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Algae Biofuels Research in Universities

Details of universities pursuing algae fuel research

Oilgae

2013

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Algae Biofuels Research in Universities

Auburn University, USA

Aim of the Project: Algae as a biodiesel feedstock: a feasibility assessment

Year: June 2007

Collaboration

1. Collaboration between AuburnUniversity energy crop researchers and the USDA ARS Soil Dynamics Laboratory is working to identify optimal systems for algae flocculation, harvest, and processing to extract constituents desirable for production of liquid fuels, electrical power, nutraceuticals, etc

2. Research collaboration between Auburn University and the Alabama Department Agriculture and Industries is examining the production of microalgae as a potential source of oil for subsequent biodiesel production.

Funding

US - Auburn University has been selected to receive up to $4.9 million of federal grant money for algae to biodiesel project. (Aug 2009)

Gov. Bob Riley has awarded a $10,000 grant to AuburnUniversity to conduct a study to determine the economic and technical feasibility of cultivating pond algae commercially as a source for biofuel (2007)

Details of the project[1]

Researchers at Auburn University have developed techniques to harvest wild algae that form a nuisance at catfish farms, and convert it to biofuels. The University believes that catfish farms should form the base of the Southeastern-based algae fuel industry, because the feedstock was already in place, calling it a win-win for catfish farmers and algae fuel producers. Auburn researchers work with the leading producers of forest
biomass for energy from algae in Alabama.

Researchers are proposing the development of algae farms in which carbon dioxide is received from carbon capture and biologically converted, via photosynthesis and anaerobic digestion, to CNG or LNG transportation fuels. This approach, using open ponds in the Southeastern US, could be the most competitive with petroleum-based fuels. While the technologies for lipids

[1] http://www.adeca.state.al.us/C17/ATF/Document%20Library/Algae%20as%20a%20Biodiesel%20Feedstock.pdf

extraction from micro-algae for biodiesel are currently infeasible from cost and energy standpoints, anaerobic digestion of biomass to methane is a commercial reality.

There were several important innovations during the course of the program:
(1) Integration of animal litter digesters to provide nutrients and energy for the algae farms,
(2) Integration of carbonation pits and their pumps with a novel linear pond design
(3) A low-cost harvesting system
(4) A scheme for integration of algaculture with catfish aquaculture to improve the competitiveness of this industry within the state.

The experimental phase of the feasibility assessment focused on the areas which is believed to be the most important for the success of widespread algaculture in Alabama, namely algae growth rates and the harvesting process

Future plans

To capture and sequester carbon dioxide emissions from stationary point sources, particularly power plants, and vehicles using algae.

Arizona State University, USA

Aim of the Projects

1. Algal-Based Biofuels & Biomaterials, 2.Cyanobacterial Biodiesel: Tubes in the Desert 3. Biohydrogen from Cyanobacteria

Year: 2009

Collaboration

1. Petro Algae licensed a library of 12 strains of high oil-yield algae from ArizonaStateUniversity for commercial algal feedstock production capabilities

2. Collaboration has been initiated for microalgal research with industrial partners for technical assistance in conversion of algae oil to biofuels (UOP and Honeywell Aerospace Division), and assistance in marketing of algal feedstock (Cargill)

Funding

Heliae Development, LLC, a private technology development company, will provide research funding of $1.5 million to ASU to support further development of the specific algal strains towards commercial production of jet fuel. The Heliae funding will be matched dollar for dollar by a Strategic Research Group award from SFAz, so that ASU will receive a total of $3 million for the project. (2008)

ASU's grants, totaling $10.3 million, are among 37 new DOE grants totaling $151 million to support the program (2009)

In October 2012, the DOE awarded the $15 million grant funds to the Algae Testbed Public-Private Partnership (ATP3), a research center at the Arizona State University (ASU) Polytechnic campus in Mesa. The five-acre site is the largest university-based algae research testbed in the world.

Details of the project[2]

ArizonaStateUniversity scientists are developing cyanobacteria and algae as sources of environmentally friendly fuel that is efficiently produced by solar energy conversion. Unlike other biofuels, ASU's production processes can be carried out in closed systems on barren lands, saving farmland for food production.

Algal-Based Biofuels & Biomaterials

An ArizonaStateUniversity algae-to-fuel project is led by professors Qiang Hu and Milton Sommerfeld. Over the past two decades, the algal-based biofuel research has progressed to the screening and evaluation of naturally occurring algal strains.

The integration of wastewater bioremediation and carbon sequestration with biofuel production in a novel field-scale bioreactor has been demonstrated. Although algal biomass residues derived from the oil extraction process can be used for animal feed or fertilizer, the university researchers are currently exploring, in collaboration with their industrial partners, the opportunity for using biomass residues to produce ethanol, and methane, and high-value biomaterials, such as biopolymers, carotenoids, and very long-chain polyunsaturated fatty acids.

The Biodesign Institute at the Arizona State University has developed a process that reprograms photosynthetic microbes to secrete lipids, making byproduct recovery and conversion to biofuels easier and potentially more commercially viable. (Sep 2011)

Cyanobacterial Biodiesel: Tubes in the Desert

A major ongoing ASU effort, funded in its initial pilot stages by BP and Science Foundation Arizona, generates biodiesel from lipid produced by the photosynthetic cyanobacterium *Synechocystis*. The genome of *Synechocystis* has been fully sequenced, and the microorganism

[2] *http://biofuels.asu.edu/tubes.shtml*

provides a facile substrate for genetic modification of metabolic pathways to optimize yields of C-16 and C-18 lipids for biodiesel production. In fact, much progress has already been made at ASU in increasing the yields of these lipids through genetic engineering.

Biohydrogen from Cyanobacteria

Researchers have started to explore the capacity of cyanobacteria for direct biohydrogen production using solar energy. This will involve both altering the metabolism of the organism to funnel more energy into the hydrogen production pathway and the introduction of genes from other organisms that have much more robust enzymes involved in hydrogen production.

The Arizona State University's scientists have also discovered how to turn algae into jet fuel.

Future plans

1. Refinement of the cultivation process, downstream processing of biomass, and development of an economic feasibility model for commercialization of algae-based biofuels and biomaterials.

2.Providing a green source of hydrogen for use in potential biohydrogen fuel cells.

3. A larger field test bed is also said to be built to refine the approach and enable industrial pilot scale efforts in the 2010 timeframe.

Brunswick Community College (BCC), USA

Aimof the Project: Algae to biodiesel

Duration: June 2009

Collaboration

Bionetwork is in collaboration with Brunswick Community College (BCC) for the algae to biodiesel project

Funding

- The researchers have received $300,000 from the N.C. Community College System Bionetwork.
- Two intrepid biofuels researchers at BrunswickCommunity College have bagged two more grants totaling more than $222,000 to support their quest to derive oil from algae.
- The Bionetwork awarded grants of $185,816 for the algae to biodiesel project

(August 2008)

Details of the project

Students in the Aquaculture and Biotechnology programs at BrunswickCommunity College are working on a project that will allow them to extract oil from algae and convert it into biodiesel. The university estimates that 50 percent of the collected algae will be converted into usable oil which will amount to approximately 75 pounds of oil each month. The oil will fuel tractors and utility vehicles on campus.

The College has 30-80gallon tanks to grow algae, three machines to extract oil from the plants and the equipments to convert it into biofuel. One of the machines uses high-frequency sound to break algae cells apart. Another takes biological molecules out of cells. A third one separates solids from liquids. But the process is still not practical for commercial purposes as the team is only able to turn a thousandth of every liter produced into oil.

The Team has a patent pending with the U.S. Patent and Trademark Office for a method to extract algal oil mechanically, which defies the norm of using chemicals in the process. BCC is growing 6,000 liters of algae, the objective being to produce enough clean fuel to operate the machines that support their aquaculture research.

The new photobioreactor which is capable of growing a large amount of microalgae on campus was demonstrated and the algae grown in the tanks were processed for oil extraction and the oil was converted into biodiesel for use as fuel.

Future plans:

The BCC plans to develop a sound-based technical process to bring down the cost of separating the oil from other algae components.

