



Algae Biomass Organization
www.algaebiomass.org
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Algae Industry Project Book 2015



Why Algae?



Algae have the power to simultaneously put fuels in our vehicles, recycle CO₂, provide nutrition for animals and people and create jobs for millions of Americans.

Algae Fuels, Feed and More



Algae are a renewable source of drop-in fuels, feed, fertilizer, nutritional oils and pharmaceuticals. They can provide waste water treatment and other remediation services. New applications are constantly being discovered.

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Algae

Energy & Fuels Food & Agriculture Health & Nutrition Materials & Services

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Innovating to Commercial Scale

The companies highlighted in this Algae Industry Project Book, all members of the Algae Biomass Organization (ABO), are just a few examples from a dynamic industry that is harnessing the unequalled potential of algae to provide us with sustainable products, drive economic growth and reduce greenhouse gas emissions.

Algae are consumers of carbon dioxide, making them the perfect tool to fight climate change because they, unlike other solutions, offer an economic incentive to reduce greenhouse gas emissions.

Algae cultivation technologies are poised to impact just about every industry:

Fuel & Energy: Algae are the original source of crude oil, and ABO members are working to bring to market renewable fuels like ethanol, gasoline, diesel and jet fuel.

Food & Agriculture: Algae can produce more protein, more feed and more oil with less water and land than any other crop.

Health & Nutrition: Omega-3 fatty acids are vital for human health, and in just the past few years the \$1.7 billion market for these oils has been shaken up by the arrival of clean and sustainable algae-derived alternatives. The algae-based products on store shelves today are just the beginning.

Materials & Services: Wastewater treatment with algae is being adopted nationwide, and soon power plants that will be required to reduce their CO₂ emissions will be looking to algae for an economic solution. Throw in the plastics and specialty chemicals algae can produce and the potential is limitless.

The innovation on display in this book is from entrepreneurs offering a sustainable and profitable way to make the products and materials required in a modern global supply chain. There is much more to come.

Sincerely,

Matt Carr
Executive Director
Algae Biomass Organization

ABO members can be found across the United States and around the world.



The Technology

Algae can be grown commercially in a variety of ways, from open ponds to enclosed photobioreactors, or in hybrid systems that combine various methods. Simply put, there are multiple ways to grow algae at commercial scale, and this versatility is one of algae's strengths.

Algae can also grow extremely well on marginal lands using salt water or wastewater, reducing impacts on valuable agricultural lands without competing with other industries for diminishing freshwater supplies.



Countless Products

Algae contain high levels of oils, carbohydrates, sugars and proteins. These characteristics make them ideal for producing renewable fuel, animal feed and even human food.

Microalgal biomass, which is rich in micronutrients, is already used for dietary supplements to advance human health. Algae have even been used to more economically produce anti-cancer drugs and in other medical applications. They can also be used to beneficially reuse greenhouse gas emissions and treat wastewater.

ALGENOL

Algenol Biofuels Inc.

Algenol recently won the 2014 Global Leadership in Biofuels award from PLATTS. Founded in 2006, Algenol has invented technologies for utilizing industrial carbon emissions to produce transportation fuels. Algenol's algae platform can produce the four most important fuels (ethanol, gasoline, jet and diesel) for a targeted cost of \$1.30 per gallon. The Company's proprietary Direct to Ethanol® process harnesses the incredible productivity of its patented strain of algae to drive yields 20 times that of corn ethanol, and requires only sunlight, saltwater and CO₂ for production. Additional sustainability benefits include the ability to produce a freshwater by-product without using arable land. Algenol monetizes waste industrial CO₂ by purchasing flue gas from emitters which allows the emitters to avoid costly carbon capture and storage or other expensive carbon mitigation strategies. Algenol is the only solution that monetizes CO₂ through utilization, drastically altering the current paradigm by turning a carbon reduction liability into a revenue generating asset.



