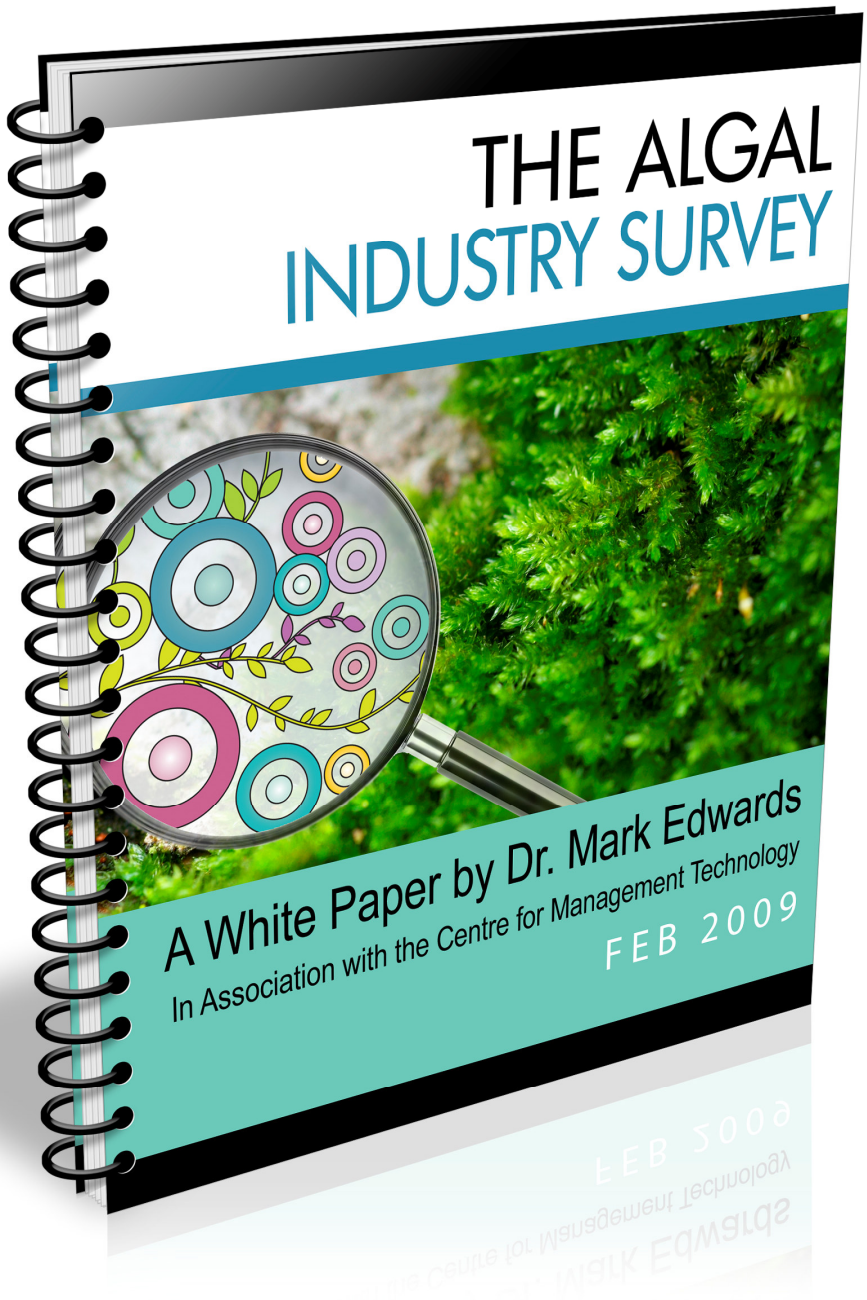
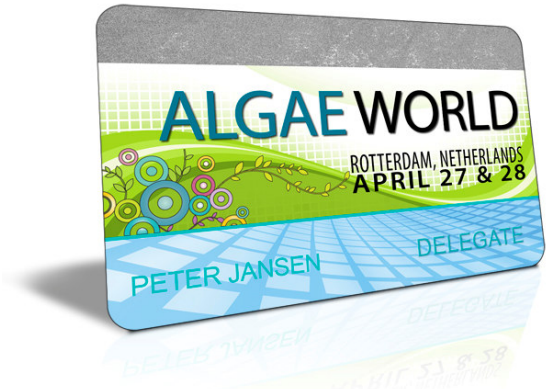

THE ALGAL
INDUSTRY SURVEY
A White Paper by Dr. Mark Edwards
In Association with the Centre for Management Technology
FEB 2009

THE ALGAL INDUSTRY SURVEY



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For decades, the algal industry moved forward very slowly. In a world economy with low prices for fossil fuels and foods, alternative food and energy production sources made no economic sense. Interest in algae as a food source spurred considerable research after each of the world wars but production problems and costs ended those efforts. Excitement about algae as an energy source reignited algal research in the 1970s but faded due to production problems and oil prices at $10 a barrel.

Recently, the combination of escalating costs for energy and foods combined with climate change has renewed interest in algae as a clean, carbon neutral energy source. Unlike other forms of green energy such as solar, wind, waves, tides and geothermal, algae offer the only practical source for liquid transportation fuels that may displace oil imports. In the U.S. and many other countries, about 97% of oil imports are liquid transportation fuels and increasing costs and availability jeopardize the stability of nations. Disruption of fossil fuel imports would be catastrophic to the economy, food supply, military and transportation for most countries. Consequently, many countries are examining the potential for algae as an energy source.

Research and production experience suggest that algal biomass offer considerable advantages over land-based biofuels such as ethanol. Ethanol production consumes its energy contribution in fossil resources required for growing, harvesting, refining and distribution. Ethanol competes with food crops for cropland, freshwater, fossil fuels and scarce agricultural chemicals thereby increases demand and prices for all agricultural inputs and drives up food and feed costs.

Algal production does not compete with food because the biomass can be grown on deserts or wastelands using no fresh water and no or few fossil fuels. Algae produce biomass use abundant resources that are surplus and cheap and will not run out. Algae use sunshine, carbon dioxide, waste or brine water and some nutrients. Algal production can use green energy for supporting biomass growth such as solar or wind.

Relatively little is known about the algal industry for three reasons: newness, intellectual property protections and extravagant claims. Minimal credible research has examined this new industry and most the major firms are extremely secretive. Intellectual property protections for proprietary strains of algae are carefully protected and proprietary production methods undermine scientific collaboration. Numerous scientists at algal conferences complain that they have signed nondisclosure agreements with their companies and cannot share critical details about what they have learned from their algal production experiences. The consequence of secrecy is that new firms are sentenced to repeat past mistakes. Companies have gone out of business repeating the same algal production mistakes because prior knowledge was locked up in intellectual property protection.

The algal industry lacks credibility because many firms make grandiose claims on their websites and corporate brochures with the intent of attracting capital investors. These firms carefully avoid reporting their actual production figures or production failures in order to maximize the probability of obtaining the next round of funding.

The Algal Industry Survey is intended to provide a baseline of industry information and to assist in creating strategy for research, development and demonstration priorities.

