to the common usage of the word. Economic viability is ultimately driven by "value" determined by supply/demand and consumer behavior. "Sustain ability therefore has more to do with economic viability than it does with environmentally friendly practices.

David Sieg
Des Moines, Iowa, USA
March, 2013

Forward

> **If we knew what it was we were doing, it would not be called research, would it?**
>
> **Albert Einstein**

This book wants to start you on the road to many destinations. It wants you to...

- Start making your own energy.
- Start eating organic food you raised.
- Start using organic fertilizer you made.
- Start raising organic meat and dairy products from the organic feed you made.
- Start making your own soaps from the by product of your fuel making.
- Start eating the organic fish you harvested.
- Start taking all natural supplements you grew for your on-going health.
- Start using organic medicines for more acute problems.

It is not designed however to show you all the "How To" details of building these units. For that you'll have to see my other books. In them I've detailed, how to build open ponds, build bioreactors, and make biofuels. This book will however show you how to;

- Start easily, quickly, and cheaply.
- How to scale up to any size you desire.
- How to make money from your "bio crop."
- How to save money using your bio crop.

Also, "size doesn't matter" here. :+) Truly, whether you're building a unit in your spare bedroom closet, backyard, spare lot, or the back 40 acres, space is not a problem. It is a consideration, yes, but don't let it stop you. Nor is it a good excuse not to continue. While building a bioreactor in a closet won't get you enough algae to make biofuels, it will make enough for health food supplements. It will make enough for cosmetics, and many other products besides.

Food and fuel production are intricately interconnected. In a carbon-smart society, it is imperative to produce both food and fuel sustainably. Integration of the emerging biorefinery concept with other industries can bring many environmental deliverables while mitigating several sustainability-related issues with respect to greenhouse gas emissions, fossil fuel usage, land use change for fuel production and future food insufficiency.

A new biorefinery-based integrated industrial ecology encompasses the different value chain of products, co-products, and services from the biorefinery industries.

It should also be stressed that this information is what I have discovered as a result of my own interest and investigation. So please understand this manuscript is an attempt to aid in your own discovery and investigation. It is not meant to be the "be all, end all" of knowledge of the subject. It scratches the surface.

While it can certainly be proved that the devices, methods and techniques mentioned have been proved, either through peer review or third party replication, it doesn't mean you'll get the exact same results. The most that can be said is that you made an unsuccessful attempt to replicate it. That doesn't mean the information is false, it just means something was wrong in your attempt.

Since, at this point, 100'000's of thousands of people all over the planet, from individuals, to multi-national corporations, to non-profit organizations have all been able to reproduce the same product, there isn't much doubt left.

As stated above this work isn't meant to the definitive answer to all questions algae. As the old saying goes, "if you think you know all the answers, then that means you haven't heard all the questions." So this material is simply an introduction to the subject, not an encyclopedia.

How To Use This book.

This book is arranged in a way to give you as much, or as little information you need to get the job done.

It give you an outline to follow, and a plan to use.

It shows you the most important considerations to take into account, but doesn't bog you down in details.

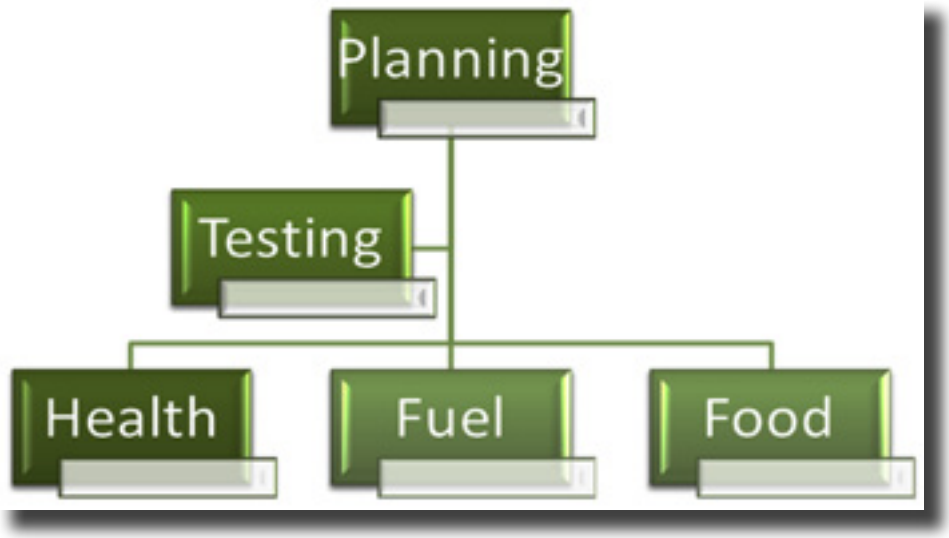
Any intelligent fool can make things bigger and more complex... It takes a touch of genius - and a lot of courage to move in the opposite direction.

Albert Einstein

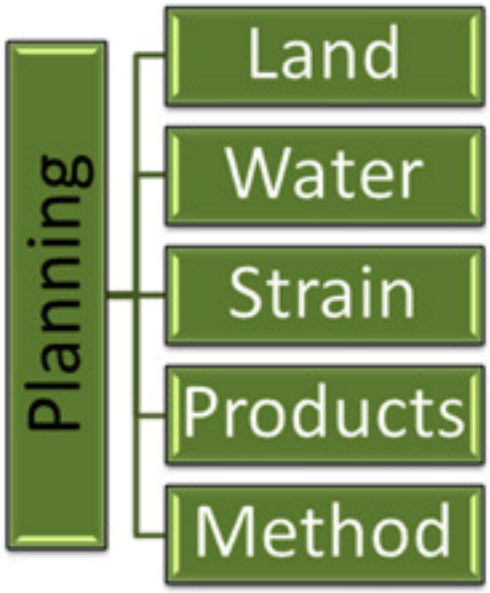
It shows you how to get started, easily and cheaply. However, at the higher levels of production, you need to invest in some of my other books. Namely "Building Open Ponds" Or "Making Algae Biofuels at Home" or "Algae to Ethanol" if you want in-depth knowledge in those areas.

This book follows the path of "General to Specific." Meaning it starts off with an 30,000 foot overview, and gradually works it way to ground level to the smallest, relevant details. Namely:

- Planning
- Testing
- Health
- Fuel
- Food



From there it will it go into each area individually, giving you the necessary information you need, when you need it.



Each stage will become progressively as detailed as necessary.

It is my hope to convey this information as simply and directly as possible, staying away from complex formulas and industry jargon as much as possible.

It is also my hope that you use this book as your field guide. That it gets dirty, torn, and stained, as you plan, build, maintain, and reap the harvest of what has got to be one of the most useful, prolific, organisms the earth has ever produced.

Prologue

People are calling it "The Algae Revolution" with good reason.

There is no doubt that algae is generating a lot of attention, and getting a lot of scrutiny lately. With so many advantages it's easy to see why. No other organism comes close to it in the sheer number of possible uses.

For example, in biofuels alone, depending on the biomass components, algae can be used to produce

- Biodiesel (through transesterification)
- Biojetfuel (Through hydrocracking)
- Bioethanol (Through fermentation)
- Bio gas (Through anaerobic digestion)
- Bio hydrogen

The various components of the biomass are generally dependent on the algal variety used. Different species have different characteristics. Some species have collect and store lipids, (oils) other's carbohydrates or sugars. Still others store proteins. Some species will store as much as 30%-70% of their weight in oils.

These lipid rich algae are an outstanding source of biodiesel and introduction into our petrol refineries. While the high starch and sugar species are ideal for bioethanol. In addition, by controlling various inputs, or production "triggers" through environmental factors, algae can be "custom designed" to be even higher quantities of oils or carbohydrates.

Compared to land based crops, algae puts them to shame. They are 10 times more efficient in water and solar use. While a land based crops, corn or soybeans for example, can reproduce and have one crop per year, algae can double their mass in as little as 3-4 hours.

Everyone agrees that major, emerging opportunities are available in the use of algae as a "crop." Algae directly, or indirectly supplies many billion dollar industries, including cosmetics, nutraceuticals, and pharmaceuticals. These three industries alone are always looking for new, groundbreaking, innovative, and marketable products that will give them a competitive edge in the marketplace.

In addition to the biofuels, in industry algal extracts also supply pigments, vitamins, health food supplements, food supplements and much more. In fact, no matter what you did today you've come in contact with something that was made from, or made with, algae.

That is the tip of the iceberg. Algae will also grow just about anywhere, in any scale. But algae thrive in the small scale. Whether is it is a closet bioreactor, a backyard open pond, or 10's of acreas under cultivation.

Algae require simple, cheap, resources to grow. They require water, sunlight, CO2, and nutrients. The first three are free, and the last is dirt cheap.

Waste water can also be an ideal medium to grow algae. Many cities and towns throughout the country are embracing the idea of letting algae clean their sewage and make biofuels at the same time.

Algae can also be grown just about anywhere, all year around. Some species prefer winter, others do better in warmer climates. There is even the possibility of having seasonal crops of (different) algae, or rotating algal species depending on season, and products needed.