California Polytechnic State University, USA

Aimof the Project: Microalgae to biofuels production

Year: December 2007

Collaboration

The team is in collaboration with the USDA (United States Department of Agriculture), ARI (Agricultural research institute), BKS Energy and Energy Alternative Solutions, Inc. for the research of microalgae-to-biofuel production

Funding

The team received a $400,000 grant from the USDA, ARI, BKS Energy and Energy Alternative Solutions, Inc. for the continued research of microalgae-to-biofuel production in controlled environments. (2008)

Details of the project[3]

California Polytechnic State University, USA performs research on algae as a feedstock for biofuel.A Cal Poly research effort won a Grand Challenge award for the development of systems or technology that will help farms and ranches produce 25 percent of the nation's energy by the year 2025 without impacting food production.

Cal Poly's winning entry, "Sustaining Civilization Under Cover," used photobioreactors, a system of enclosed solar tubes to mass-produce algae.

In addition to generating a renewable energy source, the photobioreactors use carbon dioxide in the production of algae. A powerful example of this conversion is the capture of flue gases from industrial venting by the algae, utilizing it for their growth. A byproduct of the algae biofuel production can even be used as a protein-rich source of animal feed. The process is a completely sustainable and enriching cycle. Cal Poly is fast becoming a leading institution for the applied research and development of controlled-environment algae-production systems.

Another project was undertaken on the lipid productivity of algae grown on dairy wastewater as a possible feedstock for biodiesel in which bench-scale tests were conducted to determine potential algal lipid productivity with mixed-cultures of algae grown on anaerobically-pretreated dairy wastewater in batch mode.

In January 2012, California Polytechnic State University entered into a partnership with the California Energy Commission to launch an algae-based wastewater treatment plant at the San Luis Obispo Water Reclamation Facility. The facility is a pilot development based on a system designed at Cal Poly called Reclamation of Nutrients, Energy and Water (RNEW) whereby algae feed on polluting nutrients in the wastewater and produce biofuel as a byproduct.

Future plans

To develop a biological wastewater treatment system that utilizes algal growth to simultaneously create renewable energy in the form of biodiesel and digester biogas, remove polluting nutrients, and abate greenhouse gases.

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[3] *http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1022&context=pao_pr*

Clemson University, USA[4]

Aimof the Projects

1. Using algae for food, fertilizer and fuel
*Year:*June 2006

2. Ethanol production from algae:
*Year:*May 2009

Collaboration with companies

1. A $2 million grant from the U.S. Department of Energy (DOE) was recently awarded to ClemsonUniversityand scientists at the Savannah River National Laboratory.

2. ClemsonUniversity and ArborGen LLC have partnered to develop algae as feedstock for the biofuels industry.

3. Kent SeaTech and ClemsonUniversity have collaborated and evaluated novel and promising concepts for harvesting algal biomass
4. Kent BioEnergy Corporation acquired worldwide exclusive rights to ClemsonUniversity's patented technologies for harvesting and converting microalgae biomass to biolipids.

Funding

$1.2 millionwas granted from the U.S. Department of Energyfor the Clemson biofuels research. *(October 2008)*

Details of the projects[5]

1. *Using algae for food, fertilizer and fuel*

ClemsonUniversityfigures out ways to use algae to convert solar energy into fuel, food and fertilizer by combining engineering with biological and environmental sciences.

Algae grow in the raceways and feed on the sludge. Shallow water and continuous movement maximize algae production by allowing growth at all levels of water. Tilapia, in the raceways, eats the algae to complete the waste removal process. Algae feed on the waste while tilapia feed on the algae, producing clean water, no waste discharge and a valuable secondary crop.

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[4] www.clemson.edu

[5] http://agroecology.clemson.edu/images/sg_conference/walker_biodiesel.pdf

About 3,000 miles from Clemson is another Brune project. Instead of working in ponds, the university is working in California's Salton Sea.

The researchers capture phosphorous that comes in at very low concentrations and grow micro-algae on it, concentrate it to useful levels and send it back to the farmers. Thus they can use less chemical fertilizer, which reduces the pollution load to the sea. Algae grown on sea are collected, processed and returned as fertilizer to the farmers. In the process, algae make methane gas, which is a bio-fuel.

1. *Biodiesel production from algae*

Biosystems Engineering Department of Clemson University is performing research in producing biodiesel process from algal oil.

The Equipment and Process:

- The reactor tank is filled with algal oil
- Premixed alcohol (ethanol) and catalyst (potassium hydroxide, KOH) are pumped into reactor tank and mixed thoroughly.
- The heating coils use hot water from the water heater to warm the reactants and increase reaction speed
- After the reaction is complete, cold water is sprinkled into the reactor tank in a fine mist – The water settles at the bottom with glycerol while removing excess alcohol, and unwanted soaps, waxes and acids, effectively "washing" the biodiesel
- The glycerol/wash water is drained out of the bottom into a separate collection tank
- The processed biodiesel is then filtered and pumped into a storage tank

Future plans

Increase biodiesel production to support:
–On-campus generators
–Clemson agricultural equipment

Clemson scientists are searching for clean, renewable and environmentally sustainable fuels from algae. The university in collaboration with the U.S. Department of Energy's Savannah River National Laboratory plans to build a biofuels pilot plant. The $14 million plant will be used to investigate commercial bioethanol production using feedstocks like algae available in South Carolina.

Cleveland State University, Fenn College of Engineering, USA

Aimof the Project: Computer-Aided Design of Gravitational Settlers for Bio-fuels Production from Microalgae

Year: 2009

Details of the project[6]

The process of removing the water and concentrating the cells, called the "dewatering" process, is both energy and equipment intensive. The purpose of this research is to optimize the design of gravity settlers for algae dewatering for large-scale biofuel production. This project is aimed at formulating a FEM CFD model of cell-fluid interactions in the process equipment to simulate dynamic and steady-state particle settling scenarios. The model will be validated and refined using data collected from a laboratory-scale settler prototype. The CFD model is then anticipated to be used in design optimization of pilot-scale configurations and identification of [optimum] operating conditions to maximize equipment performance.

Future plans

To develop methods for separation of the algae from the perfusion fluid and extraction of the oil from the algae those are low in energy use and manufacturing cost.

Colorado State University, USA

Aim of the Project: Algae to biodiesel

Year: June 2006

Collaboration

1. Colorado State University is heavily involved in the algae-based biodiesel research in collaboration with the EECL (Engines and Energy Conversion Laboratory) focusing on the emissions aspects of using such fuels.

2. Solix Biofuels is working with Colorado State University's Energy Conversion Laboratory on a 20m long fifth-scale PBR that will utilize CO_2 emissions from New Belgium Brewing Co facility to make algae-to-oil technology work on a large scale and at an affordable price.

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[6] http://www.csuohio.edu/engineering/chemical/academic/hnrprjt.html

Details of the project[7]

ColoradoState is working with Solix Biofuels to develop technology that can cheaply produce biodiesel fuel from algae – an environmentally friendly solution to greenhouse gas emissions, high gas prices, and finite fossil fuel supplies.

The photo–bioreactors, developed by Solix Biofuels, consist of transparent plastic tubes that house the algae. The design includes weighted rollers that travel slowly across the tubes, constantly circulating the algae to allow maximum photosynthesis.

Once the maximum levels of algae are reached, the algae cells are continuously harvested from fluid with a centrifuge and the oil is extracted and refined into biodiesel.ColoradoState researchers are working on ways to extract its oil to help reduce the world's dependence on finite fossil fuels and volatile energy markets.

The beauty of the algae-to-oil project is partly due to the best places to site the reactors, which includes power plants and other industries that produce copious amounts of CO_2.Algae-to-oil facilities would be an ideal solution for producing liquid transportation fuels while absorbing greenhouse gas emissions in the bargain.

Future plans

To set up larger reactors on land leased by New Belgium, a brewery located close to the Engines lab.

Florida Institute of Technology, Melbourne, Australia

Aim of the Project: Microalgae to biofuels

Year: Jan 2008

Collaboration

The university is collaborating with Aurora Biofuels Inc. of Alameda, CA (Known as Aurora Algae now) at Florida Tech's Vero Beach Marine Laboratory for the production of biofuels and animal feed from microalgae.

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[7] http://www.colostate.edu/features/biofuels-from-algae.aspx

Funding

The Florida Department of Agriculture and Consumer Services have awarded a $415,000 grant to a Florida Tech project for the production of biofuels and animal feed from microalgae.

Aurora will also provide $507,419 toward the project. The new state grant was awarded to the university through a $25 million package of renewable energy grants funded by the Florida Legislature. (Jan 2008)

Details of the project

The Florida Tech research focuses on developing biofuel with co-products to enhance animal feed as a means to improve the economics of the fuel-production process. A key goal is to produce algae biomass with a high content of triglycerides suitable for conversion to biodiesel and with a high content of valuable omega-3 fatty acids and carotenoids, which can augment animal feeds.