Methodology

The Algal Industry Survey examines the critical industry issues including especially algal production. Survey responses came from participants of **Algae World 2008** which met in Singapore in November and yielded 137 respondents. Algae World 2008 was among the first few high profile international conferences focused on the algal industry. Algae World had attracted close to 150 participants. The conference emphasized algal biomass production for energy and the speakers emphasized growth, development, extraction and processing issues focused on maximizing algal oils for energy production.

The Algae World 2008 Conference in Singapore included many international respondents from all over the world but primarily from Pacific Rim countries and India. About 40% of the respondents identified themselves as scientists, 30% consultants and 20% academics. Roughly 50% of respondents had less than five years experience in the algal industry while about 16% with over 20 years of industry experience. The algal industry is new so it is not surprising that most participants have relatively short experience in the industry. In the U.S., there has been no government funding for algal research for over a decade so most people with algal experience work for international firms.

Survey research includes several limitations. The sample size for the Algal Industry Survey is relatively small which limits its reliability and generalizability. The questions inquire about respondent beliefs so the results are perceptual rather than factual. Future industry surveys need to reflect the insights and beliefs of more experienced participants. Larger sample sizes will enable analysis of possible differences between experienced and less experienced respondents and possible differences between algal producers focused on different products or producers from different countries.

Results

The survey began with a question about which biofuels would be produced from algal biomass.

What will be the top three biofuels made from algae?

Biodiesel, gasoline and jet fuel were the dominant biofuels respondents believe will be made from algal biomass. Several respondents felt that methane or hydrogen would be produced. There was little support for ethanol.

What feedstocks make the most sense for algal oil

Feedstock	World
Marine algae	58%

production?

Several presentations on the use of marine microalgal feedstock which may have skewed this result. Respondents indicated a significant preference for naturally occurring species over genetically modified organisms. GMOs are likely to create ecological and political challenges for producers.

Carefully selected strains	58%
Naturally occurring species	42%
Fresh water algae	28%
GMO strains	16%

Percentages do not add to 100 because respondents were able to select multiple methods.

Growing system

The type of growing system was the most common question most attendees asked. Producers have the most experience with open pond production and open ponds offer the lowest cost production method. Natural algal stands are not favored probably due to their low productivity for target organisms.

Growing system	World
Natural stands	13%
Open or semi-closed ponds	58%
Semi-closed systems	42%
Closed systems	28%

Where will algal production occur?

Respondents were split on where algae production will occur indicating a slight favoritism to the tropics and mid-latitudes.

Location for algal production	World
Tropics	38%
Mid-latitudes	35%
All over the Earth	27%

The critical variables for algal production systems put species selection at the top.

Critical variables

Species selection dominates the important production issues. Secondary issues include light penetration, the type of growing system and controlling culture variables. Less emphasis was given to the cost of nutrients, methods of mixing the culture, the type of monitors and the avoidance of algal build up on or in the production containers.

Critical system parameters	World
Algae species	4.1
Light penetration	4.0
Growing containers	3.9
Variable controls, e.g. temperature and pH	3.6
Nutrient costs	3.2
Mixing methods	3.2

Monitors	2.9
Fouling	2.9

Production systems seem to be most critical to the algal industry.

Critical issues for the algal industry

Production systems represent the most tangible elements of algal biomass growth and development. Speaker emphasized a wide variety of different biomass production models.

Numerous people indicate concerns about staffing algal R&D and production because so few people are trained, especially in the U.S. where few universities have algae labs. Developing or selecting the best algal strains is a key issue because many firms use species selection for proprietary differentiation. Cost for algal production inputs was also seen as a critical issue.

The set of production issues beginning with component separation, light management, extraction are important but not as critical as production systems, personnel and strain selection.

Most critical industry issues	World
Production systems	4.3
Trained personnel	4.2
Algal strain selection	4.2
Input costs	4.0
Develop high lipid strains	3.6
Component separation	3.6
Light management	3.6
Extraction	3.6
Contamination	3.4
Nutrient delivery	3.2
Temperature management	3.1
Intellectual property	3.0
Monitoring systems	3.0
Mixing	2.9
Public image	2.8

Supply-chain

The supply-chain results were consistent with the results from the critical algal industry issues. Conference interviews indicated that many people were concerned about the availability of capable people for staffing the necessary disciplines to build a new industry.

It remains unclear whether upstream, input supply, and downstream, processing will be integrated with producers or separated in vertical marketing channels. The level of concern about processing, monitoring, extraction and nutrient supply were about

Supply chain issues	World
Growing systems	4.3
Trained personnel	4.2
Component separation	4.2
Design / construction	4.0
Processing	3.6
Monitoring systems	3.7
Extraction	3.6
Nutrient supply	3.6
Distribution / logistics	3.4

equal.

Water remediation dominated social and economic issues.

Likelihood that algae will play out significant role in social and economic issues

Water remediation was the highest rated issue possibly because of the excellent presentation by Professor Avigad Vonshank of Ben Guiron University that included cleaning polluted water. Practically all nations of the world need water remediation and algae provide a low-cost, low energy solution.

Displacing oil imports, fossil fuels and sequestering CO_2 all received high scores. Narrative comments from Algae World indicated a strong focus on algal energy production with significantly less interest in coproducts such as animal fodder, pharmaceuticals, fertilizers or moderating world hunger.

Social and economic issues	World
Cleaning polluted water	4.5
Displacing oil imports	4.1
Displacing fossil fuels	3.8
Sequestering CO_2	3.7
Cleaning polluted air	3.5
Animal fodder	3.4
Health foods	3.3
Medicine / pharmaceuticals	3.0
Moderating world hunger	2.8
Creating organic fertilizer	2.7
Reducing transport costs	2.6
Clean burning cooking fuel	2.5

Respondents were presented with the question: “If your country focused on algaculture and made it a top priority, how soon could industry replace 100% of imported oil?”

Replace 100% of imported oil for your country

Respondents were optimistic regarding the probability of replacing imported oil with home grown algal oil. Several narrative comments indicated that replacing oil imports was the top priority.

Replace 100% of imported oil	World
10 – 20 years	47%
21 – 40 years	34%
never	19%

The following two questions requested narrative comments.

What three key things need to happen to move the algal industry forward?

The dominant words used to enhance the industry were information, financing, funding sources, education and production. The industry needs government investment because the initial investments and risks are very high. The recommendations are grouped and ordered based on how often respondents recommended the action.

INFORMATION

The industry needs information sources to convey the algae story.

- Why isn't there a website that summarizes key algal sources, links and resources?
- Is there a profile of businesses and what they're doing in the algal industry? See Appendix 1 at the end of this document.
- Can we create information sheets, pamphlets and books to inform people about algae?
- Can we create a PR campaign, a political action committee and lobbyists?

FINANCING

The industry needs considerably more funding from both public and private sources.

- Where are existing firms getting their funding?
- How can the algal industry persuade government to provide more R&D funding?
- How can investors evaluate algal investment opportunities?

EDUCATION AND TRAINING

The industry needs to find ways to train people in algal production.

- Where can algal companies find trained technical and professional personnel?
- What kind of algal training is available and where?
- What technical skills and competencies are critical for building an algal industry?
- Is there a grade school and college curriculums for algae?

PRODUCTION

The industry needs to describe and define algal production.