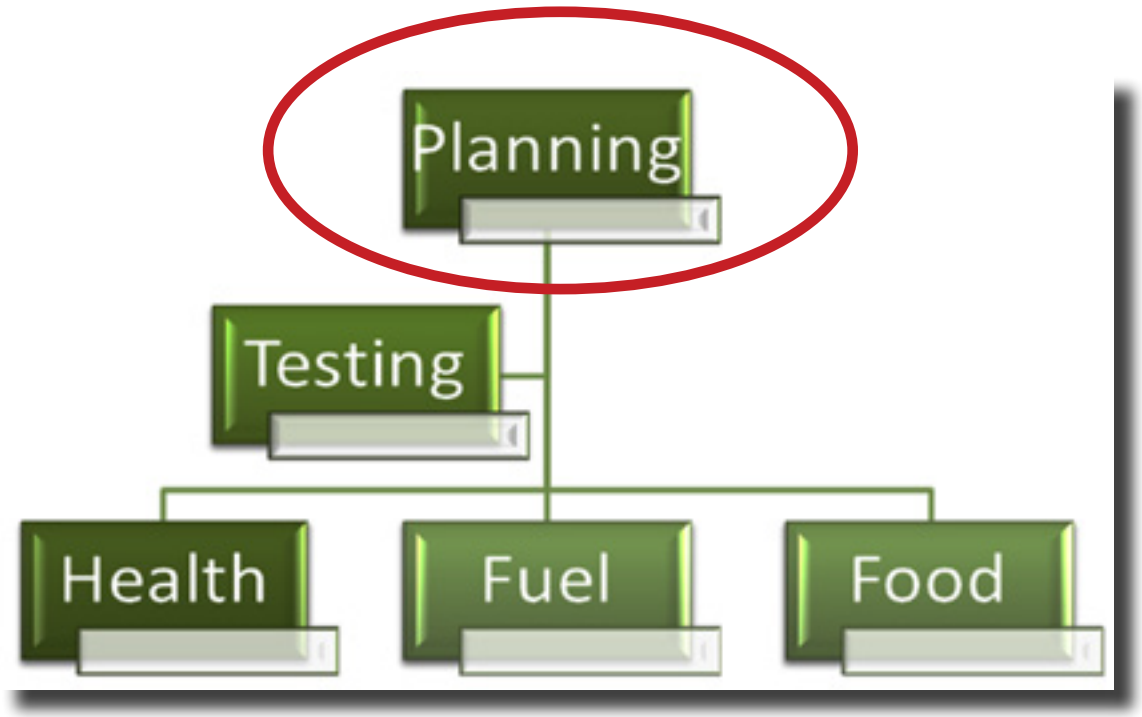
Since they can double, or even triple, their mass daily, they can produce 100 times to 1000 times more oil per surface area than traditional crops.

Best of all, they can be grown and processed locally. This means no expensive shipping, or relying on neighbor states which are politically unstable or undermining our national security. Because they are grown locally, they can employ local people, adding much needed tech jobs to the local economy. That money, created locally, is in turn, spent locally, in terms of employees, nutrient inputs, real estate, etc. In short, that money goes straight back into the local economy, not overseas to oil rich nations, or multi-national companies.

This isn't to say that growing algae doesn't have its challenges...it does. However, most of the challenges facing algae are being faced in mass scale up to commercialization. Most of those problems, and expense, aren't applicable for algae when grown on a small scale.

In short, algae based technologies offer a viable method of producing a 21st. century income in an industry that has been around for 100's of years, but is only now getting ready to boom.

CHAPTER ONE



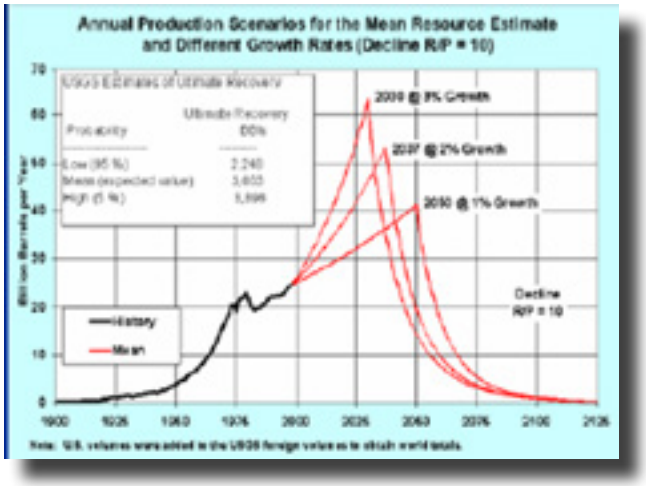
THE ISSUES

The World is Ready for a Solution

In a world faced with such massive challenges, some of which threaten generations for years to come, if not the species as a whole, the world is looking for, and ready for new solutions. Countries all over the world are investing in algae technology. 1000's of people all over the world are seeing real opportunities in algae and they are voting with their checkbooks.

Peak Oil.

We haven't heard much about Peak Oil lately but it hasn't gone away. Ramon Sanchez at Harvard University put together a startling paper outlining the various reason why now is the time to promote algae production.



The theory of peak oil -- the point at which the Earth's oil supply begins to dwindle -- has become a hot-button topic in recent years. At this point, production of oil no longer continues the upswing that helped create the modern world as we know it.

The Earth's combined oil supply should follow this bell curve, and the point where it begins to decline forever is the oil peak. This point will come eventually, since oil is nonrenewable. But exactly how long we have until that happens is a matter of heated debate.

Instead, the upswing becomes a downturn. And if demand continues to grow while production begins to decline, we have a problem.

State of oil world reserves.

- Tipping point:-20 years (business as usual)
- -27 years (moderate
- -40 years (good conservation)

Agricultural Land Availability Issues

Land requirements needed if gasoline is replaced with corn ethanol in the USA and Mexico are unsustainable if traditional farming crops are used. This is the classic "fuel for food" debate. The answer is it depends on who you ask and on what side of the energy/biofuel spectrum they sit on.

Food vs. fuel is the dilemma regarding the risk of diverting farmland or crops for biofuels production in detriment of the food supply on a global scale. The "food vs. fuel" or "food or fuel" debate is international in scope, with valid arguments on all sides of the issue. There is disagreement about how significant the issue is, what is causing it, and what can or should be done about it.

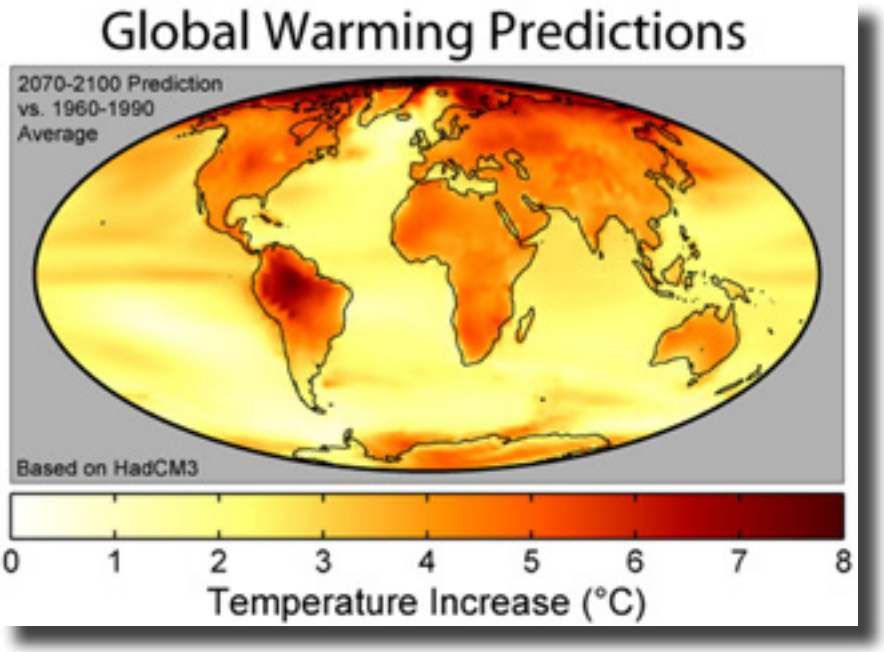
What is not debated is the increase is food prices world-wide.

Algae, as a feedstock for biofuels completely avoids this issue. Algae is not in direct competition with food crops.

Global Warming Issues

Carbon Dioxide Debt of bio-fuels due to land use changes

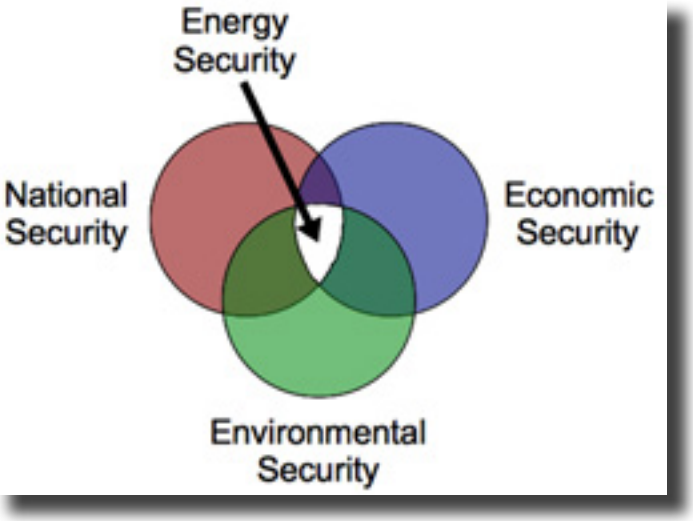
- -17 years for transforming wood land (savanna) into a sugar cane field in Brazil
- -93 years for transforming grassland into a corn field in the USA
- -420 years for transforming peat rainforest land to palm oil in Indonesia and Malaysia



The use of deserts or seas to grow micro-algae for biofuels does not cause a Carbon Dioxide Debt.

Energy Security

Energy security is a term for an association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities.



Energy Security is a very important issue due to changing external factors in the global economy.