Commercial Development Campus Fort Myers, Florida

Funds Raised: \$260 million

Current yield is 8,000 gallons per acre per year

Employees

200

Products

Ethanol
ULS Diesel
Jet Fuel
Gasoline

PARTNERS

Strategic Partners: Reliance Industries Limited; BioFields S.A.P.I. de C.V.; Hitachi Zosen Corporation; and Tredegar Corporation

Federal/State Partners: United States Department of Energy; Lee County, Florida

University Partners: Florida Gulf Coast University; Georgia Institute of Technology's Strategic Energy Institute

National Lab Partners: National Renewable Energy Laboratory; Pacific Northwest National Laboratory

TIMELINE

2006

Algenol is founded after securing first round of private financing. Laboratories established in Palm Beach County, FL, Baltimore, MD and Berlin, Germany.

2010

Commercial Development Campus in Fort Myers begins operations, consolidating American operations in Florida.

2014/2015

Commercial demo, announcement of first commercial project, likely in Florida, and evaluation of sites in Gulf Coast and international locations.

2016

Groundbreaking and initial operation of first commercial facility with nameplate capacity of 20 million gallons per year.

2020

Projected 1 billion gallons of annual production utilizing Direct to Ethanol® technology.



Future Commercial Facility

Investment: \geq \$50 million equity plus debt

ALGENOL

Algenol's first commercial facility will include phased deployments of photobioreactors on an initial site of up to 2,000 acres of photobioreactors, with additional acreage available for future scale-up, along with upstream and downstream processing equipment and related infrastructure. It will be located on marginal land with access to salt water, an industrial source of CO₂ and distribution infrastructure.

Projected jobs by 2020:
**100-200 permanent
jobs per facility +
on-going R&D staff
in Ft. Myers**

Production in 2020:
**1 billion gallons
of ethanol per
year**

Construction jobs:
2,000 per facility



Algenol uses fully closed and sealed photobioreactors for ethanol production directly from enhanced algae. Waste algae are converted into diesel, jet fuel and gasoline using hydrothermal liquefaction and other conversion technologies.



Sapphire Energy

San Diego based Sapphire Energy is pioneering an entirely new industry – Green Crude Oil Production. Green Crude is a renewable, drop-in replacement for petroleum, made from algae, sunlight and CO₂. Green Crude is compatible with existing infrastructure and is low carbon, renewable, and scalable. Sapphire Energy was the first algae-to-energy company to successfully test jet fuel in two commercial airline flights in 2009 (Continental and Japan Airlines). The company has an R&D facility in Las Cruces, NM, and is currently operating and producing crude oil daily from the world's first Integrated Algal BioRefinery (Green Crude Farm) commercial demonstration facility in Columbus, NM.



Research and Development Site Las Cruces, New Mexico

Investment: \$30 million Jobs: 30

**Full scale pilot and demonstration of all unit
operations from molecular biology to extraction of oil**

Employees | 150

Funds Raised | \$350 million

**Products | Green Crude Oil,
a direct substitute
for fossil crude**

PARTNERS

Investment Partners: ARCH Venture Partners; The Wellcome Trust; Cascade Investment, LLC; Venrock; Arrowpoint; and Monsanto

Strategic Partners: Monsanto, The Linde Group; Tesoro Refining and Marketing Company, LLC; and the Institute of Systems Biology (ISB)

Federal/State Partners: The US Department of Energy and the US Department of Agriculture

University/Research Partners: The Department of Energy's Joint Genome Institute; University of California, San Diego; the San Diego Center for Algal Biotechnology; The Scripps Research Institute; University of Tulsa; Sandia National Laboratory; and the Pacific Northwest National Laboratory

TIMELINE

2008

One year after its founding, Sapphire Energy creates the world's first renewable gasoline from algae.

2009

Sapphire Energy's algae jet fuel powers the test flights of renewable fuels on two commercial airliners.

2012

On-time and on-budget completion of first phase construction for the Green Crude Farm.

2013

Sapphire Energy announces agreement with Tesoro Refining and Marketing LLC, to purchase barrels of Green Crude oil for refining at its west coast operations.

2018

Anticipated launch of first commercial scale facility with production of 5,000 to 10,000 barrels per day of Green Crude oil.