- What are the key production issues and how are they solved?
- What is the level of investment necessary for algal production?
- How can production losses be minimized from invasive species or grazers?
- What are practical methods for algal extraction and biomass processing?
- Can small community sized production systems be developed?

COLLABORATION

The industry needs to find ways to enhance networking and shared knowledge.

- How can information be shared and still maintain a little property protections?
- What kind of collaborative social network might work for algal professionals?
- Is there a summary of bloggers and journalists who follow algae?

What algae information would most benefit you?

Respondents indicated a desire for better information on algae, insights on financing, support for education and training, production information and stronger collaboration. Additional requests included the ideas below.

- **Industry summary.** The algal industry may follow the lead of other forms of renewable energy such as solar and wind to create a summary of the industry.
- **Demonstration units.** The algal industry should build and operate demonstration facilities so that people can see algal production.
- **Decision support.** Information on production, extraction and processing are too distributed and need to be more accessible.
- **Products and coproducts**. What is the total product array for algal biomass and what production strategies are used to maximize each product?
- **Real production numbers.** Actual rather than theoretical production numbers would be a huge breakthrough.
- **Ideal strains.** What are the ideal strains for various products and what are sources for these strains?
- **Market trends.** What are market trends in the algal industry?
- **Independent reviews.** Are there independent reviews of algal production methods?

Summary

The Algal Industry Survey was designed to provide a baseline of information about the emerging industry. Respondents were generally positive about the future of the industry and optimistic about algae's potential to help solve critical social and economic problems.

Most industry participants believe algal production will focus on three biofuels; green diesel, gasoline and jet fuel, JP-8. There seems to be no industry consensus on a best approach to algal biomass production including growing systems or production locations. Algal producers are experimenting with a diverse set of production models. Production models seem to vary based on the production objectives, type of feedstock and location. International producers tend to use open ponds while U.S. producers are planning to use closed or semi-closed cultivated algal production systems. International producers are using naturally selected algae species while U.S. producers are planning to use a combination of species selection and genetically modified organisms that maximize the production of algal oil.

The critical industry issues are stable production systems, trained personnel, strain selection and costs. Besides the production of liquid transportation fuels, respondents believe algae will play a major role in carbon capture and recycle, water remediation and feed for fish, fowl and animals.

Nearly half of respondents believe that a focused algaculture program could replace oil imports for their country in 20 years. Conversely, roughly 20% of respondents believe that algae will never replace oil imports.

Recommendations to move the industry forward include better access to information, substantial increases in public and private funding for algal R&D, stronger education and

training, more information on production issues and better networking and collaboration. Industry participants want to see demonstration projects, decision support systems and independent reviews of algal production systems.

Future of algal industry research needs to drill down on production, supply chain and social and economic issues. Improved information on industry needs will support industry participants and provide critical information needed for public policy decisions and support.

Acknowledgments

Several key people assisted in the development of the survey including:

- Mark Allen, CEO and President, A2BE
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- Jeff Mettais, Marketing Officer, A2BE
- Greg Mitchell, Research Biologist, Scripps Institution of Oceanography
- Qiang Hu, Assoc. Prof. Arizona State University
- Al Darzins, Applied Sciences Manager, NREL

About the Author

Dr. Mark Edwards is Director of GreenIndependence.org, the Algae Collaboratory that brings together scientists, academics, practitioners, students and communities who share knowledge and biotechnology tools to bring algae's full promise to the world.

He recently released his book "Green Algae Strategy" which has been enjoying considerable success and rave reviews from peers and industry experts. Dr. Edwards provided excellent long term projections for Algae biofuels.

Please send your questions and feedback about **'The Algal Industry Survey'** to Mark Edwards, Arizona State University via email at **drmetrics@cox.net**.

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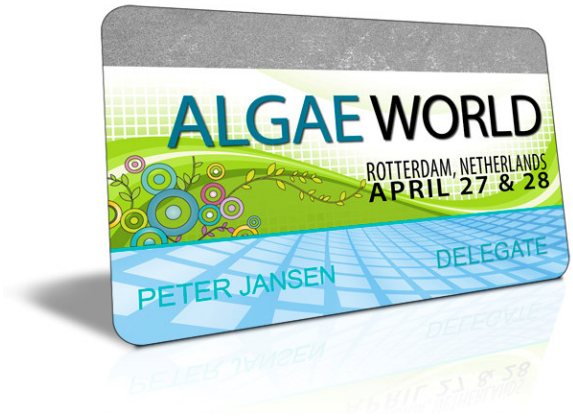

Algae World 2009

Algae World 2009 will be held from 27-28 April 2009 in Rotterdam, The Netherlands.

Algae World 2009 is a communications platform for the algae community to meet, pinpoint and discuss key strategies adopted by successful algae businesses in integrating future and upcoming trends into their business value chains.

In fact, at Algae World 2009, you will hear from the algae sector's top experts and decision makers as they share their frank insights on **overcoming technical, organizational and financial challenges**, as well as triumphing over the uncertain years ahead.

Algae World 2009 is a must attend forum dedicated to **mapping the entire algae value chain, from cultivation to application**, and will give your Algae business the edge to stay ahead in this very competitive environment!

The very exciting sessions at Algae World 2009 will begin with a **focus on upcoming opportunities and successful business models shared by the sector's top project managers and investors**.

To find out more about **Algae World 2009**, and how to sign up for this authoritative event today, please visit **www.futureenergyevents.com/algae/attend/** today.

Appendix 1

Algal Industry Producer Profiles

About 98% of the algal industry focus today is on algal biofuel production but has not produced a hundred barrels of oil. Within three years, the industry will be producing millions of gallons of algal oil and valuable coproducts. Green solar production will expand exponentially.

The algal industry has moved from staid to super charged with breakthroughs occurring weekly. [1] Most innovations are coming from the private sector because U.S. government R&D and grants have been zero. Some of the leading players in the industry are getting $10 million in private equity but that is hardly enough to build a lab, let alone a small pilot plant. The industry needs substantial government investment to achieve Green Independence.

The industry faces two major threats:

1. **Insufficient investment** slows R&D and the world food crisis may degrade into mass migrations and war over insufficient food, clean water and energy.
2. **Commercial firms control R&D** and put a lock on algal production and biotechnology breakthroughs.

If private firms locked up the basic production methods, then sustainable world food solutions would exist but are likely to be beyond the financial means of the people who most need them. Widespread adoption and diffusion require open source, public access to technologies. [i]

Three companies – BASF of Germany, Syngenta of Switzerland and Monsanto of St. Louis – have filed applications to control nearly two-thirds of the climate-related gene families submitted to patent offices worldwide. These "climate ready" genes will help crops survive drought, flooding, saltwater incursions, high temperatures and increased ultraviolet radiation – all of which are predicted to undermine food security in coming decades.[2] Company officials deny the climate-ready seed applications amount to an intellectual-property grab. They say GMO seeds will be crucial to solving world hunger but would not be developed without patent protections.

Monsanto, for example, makes 60% of its revenue from genetically modified seeds.[3] In 2006, over 78% of U.S. corn used for all purposes came from genetically modified seeds. Big agribusinesses are eager to control access to genetically modified algal strains.

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[1] See www.BiofuelsDigest.com.