- Foreign oil supplies are vulnerable to unnatural disruptions from in-state conflict,
- exporters' interests,
- and non-state actors targeting the supply and transportation of oil resources.
- The political and economic instability caused by war or other factors such as strike action can also prevent the proper functioning of the energy industry in a supplier country.
- Terrorist attacks targeting oil facilities, pipelines, tankers, refineries, and oil fields are so common they are referred to as "industry risks" Infrastructure for producing the resource is extremely vulnerable to sabotage.
- One of the worst risks to oil transportation is the exposure of the five ocean chokepoints, like the Iranian controlled Strait of Hormuz. Anthony H. Cordsman, a scholar at the Center for Strategic and International Studies in Washington warns, "It may take only one asymmetric or conventional attack on a Ghawar Saudi oil field or tankers in the Strait of Hormuz to throw the market into a spiral."[9]

New threats to energy security have also emerged.

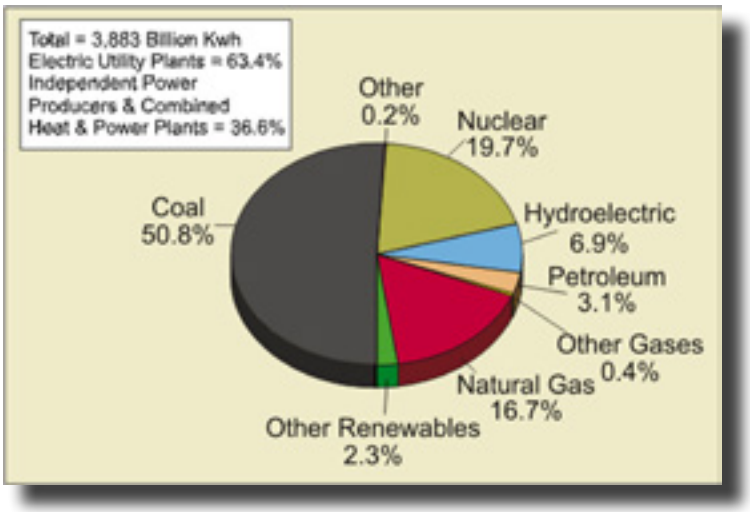
- Increased world competition for energy resources due to the increased pace of industrialization in countries such as India and China.

An oil importer, such as the United States, could achieve energy independence, energy security and comply with their goals to mitigate climate change by means of Micro-Algae farming in the future.

Potential Depletion of Fisheries

Oily fish species are the most important source of Omega 3 fatty acids for both human and animal consumption. Constant over-fishing of our ocean resources might lead to adverse effects to fisheries. Algae is the original source of Omega 3 Fatty acids, so it could potentially substitute fish in a sustainable and environmentally conscious way.

Why Algae?



Algae are single celled organisms and are one of the fastest growing plants in the history of life on this planet. They can grow both in fresh water and marine (salt water) environments. They are photosynthetic and like all other green plants they convert carbon dioxide to organic carbon. Over half of the world's oxygen that is released into the environment is a result of photosynthesis. There are over 65,000 known species of algae with a variety of red, blue-green, green and brown algae.

- More solar efficient converters of energy (3 times more efficiency than land plants)
- Very simple cellular structure
- They don't require:
  - Freshwater
  - Farmland (so they don't compete with food)

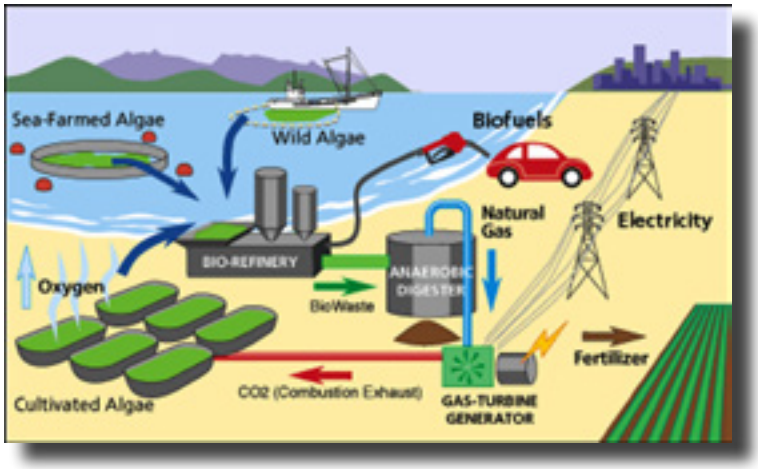
The industrial sector has been a flourishing sector over the past few years. Most of the chemical industries were heavily dependent on synthetic materials and petrochemicals. With quick consumption of non-renewable energy sources industries today face an energy crises of global proportions. Increased global warming also poses a constant threat. Industries are looking for alternate renewable sources of energy.

Algae are all set to transform industries in ways which can't now even be imagined. Algae have become a prime target for obtaining chemicals which are in considerable demand. Alga culture is promoted in different parts of the world in many different applications. The use of natural chemical constituents in industries has increased enormously in the past decade, and show little sign of slowing.

Algae were once thought as a nagging issue which clogs ponds, smells bad and makes coastlines look like from a horror movie. Algae cultivation has added an environment friendly aspect to potential chemical constituents which can be extracted from algae species.
Algae are a part of our daily life. Without Algae derivatives life would be remarkably different. We are in contact with algae derivatives all the time and it would be difficult to survive without using them. Various derivatives and algae constituents are part of our food, drugs, cosmetics, clothes, paints and many other products.

Algae have emerged as one of the most promising potential sources of biofuels. Studies have confirmed that algae-based biofuels can help reduce the greenhouse effect. Algae are also efficient carbon fixers. They can absorb up to 50% of atmospheric carbon converting it to organic carbon. During the process of photosynthesis algae produce oxygen. Some believe ocean algae is responsible for more plantary oxygen than even the rain forests.

Why is Now the Time to Pursue Algae Biorefinery?



The Race Is On. Producing fuel from algae relies on a number of technologies, handful of which are already broadly implemented commercially for algae biofuels manufacturing. Numerous strategies to ponds and covered growth techniques, photosynthesis and dark fermentation, genetic customization of algae, optimizing techniques relevant to light, water, carbon dioxide, harvesting, and methods to eliminate water and extract oil for algae fuels are in the process of becoming created and improved upon.

For every strategy, various systems, techniques, and procedures have been produced and presented. A few of the readily available systems and products are already employed only in pilot projects and some are in the process of commercialization. Additionally, a number of strains or mixtures of strains of algae are "proprietary" and governed by licensing conditions.

In effect, there's a rush to the marketplace. Quite a few inventors and corporations are seeking technologies to economically produce algae fuels. The possible ecological advantages and high output of algae biofuels, when compared with crop-based biofuels, have helped to seduce significant investment funds from private investors, investment capital firms, and key oil companies.

If algae were a business corporation it would be a huge multi-national conglomerate combining

- Exxon Oil
- Edison Power and Light
- Duke Energy
- General Mills
- Borden
- Dole

- Nestle
- Morton Salt
- Proctor and Gamble
- Purina
- Waste management systems
- Southwest Water company
- Merck
- Pfizer
- Safeway
- Hi-Health5

For the last 50 years algae producers have been limited to a narrow range of products, mostly health foods, and some ingredients for the food industry. Today, the marketplace is very different as algae producers can examine an array of valuable co-products that have many times more value.
There are a number of political and market factors converging together at this time to create a "perfect storm" to support the idea of mass utilization and cultivation of algae on a global scale.

Global Considerations:

- Oil prices: Low oil prices of the previous decades provided no financial incentive to pursue algae as a serious source of oil. Today however it is dramatically different. Soaring oil prices are effectively destabilizing the entire world. Concerns about national security are motivating substantial investments in renewable fuels. The first and foremost of which are algae.
- Natural Gas prices: Heavy agricultural consumption of natural gas for fertilizers, herbicides, and pesticides has led to a 500% increase in the price for these commodities in recent years. Much of this cost increase can be attributed to lack of domestic supply and increased reliance on imports.
- Food Prices: In decades past, food grains could be produced at 10% of the cost of growing algae. In the last few years food prices have been rising dramatically, doubling and tripling in response to the price of oil. New algae strains and growth models promise to slash production costs as well as provide an alternative to using food crops in the production of biofuels.
- Food Security: Inexpensive food grains sold on the world markets allowed governments to buy food cheaply to feed their growing populations. The rising cost of food has resulted in social unrest and riots in many countries. This trend is only beginning and promises to cause global unrest in the future.
- Ethanol Inflation: First generation Ethanol and biofuel induced price increases on the global food supply chain have increased the costs on all foods worldwide.
- Governmental Action: Governments around the world have recognized the need for truly renewable food and biofuels, and algae are the leading contender. As a consequence, gov-

ernment grants and research are starting to pour into this field.

Consumer Interest:

- Increasing food and fuel prices, water scarcity global warming, and pollution are motivating consumers to "Go Green" like never before.
- Traditional products like "Fair Trade" coffee, and organic vegetables have proven consumers are aware of, and willing to pay a premium for, products which they see as non-exploitive and contributing to the general welfare of everyone.

Changes in Nature:

- Natural disasters: Tsunamis in SE Asia, Earthquakes in China, Flooding in the Mid-West USA, famine in Africa, draught in Australia have severely impacted food production in the each of these places. As the weather worldwide becomes more complex, new answers will be needed to address global food production. Algae can be used to address world hunger.
- Water Scarcity: many communities and cities worldwide are facing shortages in water because as much as 80% of available water goes to irrigation of crops and other food related activities. Algae are very water efficient and require much less water to cultivate. In addition, algae can be cultivated in ANY type of water, even raw sewage.
- Dead Zones: Agricultural waste has been flowing into lakes, rivers and oceans creating "dead zones" where just about all life dies from a lack of oxygen. Algae have the ability to bring these coastal and inland waterways back to life.
- Greenhouse Gases: It's estimated that each acre of farmland production adds about 2.25 tons of CO2 into the atmosphere.1 Algae on the other hand, "eat" CO2 and exude oxygen.
- Climate Change: I think everyone has noticed the unusual weather patterns. Every year since 1993 has been reported to be in the hottest 20 years on record. This year (2011) Texas experienced over 100 days, of 100 degree heat. Traditional food crops have been, and will continue to be, devastated and suffer from diminished production.
- Water Pollution: Urban and rural communities have had their water contaminated by

agricultural run-offs for years. The EPA has reported that 37% of US lakes are unfit for swimming due to this condition.2

- Fossil Fuels: Heavy use of petroleum products have led not only to "oil wars" but to price increases, which have had severe implications to the world's food supply, resulting in food cascades and famine in some parts of Africa.
- While natural climatic changes linked to growing food crops put the entire food chain in jeopardy, this same condition improves the commercial landscape for alga culture.