Green Crude Farm Columbus, NM

Investment: \$135 million Jobs: 30

Full capacity: 100 barrels of green crude per day



Sapphire Energy's Green Crude Farm features 100 acres of cultivation ponds and all the necessary mechanical and processing equipment needed to harvest and extract algae and recycle water. At full capacity the facility will be 300 acres. The Green Crude Farm was funded by \$85 million in private investment, as well as a USDA loan guarantee and a \$50 million grant from the US DOE, totaling \$135 million.

Continuous operation of all unit
processes at the Green Crude
Farm since:

2012

Barrels per day of Green Crude at
a commercial scale facility:

5,000 - 10,000

Jobs created during the
construction of the Green Crude
Farm:

634



Sapphire Energy is operating the most advanced, algae crude oil production facility in the world. The company's Green Crude Farm is the world's first commercial demonstration scale algae-to-energy site, integrating the entire value chain of algae-based crude oil production, from cultivation, to harvest, to extraction of ready-to-refine Green Crude.



BioProcess Algae

BioProcess Algae, LLC (BPA) designs, builds and operates commercial scale bioreactors that enable efficient conversion of light and CO₂ into high value microbial feedstock.

BioProcess Algae is focused on fulfilling feedstock needs in the animal feeds and transportation fuels industries for cost competitive alternatives with favorable carbon balances. BioProcess Algae is based in Omaha, Nebraska and is currently running a demonstration plant at the Green Plains Inc. ethanol plant in Shenandoah, Iowa. Grower Harvester™ bioreactors installed in Shenandoah are tied directly into the plant's CO₂ exhaust gas and have been operating continuously since inoculation in October 2009.



Company Headquarters Omaha, Nebraska

BioProcess Algae houses engineering, manufacturing, business development and administration

Employees

40

Products

Animal Feed
Nutritionals
Fuels

PARTNERS

Investment Partners: Clarcor (NYSE: CLC); BioProcessH2O, LLC and Green Plains Inc. (NASDAQ: GPRE).

Federal/State Partners: The US Department of Energy

TIMELINE

2008

BioProcess Algae LLC is a joint venture among Green Plains, Clarcor Inc. and BioProcesH2O.

2009

Demonstration plant co-located with a Green Plains' ethanol plant in Shenandoah.

2012

Successful completion of algae-based poultry feed trials, signs commercial agreement for Omega-3 oils with KD-Pharma for nutrition and pharmaceutical applications.

2013

BPA completes its Phase III project, which consists of commercial scale Grower Harvesters. Selected by DOE for Integrated Biorefinery funding.

2015

Commercialization efforts continue at one of the longest-standing biological sequestration carbon capture and utilization facilities in the U.S.



Commercial Demonstration Facility

Shenandoah, Iowa

BioProcess Algae's technology is enabling the Green Plains ethanol plant to capture the last third of kernel value typically emitted as CO₂



BPA technology enables algae to be produced as a crop, and growing crops is something Americans do phenomenally well. Not only does that give BPA an ideal opportunity to create agricultural jobs, but it also means that the company has no reason to outsource operations. BPA is producing a home-grown and home-processed product that can help achieve our country's most long-term goals: feeding the world and a sound financial standing.

BPA can utilize waste streams from any site with more than 5% CO₂ content.

BPA's carbon utilization technology can be implemented in parallel with sequestration.

Algae is the only profitable carbon co-location platform.



BioProcess Algae designs, manufacturers and operates integrated systems using a unique patented *attached growth* approach to enhance light penetration, harvest density and gas transfer, overcoming these traditional bottlenecks to low-cost algae cultivation.



Algae Systems

Algae Systems treats wastewater, converts algae and biosolids into fuel and creates a high protein fertilizer byproduct.

After proving the technology at its demonstration plant in Daphne, AL, we're evaluating several candidate sites for commercial-scale plants. Having demonstrated low-cost, energy-positive wastewater treatment, the system proves that wastewater is a resource that can be harvested for profit by utilities across the globe.