[2] Weiss, Rick. Firms Seek Patents on 'Climate Ready' Altered Crops, Tuesday, May 13, 2008; Page A04ps, Washington Post, May 13, 2008; A4.

[3] Marrero, Carmelo Ruiz. Biotech Bets on Agrofuels, Center for International Policy (CIP), April 24, 2008. http://americas.irc-online.org/am/5179

Lack of government R&D investment has pushed the industry towards private investment that focuses predominately on biofuels. Algal solutions for food, medicines, vaccines and fertilizers are getting very little attention.

Industry activity is difficult to decipher due to extensive puffery and trade secrets. Executives talking about their companies at conferences, interviews, press releases and websites tend to make grandiose claims designed to impress investors but too often tend to be more hype and hope than fact. Neither production efficiencies nor costs are typically revealed because they are considered proprietary. The other challenge is that the industry is so new, few participants have either a background in biotechnology or a track record in producing algae.

Algae's potential has seduced many investors, including prominent Silicon Valley venture capitalist firms. De Beers Fuels, a South African company, collapsed in 2007 following several years of false promises. Over 75% of the companies researched for this project that had high hopes in the 1980s and 1990s no longer exist.

The Department of Defense estimates that current production cost of algal oil currently exceeds $20 per gallon. A crude oil barrel contains 42 gallons. Crude oil gets changed into petroleum gas, gasoline, oils, tar and asphalt. Roughly 28 gallons of gasoline is refined from each barrel of crude oil.

Therefore, a $120 barrel of crude yields about $112 worth of gasoline when gasoline costs $4 a gallon. Algal fuel at $20 a gallon would cost $560. Obviously, algal fuel is not economic until the cost of production decreases by a factor of five. In spite of the current cost difference, over 50 companies and 20 universities are working on algae, primarily for the production of algal oil. The organizations profiled here are sorted based on their algae growing strategy, not their investment potential.

Growing strategies include open ponds, natural settings and closed algaculture systems. *BiofuelsDigest.com* tracks activity in algae and the biofuels industry.

Open ponds

LiveFuels, based in Menlo Park, California plans to extend the Aquatic Species Program research and use open-pond algae biofactories to commercialize its technology. John Sheehan, who led the Aquatic Species Program, joined Live Fuels in 2007 as VP of Sustainable Development. Instead of attempting to convert algae directly into ethanol or biodiesel, this startup is trying to create green crude that could be fed directly through the nation's current refinery system.

LiveFuels created a national alliance of scientists led by Sandia National Laboratories, a U.S. Department of Energy National Laboratory focused on producing biocrude oil by the year 2010. The alliance is expected to sponsor dozens of labs and hundreds of scientists by the year 2010.

The company's web site displays technical exuberance in predicting that algae can produce up to 20,000 gallons of oil per acre. The company goes on to state that the entire U.S. supply of imported oil could potentially be grown on 20 million acres of marginal land.

OriginOil, Inc. in Los Angeles, California, received its first funding in 2005 and is developing a technology that will transform algae into a true competitor to petroleum. The company claims its patented technology will produce "new oil" from algae, through a cost-effective, high-speed manufacturing process. This supply of new oil can be used for many products such as diesel, gasoline, jet fuel, plastics and solvents without the global warming effects of petroleum.

Seambiotic's Algal Ponds

Seambiotic, located in Ashkelon, Israel was founded in 2003 and produces algae for a variety of applications, including health foods, fine chemicals, medical products and biofuels.

The firm is working with Inventure Chemical and with the Israeli Electric Company, using IEC's smokestack for a source of CO2 while it grows algae in eight open algal ponds.

PetroSun based in Scottsdale, Arizona is publicly held and the management team comes from the petroleum industry. Petro Sun began their algae-to-biofuel production factory in Rio Honda, Texas, in April 2007. The algae farm is a network of 1,100 acres of saltwater ponds that PetroSun thinks will make 4.4 million gallons of algal oil and 110 million pounds of biomass per year.

PetroSun intends to extract algal oil on-site at the farm and transport it to company biodiesel refineries via barge, rail or truck. The company plans to open more farms in Alabama, Arizona, Louisiana, Mexico, Brazil, and Australia in 2008.

The company also offers environmentally-friendly energy production: recycled energy. Their recycled-energy technologies capture the energy content of waste exhaust heat from industrial processes and internal combustion engines.

PetroSun's markets for the Waste Heat Generator include algae and other biomass facilities, oil refineries and drilling rig power plants. It is estimated that 60% of all fossil fuel burned for these and other industrial uses is wasted in the form of heat, pressure and polluting emissions. Their goal is to capture this wasted energy and convert it to usable electricity. The Company is focusing its initial efforts in Louisiana, Texas, New Mexico and Arizona.

PetroSun BioFuels Refining recently signed a joint venture to develop and operate a 30 million gallon a year algal biodiesel facility in Coolidge, Arizona. Construction is projected to commence in the third quarter of 2008. In 2007, PetroSun announced a letter of intent to supply 54 million gallons of algal oil a year to a new Bio-Alternatives biodiesel plant in south Louisiana. The initial delivery to Bio-Alternatives refinery will be in the third quarter of 2008.

PetroSun created an algae-to-jet fuel team relationship with Science Applications International. The companies are working to transition algal biofuel technology to the commercial sector with government contracts. PetroSun has made twenty acres of ponds available at its Rio Hondo, Texas facility for R&D related to an algae-to-jet fuel. Refiner

Neste Oil in Helsinki, Finland is refining imported vegetable oils, palm oil and algae to make 170,000 tons of biodiesel a year in Porvoo, southern Finland. The renewable fuel is suitable for all diesel engines and is the strategic cornerstones for Neste, who say the technology outperforms both existing biodiesel products and crude oil-derived diesel products available.

Neste's renewable fuels goal is to have 70% of its raw materials coming from nonfood feedstocks in ten years. By 2020, they want to have all their raw materials they use from outside the food chain.

Ingrepo, a Netherlands-based biotechnology company specializing in industrial largescale algae production, plans to build algae production facilities in Malaysia. Partnering with Biomac Sdn Bhd, they will provide Malaysians with the opportunity to grow large-scale algal production for biofuels. Biomac CEO Syed Isa Syed Alwi says the algal PowerFarms will be ready for commercialization in the next year. Malaysia was chosen for its good weather conditions to grow algae, infrastructure and government interest in agro-biotechnology.

Natural settings

The aquaculture industry began when producers enhanced natural settings to produce more oysters, clams and fish in open, semi- and closed-growing environments. Algae producers around the world have similarly been enhancing algal stands in natural settings by reducing predators and improving water mixing.

The advantage of finding algae growing and cultivating the growth in natural settings seems obvious: nature provides the growing container and most the nutrients. However, challenges similar to controlled settings occur in natural settings, including especially controlling growth and stability.

Kelco, based in San Diego, harvests natural kelp beds with a specially designed mowing machine. They load the heavy biomass onto barges for transport to the processing facility to produce alginic acid.

Neptune Industries, based in Boca Raton, Florida, creates sustainable, eco-friendly aquaculture with integrated solutions. Dwindling supplies of wild-caught stocks, continued environmental damage, escaping fish and disease from self-polluting net pens have restricted industry growth.