Changes in Technology:

- Biotechnology: New genomic advances are making it much easier to understand and implement in algal oil production. Current breakthroughs underway will make harvesting and oil extraction not only much easier and more economical, but should also lead to methods which will enable future entrepreneurs with the ability to manipulate algae species to their specific needs.
- Nanotechnology: Current alga nanotechnology is enabling scientists to coat thin filaments, to grow human cells inside the human body.3
- Chemical and Mechanical Engineering: is enabling scientist with new methods of optimizing plant growth and algae conversion into useful and valuable co-products.
- Private and Government Sector Funding and Growth: "Peak Oil" has motivated private sector and government funding on a large scale to find a replacement for fossil fuels. Exxon-Mobil recently announced 600 million in R&D. The US Department of Defense is currently conducting a "Manhattan Project" of algae biofuels as it is seen as one of the major replacements for "drop-in" fuels. Their fear is that they could run out of Fuel as early as 2016.
- Current feed stocks of biofuels not only consume our ever diminishing crop lands but also consume trillions of gallons in water in order to provide a disappointing yield in biofuels.

Many scientists now believe commercial algae farms can produce up to 5000 gallons of oil per acre. Corn, in comparison only produces 18 gallons. In addition, corn ethanol only produces 64% of the energy of gasoline. This makes corn ethanol and energy loser in the highest sense. Therefore, 350 gallons of ethanol * 0.64 = 224 equivalent gallons of gasoline.

Because algae have a longer chain of hydrocarbons which can be made into gasoline, jet fuel or green diesel, they burn 30% to 50% hotter than gasoline. This makes algae energy calculation, 5000 gallons of algae oil * 1.30 =6,5000 equivalent gallons of gasoline.

Algae's potential as a biofuel is 30 times higher than that of corn ethanol. In addition, since valuable co-products exist as well, algae become the clear choice when choosing a biofuel feed stock.

Algae's Competitive Advantages:

Survival strategies adopted after several billions years on earth have made algae different from land based plants in many ways.

- Composition: land based green biomass, such as corn, may be up to 97% non-oil or waste because most plant composition is cellulosic rather than protein for food, or energy producing oils. Some strains of algae have been known to produce 60% lipids. These are oils which can be used for a variety of commercial applications, including biofuels, jet fuels, or biodiesel.
- Stored Energy: The stored energy in conventional land plants such as corn can be converted to ethanol however they burn with less heat and only 64% of the energy of gasoline. Algae can convert solar energy and Co2 into longer carbon chains resulting in more powerful liquid transportation fuels.
- Growth Speed: Food grains require a full growing season to mature-from spring to fall-often up to 140 days or more to produce one crop. Algae in comparison can grow to maturity in a single day.
- Direction of growth: Land based plants tend to grow slowly in only one direction…up. Algae grow in 360 degrees.
- Superstructure: Land based plants devote most of the growth energy into building roots, trucks, leaves, etc. Algae on the other hand require no such support. Water support algae in its natural environment.
- Consistent, Reliable Production: Algae aren't subject to same conditions as land based crops. Therefore draught, insects, wind, rain, can devastate a traditional crop has no such effect on algae. Algae can weather natural cycles with ease, and have for several billion years.

Notes

CHAPTER TWO

Basics of Micro Algae Farming and Biorefineries

A SWOT Analysis of Biorefineries

Strengths

- Adds value to the sustainable use of biomass
- Maximises biomass conversion efficiency – minimising raw material requirements
- Produces a spectrum of bio-based products (food, feed, materials, chemicals) and bioenergy (fuels, power and/or heat) feeding the full bio-based economy
- Strong knowledge of infrastructure available to tackle any non-technical and technical issues potentially hindering the deployment trajectory
- Is not new, and in some market sectors (food, paper, etc.) it is common practice

Weaknesses

- Broad undefined and unclassified area
- Needs involvement of stakeholders from different market sectors (agro, energy, chemical, ...) over the full biomass value chain
- Most promising biorefinery processes/concepts not clear
- Most promising biomass value chains, including current/future market volumes/prices, not clear
- Still at a stage of studying and concept development instead of real market implementation
- Variability of quality and energy density of biomass

Opportunities

- Make a significant contribution to sustainable development
- Challenging national, European and global policy goals – international focus on sustainable use of biomass for the production of bioenergy
- Biomass availability is limited so the raw material should be used as efficiently as possible – i.e., development of multipurpose biorefineries in a framework of scarce raw materials and energy
- International development of a portfolio of biorefinery concepts, including designing technical processes
- Strengthening of the economic position of various market sectors (e.g., agriculture, forestry, chemical and energy)

Threats

- Biorefinery is seen as hype that still has to prove its benefits in the real market

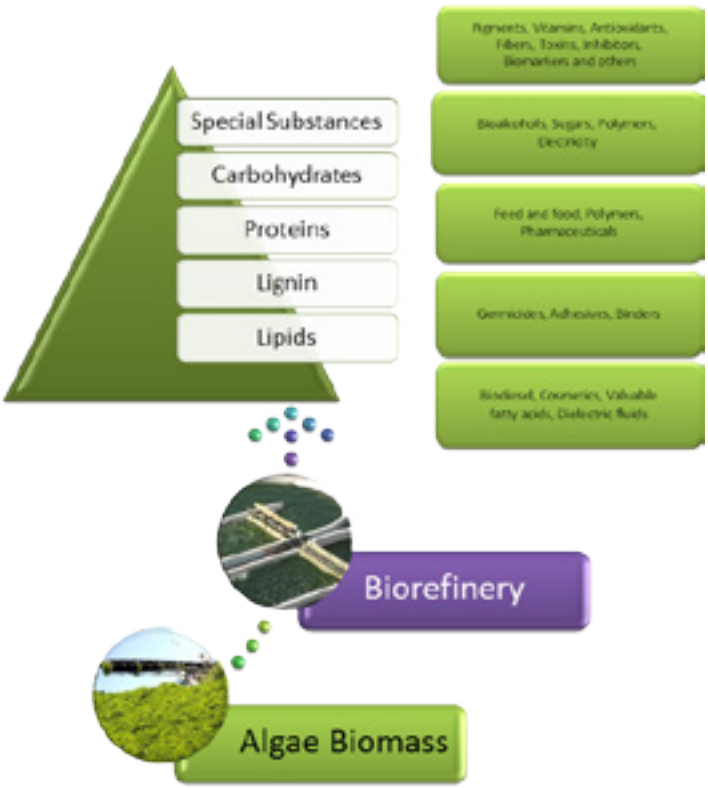
• Economic change and drop in fossil fuel prices
• Fast implementation of other renewable energy technologies filling market needs
• No level playing field concerning bio-basedproducts and bioenergy (assessed to a higher standard)
• Global, national and regional availability and contractibility of raw materials (e.g., climate change, policies, logistics)
• High investment capital for pilot and demonstration initiatives difficult to find, and existing industrial infrastructure is not depreciated yet
• Fluctuating (long-term) governmental policies
• Questioning of food/feed/fuels (land use competition) and sustainability of biomass production
• Goals of end users often focused upon single product

Overview:

What is a "Biorefinery?"

A biorefinery, or a micro farm, and I use the term interchangeably, is a facility that integrates biomass conversion processes and equipment to produce fuels, power, organic compounds and chemicals from algae biomass. The biorefinery concept can be compared to today's petroleum refineries, which produce multiple fuels and products from petroleum are produced. Industrial biorefineries have been identified as the most promising route to the creation of a new domestic biobased industry. The difference is, biorefineries can produce many more products than a petrol refinery.

By producing multiple products, a biorefinery can take advantage of the differences in biomass components and intermediates and maximize the value derived from the biomass feedstock.



A biorefinery might, for example, produce one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel, while generating electricity and process heat for its own use and perhaps enough for sale of electricity.

The high-value products enhance profitability, the high-volume fuel helps meet national energy needs, and the power production reduces costs and avoids greenhouse-gas emissions.

Algae Biorefineries can produce energy in the form of heat or by producing biofuels, molecules for fine chemistry, cosmetics or medicinal applications, materials such as plastics and sources of human food and animal feed.

Advanced or second generation biorefineries are developing on the basis of more sustainably-derived biomass feedstocks, and cleaner thermochemical and biological conversion technologies to efficiently produce a range of different energy carriers and marketable co-products.

To avoid the criticism attributed to first generation biorefineries, these new designs should aim to reduce the impacts and maximise the benefits of social, economic, and environmental factors on a lifecycle basis.

These emerging advanced biorefineries promise to provide complex materials for supplying our chemical and manufacturing industries in the near future, as well as contributing partially to energy needs in a more sustainable way.

It is necessary to define what is meant by biorefineries. Aware that biorefineries exist in a wide variety of configurations and generate many different end products, required a succinct definition that encompassed these many facets and decided upon 'the sustainable processing of biomass into a spectrum of marketable products and energy'.
This biorefinery definition includes systems that may exist as a concept, a facility, a process, a plant, or even a cluster of facilities. In this overview we present the different kinds of biorefineries, (i.e., commercial, demonstration or pilot) at which these biorefineries are currently operational. As an example, the port of Rotterdam has a cluster of facilities that act together and can be considered a 'biorefinery'.