PRODUCTS

- Water, fuels, fertilizers



Demonstration Plant Daphne, Alabama

Company Employees: 32

One acre of algae growth area with fully integrated and automated facility; all discharge is fed back to Daphne Utilities



Algae Systems' 40,000-gpd treatment facility. Commissioned in June 2014 it has been operating continuously since.

TIMELINE

2009

Company Founded

2010

Green Fuels Corp. IP
Acquired Angel
Financing

2011

Technical Development
\$15M Series-A
Financing from IHI
Corporation (Tokyo,
Japan)

2012-2013

Commence R&D
Engineering &
Construction of Pilot
Plant

2014-present

Pilot Plant Operations
Scaled to Commercial
Demonstration



Aurora Algae

Aurora Algae is an innovative bioenergy company that manufactures fuel from optimized algae in a patented production process. Leading technologists at Aurora Algae have engineered a scalable method for fuel generation, using robust and highly productive proprietary algae strains. The Aurora Algae process is carbon-mitigating and non-competitive with agricultural resources, and capable of industrial yields with minimal facility footprints. When produced in conjunction with other high-value products, Aurora Algae's biofuel can be sold at cost-competitive market prices.

PRODUCTS

- **Biofuel**
- **Omega-3 Essential Fatty Acids**
- **Protein and Animal Feed**



R&D and Pilot Processing Facility Hayward, California

Jobs: 70

Corporate Headquarters with R&D laboratory for genetic research and product development

PARTNERS

Oak Investment Partners, Noventi Ventures, Gabriel Venture Partners

Aurora Algae's proprietary algae strains and production process uses arid land, seawater and captured carbon pollution from industrial emitters, resulting in more capital efficient and more environmentally sustainable algae farming.



Aurora's Pilot-Scale Demonstration

Western Australia

Jobs 50

Six 1-acre production ponds and more than 40 smaller ponds producing 15 tons of biomass per month.

TIMELINE

2007

Aurora Algae founded under original name "Aurora Biofuels."

2009

Completes successful pilot operations in Florida. Biofuel production successfully passes ASTM standards.

2010

Introduces the industry's first platform for the production of products in the pharmaceutical, nutritional supplement, aquaculture and fuels markets.

2011

Completes build out of new US-based headquarters and labs. Completes construction of new plant in Western Australia.

2012

Successfully completes requirements for two million dollar (AUD) Low Emissions Energy Development grant to advance biomass production.



Cellana

Cellana, a leading developer of algae-based bioproducts, uses the most productive plants on earth—marine microalgae—to photosynthetically produce its ReNew™ line of Omega-3 EPA and DHA oils, food and feed, and biofuel feedstocks.

PRODUCTS

- **Omega-3 Nutritional Oils**
- **Food and Feed Supplements**
- **Biocrude Oil**



Kona Demonstration Facility Kailua-Kona, Hawaii

Jobs: 25-50 Investment: \$20 million

PARTNERS

U.S. Department of Energy and the Department of Agriculture

Since 2009, Cellana has operated its Kona Demonstration Facility, a 6-acre, state-of-the-art production and research facility in Hawaii. To date, more than 20 metric tons of whole algae (dry weight) have been produced using Cellana's ALDUO™ process with highly diverse strains, making ALDUO™ one of the most flexible, thoroughly tested, and validated outdoor algae production technologies in the world.



Cellana is in the process of evaluating commercial algae facility locations in Hawaii, the mainland U.S., the Middle East, North Africa region and in Southeast Asia. Cellana's biorefinery business model involves establishing off-take agreements for biofuels, food/feed and Omega-3 nutritional oils to be produced in algae facilities throughout the world with a total capacity of at least 100,000 metric tons of biomass per year.

TIMELINE

2007

Cellana LLC, a joint venture between Royal Dutch Shell and HR BioPetroleum is formed.

2009

Cellana's Kona Demonstration Facility is commissioned and comes online.

2013

Cellana signs commercial-scale agreement with Neste Oil, the world's largest producer of renewable diesel.

2014

Projected supply agreements for all three algae-derived products: Omega-3 oils, food/feed, and biofuels.