In addition to hydroponically grown vegetables, lettuce, herbs and fish ponds, Neptune's patented Aqua-Sphere system uses fish waste to create additional revenue streams through the growth of algae for biofuels and methane gas.

Blue Marble Energy, based in Seattle, searches for unwanted wild algae growth and has developed methods for cleaning polluted water where excess nutrients lead to algal blooms that plague water systems. BME converts algal biomass to energy by creating, centralizing, and harvesting wild algae blooms.

BME's technology and process of harvesting remediates polluted water through biomass generation. BME technology harnesses nutrients and converts polluted environments into natural biofactories for generation of renewable energy feedstock while cleaning the environment. The company's business model is smart, they get paid to clean water and they produce biomass that can be processed or sold. BME marine technology can be placed in a broad array of geographies:

- Waste water systems
- Fresh water lakes, rivers, and streams
- Metal remediation for mines and other polluting industries
- Coastal remediation

By addressing wild algae growth versus the traditional mono-culture growth for biomass generation, the company keeps capital costs low and is able to produce a volume output that is multiples above closed- and pond-based systems.

Aquaflow Binomics, based in New Zealand, has a goal to become the first company in the world to economically produce biofuel from wild algae harvested from open air environments. The three-year-old startup sources its algae from algae-infested polluted water systems; cleaning the polluted environment in the process.

Aquaflow Binomics harvests algae directly from the settling ponds of standard effluent management systems and other nutrient-rich water. The process can be used in many industries that produce a waste stream including the transport, dairy, meat and paper industries.

The two-step process first optimizes the ponds' productive capacity and then determines the most efficient and economic way of harvesting the pond algae. Algae are provided with full opportunity to exploit the nutrients available in the settling ponds, thereby cleaning up the water.

Algae are harvested to remove the remaining contaminants. A last stage of bioremediation, still in development, will ensure that the water discharge from the process exceeds acceptable quality standards.

The water and sludge treatment process offers a clean-up and management service for sewage treatment systems while also generating a low-cost feedstock for conversion to fuel. The result is an algae-based extract that will ultimately be converted to an alternative fuel source. Aquaflow Binomics expects to be able to produce a viable biofuel on a commercial scale.

In 2007, publicly held Aquaflow used its algae-based biodiesel to run a Land Rover driven by New Zealand's Minister of Climate Change. The company has been working with Boeing on algae-to-bio-based jet fuel.

Biofuel Systems, a Spanish company, is developing a system for producing energy from marine algae, with the hope of replacing fossil fuels and reducing pollution. Biofuel Systems predicts the process will produce massive amounts of biopetroleum (their term for biodiesel) from phytoplankton in a limited space and at a very moderate cost.

The company says their system produces biodiesel from marine plankton and is very different from existing systems that are producing biodiesel. The company envisions producing biopetroleum using a proprietary energy converter. The system will use phytoplankton as feedstock.

Closed systems

Closed systems offer far more control over growing parameters than open ponds or natural settings. Stressing algae to create more production of desired components by changing production parameters is practical only in closed systems. Closed systems also avoid water loss from evaporation.

A2BE Carbon Capture of Boulder, Colorado builds carbon capture and recycle, CCR, systems that take advantage of algae's capacity to profitably recycle industrial CO2 emissions into fuel and other coproducts. Mark Allen, CEO, says their advanced energy-conversion system combines algal CO2 capture technologies with biomass gasification and creates an integrated renewable fuel production system. The CO2 can be recycled from any source and the biomass feedstock for gasification into syngas may come from wood waste, municipal solid waste or the processed algae waste. The CO2 produced from the biomass gasification process is recycled to grow algae.

Jim Sears, President and CTO developed the patented system design and notes that the Carbon Capture and Recycle (CCR) biofactories can be scaled from a few acres to large farms that recycle industrial CO2 emissions into algal biomass that can be further processed into valuable commodities including biofuel, animal feed protein and organic fertilizer.

At the core of the technology is the algae growing and harvesting biofactory. Each machine is 450' long and 50' wide consisting of twin 20' wide x 10" deep x 300' long, transparent plastic algae water-beds. It holds 150,000 gallons of algae. The biofactories work with any species of algae including cyanobacteria and diatoms.

The harvesting technology is similarly adaptable to fit local needs. A2BE offers a novel bioharvesting technology where brine shrimp feed on the algae and the shrimp are harvested and processed. The CCR machine is climate adaptive due to thermal barriers above or below the culture flow that regulate temperature. This allows deployment nearly anywhere there is sunshine.

The A2BE business model shows how CO2 recycling is profitable. Their business plan shows each ton of CO2 may be captured at a cost of about $40 for nutrients and $10 for the CCR biofactory and operations. The net revenue of $200 per ton of CO2 captured is based on: oil ($40), protein ($90), methane ($25), fertilizer ($40), oxygen ($30) and CO2 credit ($25).

A2BE has created an even more compelling production attribute than the profitability per ton of CO2. Their CCR biofactory creates a carbon negative process because each ton of carbon captured and recycled into the various algal coproducts displaces and avoids about 1.25 tons of carbon entering the atmosphere. The carbon negative process holds true when the original carbon is fossil sourced and the resulting products are burned as fuel.

A2BE is not only building a company to take on the substantial challenge of carbon capture but they are building a collaborative group of select institutions, corporations, and key researchers to address the spectrum of talents and disciplines needed to rapidly commercialize a solution called algae@work.

GreenFuel Technologies of Cambridge, Massachusetts is led by Bob Metcalfe who has a telecom background. The company reached an agreement in 2008 to build a fuel plant in Europe — worth $92 M.

GreenFuel Technologies evolved from MIT and government grants for research and demonstration projects. The company has a world-class board of directors but has made some serious mistakes in executing strategy. Essentially, the company discovered, similar to many other startups, that growing algae was more expensive than they had planned. In 2007, the company had to change CEOs, lay off a large proportion of their staff and shut down some projects such as the Arizona Public Service greenhouse in Arizona.

Recent tests of an algae-based system developed by GreenFuel reported that it could capture about 80% of the CO2 emitted from a power plant during the day when sunlight is available.

GreenFuel Technologies claims that using its patented technologies for growth on a one acre site the company can produce algal biomass in a year that can be separated to components that include:

- 7,000 gallons of jet fuel
- 5,000 gallons of ethanol
- 1,000 tons of protein for foods
- 200 pounds of specialized nutrients
- 20 pounds of pigments

These production parameters lead the industry in hope and hype. GreenFuel Technologies builds algal biofactory systems which use recycled CO2 to feed the algae. Their process uses the containers to carefully control the algae's intake of sunlight and nutrients. The algae are refined to biofuels. GreenFuel is backed by Polaris Ventures, Draper Fisher Jurvetson and Access Private Equity.

Solazyme, Inc., based in San Francisco, is a five year old biotechnology company that harnesses the power of microalgae to produce clean and scalable high performance oils, biofuels, and “green” chemicals. The company focuses on new methods to improve production productivity.

Solazyme ignores the sun and grows algae in the dark in large tanks where they are fed sugar to supercharge their growth. Harrison Dillon, a geneticist and patent lawyer who serves as the company's president and chief technology officer claims it’s a thousand times more productive than natural processes.[4] Solazyme says it has already made thousands of gallons of high-grade biodiesel and even light sweet "biocrude" with its processes, which can use anything from chemical waste to wood chips as a source of carbon.