A main driver for the establishment of biorefineries is sustainability. All biorefineries should be assessed through the entire value chain for environmental, economic, and social sustainability.

This assessment should also take into account the possible consequences due to competition for food and biomass resources, the impact on water use and quality, changes in land-use, soil carbon and fertility, the net balance of greenhouse gases, the impact on biodiversity, potential toxicological risks, and energy efficiency.

Impacts on international and regional dynamics, end-users and consumer needs, and investment feasibility are also important aspects for consideration.

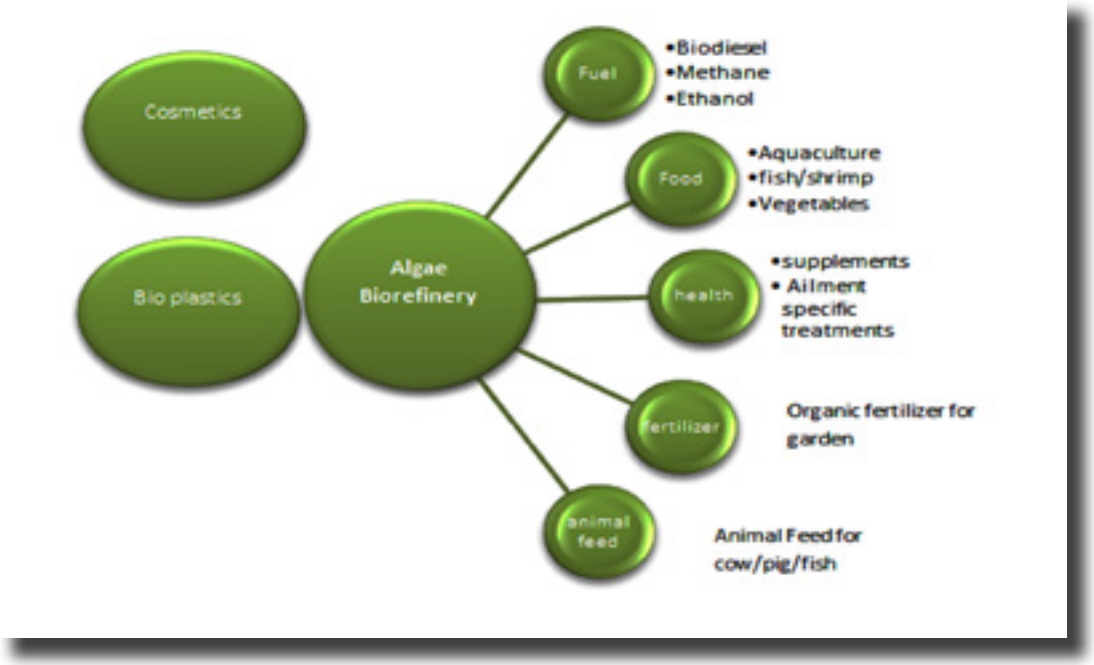
A biorefinery is the integrated upstream, midstream and downstream processing of biomass into a range of products. In the classification system we have differentiated between mechanical pre-treatments (extraction, fractionation, and separation), thermochemical conversions, chemical conversions, enzymatic conversions, and microbial fermentation (both aerobic, anaerobic) conversions.

A biorefinery should produce a spectrum of marketable products and energy. The products can be both intermediates and final products, and include food, feed, materials, chemicals, and energy (defined as fuels, power and/or heat). A true biorefinery has multiple energy and non-energy products.

The biorefinery systems which will come into operation within the next years are expected to focus on the production of transportation biofuels. Some of the most interesting biofuels might be ones that can be mixed with gasoline, diesel and natural gas, reflecting the main advantage of using the already existing infrastructure in the transportation sector.

Understanding the Biorefinery concept.

Literally dozens of useful products can be realized from growing algae. Below is a small sampling of benefits which anyone could realize from growing algae



Algae are well known for their production of lipids. (oils) Currently there is a world wide movement, led by government as well as private sector business rushing to commercialize algae on a mass scale for biodiesel. What is not so well known is that the carbohydrates can be extracted to produce ethanol. In addition the left over biomass can be further used to produce methane, or biogas through aerobic digestion.

Just in looking at algae from a biofuels perspective, from an open pond system, we can make…

- Biogas (Methane…to run generators, cook stoves, lighting, etc.)
- Biodiesel (To run transportation vehicles)
- BioJet fuel
- BioGasoline (To run transportation vehicles)

- Bioethanol (To run transportation vehicles)
- Hydrogen
- Methanol (To use in biodiesel process)
- Biochemicals
- Bioplastics

- **Food**
  - Aquaculture

Aquaponics and/or aquaculture is the marriage between hydroponics and fish farming with the waste of each part feeding the other. In other words, the fish eat the algae. Then the fish excrete waste nutrients, which in turn, nourish the plants. The plants in turn excrete carbon dioxide, which nourishes the algae. It forms a perfect biological circle.

For Bio-fertilizers:

Bio fertilizers are defined as biologically active products or microbial inoculants of bacteria, algae and fungi (separately or in combination), which may help biological nitrogen fixation for the benefit of plants.

Bio fertilizers also include organic fertilizers (manure, etc.), which are rendered in an available form due to the interaction of micro-organisms or due to their association with plants. Biofertilizers thus include the following:

- Cyanobacteria are used and with an emphasis on the blue/green algae's namely Spiru lina and Chlorella can be used.

The need for the use of biofertilizers has arisen, primarily for two reasons.

- 1.) increase in the use of fertilizers leads to increased crop productivity,
- 2.) Increased usage of chemical fertilizer leads to damage in soil texture and raises other environmental problems.

Therefore, the use of biofertilizers is both economical and environmentally friendly. The pragmatic approach will be to develop the integrated nutrient supply system involving a combination of the use of chemical fertilizers and biofertilizers.

Algal Fertilizers -

Blue green algae (BGA) and Azolla constitute a system, which is the main source of algal biofertilizer in south and Southeast Asia, particularly for lowland paddy. BGA inoculation (without Awl/a)

with composite cultures of algal genera Anabaena, Nostoc, Plectonema, Aulosira, Oscillatoria, Tolypothrix, etc. have been found to be more effective than single cultures.

Production and multiplication of BGA cultures is done at centers. Application of dried blue green algae flakes at the rate of 10 kg. /ha is recommended ten days after transplantation.

- Besides being a source of N2, BGA provides for the following other advantages:
- Algal biomass accumulates as organic matter;
  growth. promoting substances are produced, which stimulate growth
- it provides partial tolerance to pesticides and fungicides;
- It also helps in reclamation of saline and alkaline soils.

For health food supplements:

- Spirulina and chlorella are the usual algae of choice for food supplements. Both are grown commercially all over the world and sold in health food stores in pill, powder, and capsule forms. Blue green algae are one of the most nutritional foods you can have. It has been touted as a super food. It is organic, easily digested and full of antioxidants. It is extremely rich in minerals and has a higher concentration of beta-carotene than broccoli.
- Blue green algae also contain about 60 to 70% of vegetable protein, and provide all the essential amino acids. All these benefits without the risk of consuming meat, which is high in cholesterol and is difficult to digest.
- A rich source of calcium, iron, vitamin B12, enzymes and antioxidants make the blue green algae an ideal food for both adults and children. Even pets can benefit greatly from this nutrient-packed food.
- Being highly concentrated in so many nutrients, blue green algae offer numerous benefits to our well-being.

The top ten health benefits of blue green algae:

Top 10 Health Benefits of Blue Green Algae

- Anti-Aging: Loaded with more essential nutrients and iron than most foods that we con sume, blue green algae are perfect as an anti-aging food. Its high concentration of antioxi dants means our bodies can combat more free radicals and toxics.
- Relief from headaches aches and pain: our immune systems are strengthened.
- Energy Booster – has rejuvenating effects
- Better Digestion – it coats the stomach lining and is packed with enzymes that help to im prove digestion.
- Sleep better – it is detoxifying, resulting in better rest.

- Lose weight – Less food cravings, a more balanced appetite.
- Greater concentration and focus – increase in energy and clarity of mind
- Strengthen the hair, skin and nails – high in protein which is the main building block for healthy hair, skin and nails
- Less anxiety – it has beneficial effects on our brain development and can help us cope with stress better.
- Improves memory – as it has effects on our brain development, regular consumption of blue green algae has also shown to have an impact on our memory.

For Animal Feeds:

Many studies have been done using

- Chlorella
- Spirulina
- Scenedesmus
- Oocystis

These species being used as a replacement for land based protein supplements in animal feed. Most studies showed a significant weight gains for all animals involved.

For Cosmetics:

In cosmetics, algae are used as thickening agents, water-binding agents, and antioxidants. But some algae are also potential skin irritants. For example, the phycocyanin found in blue-green algae has been suspected of allergenicity or causing dermatitis on the basis of patch tests (Source: Current Issues in Molecular Biology, January 2002, pages 1–11).

Other forms of algae, such as Irish moss and carrageenan, contain proteins, vitamin A, sugar, starch, vitamin B1, iron, sodium, phosphorus, magnesium, copper, and calcium. For the most part, algae, in their many forms, are probably less of a risk and more of a help to skin when used as antioxidants.

Names of the algae typically found in cosmetics include

- Ulva lactuca,
- Ascophyllum,
- Laminaria longicruris,
- Laminaria saccharine,
- Laminaria digitata, A
- laria esculenta, various Porphyra species,
- Chondrus crispus, and
- Mastocarpus stellatus.