The researchers will enrich, isolate, screen and select algal strains with high oil content; test the performance of selected strains in outdoor ponds; demonstrate mass cultivation of the most promising strains; harvest the cells to yield a concentrated biomass content; and process the biomass to recover valuable co-products.

Future plans

-Working with Aurora Biofuels (Known as Aurora Algae now) to develop and test algal strains for their long-term outdoor production viability. (Not able to find any recent information about their collaboration project)

-Harvesting alga by a low-cost sedimentation process for biofuel.

James Cook University (JCU), Queensland, Australia

Aim of the Project: Algae to biofuels

Year: May 2008

Collaboration

Melbourne-based MBD will partner with the university in its effort to prove the algae technology by developing a local algae strain and expertise in algae production and also optimizing an algae variety for oil output.

Funding

The Queensland, Australia, Government is providing A$166,000 (US$160,000) in funding to support the development of an algae biodiesel process by James Cook University (JCU) and Australian biodiesel company MDB Biodiesel Ltd.(May 2008)

Details of the project[8]

Queensland's JamesCookUniversity developed a technology that allows algae to capture half or more of the greenhouse gases emitted by a power station. The micro-algae thrive on carbon dioxide, producing food for livestock as well as biofuels and material for plastics. JCU was isolating algae for the project from the Great Barrier Reef.

The idea is to pump emissions from power stations into photo-bioreactors, which are large tubes filled with algae. When carbon dioxide from the power stations is mixed with water, the algae soak up much of it, using it as a nutrient.

Once the algae are removed from the tubes, they can be buried in the seabed, where they could store indefinitely the carbon they have ingested. The algae can also be processed and used to create biodiesel fuel and fertilizer, as well as food for farm animals.

Future plans

MBD will provide the algae photo-bioreactor which will be situated at JCU. The partners planned to build a 35,000 tonne algae pilot farm next year followed by a 400-hectare algae farm in 2010 which can ultimately consume in excess of 2,000,000 tonnes of carbon dioxide and provide algae oil for a 250,000 tonne biodiesel plant.

Eastern Kentucky University, Richmond, USA

Aim of the Project: Algae to Biodiesel

Year: Feb 2009

Collaboration with companies

EKU is partnering with San Diego-based General Atomics for algae biodiesel and jet fuel projects.

Funding

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[8] *http://www.greencarcongress.com/2008/05/queensland-gove.html*

According to the university, the project is being funded through a $4 million federal appropriation in the Consolidated Security, Disaster Assistance and Continuing Appropriations Act of 2009.(2009)

Details of the project[9]

Researchers at the Center for Renewable and Alternative Fuel Technologies at EasternKentuckyUniversity in Richmond, Ky., are studying the potential for converting cellulosic biomass into biodiesel and ultimately jet fuel

General Atomics is best known for its affiliated company General Atomics Aeronautical Systems Inc., the manufacturer of the U.S. military's Predator unmanned aircraft system. The partnership links Kentucky and EKU with an international business leader that is turning its focus and considerable resources to biomass-to-fuel initiatives.

EKU will look at using commercially available cellulase enzymes to convert cellulosic biomass to sugars, which will then be fed to heterotrophic algae that can convert sugars to oils without photosynthesis. These are not the phototrophic types (of algae) that use sunlight. These are membranous-type algae, and they are heterotrophic. These strains of algae have very high oil content. The oils are then extracted from the algae and to biodiesel.

The researchers are choosing to produce biodiesel instead of ethanol because biodiesel is a key fuel for heavy industry. As a partner, General Atomics will provide input on the cost of converting various feedstocks to biodiesel and will design the processing system that will produce biodiesel from cellulosic biomass.

Future plans

1. EKU will also examine the logistics of transporting feedstocks to regional biodiesel processing facilities
2. Uses for byproducts in fuel production will be explored.

Massachusetts Institute of Technology (MIT), USA

Aim of the Project: Using algae to transform greenhouse emissions into green fuel

Year: May 2005

Details of the project[10]

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[9] http://www.biodieselmagazine.com/article.jsp?article_id=3145

[10] http://web.mit.edu/erc/spotlights/alg-all.html

Exhaust from MIT's main power plant has been bubbling up through tubes of algae soup. Utility companies have been watching field trials of the algae-soup system with keen interest, hoping to combine low-cost exhaust cleanup with renewable-fuel production.

MIT became intrigued with using algae to clean up exhaust from power plants burning fossil fuels, especially coal. Coal is an abundant resource but an undesirable fuel because of its high CO_2 emissions.

The installation on MIT's 20-megawatt cogeneration plant demonstrates their abilities. At the top of the plant, there are 33-meter-high triangles of clear pipe containing a mixture of algae and water. Bubbling the plant's flue gases through the mixture has reduced CO_2 emissions by 82 percent on sunny days and 50 percent on cloudy days (during daytime) and has cut nitrogen oxides by 85 percent (on a 24-hour basis).

MIT "tailor" algae to perform well at a specific power plant. They use a terrestrial cousin of a miniature bioreactor designed for the International Space Station. As algae grow inside the bioreactor, their environment is gradually shifted to conditions they will encounter at the plant. Within three months, the tailored algae are thriving on flue gases instead of air. No genetic engineering is involved.

In fall 2005, the algae system was installed at a 1000-MW power plant in the Southwest. Initial field trials at the plant were successful, and testing is now moving into a pilot phase. MIT estimates that more than 1000 power plants in the United States have enough flue gas, water, and land to host a commercial-scale installation.

The project resulted in dramatic cut in carbon dioxide (CO_2) emissions from MIT power plant and abundant algae that can be turned into biofuel for the power plant or a diesel vehicle.

Future plans

MIT is planning to expand its collaboration with algae biofuel companies to process the algae on campus into biodiesel for possible use on campus in an innovative renewable fuel cycle.

Massey School of Engineering, Wellington, New Zealand

Aim of the Project: Oil from microalgae

*Year:*August 2008

Collaboration

The Finnish oil company Neste Oil collaborates with the University for producing algal oil from marine microalgae in photobioreactors.

Funding

a. The Finnish oil company Neste Oil will invest $850,000 in microalgae research
b. Massey researcher has been awarded $101,595 for the project Enhancing Algae Biofuel production from Wastewater Treatment Ponds.

(Aug 2008)

Details of the project[11]

Massey School of Engineering, north of Wellingtonis said to conduct microalgae research. The researchers are led by Professor Yusef Christi to produce algal oil from marine microalgae. *Botryococcus braunii*, one of the algae that bloom in fertiliser-polluted lakes and estuaries was studied to convert it into a substitute for diesel, gasoline and jet fuel.

It was shown that to be competitive with oil at US $100 a barrel, it is necessary to produce microalgae around nine times more cheaply than is currently being achieved.Every 100 tonnes of algal biomass fixes around 183 tonnes of carbon dioxide and production of fuels from microalgae can be carbon neutral.

The Massey School of Engineering has produced algal oil from marine microalgae in tubular photo bioreactors. The university has developed harvest and oil extraction processes

Future plans:

The university plans to find better ways to develop and recover the algal biomass from the broth and to extract the oil from moist rather than dry biomass.

Montana State University, USA

Aim of the Project: Algae to fuel

Year: Jan 2008

Collaboration

Montana State University algae strains are produced with A2BE Carbon Capture Advanced Photobioreactor Technology. The university is in collaboration with the U.S. Department of Energy to study the oil produced by algae.

[11] http://www.massey.ac.nz/massey/about-massey/news/article.cfm?mnarticle=the-other-biofuel-25-04-2009

Funding

The U.S. Department of Energy awarded MontanaStateUniversity and UtahStateUniversity a three-year, $900,000 grant to study algae-biodiesel production.
(May 2008)

Details of the project[12]

The university developed a strain for algae, called Nile Red. When treated with the stain, the algae became fluorescent under certain conditions, making it easier to measure their oil content.

The MontanaStateUniversity and UtahState project will screen different kinds of algae to learn which species produce the most oil and which can produce those oils most efficiently. The test algae will come from existing stocks at labs across the country and from field sampling. Once the researchers find a candidate species, they will grow large numbers of the algae in a "raceway" bioreactor at UtahState

Montana State University microbiologist and project collaborator Matthew Fields will use modern molecular biology and genomics to learn how to make algae produce more oil.