Solazyme, raised $10 million in equity financing and $5 million in debt in 2007, and is experimenting with different feedstocks, algal species and oil extraction methods. The company hopes to reach commercial-scale biodiesel production in two or three years. Refiner Imperium Renewables of Seattle and Chevron have recently signed partnership agreements with the company.

Solazyme is using its technology to make specialty oils for the cosmetics industry in order to meet cash flow commitments. Solazyme demonstrated to the Department of Defense that their algal diesel, Soladiesel has superior cold weather properties to any commercially available biodiesel and is more suitable for cold weather climates where the military has been unable to use biodiesel.

Algenol Biofuels of Fort Meyers, Florida, was founded in 2006 to develop industrialscale algaculture systems to make ethanol from algae on desert land using seawater and CO2. Algenol uses a patented technology with blue green algae, cyanobacteria that are nitrogen fixing which reduces their fertilizer cost. The firm uses natural and environmental selection combined with molecular biology to produce low cost and environmentally safe biofuels.

Algenol plans to make ethanol with blue green algae that produce oil and then secrete it. They will use 3.5 million biofactories to grow the algae that are three-feet by fifty-feet and shaped like soda bottles. Most algae companies are trying to make biofuels by drying and pressing the biomass to make vegetable oil that can be processed into biodiesel. Algenol will use a process to coax individual algal cells to secrete ethanol. The fuel can be taken directly from the algal tanks while the algae continue to thrive. This process uses significantly less energy than drying and pressing the biomass for oil.

Algenol signed an $850 million deal with the Mexican company **BioFields** to grow algae for biofuel. Algenol plans to make 100 million gallons of ethanol annually in Mexico's Sonoran Desert by the end of the 2009. By the end of 2012, Algenol plans to increase production to one billion gallons. The U.S. will produce about 10 billion gallons of corn ethanol in 2008 but will consume 40 million acres of cropland, two trillion gallons of fresh water and 5 billion gallons of fossil fuel.

[4] Solazyme web site, http://www.solazyme.com/news080415.shtml

Algenol operates the world's largest algae library in Baltimore, Maryland to study the organism that can grow in salt or fresh water, and expanding the technique to locations beyond Mexico. The company hopes to build algae-to-ethanol farms on U.S. coasts.

Sapphire Energy

Sapphire Energy, based in San Diego was launched in May of 2007 and initiated a new biofuel category called green crude production. CEO Jason Pyle says his team has built a revolutionary molecular platform that converts sunlight and CO2 into renewable, carbon-neutral alternatives to conventional fossil fuels without the downsides of current biofuel efforts. The end product is not ethanol or biodiesel but biocrude, renewable 91 octane gasoline.

Sapphire's fuel products are chemically identical to molecules in crude oil, making company products entirely compatible with the current energy infrastructure — cars, refineries, and pipelines. Sapphire's scalable production facilities can grow economically because production is modular and transportable. The green crude produces fewer pollutants in the refining process and fewer harmful emissions from vehicle tailpipes.

Sapphire will not reveal the type of algae they use but it is most likely a genetically modified cyanobacteria, blue-green algae. The advantage to this form of algae is that the algae secrete the biocrude oil which rises to the top of the tank and can be skimmed. Avoiding harvesting the algae saves time, cost and may be more productive if the plants secrete enough oil.

Inventure Chemical Technology based in Seattle is working on their patent-pending algae-to-jet fuel product and has produced algae-based fuel in 10 gallon tests. The company plans to set up a test plant to produce up to 15 million gallons of biofuel a year. The algae used for biodiesel conversion is sourced from facilities in Israel, Arizona, and Australia. Inventure expects its technology will deliver a viable ROI for companies that use algae technology for sequestering CO2. Inventure also provides expertise in both process conversion and plant design and construction.

Vertigro Energy, based in San Diego, is a joint venture of eco-technology companies, Valcent Products and Global Green Solutions focused on producing vegetable oil which can be used directly as biodiesel.

Valcent's High Density Vertical Growth System maximizes algae growth in a closed loop, vertical system. In addition to biofuel, the algal oil can also be used in foods, feed stocks, pharmaceutical supplies, and beauty products.

The company says 90% by weight of the algae is captured carbon dioxide, which is sequestered by this process and contributes significantly to the reduction of greenhouse gases. Valcent has commissioned the first commercial-scale bioreactor pilot project at its test facility in El Paso, Texas. The company believes it can significantly lower costs over oil-producing crops such as palm and soybean.

Solena, based in Washington State, uses its patented plasma technology to gasify algae and other organic substances with high energy outputs. Solena's plants produce clean, reliable electricity, using no fossil fuels and no CO2 emissions.

The company is talking with Kansas power firm **Sunflower** to build a 40-megawatt power plant which will run on gasified algae. The algae would be grown in big plastic containers and fed by sunlight and sodium bicarbonate, which is a byproduct of an adjacent coal plant.

Using a plasma gasifier, Solena's technology converts all forms of biomass into a synthetic gas, syngas. The syngas is then conditioned and fed into a gas turbine to produce electricity. Solena's sequestration process recycles CO2 and in the process produces biomass for a continual renewable source of fuel.

Solix Biofuels, based in Fort Collins, Colorado, was founded in April 2006 and backed by Colorado State University's Engine and Energy Conversion Laboratory. Solix Biofuels intends to use microalgae to create a commercially viable biofuel that will play a vital role in solving climate change and petroleum scarcity without competing with global food supply. The company announced in 2008 that it will build its first large-scale facility at the nearby New Belgian Brewery, where CO2 produced during the beer-making process will be used to feed the algae.

Solix says their success comes from knowing how to select the right algal species, to create an optimal photo biological formula for each species and to build a cost effective biofactory that can precisely deliver the formula to each individual algal cell, no matter the size of the facility or its geographical location.

XL Renewables, based in Phoenix, Arizona, is a 2007 start-up with a patent pending algal production system called Simgae for simple algae. The company changed its name from XL Dairy Group to XL Renewables in 2007 to emphasize its focus on creating renewable energy using dairy waste streams.

XL Renewables uses common agriculture and irrigation components to produce algae at a fraction of the cost of competing systems. The XL Super Trough uses a miniature greenhouse-type process to produce the algae in laser-leveled 18-inch deep, 1,250- foot long troughs. Mechanized equipment installs the specially designed plastic liner sheets with integrated aeration and lighting systems along the six-foot wide troughs.

Depending upon need and customer demand, a plastic sheet can be installed on top of the trough to make it a closed system and increase algae production during cooler temperatures.

The XL Super Trough has no moving parts and no connection points except at the end of the troughs. The water used in the process is fortified to enhance production and is pumped through the troughs to a harvest system where the algae are extracted. The water is recycled back through the troughs.

Carbon dioxide is injected periodically and after roughly 24 hours the flow leaves the trough with a markedly greater concentration of algae than when it started.

Supporting hardware components and processes involved are direct applications from the agriculture industry. Re-use of these practices avoids the need for expensive hardware and costly installation and maintenance. The Super Trough System for algae biomass production is available for $25,000 per acre.