Algae Microfarms

Treated as a curiosity by the press, informed scientists and researchers world-wide are projecting micro algae will be the most common source of our transportation fuel within the coming decade. Micro algae farms produce biomass which is then processed into biodiesel, biomethane or synthetic diesel. Large scale micro algae farms will play a role in the Green Energy portfolio of southern Nevada.

Algae - "seaweeds" in Latin were the first plant-like organisms to evolve on Earth. They are photosynthetic, like land (terrestrial) plants. Some algae species are so rich in lipids (vegetable oil), the amount we can extract is nearly 100 times greater than the amount of oil that can be collected from an equal amount of terrestrial biodiesel feed stock such as soybeans. Algae does not require fertile farmlands so does not compete with the resources necessary to grow food and animal feed stocks.

The US National Renewable Energy Laboratory released this formal research paper on the theoretical maximum oil yields for micro algae in various climates. For the southwestern US states (Phoenix, AZ), they claim 38,000 gallons/acre/year is possible with a flat ground solution. With vertical photobioreactors (PBR), firms are already producing 14,000 gallons/acre/year and are projecting over 200,000 gallons/acre/year in the future. Even the practical operational estimate of 6,500 gallons/acre/year for the same region is impressive and inspiring considering bio oil from soybean crops generate only about 50 gallons/acre/year.

There are now 4 micro algae firms that are in production generating 14,000gallons/acre/year at about $2/gallon based on a petroleum refinery business model. Calculating at only 10,000 gallons/acre/year and producing enough transportation fuel to provide 100% of the fuel used by the US in 2009 (converting to the higher energy density of biodiesel) results in less than 12 million acres of land. Corn for ethanol is currently using 27 million acres of prime US farmland generating about 300 gallons/acre/year and biodiesel from soy was until recently, using over 20 million acres of farmland at 50 gallons/acre/year.

Robert Henrikson, in his article on "Why algae microfarms are emerging today" posits "Parallel

to very large algae production systems envisioned by well-funded algae ventures, is the emerging interest in smaller, algae micro farming scalable algae farms and business models. 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."

Algae technology has advanced remarkably in the last 30 years. Effective algae farming necessitate a more healthful environmental method than industrial agriculture. As an existing species, if one element alters in an algae network, the whole ecological domain transforms rapidly. Because algae produce quickly, the end product can be viewed in hours or days, unlike traditional agriculture which takes seasons or years. Algae scientists stabilize environmental ecosystems to limit weed algae and zooplankton algae eaters without utilizing pesticides or herbicides. Algae farming are a new inclusion to eco-friendly food cultivation.

Some visualize massive consolidated algae farms generating food and energy on large graduated systems. But others envision complexes of more modest farms. Low-cost, creative and adept small systems have been functioning in villages in the developing world for many years.

The advantages of micro farms are obvious:

- No sizable investment in equipment.
- No expensive personnel.
- No massive land requirements.
- Algae reproduce much faster than terrestrial crops.
- Algae crops can be used directly in the community as fuel, fertilizer, and animal feed, even waste treatment.
- Makes use of unused land.
- Doesn't compete with farm crops.

Algae microfarms for family and community gardening are advancing

The original microfarms practiced growing spirulina. This is because spirulina is a recognized healthfood with a growing world-wide market.

For the last 30 years algae microfarming has been tested all over the world. Coinciding with huge commercial algae farms are the growth and progress of village scale algae systems, concentrated

mainly in evolving countries like Africa and Asia. There are also over 100 algaepreneurs in France producing algae on microfarms, and school programs now exist for growing algae; and this has progressed to Spain. These local farmers then sell their own goods in their home communities. In addition, organic fertilizers and animal feeds also reduce costs and/or produce extra profit streams.

The algae Spirulina and chlorella has been implemented and proven money makers on farms globally, perhaps in as many as 40 countries due to its lower cost of cultivation.

Why spirulina or chlorella?

The major benefits are:

- Tested safe and commonly consumed
- Simple to produce crop
- Simple to yield harvest
- Major scientific studies completed on health and medical achievements
- Existing global market developed by large commercial farms
- Low cost of entry for small-scale production
- Ability to create multiple co-products
- Able to “grow” bio fuel as a cash crop.

However, with greater knowledge of how to manage and grow other essential algae and the use of mechanical systems, most likely other kinds of algae will also become contenders for microfarming in the near future.

Higher fuel prices leads to more expensive food to purchase in stores, so growing gardens and small scale farms in communities will become more crucial. Cultivating microalgae on small areas of land would help communities meet a portion of their food requirements, and help free cropland for community recreation or reforestation.

Algae farming, both micro and macro, will soon be a cash crop in many locations, growing alongside, or instead of, many traditional crops today. With the advantages of biofuels, organic fertilizers, animal feeds, and waste treatment, algae promises to be a growth industry this century.

An Algae Microfarm Case Study

Michael Smith of Algae Aqua-Culture Technology's Green Power House™ is an environmental innovator. His love for Montana's natural surroundings combined with his software and engineering skills manifested a green biorefinery into a reality. The first of its kind 5,000 square-foot, eight-sided, three-story dome structure is located at F.H. Stoltz Land and Lumber in Columbia Falls, Montana. The concept behind the GPH™ is to generate power, but also to regenerate natural resources using carbon-negative technology.

"Imagine walking into a space filled with hanging gardens and diffused with dappled light, Eight shallow, wedge-shaped vats of algae comprise most of the floor space in the main part of the building. "These algal raceway ponds are the photobioreactor," explained Smith, "the first of the three components of the Green Power House that serves as essentially a biological solar cell."

"It's a closed-loop biorefinery," he said, "that is based on simple, long-standing, biological principals. It uses local algae, waste heat and wood waste to produce a unique and highly effective fertilizer that rejuvenates depleted soil."

A component of the "closed-loop" green network is eight algae raceway ponds that hold about 1500 gallons is what creates this algae microfarm. The algal channels produce energy-rich algae fueled by woody biomass – including wood waste from the mill, and also water, sunlight and carbon dioxide. Algae grow extremely fast and a pound of fresh algae can generate a 1,000 more btu's than a pound of coal.

The harvested algae get pumped into photobioreactor tanks where it absorbs carbon dioxide and nitrous oxide generated from the Organic Carbon Engine™ (OCE).

The OCE also performs other functions. It gasifies wood chips and other wood waste using high heat to partially run the system, and then channels left-over energy to heat exchangers to regulate the photobioreactors and anaerobic bioreactor.

The algae then enter the second component, the anaerobic bioreactor which converts the algal biomass to methane and hydrogen gases, and algae 'manure' – a nutrient-rich concentrated substance. The gases produced can be converted into electricity and other forms of energy to power the mill.

The operation also generates a mix of biochar, the organic carbon created from pyrolysis of waste biomass and algae digestate which creates high-grade organic fertilizer and soil amendments.

Each AACT component utilizes a proprietary artificial intelligence system – Autonomic Networked Technology (ANT), and each integral part can work independently or together. These bioprocessors allow each component to adjust its performance imitating the workings of nature.

A half-acre of vertical farming to grow organic food could also be sustained in the atrium space of the greenhouse.

His Primary products are:

- Organic Soil Fertility Conditioners/
- Soil Regenerating Products

Secondary Products include:

- Methane/Syngas
- Greenhouse space for crops
- Electricity-250kWh of power can be produced continuously through the biorefinery.
- Bio-oils
- Heat for industrial applications, such as drying kilns

The greenhouse also generates methane, bio-oils, syngas and thermal energy that can be utilized to run the greenhouse and power electricity.

Water is also recaptured through pyrolysis and utilized on site.

Here are some interesting facts relating to Green Power House™ facilities:

- One GPH™ and one OCE together can produce 1250kW of energy continuously, or 6 MWh/day. This works out to $264,000 annual savings, based on a national average power rate of $0.12/kWHr.
- Each GPH™ only uses 5kW per day to run, in comparison, the average American home consumes about 100 kW per day.
- Conservatively one GPH™ can power 100 homes with electricity.

Here are several species of algae worth considering for small scale production:

Spirulina has been the most extensively harvested algae since the 1970s. For over 40 years thousands of tons of Spirulina have been marketed as dietary and nutritional supplements and feed supplements in aquaculture and poultry industries. Big commercial producers cultivate it in the USA, Mexico, China, Thailand, India and other countries, and there are numerous microfarms and algaepreneurs in Europe, Africa and Asia.

- Chlorella is a single-cell, water-grown microalgae, and the first to be commercially harvested starting in the 1970s and sold as a food supplement. It is mainly cultivated outside in mineral-rich freshwater ponds under direct sunlight in Japan, China and Taiwan for global consumption. Chlorella is also commercially produced in closed pure tank culture systems using a fermentation process in Korea.
- Dunaliella is a type of green micro-algae found in highly concentrated sea salt fields in places like Australia and Israel. It is commercially cultivated and sold as a food supplement for its beta carotene and anti-oxidant benefits. Dunaliella is produced different ways – from comprehensive low-technology in lagoons to high cell density industrial systems.
- Haematococcus is raised in both open-air ponds and closed systems as the main source for Astaxanthin, a carotenoid pigment. Humans mainly consume it as an anti-oxidant food supplement. It is also used as a feed supplement for animal and aquaculture consumption like salmon, crabs, shrimp, chickens and egg production.
- Schizochytrium are marine microalgae that produce rich nutrients and developed as a source of docosahexaenoic acid (DHA) – vegetable-like oil that contains an essential polyunsaturated fatty acid. DHA is also commercially grown from microalgae by fermentation in vats, and widely used as a food supplement in infant formulas, food, beverage and animal feed products.
- Aphanizomenon flos-aquae are blue-green algae that use the available nitrogen during

harvest season from Klamath Lake in Oregon, creating massive bloom of nutrient solution. Condensed tablets of powdered A. flos-aquae are sold as a dietary food supplement.