MSU researchers have also discovered that baking soda can dramatically increase algae's production of the key oil precursors for biodiesel. When added at a particular time in the growing cycle, baking soda more than doubled the amount of oil produced in half the time in three different types of algae.

Future plans

1. Researching for using microorganisms to clean up environmental contamination.
2. Finding the best species of algae to use and the best practices by which to make them produce oil for biodiesel

New Mexico State University (NMSU), USA

Aim of the Project: Algae biofuels

Year: February 2009

Collaboration

[12] *http://www.montana.edu/cpa/news/nwview.php?article=5461*

NMSU researchers are working with the Center of Excellence for Hazardous Material Management (CEHMM), based in Carlsbad. NMSU's AgriculturalScienceCenter at Artesia has provided CEHMM a site to run open-pond and bioreactor experiments.

Funding

To support the research for the potential of algal-based fuel, an internal award of $50,000 was presented to theNew MexicoStateUniversity.*(Feb 2009)*

NMSU is part of a consortium awarded $49 million by the U.S. Department of Energy to study the commercialization of algae-based fuel. The University has also received a grant of $2.3 million to study algae-based jet fuel for the Air Force. (2011)

Details of the project[13]

NMSU is coordinating the efforts in the algal biomass approach to the alternative energy equation by developing different strains to optimize the lipid and reproductive growth of algae.

One of the things NMSU does in the lab is investigating the inverse relationship between growth rate and oil content. The faster a population of algal cells is growing, generally the lower the oil content they have. When the algae become nutrient limited, the oil content begins to increase.

The algae with which the researchers are working, can divide as fast as once per day in the peak season or summer time. The researchers are looking at the triggers for accumulating higher concentrations of oil in algal cells and trying to integrate algal cultivation practices with our knowledge of this dichotomy between growth rate and oil content. They are trying to develop cultivation practices that are built on understanding of algal physiology; trying to put together a staged process where we can always harvest the algae at the highest oil content. The idea is to make the most efficient use of the land requirements, the availability of sunlight and manipulate nutrient concentrations so we are getting maximum biomass content and the maximum oil content out of the algal harvest.

The university is also trying to produce a device that will reduce the three steps needed to produce a biofuel product into a one-step process. At this time, a chemical extraction process is used to separate algal oil from the biomass. Then the solvents have to be separated from the algal oil and the oil undergoes a conversion process to make a biofuel product like biodiesel. The biofuel can be refined further to make gasoline or jet fuel.

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[13] *http://researchmag.nmsu.edu/2009_SP/feature_algae.html*

NMSU has created a bench-size model, or what is called a “racetrack reactor,” to grow algae in an enclosed structure, stimulated by artificial lighting.There are several factors involved in this process, for example: the intensity of the sunlight; the time it spends in the reactor; the amount of algae that is growing and the rate at which they are growing; and the amount of nutrients fed.

In April 2012, the University installed a new 4,000-liter photobioreactor system at the Fabian Garcia Research Center. The Solix BioSystems Lumian AGS4000 is an algae-cultivation system that allows faster and denser production of algae than open “raceway” systems.

The university is building several economic models that take into account the many materials, manpower, time and production costs to produce biofuels that would compete with today’s fuel prices.

Among the factors that greatly affect cost are labor and algal biomass yield. According to the University, because a commercial model has never been built, it is hard to determine the best formula. The current models are adding up to a cost scenario of $4 to $15 a gallon for biofuel.

Future plans

The university plans to perform research to develop estimates for a commercial scale algal-based fuel industry in New Mexico.

Oregon State University (OSU), USA

Aim of the Projects:

1. Biodiesel and bioethanol from algae
2. Hydrogen from algae
3. Diatoms for biofuel production

Year: March 2009

Funding

The Agricultural Research Foundation awarded grants totaling more than $500,000 to Oregon State University scientists for projects including algae biofuel research.(May 2009)

The U.S. Air Force Office of Scientific Research also recently awarded a grant of $938,000 to OSU, the University of Oregon and IndianaUniversity to continue research on hydrogen production using algae.(March 2009)

Oregon State University received a four year grant of $2mil from the National Science Federationto study if diatoms can make biofuel production from algae. (September 2012)

Details of the projects[14]

1. Biodiesel and bioethanol from algae

Researchers at OregonStateUniversity are working to find an efficient method of processing bio-diesel fuel and ethanol from algae, which could lead to breakthroughs in reducing the world's dependency on petroleum.

At the OSU Sustainable Technologies Laboratoryhas built two small photobioreactors to grow microscopic algae in a closed system. It takes about three weeks for the algae—combined with light, water, carbon dioxide and mineral nutrients—to multiply and turn the water green.

The primary focus of the OSU lab is to discover efficient ways to extract the oils (also called lipids) and process them into bio-diesel fuel and ethanol, with fertilizer and animal feed as co-products. The biggest challenge is separating water from the micro algae *Chlorella* and *Dunaliella*, which must continually be mixed with carbon dioxide and light as they grow. A combination of straining and centrifuging is the current method of extraction employed by the university.

Of the more than 3,000 known strains of algae, OSU grows both fresh water and salt water varieties. The photobioreactors hold about six gallons of water and produce about 17 pounds of algae with each batch. Depending on the algae growth conditions usually 20 to 30 percent oil can be extracted from it, and up to 60 percent is possible. (March 2008)

2. Hydrogen from algae

Details of the project

OSU researchers successfully discovered one type of cyanobacteria, more commonly known as blue-green algae to live, grow and produce hydrogen while the cells were “encapsulated” in a solid state system- an important preliminary step to control this interaction of water, light and bacteria for practical use.

Significant progress still needs to be made in making the process more efficient and using light energy more effectively, but the advance demonstrates the feasibility of using these biological processes to produce hydrogen which could be used directly as a fuel, or in hydrogen fuel cells to power the electric automobiles of the future.

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[14] *http://www.americanfuels.info/2009/03/oregon-state-researchers-using-algae-to.html*

The OSU engineers accomplished part of that with the encapsulation approach that keeps the bacteria isolated from the environment, resistant to contamination, and able to live longer and to produce larger amounts of hydrogen. The glass sponge material creates a solid framework that provides structural, thermal and chemical stability to encapsulated cells.

Such solid state devices could potentially be encased in treated glass or another suitable material and engineered as biocassettes in a variety of configurations, such as sheets, thin films, or designed layers that could be versatile, portable, contained, stable, efficient and inexpensive.

Future plans

1. To find ways to make the algae use more of the sunlight that is available to them to “harvest” the light energy more efficiently.
2. To continue their work with variable levels and lower intensities of light for hydrogen production.

Southern Illinois University Carbondale (SIUC), USA

Aim of the Project: Algae as alternative energy source

Year: Jan 2009

Collaboration

Ag-Oil International LLC, a biofuel company with its corporate office in Boca Raton, Floridahas forged strategic partnership with Southern Illinois University Carbondale to become a leader in the production of green fuel from algae.

Funding

Southern Illinois University has received $676,722 as a grant for expansion of bioethanol production in the UpperMississippiRiver Basin.
(Oct 2006)

Details of the project[15]

A Southern Illinois University Carbondale researcher is exploring the potential use of algae as an alternative energy source. The university is working on ways to improve and extract naturally occurring substances in certain algae strains that can be used to create biodiesel fuel.

[15] http://www.thesouthern.com/news/local/article_70f81c70-f607-5679-9d34-71bc6a4aa1da.html

The university is focusing her research on two varieties that appear to have particular potential. One, *Chlorella vulgaris*, is a fresh-water alga that uses carbon dioxide to grow and create lipids. As an autotrophic organism, it is relatively slow growing but produces cells with high lipid content.

The second strain *Schizochytrium limacinum* SR21 is a seawater alga that is heterotrophic, meaning it must be "fed" a carbon source in place of carbon dioxide. This particular strain can use glycerin, which is a byproduct - often a waste product - of biodiesel production. Depending on its species and its environment, algae grow at different rates and can produce 30 to 70 percent lipids per cell. Another advantage is that *Schizochytrium limacinum* SR21 grows fast and produces up to 50 percent lipids per cell. Even though the lipid content is less than other types, the fast growth rate means this type of alga can produce more lipids than slower-growing varieties. The strain might be integrated into the production stream at some point, creating greater efficiency and less waste.