2015/2016

Projected completion of Cellana's first commercial production facility.



East Bend Demonstration Union, Kentucky



Duke Energy and the University of Kentucky

Duke Energy is the largest electric power holding company in the United States with more than \$121 billion in total assets.

The University of Kentucky's Center for Applied Energy Research (UK CAER) is an interdisciplinary research center focused on the energy needs of the Commonwealth of Kentucky. The Center, through its technology innovation and service to the community, contributes to improving the lives of Kentuckians by creating jobs and economic opportunities; by sustaining vital industries and public services; and by improving energy efficiency and protecting the environment.

PRODUCTS

- **CO₂ Remediation Services**
- **Algal Biomass**
- **Fuel, Aquaculture, Bioplastic and Feeds**



Investment: \$200,000 Capacity: 1,135 - 26,000 Liters

PARTNERS

KY Department of Energy Development and Independence; US-China Clean Energy Research Center-Advanced Coal Technology Consortium; ENN Group; Pittsburgh State University; University of Delaware.



A demonstration scale photobioreactor (PBR) is currently being operated at Duke Energy's East Bend Station using coal-fired flue gas as the CO₂ source. The PBR converts the CO₂ in flue gas to algal biomass, via photosynthesis. The biomass is then periodically harvested to supply feedstock for upgrading into value-added products. The low energy harvesting system recycles water and unused nutrients.

TIMELINE

2008

The University of Kentucky begins its algae project.

2010

ENN performs strain evaluation using flue gas at Duke Energy's East Bend Station.

2012

Algae based CO₂ mitigation demonstration project started at Duke Energy's East Bend Station.

2013

System volume expanded, first periods of sustained operation off of flue gas.

2015

Continue and improve flue gas utilization studies/enhance collaboration with other strategic partners.



Earthrise Nutritionals

Earthrise Nutritionals is the largest producer of Spirulina algae in the world. It is a 30-year pioneer in the field of Spirulina research, biomass production, sales and marketing. Earthrise distributes Spirulina and Spirulina-based products for the functional food, beverage, dietary supplement, nutraceutical, and animal feed markets in more than 20 countries worldwide. Earthrise is currently engaged in research collaboration with major algae biofuel and bio-product companies worldwide. Earthrise is a wholly-owned subsidiary of DIC Corporation.

PRODUCTS

- **Spirulina and Spirulina-based formulated green products**
- **Spirulina extract (natural blue colorant) product**



Earthrise Calipatria Imperial Valley, California

Jobs: 80-90

600 tons of Spirulina powder are produced each year in 37 ponds roughly 1.3 acres each

In addition to its currently operational ponds the company is testing two 2.5 and 4.5 acre ponds for biomass production, the latter being the largest fully lined outdoor raceway pond ever tested for algae biomass production. The facility has 80 additional acres of vacant land for future expansion.



Earthrise operates the world's largest Spirulina farm on a 108-acre site supplying more than 20 countries with the world's best known Spirulina. In the clean, sunny California desert, Earthrise® Spirulina yields more nutrition per acre than any other food.

TIMELINE

1972

The progenitor of Earthrise, Proteus Corporation, is founded to develop Spirulina blue-green algae as a world food resource.

1982

Earthrise develops a partnership with Japan's Dainippon Ink and Chemicals, Inc. (now DIC Corp.). Earthrise later becomes wholly owned by DIC.

2012

Earthrise enters agreement with Sapphire Energy to license a Spirulina strain and production technology for algae-to-energy production.

2013

Earthrise operates the world's largest Spirulina farm, and together with its sister company's farm, DIC group is the largest Spirulina producer in the world.

2015

A new \$10 million extraction plant strengthens leadership in Spirulina based food colorings market. A new lab facilitates collaborative research.



**GLOBAL ALGAE
INNOVATIONS**

Global Algae Innovations

Global Algae Innovations is a leader in low cost algae production technologies. The company is developing a suite of advances in open pond algae growth with novel, low-cost production technology in every process step. Many of these technologies have been demonstrated in the company's operation of the 8-wetted acre Kauai Algae Farm, which operates solely on CO₂ supplied from the adjacent power plant's flue gas. As a result, economical, sustainable production of protein and biofuel are now within reach.