- Botryococcus braunii is cultivated for the hydrocarbons it produces for conversion into algae biofuel.
- Nannochloropsis is being developed for alga biofuel and the energy-rich nutritional food source omega-3 oil.

What Algae Aqua-Culture Technology and the GPH™ system has proven is that it can function in all climates, create jobs, produce fuel, grow healthy soil and food for communities all over the world.

A Biofuels Case Study

Let's face it, algae biofuel is sexy.

These days it has panache, glitz, it is a celebrity of biofuels. If you say you're in "algae biofuels" people want to listen. You're a part of the "in" crowd of bio fuels. With good reason…

The US National Renewable Energy Laboratory released this formal research paper on the theoretical maximum oil yields for micro algae in various climates. For the southwestern US states (Phoenix, AZ), they claim

- 38,000 gallons/acre/year is possible with a flat ground solution.
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Corn for ethanol is currently using 27 million acres of prime US farmland generating about 300 gallons/acre/year and biodiesel from soy was until recently, using over 20 million acres of farmland at 50 gallons/acre/year.

Which is why it is ironic to find an algae biofuels pioneer tucked away in a far corner of unassuming Iowa.
algae micro farming

BioProcess Algae project, co-located at the Green Plains Renewable Energy plant in Shenandoah, Iowa in the far southwest of the state.

The company is now in the process of upgrading to a 5-acre demonstration algae micro farm of its modular technology – which is expected to be the final step before active commercialization at Shenandoah and other sites.

There are 4 things worth noting about this project.

First, it's confirmed that they'll utilize localized carbon dioxide from local businesses, in this instance an ethanol factory to create micro algae.

Second, it's verified (at pilot size) its exclusive growth content can function – which is a significant advancement, since the organization is growing micro algae from fluid, utilizing a biofilm, massively lowering the quantity of water that has to be transferred so as to grow algae.

Third, Green Plains continues to promote the venture. Along with the "a penny really matters" arena of corn ethanol, GPRE is well-known to have a persistent concentration on viability and profitability – and they've been insistent that this BioProcess Algae project isn't a science project – but a concentrated investigation of value-add prospects with regard to their ethanol fleet – understanding that if the project demonstrates that it isn't achieving GPRE's difficult success standards, it can be closed down. Well, it's not closed down.

Fourth, one more noteworthy element is its hybrid model – a semi-closed process, utilizing some components of greenhouse design in order to safeguard and heat the algae, but while also using some of the better, low-cost elements of raceway-style, open pond design. That provides a price framework along with a process that works well in the temperate climates where staple grains generally grow – means that you can place the plant beside the CO2 supply and easily share systems.

The proof is in the performance.

The company is already taking orders. In June, BioProcess Algae and KD-Pharma Bexbach announced that they have entered a commercial supply agreement for the production of EPA-rich Omega-3 oils for use in concentrated EPA products for nutritional and/or pharmaceutical applica-

tions. Under the agreement, BioProcess Algae will supply microalgal oils which will be refined by KD-Pharma's proprietary Supercritical Fluid Technology to produce highly-concentrated vegetable sourced EPA oils.

It isn't: 'Can you do it, It is: Can you do it economically?'

Howard Walker III of Westmont says he's found a recipe to convert algae into what is essentially crude oil, like the petroleum pumped from wells.

"This is a direct result of using acidic mine discharge to grow the algae," he said. "Anybody using (other) algae is not doing anything like this."

U.S. Alternative Fuels at 432-438 Horner St. has worked on the creation of biodiesel from algae for around six years. The concept ended up being to utilize the technologies used to produce ethanol from corn oil and modify it to obtain fuel from algae oil. Similar work has actually been taking place since the 1970s all over the country.

They chose to concentrate on algae since it is expected the water-grown plant can generate 10,000 gallons of biofuel per acre of "crop." Corn generates around 18 gallons an acre, he explained.

"It will alter how the petroleum industry operates. I have full confidence we can actually control how the process is done so we don't have to worry about any major environmental disaster like the BP spill (in 2010 in the Gulf of Mexico) It isn't: 'Can you do it'" he said. "It is: 'Can you do it economically?'

Walker is expecting the Johnstown factory will be in commercial use within a couple of years, without the need of outside funding. The small-scale factory presently running can generate around 51/2 gallons of fuel an hour from 30 gallons of algae.

He anticipates the price under $30 for a 42-gallon barrel.

A Developing World Case Study

Spirulina is being grown on village microfarms around the globe.

Spirulina contains many healthful micronutrients – vitamins, minerals and complete proteins, including essential amino acids.

It has been proven to cure eye problems in people lacking Vitamin A due to being a rich source of beta carotene. Some facts:

- Consuming 1 cup of Spirulina is sufficient to give 13 percent of vitamin A required by an adult on a daily basis.
- One cup of Spirulina contains 19 percent of vitamin C of an adult's daily requirement.
- Other vitamins identified from Spirulina are vitamin B1, B2, B6 and B9.
- Dried Spirulina is composed of approximately 60% protein. A 112g serving of good quality spirulina offers about 64g of protein, a considerably very high value.
- The protein and B-vitamin complex nutritional benefits in Spirulina improve an infant's diet considerably.
- It is rich in essential GLA fatty acids which improve hormonal balance, and Spirulina is the only other food origin besides mother's milk.
- Consuming spirulina as whole food or supplement, you can reap the healthy benefits of several minerals like calcium, iron, potassium, magnesium, phosphorous, selenium and chromium. Iron anemia, the most common mineral deficiency can be eliminated by one tablespoon a day.
- Ingesting spirulina improves a diet lacking proper vitamins and minerals, and also children's physical well-being and mental development.

Spirulina is a highly digestible protein food for people who suffer from malnutrition and whose intestinal systems cannot absorb nutrients effectively. Clinical research shows how it restores healthy intestinal flora and makes the immune system stronger.

Spirulina thrive in open ponds and develop naturally in tropical and subtropical lakes. Many enterprises have organized farm cooperatives in small villages around the world since this method of cultivating spirulina requires low monetary investment and low technology. Many programs over the past 30 years have been growing spirulina to feed the people locally in Africa, Asia, and South America.

Here is a summary of the ground breaking projects and models from the various projects in Africa and Asia now.

Ripley and Denise Fox of France created the non-profit Association Pour Combattre la Malnutrition par Algoculture (ACMA) to help establish and develop the Integrated Health and Energy System in a remote village in Northern Togo from 1984-1989. Properly handled through sanitation and waste treatment, recycled wastes in the villages were used to cultivate spirulina.

Spirulina produced from one 100 square meter pond supplemented the diet of 100 children daily. Power generated from solar panels churned the pond paddle wheels. After pouring the pond water through a screen, the algae became a thick paste to be dried in a solar heated dryer. Then the local health clinic distributed the dried spirulina as a daily supplement to malnourished children. Just one tablespoon mixed with water produced exceptional results within a week.

Burkina Faso has nine spirulina microfarms or more today

The first algae micro farm in the country of Burkina Faso (spirulineburkina.org) got underway in in the town of Koudougou in 1999 under the patronage of the Catholic Organization for Development and Solidarity Algae "Micro Farming"-A Developing World Case Study(OCADES). The three main purposes were to

- 1) supply a percentage to the health clinics of the Diocese (CREN- Centre de Récupération Nutritionelle) and other health centers in Burkina with spirulina to fight malnutrition,
- 2) sell remaining stock quantities commercially to offset production costs while offering the community at large a

nutritious food supplement at low cost,
- 3) create jobs at the farm to combat unemployment in Koudougou.

Since 2001 with the remarkable achievement of the Spirulina farm in Koudougou, the Burkina Government participated in another large project, the Nayalgué farm, in cooperation with the diocese of Koudougou and the French NGO TECHNAP. Nayalgué, means in Mòoré language "that which expands". This algae microfarm is 3600 square meters and has the ability to produce approximately 8 tons a year.

Over production on this large farm lead to the local market in exporting spirulina to France in particular. The need right now is to increase export supplies to help finance its humanitarian operation (45% of production is given or sold at humanitarian prices), and become fair-trade certified.

Nayalgué strives to be a model farm in Africa, successfully operated by locals and working to be self-financing and open to those who wish to study its thriving program.

ANTENNA Spirulina Programs in Africa and Asia

Denis von der Weid established Antenna in Geneva, Switzerland in 1989 by advocating spirulina against malnutrition, with a goal to create a sustainable economic activity while feeding the poor.

With over 20 years of out in the field practice, the Antenna Foundation (antenna.ch) has been committed to advancing the necessary means and training procedures for the cultivation of the extraordinary food supplement to those in need in developing countries in Africa and Asia. Antenna France (antennafrance.org) and its teams in those communities initiated programs for the local production of spirulina on an enduring and small financial outflow model.

The advantages of spirulina in fighting the war against malnutrition:

- Effectiveness: it only takes about 4 to 6 weeks of 1 to 3 grams of spirulina per day to improve the health of a malnourished child.
- Stability: spirulina is cultivated and dispensed locally, to lessen the risk of relying on imported food supplements. Self-sufficiency continues to be the main objective.
- Financial Value: the construction and installation of ponds or tanks costs between 10 and 20€ per square meter. Each square meter of the pool produces 2 kg of dried spirulina per year and provides for the treatment of 20 children in need. A basic pond of 200 square meters guarantees that 1500 children per year will receive a nutritional diet.
- Ecosystem: spirulina requires less land and water than traditional agricultural products, and contains beneficial micronutrients and protein.

The results of Spirulina cultivation:

- Cultivation: 18 spirulina production farms have been created in 11 countries in Asia and in Africa. In 2010 over five tons of spirulina were cultivated.
- Recipients: as humanitarian relief, among 13'000 malnourished children in Africa of the over 80'000 children have benefited from spirulina cultivated by these units.
- Commercial Growth: in Africa and in Asia around one hundred jobs were generated by the production of spirulina, in addition to which local communities profited by its distribution and sales.