Future plans

To find the cheapest carbon source to feed algae and grow lipids for use in biodiesel

Texas A&M University, USA

Aim of the Project: Biofuel from microalgae

*Year:*2008

Collaboration

San Ramon-based Chevron Corp. has formed research alliance with the University of Texas A&M to study ethanol and other biofuels.

The partnership between Texas AgriLife Research, part of the Texas A&M University System and General Atomics involves a phased research and development program, which includes evaluating new, promising algae strains, developing and testing algae production systems and designing and testing algae/oil separation systems.

Funding

Externally funded research brings in almost $620 million every year and helps drive the state's economy. (July 2007)

Texas AgriLife Research and General Atomics, a San Diego-based technology company, have received a $4 million grant from the state's Emerging Technology Fund for biofuel microalgae research.

The ETF grant authorized by Gov. Rick Perry is for developing microalgae-derived biodiesel fuels to support U.S. domestic and military needs.(Feb 2008)

Texas A&M's algae program totaled about $7 million by 2010. Since 2010, the University has also been working on its share of a $44 million, multistate biofuel research project funded by the Department of Energy.

Details of the project

Texas AgriLife Research is involved in biofuel microalgae research. Texas is committed to create a diverse energy portfolio that provides stability and reduces dependence on foreign energy. Developing alternative energy sources through Texas-based research is of tremendous value to a fast-growing state like Texas and to the nation as a whole.

A demonstration facility has been constructed at the AgriLife Research and Extension Center in Pecos, Texas, with two sets of four ponds each: one large pond feeding into or from three smaller ponds.

The facility is said to become the national center for algae research and development for biofuels.

Texas AgriLife Research has already identified strains of algae that have high-producing oil potential. These strains require large amounts of sunlight, salty water and carbon dioxide to thrive and produce oil - all of which is readily available in the PermianBasin of Texas. Researchers anticipate the algae systems may be tied to coal-fired power plants in the future, using carbon dioxide emissions and waste heat for algae growth.

Researchers at the university focus on the following key areas:

- To create methods that would generate higher yields from algae
- Developing technology to harvest the algae more cheaply by cultivating it into a pellet
- Researching on Photorespiration, which is an alternative to photosynthesis, where sugar is combined with oxygen.

The first phase is said to demonstrate algae production systems up to approximately a quarter of an acre. The second phase will include a pre-commercial scale system and the final phase would be a commercial-size operation of 50 to 100 acres.

Future plans

The university has planned to accelerate the entire research and development process and commercialize a number of technologies in biofuel microalgae production. Production systems up to 2,000 acres could be implemented in the PermianBasin of Texas and the Southwest. Economists within the A&M System predict for each 2,000-acre unit, the local economic impact would equal approximately $190 million annually.

Western Michigan University(WMU), USA

Aim of the Project: Algae to ethanol, biodiesel

Year: April 2008

Collaboration

1. Partnering with MuskegonCounty, to harvest algae from wastewater treatment lagoons and to extract recoverable energy.
2. Partnering with the National Museum of Natural History and HydroMentia to incorporate energy recovery from algal biomass in nutrient remediation using Algal Turf Scrubbers. ™

Funding

The professors are awaiting a $984,000 U.S. Department of Energy grant to support the algae-biofuel research.

Details of the project[16]

A group of WesternMichiganUniversity researchers working to transform grease into biodiesel for city buses is planning to research how to effectively convert algae into ethanol.

The WMU will be looking at the use of algae as ethanol in part because of concerns that there isn't enough land for growing crops to meet the country's demands for transportation fuel.

Researchers at Western Michigan University (WMU) are working to develop two biofuel production processes that could help the city of Kalamazoo, Michigan move toward environmental sustainability. The goal of the first project, Bronco Biodiesel, is to perfect a process to convert trap grease, used vegetable oil from restaurants and other facilities, into biodiesel. The second project, which is still in its early stages, will attempt to find a viable algae

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[16] http://www.renewableenergyworld.com/rea/news/article/2008/04/wmu-researchers-create-biofuels-from-waste-oil-algae-52163

strain that could be used for both waste treatment and as a feedstock for biodiesel or ethanol production.

The main goal of the project is to help enhance urban sustainability. Bronco Biodiesel is working out a way to standardize the processing so that all of their feedstocks can be processed at once. Thisis the biggest challenge to scaling up to the 500,000 – 1 million gallon production level the team is hoping to reach in the near future.

The university is hoping that this project will aid the city of Kalamazoo by relieving the strain that trap and other waste greases put on the waste management system and by using the finished product to fuel its bus fleet.

Algae are also on the radar at WMU. The group is currently looking for grant funding to explore using algae as both a feedstock for fuel and, in keeping with the idea of sustainability, in water treatment applications.

The project is in its early stages and the researchers are open to all possibilities regarding the strain of algae they're looking for and what type of biofuel would come out of the process, though Bertman admits that ethanol would be a better option since the commercial infrastructure for it already exists. The plan is to cultivate the algae by using it at water treatment facilities where it would feed on the nutrient rich waste water, removing content that would need to be removed by other means anyway. From there, some of the algae would be removed and either drained of oils for ethanol production or used as organic feedstock for biodiesel production.

This project is also a waste management project. WMU is getting algae from wastewater treatment systems (phosphorous and nitrogen) — including systems designed to remove excess nutrients from natural rivers.

Bioalcohols from wastewater algae

Algae blooms generated by nutrient run-off and overloading have dramatically altered coastal ecosystems and inland waterways across North America. Through partnerships with government and private industry clean-up initiatives, WMU is developing processes for converting the hundreds of millions of tons of weedy algae biomass that grows in the United States each year into distilled fuels that can replace petroleum products in gasoline powered engines. This undertaking seeks to link the vital importance of aquatic clean-up to alternative energy development.The University extracted bioalcohols from algae and converted them into ethanol and biobutanol. (Nov 2011)

Future plans

- Reclaim energy from biomass liquid waste streams

- Offer a business model for “town-gown” cooperation (to show how cities and universities can collaborate with private business to combine environmental clean-up with energy conversion)
- Educate the public about biofuels, waste recovery, and urban energy infrastructure.

University of Adelaide, Australia

Aim of the Project: Fuel from algae

Year: March 2009

Collaboration

The University of Adelaide'sSchool of Chemical Engineering, India's Parry Nutraceuticals and MurdochUniversity in Perth are collaborating to work on biofuel production from salt water algae.

Funding

The Adelaide research led by Dr David Lewis and Dr Peter Ashman is part of an innovative $1.89 million project funded by the Federal Government

Details of the project[17]

The University works to develop a clean, "green" fuel that could help solve the global energy crisis. Researchers from the School of Chemical Engineering are focusing their attention on using green algae as a potential source of biofuel.

Headed by MurdochUniversity in Western Australia, the project involves research partners in India and China. The project hopes to identify a clean, affordable method of producing biodiesel from algae on an industrial scale, which is currently cost prohibitive.

In Adelaide, researchers have begun cultivating algae on a small scale in two-metre square tanks specially built by Chemical Engineering technical staff. Based on the roof of one of the University's many North Terrace Campus buildings, the tanks are exposed to the sun and the elements, simulating the real conditions of a much larger scale operation.

In order to produce biofuel on an industrial scale, millions of cubic metres of algae would need to be cultivated in marine ponds covering about 50-100 square kilometres. These small-scale tanks in Adelaide are just the very beginning. The project was started with only 5ml of algae,

[17] *http://www.adelaide.edu.au/adelaidean/issues/31921/news31922.html*

and now each pond contains about 400 litres of algae. The university is extracting between 50-100 litres of microalgae culture per day for the experiments.

Another key aspect of this project is that it looks at so-called `second generation' biofuels, which do not compete for resources with food crops. Algae will grow on non-arable, arid - land without any need for fresh water in cultivation. Canola needs lot of fresh water and good-quality farming land.

The algae cultivated and harvested in Adelaide enables the researchers to test various methods of extracting oil. This involves breaking the algae cells open to release the natural oil they contain. The algal oil can then be converted into biodiesel.

In addition to that work, the team is also conducting an economic and lifecycle assessment to find the use of algae byproduct.

In November 2010, university's algae biofuels pilot plant was commissioned. The pilot plant is located in Karratha, WA., next to the Yurralyi Maya Power Station power station. The pilot plant allows the testing at scale of the saline algae biofuels process developed by Murdoch University and the University of Adelaide. A new large-scale harvesting process is being tested and further processing of the biomass is taking place in Adelaide.