Global Algae Innovations is also leveraging these advances to bring disruptive, low-cost production to other algae markets such as functional foods, nutraceuticals, pigments and aquaculture.

Global Algae Innovations has operations in California and Hawaii.



Large algae farm operating with power plant CO₂

Kauai Algae Farm Lihue, Hawaii

Jobs: 19 Annual Capacity: 240 tons
Integrated, large-scale demonstration of cutting-edge algae technologies

PRODUCTS

- Algal Biofuels
- Commodity Protein
- Functional Foods
- Nutraceuticals
- Pigments
- Aquaculture Feed Ingredients

PARTNERS

Algaeventure Systems; Evodos; General Electric Power & Water; Hawaii BioEnergy; Kuehnle AgroSystems; Texas A&M AgriLife Research; TSD Management Associates; University of California at San Diego - Scripps Institution of Oceanography; the U.S. Department of Energy.



The largest raceway at the Kauai Algae Farm is 3.2 acres, and the design is scalable to individual raceways of over 50 acres. The harvest technology attains 100% harvest efficiency, and the recycled water is crystal clear with 10 times greater clarity than the tightest drinking water standard.

The 50 foott tall CO₂ absorber receives power plant flue gas directly with no pretreatment required.

2014

In its first year of operation, Global Algae Innovations retrofitted the Kauai Algae Farm with over 25 technology advances including state-of-the-art, low energy use harvesting technology; massively scalable open pond raceways; and high efficiency CO₂ capture and use from the adjacent power plant flue gas. The company was awarded three U.S. government contracts for development of advanced algae production technologies.

2015

Global Algae Innovations is currently working with and seeking additional partners for scale-up and construction of commercial algae facilities for protein, nutraceuticals, pigments and CO₂ capture and reuse.



Joule

Joule has pioneered a CO₂-to-fuel production platform, effectively reversing combustion through the use of solar energy. The company's platform applies engineered catalysts to continuously convert waste CO₂ directly into renewable fuels such as ethanol or hydrocarbons for diesel, jet fuel and gasoline. Free of feedstock constraints and complex processing, Joule's process can achieve unrivaled scalability, volumes and costs without the use of any agricultural land, fresh water or crops. Joule is privately held and has raised over \$200 million in funding to date, led by Flagship Ventures. The company operates from Bedford, Massachusetts and The Hague, The Netherlands, with production operations in Hobbs, New Mexico.

PRODUCTS

• Ethanol

With a total workforce of 120, Joule currently holds 61 patents and allowances plus 95+ applications pending. In 2012, Joule was named a World Economic Forum Technology Pioneer and in 2013, the company was named a Bloomberg New Energy Pioneer.



The Hobbs plant is designed to test and optimize Joule's technology and process at increasingly larger scale. The catalysts and systems undergoing optimization in Hobbs, along with the operational knowledge gained, will form the fully-validated blueprint for future commercial plants.



Joule Demonstration Plant Hobbs, New Mexico

Jobs: 30

At full-scale commercialization Joule is targeting productivity of up to 25,000 gallons of ethanol/acre/year and 15,000 gallons diesel/acre/year.

PARTNER: Audi

TIMELINE

2007-2011

Initial Invention and Lab Demonstration.

2011-2014

Field Demonstration.

2015-2017

Industrialization Phase I.

2017-2019

Industrialization Phase II and Commercial Roll-Out.



Learn more about the algae industry at www.allaboutalgae.com



About the Algae Biomass Organization

The Algae Biomass Organization (ABO) is a 501(c)(6) non-profit whose mission is to promote the development of viable commercial markets for renewable and sustainable commodities derived from algae. Its membership is comprised of people, companies and organizations across the value chain. More information about ABO, including its leadership, membership, costs, benefits and members and their affiliations, is available at the website: www.algaebiomass.org.

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