The design is expected to provide an annual algae yield of 300 dry tons per acre. Capital costs are expected to be approximately $45k - $60k, a 2 - 16 times improvement over competing systems. President Ben Cloud estimates profitable oil production costs of $0.08 - $0.12 per pound. These oil costs compare to recent market prices of feedstock oils that range from $0.25 - $0.44 per pound.

XL Renewables is developing an integrated biorefinery located in Vicksburg, Arizona, 100 miles west of Phoenix. The $260 million project integrates a modern dairy operation with a biofuels plant to produce ethanol, biodiesel, milk, animal feed and compost fertilizer. The integrated biorefinery uses the dairy manure, along with other waste streams to provide 100% of the power, heat and steam needs of the project and significantly lower production costs. The company expects to produce algal fertilizer at about $300 a ton.

XL Renewables plans to sell the XL Super Trough System and Algae Biotape globally for the economical production of algal biomass to be used as an alternative feedstock to corn for biofuels production.

Aurora Biofuels, developed at the University of California at Berkeley, uses genetically modified algae to efficiently create biodiesel. Aurora claims the patented technology, developed by microbial biology professor Tasios Melis, creates biodiesel fuel with yields 125 times higher and have 50% lower costs than current production methods.

Bionavitas, Based in Snoqualmie, Washington, says it has developed patent-pending technology for the high-volume production of algae using biofactories.

Their 2007 patent application shows their competitive advantage to be the “lighting system that includes one or more light-emitting substrates configured to light at least some of a plurality of photosynthetic organisms retained in the bioreactor.”[5] This sounds like fiber-optic lights embedded in the algaculture system.

Bodega Algae, based in Boston, Massachusetts, is associated with MIT and was founded in 2007. Bodega Algae says it has developed a patent-pending system to grow algae in algaculture systems with light and nutrients that it says is lower cost and more efficient than the current methods. However, Bodega Algae’s website is now inactive.

Cellena, based in Hawaii, is a joint venture created by the algae-to-biofuel startup HR Biopetroleum and Shell oil. Shell has majority share of the company, which is in the process of building a demo facility on the Kona coast of Hawaii.

Cellena announced in 2008 a new process for extracting algae oil without using chemicals, drying or an oil press. The company said that its patent-pending technique uses 26

[5] Patent application, www.wipo.int/pctdb/en/wo.jsp?wo=2007070452&IA=WO2007070452

kilowatts of power to produce 12,000 gallons of algal oil per hour with a yield of 50% from the initial algal paste.

The company also constructs and operates algae biofuels plants that use effluent gases from power plants to produce renewable fuels and to mitigate emissions of carbon.

Canada. Backed by oil companies and utilities, Canadian researchers have plans to develop algae farms that convert CO2 from oil sands projects and coal-fired power plants into biofuels, chemicals and fertilizers. A consortium led by the Alberta Research Council has completed research that suggests the algae would thrive under northern light and temperatures with an appropriate covering for winter months.

The $20 million algal project is being funded by major Canadian energy companies, including Petro-Canada, Royal Dutch Shell, EnCana Corp. and Epcor Power, a coal dependent Alberta-based utility.

Their research indicates that for the large industrial emitters, the system could take about 30% of their emissions. Their goal is eliminating 100 million tons of CO2 emissions a year; about a third of Alberta's current production of greenhouse gas emissions. The researchers include scientists from Alberta, Saskatchewan, Manitoba and Quebec; believe they can boost the productivity of the system so that CO2 can be removed at a cost of about $25 a ton.

Health foods and nutraceuticals

The nostoc commune represents a broad set of patents for a wide variety of algae food, fuel, water, pharmaceutical and health applications.

Nostoc commune. Filed by Fan Lu in North Carolina and others, U.S. Patent 6,667,171 describes a process for producing Nostoc formulations using a plurality of photosynthetic microns including cyanobacteria. U.S. Patent 6,579,741 discloses a method of culturing algae capable of producing large amounts of unsaturated fatty acids and phototrophic pigments and/or polysaccharides.[6]

These patents describe methods for cultivating edible nostoc commune formulations and their use for promoting health. In addition, the invention relates to methods for promoting the health of an individual utilizing the Nostoc formulations, dietary supplements, food products and/or pharmacological compositions. This invention also provides a method for cultivating Nostoc commune comprising (a) isolating and purifying Nostoc commune; (b) culturing the Nostoc commune; and (c) conditions suitable for optimal growth of Nostoc commune. These Nostoc patents, similar to other broad patents, threaten to lock up a major algal species from public use. It will take years to determine how broadly algal patents will be enforced.

[6] Colonies of nostoc commune: methods for cultivating edible nostoc commune and edible nostoc commune formulations and their use for promoting health, http://www.freepatentsonline.com/70160704.html

Most of the companies in this health food category harvest natural stands of algae or produce Spirulina in ponds.

Earthrise, based in southern California, began producing Spirulina in 1982. Today, Earthrise Nutritionals' farm is the world's largest Spirulina farm. Earthrise products are marketed in 30 countries on six continents.

Hainan DIC Microalgae Co. of China has a joint marketing agreement with Earthrise. The two firms produce over 800 tons of Spirulina each year in open ponds. A third facility in Thailand closed in 2006.

Cyanotech, based Hawaii, produces natural astaxanthin and Hawaiian Spirulina Pacifica—all natural, functional nutrients that the company claims enhance human health and nutrition. The algae is grown at its 90-acre facility in Hawaii using patented and proprietary technology and distributes them to nutritional supplement, nutraceutical, and cosmeceutical makers and marketers in more than 40 countries.

BioEarth Spirulina, based in Italy, and **Green Valley**, based in Germany, get their product, Spirulina Maxima from producers using artificial lakes in Mexico where the product has been grown, harvested and eaten for centuries and more recently from China. The product is sold in tablet form as a health food.

Omega Tech, of Boulder Colorado, markets its patented algal chicken feed rich in omega-3 fatty acids. The chicken feed, called DHA Gold for docosahexaenoic acid, the long-chain fatty acid that it contains Omega Tech president, William Barclay, claims chicken meat from animals raised on DHA Gold contain five to seven times the amount of DHA in normal commercially bred chicken.

The feed is made from schizochytrium, a tiny single-cell organism dense with DHA. When harvested and dried, the algae look like wheat flour that has a golden hue. The company grows the algae in stainless steel vats. Monsanto is analyzing the product for vitamins and to fortify food or infant formula. Infant formula, unlike human breast milk, does not contain the omega-3 fatty acids.

Dolphin Sea Vegetable Company in Northern Ireland, established in 1993, harvests red marine algae and markets a variety of products and food supplements directly. They also sell products to kill bacteria and viruses. DSV supplies wild red marine algae to other manufacturers and carries out research into the pharmacological benefits of seaweeds and algae for various medical, pharmaceutical and health foods.

The company is developing PhycoPLEX through clinical trials to examine its effects on immune system function and modulatory action. The clinical trials are conducted at the University of Ulster, supported by a European Union grant.