Future plans

- The company proposes to apply the techniques they have learnt from these small-scale ponds to a larger, pilot-scale saline pond, which will be about 250 square metres.
- To determine the best methods possible for harvesting the algae and extracting the oil from algae that could potentially be applied to an industrial setting.

University of Arizona (UA), USA

*Aim of the Project:*Biodiesel and jet fuel from algae

Year: November 2008

Collaboration

University of Arizona team works on USDA-DOE project with Petrosun, Purdue University School of Aeronautics and Astronautics, Renascent Energy, Carbon2Algae, Innovative Trade Development Center, USDA Laboratory (Peoria, IL) and Pukyong University (South Korea) for production of advanced biofuels from algae

Funding

As a project participant in a number of USDA-DOE and DOE projects, the university has filed applications for federal funding.*(March 2009)*

Details of the project[18]

UA researcher Joel Cuello's main research interest is using algae to produce oil – biodiesel as well as jet fuel.

The UA agricultural and biosystems engineering department believes that the desert is very well suited for growing algae. The desert's abundant wastelands or marginally arable lands can be fertile fields to grow algae. This means that unproductive lands can be put into production. Algae provide a bigger payoff than higher crops. Also of special interest to Arizona is that some algae can thrive on non-potable saline and brackish waters.

A pilot scale Arid Raceway Integrated Design was designed in collaboration with Petrosun.

Future plans

To set up production plants and operate in Arizona to convert algae into biofuels

University of Arkansas, USA

*Aim of the Project:*Algae to biodiesel and butanol

Year: August 2008

Collaboration

Smithsonian Institution and the University of Maryland ship the algae to partners at the University of Arkansas, who distill the plant sugars into butanol, a form of fuel that can be burned by cars and power plants.

Funding

The project is sponsored by the Smithsonian Institution's Museum of Natural History and National Science Foundation Research Experience*(2008)*

Details of the project[19]

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[18] http://uanews.org/node/22431

[19] http://dailyheadlines.uark.edu/13245.htm

Students at the University of Arkansas are designing a sustainable future using algae from local streams. A potential feedstock is algae oil, which could provide extremely high oil yields per acre of land. Division scientists have initiated an algae production system research and demonstration project in CrittendenCounty. The researchers draw water from the Mississippi River, grows algae from the nitrogen and phosphorus in the water and returns cleaned water to the river. Algae samples are being converted to biodiesel and butanol, which is similar to ethanol.

The University designed and built a 300-foot-long, 1-foot-wide artificial stream designed to grow algae for use as a biofuel. This project is an experiment to determine if such algal production systems can produce high yields year-round in Arkansas.

They worked with the city of Springdale to build the system near the wastewater treatment plant. They are taking water from a source that has adequate nutrients like phosphorus and nitrogen and using that water to grow a community of wild algae for cellulosic and biodiesel conversion. Promoting the right algal community growth requires a “surger” – a wave machine that pulses water down the artificial stream and provides ideal habitat for the high biomass algae to grow.

Growing the algae is just part of the equation; the three other projects round out the research experience for other undergraduate student teams whose objective is to explore the factors that control how stream ecosystems function – nutrients, flow, algae and macro invertebrates and to understand how algal growth is affected by these variables is the key to making algae a viable biofuel.

Once the Smithsonian Institute system is completed in growing algae, the university will be working on ways to create fuel from the plant material.

In March 2011, the University has developed a method for converting common algae into butanol.

Future plans

To develop more effective methods to use algal feedstocks to make biofuels, especially butanol

University of California at Berkeley, USA

Aim of the Project: Hydrogen from algae

*Year:*February 2006

Collaboration

Primafuel, a privately held international team works with leading technologists and infrastructure experts from U.C. Berkeley. The collaboration is focused on developing algae bio-refinery technologies for renewable fuels.

Funding

The project has been funded recently through Lawrence Berkeley National Lab's Helios Project. (2006)

Details of the project[20]

Researchers at the University of California at Berkeley have engineered a strain of pond scum that could, with further refinements, produce vast amounts of hydrogen through photosynthesis.

The strain of algae, known as *C. reinhardtii*, has truncated chlorophyll antennae within the chloroplasts of the cells, which serves to increase the organism's energy efficiency. The University has already reached 10 percent threshold. But further refinements are still required before *C. reinhardtii* farms would be efficient enough to produce the world's hydrogen, which is the university's eventual goal.

Currently, the algae cells cycle between photosynthesis and hydrogen production because the hydrogenase enzyme which makes the hydrogen can't function in the presence of oxygen. Researchers hope to further boost hydrogen production by using genetic engineering to close up pores that oxygen seeps through.

The algal cells flicked a long-dormant genetic switch to produce hydrogen instead of carbon dioxide. But the quantities of hydrogen they produced were nowhere near enough to scale up the process commercially and profitably.

When the sulfur switch was discovered, hydrogen production was increased by a factor of 100,000. But to make it a commercial technology, the efficiency of the process had to be increased by another factor of 100

A bigger challenge is improving the efficiency of the hydrogenase itself. Seibert also points out that there is plenty of naturally occurring hydrogenase in microbes, most of which haven't been studied and some of which might be much more efficient than the one used by *C. reinhardtii*.

For all further applications, the antenna-truncated algae should be a major breakthrough, allowing higher rates of production and thus making the end product more cheaply.

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[20] *http://research.chance.berkeley.edu/page.cfm?id=11&aid=58*

University of California works on harvesting hydrogen from green algae. UC Berkeley and Lawrence Berkeley National Lab's Environmental Energy Technologies Division, is conducting fundamental research on processes that may someday facilitate the production of hydrogen or hydrocarbons from microscopic algae, or microalgae.

An important aspect of this research is that it occurs in a controlled environment. If released in the wild, these compromised cells couldn't survive the competition with wild type cells. But in photo-bioreactors, the culture performs better.

The university's research benefits both hydrogen and hydrocarbon generation, but it also have applications beyond transportation fuels, and demonstrate an overall advancement for commercial exploitation of microalgae in non-fuel industries.

The University owns the intellectual property generated from the research, named the Oleomics TM Project. The name references the scientific discipline that seeks to identify and exploit genes and biosynthetic pathways for generating hydrocarbon biofuels from unicellular green algae.

Despite the commercial interest in his research, the university was quick to note the challenges of scaling up from the lab to large bodies of water to cultivate microalgae for fuels. The university acknowledges both engineering and practical barriers to an approach that would require thousands of acres of ocean surface. According to the University, the current cost of generating hydrogen from microalgae is equivalent to generating gasoline at a cost of $15 per gallon.

Future plans

To genetically tinker with green microalgae to improve their ability to produce hydrogen, a potential fuel source

University of California at Davis, USA

Aim of the Project: Fuel from Botryococcus braunii

Year: Sep 2008

Collaboration

- Slayer has a $25 million research agreement with *UC Davis* to develop non-food biofuels
- San Ramon-based Chevron Corp. has formed research alliances with the University of California, Davis, Texas A&M and other institutions to study ethanol and other biofuels.

Funding

- Chevron Corp. will fund up to $25 million in research at UC Davis in the next five years to develop affordable, renewable transportation fuels from farm and forest residues, urban wastes and crops grown specifically for energy.
  (Jan 2009)
- $800,000 was granted by the California Energy Commission to the California Biomass Collaborative at UC Davis.
  (September 2009)
- $135 million from the Department of Energy to the Joint Beanery Institute, a collaboration of LBNL, Sandier National Laboratories, Lawrence Livermore National Laboratory, UC Berkeley, UC Davis and the Carnegie Institution for Science, based in the Bay Area.
  (Oct 2009)
- In California, UC Davis has teamed with the University of Tokyo in Japan in a project jointly funded by the U.S. National Science Foundation and the Japan Science and Technology Agency to develop bioenergy. All four projects, with a total of $12 million in grants, are based on metabolomics, an approach that uses high-tech analysis to understand all the chemicals involved in a living cell's metabolism. (Jan 2012)

Details of the project[21]

Scientists at the University of California, Davis are researching profitable ways to convert algae into biofuel.