Antenna calculates the installation costs of ponds between $15 and $30 per square meter, and a 200 square meter pond can produce sufficient crops of spirulina to benefit around 1200 children per year. It will sustain a viable food supply network and also provide local jobs and income, particularly for women.

There are spirulina farms in Burkina Faso, Cambodia, Laos, Madagascar, Mali, Mauritania, Niger, Central African Republic and India, and today eight of these microfarms are self-sustaining.

In Cambodia, local families grow mushrooms and vegetables on farms near Angkor Wat and Phnom-Penh. In Mali, students are receiving on-the-job training on farms in spirulina and bee keeping. To meet the strong demand a producer in Togo is spreading his farm from 100 to 600 square meters. Spirulina will be dispensed to poor children at nutrition houses.

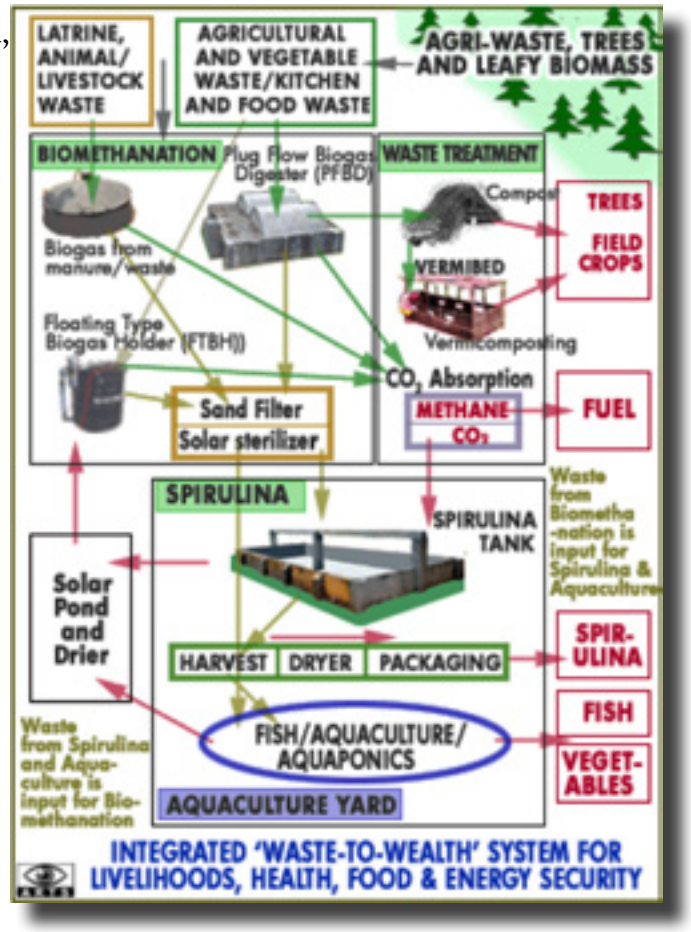
A Village Scale Case Study

In an extremely interesting case study led by The Society for Appropriate Rural Technology for Sustain ability (ARTS) and Dr. Subhrankar Mukherjee as lead investigator, they set out to reduce child mortality by doubling the productivity of Spirulina micronutrients as a food supplement to meet the nutritional requirements of 540 children in the immediate area.

The secondary objectives were to provide food, livlihoods, energy, and environmental security to the area from a single, multi-faceted unit.

The graphic on the right illustrates a small scale model designed for sustainable and integrated health, waste disposal and energy generation, which can produce:

- Methane fuel from biomethanation of agricultural, livestock, and domestic waste, with compost and CO2 as by-products.
- Spirulina and fish the production of aquaculture by utilizing the CO2 by-products from above.



The design currently incorporates:

1. Biomethanation: is the process of trapping methane and using it for
   - generation of electricity
   - fuel for industrial processes
   - domestic use in homes for cooking.

2. Biogas from leafy biomass

Biogas powerplants have proven themselves reliable, and decentralized source of energy generation for 100's of years. Leafy biomass from non ediable crop waste as well as environmental residue used in anaerobic digesters.

3. Biogas from Animal waste. The technology to convert animal manure into biogas is well established and a dependable form of energy.

4. Biogas from kitchen waste.

Good quantities of kitchen waste are also available from village households, assuming that:

- 100 inhabitants generate ~200 grams of vegetable and kitchen waste per day, which leads to the generation of ~02 x 1000 kg. = 200 kg of kitchen waste/products per day.
- Five kg. of vegetable and kitchen waste may produce 1 Nm^3 of biogas; this translate to the potential of generating 40 x 1.25 kWh = 50 kWh of energy.
- Hence, an average total availability of 200 kg per day of kitchen waste products throughout the year at one location may 40 Nm^3 of biogas per day, which in turn is equivient to running a:
    - 2 kWe electricity generator at 100% PLF, or
    - 2.6 kWe electricity generator at 80% PLF

1 Nm^3/day drum-type 'Shakti Surabhi' bio-digester from Vivekananda Kendra, Kanyakumari

Therefore in the case of kitchen waste, it would be both easier and cost effective to this as a energy distribution paradigm, instead of a central facility. The procure small digesters, which requires approx. 5 kg of kitchen/vegetable waste per day. The quantity for smaller of larger units can also be determined by extrapolation.

Biogas applications and uses:

- biogas lamps
- generate electricity
- biogas stoves

By products from biomethanation

1. CO_2 absortion in Spirulina culture

Depnding on the feedstocks and production methods, biogas contains between 35% and 45% of CO_2. The rest is methane (CH4), with some trace gases and leements. This large percentage of CO_2 makes pre-combustion CO_2 absortion technologies commercially viable. Although commonly done in biofuels, absortion of waste CO_2 into the spirulina culture is a major innovation.

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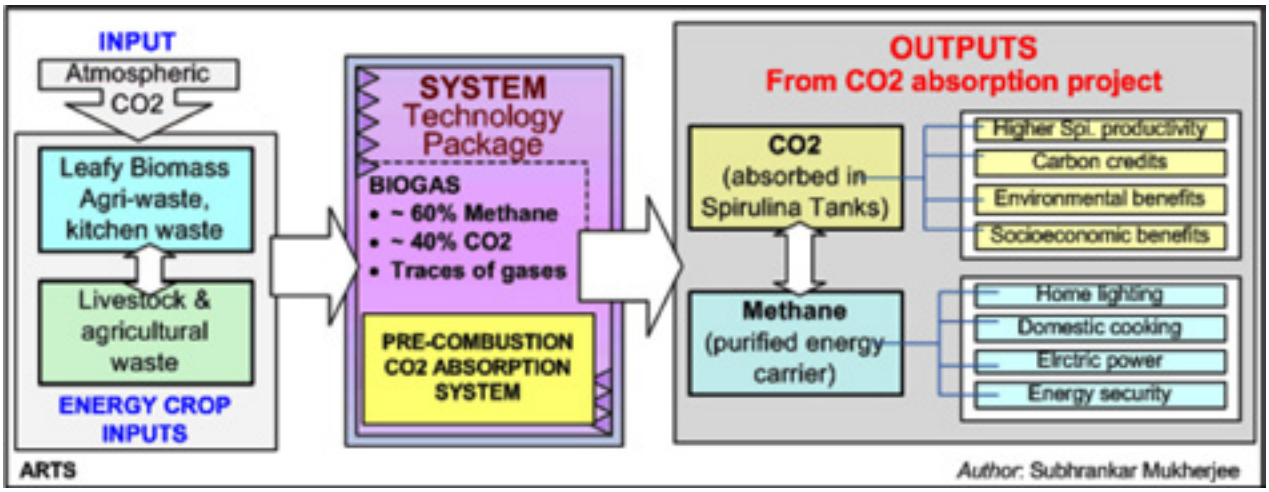

2. Compost

The left over residue from the biometanation process can also be fed directly into a verm-bed-an 100% organic fertilizer andn organic process in which earthworms consume various organic wastes such as cattle manure, dreid leaves, kitchen waste, agricultural residues-and convert them into high quality organic compost.

3. Spirulina as a "Super Food."

The benefits of Spirulina as a health food as been outlined previously so I won't go into it here. However it should be noted that it is very possible it could easily feed the world's hungry. It can also be grown on brackish water and non-arable land. It is low fat, low cholesterol, source of easily digest able vegetable protein containing all the essential amino acids that can't be produced by the body.

Another compelling fact of Spirulina is that it improves not only the actual strength of the body, but in children it also improves the cognitive development as well. As little as one gram of Spirulina can correct malnutrition in a small child in a matter of a few weeks.

The benefits of Spirulina cultivation:

- As a comprehensive solution to malnutrition;
- It is a cost-effective solution compared to artificial vitamins or other food additives.
- It is a viable commercial product and can create sustainable employment.

4. Aquaculture

While cow dung is commonly used as fertilizer in fishponds in some locations, it is suggested that the fish yeild can be more than doubled if the digested slurry from the biogas plant is used instead of raw manure.

The objective is to efficiently recycle the slurried nutrients from the biogas and Spirulina culture facilities into a aquaponic reservoirs for the production of plants and fish, which can also be marketed commercially.

If such aquaculture facility was operated close to the biogas plant, it could potentially provide energy for infrastructure, as well as nutrition for lower quality fish that in turn could used to produce fish meal for livestock, providing more profit streams to the local village.

Costs:

The total cost is estimated to be slightly more than $95,000 US dollars by a 2010 estimate. Considering that it is expected to benefit 5000 households and about 25,000 people total, this works out to approx. $3.80 per person, per year.

By any measure whatsoever, this is a small price to pay for such a large benefit.