Table 8.1 Other Firms working on Algae

- Algae BioFuels (PetroSun)
- Algaen
- Arare

- Aquaflow
- Biodiesel
- Biofuels Digest
- Biofuel Review
- Bionavitas
- Carbon Capture Corp
- Cell Tech
- Diversified Energy
- EnAgri
- Energy Farms
- Energy Update
- Ethanol India
- Genergetics
- Global Green Solutions
- GreenEnergy
- GreenShift
- Green Start Products
- GS Cleantech
- Infinifuel
- Inventure
- Kent Sea Tech
- Kiwikpower
- OriginOil
- PetroAlgae (XL TechGroup)
- Plaatts
- Pelletbase
- Raytheon
- Renewable Energy Magazine
- Texas Clean Fuels
- Simplexity
- World Oil

State and university actions

Some states are taking action to fund entrepreneurial businesses in renewable energy and biofuels.

Scripps Institution of Oceanography, in La Jolla, California, offers undergraduate and graduate degrees in marine biology. Scientists such as Stephen Mayfield in the Department of Cell Biology are studying genetic engineering on algae for biofuel production. Greg Mitchell teaches and researchers biological oceanography.

Woods Hole Oceanographic Institution, on Cape Cod, Massachusetts, offers undergraduate and graduate programs in marine biology. Scientists are working on the

impact of climate warming on ice algal production in the Arctic Ocean and others are researching the causes and consequences of red tides.

Hydrogen gas production. Scientists at the DOE's Argonne National Laboratory in cooperation with the **University of Illinois** and **Northwestern University** are working on converting algae to hydrogen gas. They are working with algae that contain an enzyme called hydrogenase, which creates small amounts of hydrogen gas. The objective is to remove the catalyst from the hydrogenase and use it during photosynthesis.

University of Washington, in Seattle and Friday Harbor in the San Juan Islands, offers a marine zoology/botany program for undergraduate and graduate studies. Students may take courses in the San Juan Archipelago doing field studies of natural history, adaptations, evolution, and taxonomy of algae and herbivores.

University of Miami. The Rosenstiel School of Marine and Atmospheric Science offer degree programs in marine biology where students study algae, sea grasses and coral reefs among other topics.

University of New Hampshire. Michael Briggs and the Biodiesel Group in the Department of Physics is working on cost effective algae-based technologies for biodiesel production.

Texas. The Emerging Technology Fund in Texas will provide $4 million to Texas AgriLife Research and General Atomics to conduct microalgal research and development.

Minnesota has made similar grants available for renewable energy sources.

North Dakota. DOE has partnered with Chevron to develop higher-oil yield strains of microalgae. The Defense Advanced Research Projects Agency, DARPA, is working on a project with Honeywell, General Electric and the University of North Dakota.

Virginia. Old Dominion University researchers in Virginia have successfully piloted a project to produce biodiesel feedstock by growing algae at municipal sewage treatment plants. The researchers hope that these algal production techniques could lead to reduced emissions of nitrogen, phosphorus and carbon dioxide into the air and surrounding bodies of water. The pilot project is producing up to 70,000 gallons of biodiesel per year.

Arizona State University Polytechnic. LARB, The Laboratory for Algal Research and Biotechnology, works on all phases of algae growth and commercial production for biofuels. The lab produces various species of algae for biofuel feedstocks and tests growing, harvesting and processing variables in the lab and at their field site.

LARB directors Professors Qiang Hu and Milton Sommerfeld supervise projects a series of projects such as producing jet fuel from algae and bioremediation of waste water from human wastes, industrial wastes and dairy waste streams. Engineers built portable algaculture systems that can test the capability of various algal species that may be used to remediate waste water at a variety of sites.

Some algae in lakes and reservoirs are capable of producing toxins that may cause fish kills and affect human health. LARB is involved in several projects where waters are monitored to check for the presence of potential toxic algae. Supported by the Salt River Project and NSF Water Quality Center, the project uses molecular fingerprinting to detect and treat toxic algae that release toxic compounds in water supplies.

ASU BioDesign Institute and the **Global Institute of Sustainability.** Professors Bruce Rittmann and Wim Vermaas, in life sciences have been studying cyanobacteria for the past 20 years. Currently, they are researching ways to bioengineer cyanobacteria to produce biofuel. This work sponsored by British Petroleum and Science Foundation Arizona and plans to design and create organisms that store more lipids for biodiesel.

Greenindependence.org. The Algae Collaboratory for Sustainable and Affordable Foods and Energy at ASU Polytechnic creates a global social network for green food and fuels. This social marketing collaboratory brings together scientists, academics, practitioners and students who share knowledge and biotechnology tools to bring algae's full promise to the world. The collaboratory operates to create sustainable and affordable foods and fuels for all people on Earth. In addition, projects focus on remediating polluted water and air and creating valuable products such as fertilizers, medicines and vaccines.

The Collaboratory supports sustainability technology development, communication, entrepreneurship and technology transfer for scale-up for commercial algal production. Initiatives are directed toward every stage of algae selection, growth and development, harvest, processing and marketing. The Collaboratory also conducts R3D, research, development, demonstration and diffusion on issues associated with small-scale algaculture systems that may be sited in villages, wasteland, inner cities, roof tops, balconies and back yards.

Patents and other forms of intellectual property are possibly the strongest threat to algal production besides ethanol subsidies. Patents may prevent wide adoption of new production technologies due to the cost of paying patent holders. For example, many of the most productive corn, wheat, rice other food seeds are patented and beyond the means for many farmers.

The Collaboratory is dedicated to maximizing open source solutions available to all people on the planet. An excellent potential solution to the intellectual property issues is the development of an IP Pool where industry members share their IP and users pay a reasonable fee based on use and scale. Educational and research opportunities are expanding and institutions and additional programs are posted on the collaboratory site.

Note: Algal firms, institutions and organizations not profiled here may be profiled in the next edition by sending information to mark.edwards@asu.edu.

Green Algae Strategy: End Oil Imports and Engineer Sustainable Food and Biofuels

Green Algae Strategy shares the fascinating story of extraordinary innovation occurring not in deep space or in deep oceans but simply under our feet. Few people are aware that one of Earth's oldest, tiniest and simplest organisms holds such great potential for desperately needed sustainable solutions for our very hungry, thirsty and needy planet.

Green Algae Strategy engineers hope for a better life for billions of people who lack sufficient and affordable food, fresh water, fresh air, fertilizer and clean burning fuel for cooking and heating fires.

Algal production holds promise for Green Independence:
1. Freedom from oil imports
2. Freedom from world hunger
3. Moderation of climate change

Algae can provide these solutions while consuming no cropland, no freshwater and no fossil fuels. Every pound of algae grown for food and fuel also captures nearly two pounds of CO2 while releasing pure oxygen into the atmosphere.

Freedom from oil imports will occur by growing algae on desert and wasteland about the size of Maine. Freedom from hunger will engage 10 million Green Masterminds globally who have the knowledge and capability for growing nutritious food and high energy biofuel locally with green solar, algaculture. Slowing climate change will occur by diffusing green solar knowledge and technology globally and seeding ocean dead zones with algae in order to capture and sequester massive amounts of carbon dioxide.

Mark Edwards is a professor of marketing and sustainability at Arizona State University and has studied algae as a food source for over 40 years and as a green energy source for the last several years