UC Davis uses the microalgae, *Botryococcus braunii,* a green colonial microalgae found worldwide in freshwater and brackish lakes, reservoirs and ponds. This algae gained a great interest in scientific and commercial world because if its ability to synthesize and accumulate huge amount of various lipids, which can be converted in to the Biodiesel, Jet-fuel, Gasoline and other important chemicals. These algae produce various types of hydrocarbons out of which botryococcenes are the most important as it produced highest quantity and have many properties similar to the various contents of crude oil. So, intensive research are being undergone to maximize the hydrocarbon contents in these algae by altering the genetic and environmental conditions, also to isolate the strain which can produce maximum amount of hydrocarbons.

Future plans

The university plans to allow the resulting sugars from *Botryococcus braunii* to be fermented into fuel in its own right, increasing efficiency.

[21] http://fiehnlab.ucdavis.edu/staff/kumar/Botryococcus/

University of California at San Diego, USA

Aim of the Project: Biofuels from algae

Year: April 2009

Collaboration

Scientists from UC San Diego joinedSan Diego Mayor Jerry Sanders, The Scripps Institute of Oceanography, The Scripps Research Institute, the Salk Institute, San DiegoStateUniversity and the local biotechnology industry in a broad-scale research effort to develop advanced transportation fuels from algae.

Funding

According to the SANDAG analysis, every $100 million of venture capital funding is applied towards the university research spending on algal biofuels. (May 2009)

The project to develop fuel from algae is expected to get $750,000 in federal funds. Itis part of a funding bill for energy and water projects.
(Oct 2009)

Details of the project[22]

The scientists of UC San Diego established the San Diego Center for Algae Biotechnology, or "SD-CAB." The primary goal of the center is to create a national facility capable of developing and implementing innovative research solutions for the commercialization of fuel production from algae.

In the Imperial Valley, where SD-CAB scientists will grow large quantities of algae and which has one of the highest rates of unemployment in the nation, the algal biofuels effort is expected to generate additional jobs and economic activity.

SD-CAB scientists are not only examining fresh-water species of algae, but those from the sea, an effort being carried out by researchers at UC San Diego's Scripps Institution of Oceanography.

Scripps Institution of Oceanography and UC San Diego have demonstrated leadership in identifying solutions for the planet's environmental challenges. Scripps Oceanography's research knowledge and expertise in the marine environment is providing a platform for developing algae as a renewable biofuel and economic driver for the future.

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[22] *http://www.universityofcalifornia.edu/news/article/21057*

By involving students in research activities at local research institutions, such as UC San Diego, SD-CAB researchers say they also intend to train a new generation of scientists for careers in entirely new occupations such as biofuels development that are likely to flourish in future years.

In November 2012, SD-CAB scientists genetically engineered marine algae to produce five different kinds of industrially important enzymes and said the same process they used could be employed to enhance the yield of petroleum-like compounds from these salt water algae, thus demonstrating that marine algae can be just as capable as fresh water algae in producing biofuels.

Future plans

To make sustainable algae-based fuel production and carbon dioxide abatement a reality within the next five to ten years

University of Georgia, USA

Aim of the Project: Algae in wastewater converted to biodiesel

Year: November 2007

Collaboration

The university is in collaboration with Dalton Utilities to build a pilot project to use its land application system along the ConasaugaRiver for growing algae to make biodiesel.

Funding

The College of Pharmacy's capital campaign has raised $7 million of the $10 million it committed to build new facilities that will "bridge UGA and Medical College of Georgia," for algae biofuel research while the state has promised to fund $36.5 million of the project. (2009)

Details of the project[23]

Wastewater generated by carpet production could potentially be used to grow algae for biofuel. Instead of applying this treated wastewater to designated areas, it could be used to cultivate algae in open ponds. With the amount of wastewater, a million gallons of biodiesel

[23] http://www.universityofcalifornia.edu/news/article/21057
http://www.uga.edu/aboutUGA/research-algae_biofuel.html

made from algae could be produced annually, enough to run the Dalton's entire fleet of government vehicles for a year.

The University is growing algae in large plastic tubes and oversized plastic bags. It has got samples of different algae in closed beakers in a growth chamber. Later, they'll place promising species in plastic ponds to see how well they grow in uncontrolled environments.

The UGA researches are working to find cost-effective ways to harvest algae and express oil from it. The oil is then turned into biodiesel, the protein is added to livestock feed and the remaining carbohydrates are used in ethanol and methane production.

Despite its upsides, algae are difficult to produce. The ideal growing location, in open ponds, is hard to regulate. It is also hard to harvest the algae. It is now harvested mainly for its protein, which can bring manufacturers $6 an ounce.

One big downside now is that it costs about $5 to make a gallon of fuel from algae. The university researchers hope their work will lower the cost to $1.50 a gallon, which would lower the cost of biodiesel and diesel blends and still give producers a profit.

Researchers from the University of Georgia and the University of Puerto Rico are creating a renewable energy center in in Rio Piedras, San Juan, Puerto Rico to grow algae-based biofuels.The project is funded by a $4 million grant from the U.S. Department of Defense.Scientists focus on the thermochemical conversion of algae and also will investigate how they can recycle the waste materials produced by both the anaerobic and thermochemical conversion processes as high-nutrient fertilizers. (Dec 2011)

Future plans

To place promising algae species in plastic ponds to obtain biodiesel and to see how well they grow in uncontrolled environments.

University of Florence, Italy

Aim of the Project: Biodiesel from algae

Year: May 2009

Collaboration

- Wageningen University & Research Centre and University of Florence, in collaboration, shared the latest R&D in Algal production and yields enhancement, providing a sneak preview into the future of the industry.
- US algae-based biofuel company Aurora Biofuels, Inc. is working in collaboration with the University of Florence.

Details of the project[24]

The University of Florence and the European Biodiesel Board, together with number of major stakeholders in the EU algae sector, have announced the launching of the association. The EABA (European Algae Biomass Association) was founded to foster synergies among science and industry, while cooperating with decision makers for the promotion of development in research and technology in the field of algae.

The objective of the newly founded EABA, which aims to support the efforts of the various actors in the algae sector, is to address technical, legal and scientific issues to bring down the final price of algae biomass to an economic level and to produce a fully reliable quality product. The development of research toward an algae industry deserves today to be supported as a priority in light of the major challenges Europe is facing to reduce greenhouse gases, improve energy supply security and promote technological excellence.

Future plans

The university plans to promote mutual interchange and cooperation in the field of algae biomass, production and use, including biofuels use and all other utilisations.

University of Nevada, USA

Aim of the Project: Algae-to-biofuels

*Year:*January 2009

Collaboration

The university is collaboratively working with their industry partners Enegis, LLC and Bebout Associates on algae-to-biofuels project.

Funding

- The project received grant funding from the U.S. Department of Transportation SunGrant Initiative.(Jan 2009)

- The University Office of Research announced funding of $73 million for research in fiscal year 2008-09 which includes growing algae for fuel.
- DOE awarded $14.3 million to University of Nevada, Reno to design bioenergy crops for arid, hot climates in September 2012.

[24] http://cleanergy.blogspot.com/2009/05/launching-of-european-algae-biomass.html

Details of the project[25]

University researchers have harvested their first outdoor cold-weather crop of algae as part of their algae-to-biofuels project. The project is on track to show that the process is an economical, commercially viable renewable energy source in Nevada.

The project, using one of two 5,000-gallon ponds at the University's greenhouse complex on Valley Road in Reno, produced several hundred gallons of concentrated algal slurry. The research has demonstrated that, with the proper technology and species of algae, it is possible to grow algae outdoors year-round in Nevada. The pond was inoculated with a "starter" culture and then the algal cells grow out until they reach a plateau or stationary phase, which takes two to three weeks. The algae thrived in the outdoor pond despite nighttime temperatures that fell into the low 20s.

A conservative estimate for this harvest is 30% lipids and 5% starches on a dry weight basis, less on a fresh weight basis.

The goal is to develop a hardy variety of salt-loving algae as alternative biofuel feedstock, which produces more than half its weight in oil - as well as developing a practical process to grow, concentrate and harvest the algae. The alga variety harvested was selected and cultured by the University, and future varieties will be developed by the University.

Nevada researchers and energy producers are uniquely enabled to leverage the geothermal, high solar radiation, ample land area, and salt basins to produce algae in a scalable and economically viable manner. Use of the uncovered ponds demonstrates that algae can be grown in commercial quantities year-round, even in a temperate climate. This will preclude the need for capital-intensive bioreactors or covered ponds.

The ponds were constructed with the help of industry partners Enegis, LLC and Bebout and Associates.

They believe that the methodologies and technologies being developed will result in high-quality biofuel that can compete in price per gallon with both current domestic biofuel production and imported fuels. There is a possibility for long-term financial benefits for the University from the development of the growing process and special algae strains.

This harvest represents the culmination of more than four years of research into developing hard varieties of algae which produce large amounts of oil or starch as well as developing a practical process to grow, concentrate and harvest the algae.

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[25] http://www.unr.edu/nevadanews/templates/details.aspx?articleid=4810

The first real-world, demonstration-scale project in Nevada for turning algae into biofuel has successfully completed the initial stage of research at the University of Nevada, Reno.

Future plans

The university researchers planned to begin growing another crop of algae to be ready for harvest in 2010.

University of New Hampshire, USA

Aim of the Project: Algae biodiesel

Year: March 2008
Collaboration

Local biofuel distribution company, Simply Green is collaborating with UNH on finding more sustainable feedstock solutions, particularly algae grown with waste resources.

Funding

The university received a $135,276 grant from the ConnecticutCenter for Advanced Technology (CCAT). The grant is awarded through the Connecticut Fuel Diversification Grant Program funded by the state's Department of Economic & Community Development. (January 2009)

Details of the project[26]

Realizing the importance of Biodiesel feedstock, University of New Hampshire (UNU) is conducting pioneering research on the production of biodiesel from algae.

Algae could also be used to scrub power plant emissions. The university emphasizes that a coal plant could bubble its carbon dioxide rich emissions through water, growing algae for biodiesel while cleaning its emissions.

The first step in growing algae in the lab is placing them in beakers, where they are given light, air and nutrients. When they are mature enough, they are moved to a larger photo bioreactor, which bubbles air through a nutrient rich solution. As the algae grow, they produce the oil needed for biodiesel. The oil is extracted by breaking the algae cells using a machine called a cell disruptor.

[26] *http://www.thebioenergysite.com/news/2533/unh-awarded-state-grant-for-biodiesel-research*
http://www.tnhonline.com/2.3536/unh-researchers-pursue-algae-in-hopes-to-make-fuel-consumption-greener-1.390750

The University researchers are trying to find the conditions that will yield maximum oil production. So far, they have tried two different types of algae and are testing different kinds of water, such as freshwater, saltwater and pond water. They are now bubbling air through the photo bioreactor, but they hope to get a carbon dioxide drip to bubble through. Producing biodiesel in the United States would cut down on imports and create jobs within the country, and using it would help clean up the air.

The University of New Haven (UNH) is to expand its biodiesel research, examining the viability of algae from Long Island Sound as a fuel resource, following a $135,276 grant from the ConnecticutCenter for Advanced Technology (CCAT).

Following the algae collections they will identify and analyze the species collected followed by enlisting the aid of a supercritical fluid extraction (SFE) system for an environmentally friendly extraction of lipids, and test the collected algae's fat content.

Future plans

To identify species of algae from Long Island Sound that could be harvested or cultivated to produce biodiesel.

University of Texas at Austin, USA

Aim of the Project: Algae jet fuel

Year: May 2009

Collaboration

Sunrise Ridge Algae Inc. has worked with The University of Texas at Austin which owns and operates a pilot production facility at the Austin Water Utility's Hornsby Bend plant in Austin to produce biofuels from wastewater.The university has also assisted AlgEternal Technologies and collaborated with 3M, a multinational corporation with a presence in Texas, to help them identify new markets in this field.

Funding

DARPA awarded $25 million to University of Texas project to transform algal oil to jet fuel *(2009)*

Two researchers at the University have been awarded a grant of $75,000 to develop computer models for algae-based fuel production and improve the security of coastal waters. (May 2012)

Details of the project[27]

Biologists and engineers at The University of Texas at Austin have been selected to be a part of a $25 million project that would transform algal oil to jet fuel.

The Defense Advanced Research Projects Agency (DARPA) is sponsoring the project to develop jet fuel, known as JP-8, for military use from biological sources. Science Applications International Corp. (SAIC) in Marietta, Ga., is overseeing the project. Al Mondelli of SAIC is the program manager of the project. The project team involves many other entities, each chosen for a specific area of expertise that will contribute to the success of the project.

Researchers are developing solutions to economically scale up the algal culturing techniques and to harvest algae economically and efficiently and to make the transition from lab to land once the suitable strains, techniques and permits are available.

At The University of Texas at Austin, the scope of the project includes identifying the best strains of algae for producing oil from sites in Texas and from the university's algal culture collection, harvesting the algal strains, breaking the algal cells to extract oil, purifying the algal oil for jet fuel production and exploring uses and markets for waste by-products from the process.

The members of the Texas team have conducted groundbreaking algae research in applied areas of science and engineering for years. The university is home to one of the world's largest collections of algae, UTEX, the Culture Collection of Algae. It has more than 3,000 strains and supplies them to scientists around the world.

Researchers at the university have already developed an electromechanical process for extracting oil from an alga cell that is rapid, energy-efficient, free of solvents and less expensive than competing methods. The technique employs electric fields to break open the cell. The system is developed in collaboration with OpenAgae, a collaborative venture between Organic Fuels Technologies, Inc. (an OFHI subsidiary) and the Board of Regents of the University of Texas.

Another group of researchers at the university is focused on the science of separations research and is identifying techniques to separate the oil from the algae biomass once it has been released.

The DARPA project is expected to spark commercial development of jet fuel for military and commercial applications and possibly diesel fuel for land transportation. One of the project's

[27] http://www.utexas.edu/news/2009/05/04/fuel_algal_oil/

goals is to produce algal oil-based jet fuel on a large scale at a cost to the user of $3 a gallon. The current cost of a gallon of diesel fuel made from algae ranges from $10-$20 a gallon.

This DARPA award provides a major opportunity for Texas and the nation to develop the technologies needed to build a commercially viable algal biofuel industry

The university's strong scientific foundation in the biological and engineering aspects of this project will ensure success in the quest to create methods for the large-scale production of algal oil to make jet fuel in collaboration with industry.

In September 2011, the University, in partnership with AlgEternal Technologies opened one of the largest of-its-kind algae growth demonstration facilities for biofuels in the country.In July 2012, a study at the University of Texas at Austin demonstrated that it is theoretically possible to produce about 500 times as much energy from algae fuels as is needed to grow the fuels.

Future plans

Plans to develop large-scale production of algal oil to make jet fuel

University of Virginia, USA

Aim of the Project: Algae biofuel

Year: August 2008

Collaboration

The university works with McIntire School of Commerce on algae biofuel project.

Funding

The university receivedSustainable Energy Seed Grantworth about $30,000(2008)

Details of the project[28]

Researchers at the University of Virginia have commenced three projects to improve yields from algae-to-fuel production. The first project will test for optimal levels of solid waste and carbon dioxide fed to the algae, with a target of improving yields by 40 percent. A second project will compare the economic and environmental benefits of algae biodiesel to soy. A third project will optimize oil extraction by testing different algae processing techniques, including

[28] http://www.virginia.edu/uvatoday/newsRelease.php?id=5985

grinding up of solid waste before feeding it to algae.

The team will try to determine exactly how promising algae biofuel production can be by tweaking the inputs of carbon dioxide and organic matter to increase algae oil yields.

The University of Virginia team hypothesizes that feeding the algae with more carbon dioxide and organic material could boost the oil yield to as much as 40 percent by weight.

Proving that the algae can thrive with increased inputs of either carbon dioxide or untreated sewage solids will confirm its industrial ecology possibilities — to help with wastewater treatment, where dealing with solids is one of the most expensive challenges, or to reduce emissions of carbon dioxide, such as coal power-plant flue gas, which contains about 10 to 30 times as much carbon dioxide as normal air.

The university will examine the economic benefits of algae fuel if the nation instituted a carbon cap-and-trade system, which would increase the monetary value of algae's ability to dispose of carbon dioxide. It will also consider how algae fuel economics would be impacted if there were increased nitrogen regulations (since algae can also remove nitrogen from air or water), or if oil prices rise to a prohibitive level.

The team will experiment on a very small scale — a few liters of algae at a time. They will seek to optimize the oil output by using a pragmatic engineering approach, testing basic issues like whether it makes a difference to grind up the organic material before feeding it to the algae.

Wastewater solids and algae, either dead or alive, are on the menu. Some of these pragmatic issues may have been tackled already by the various private companies, including oil industry giants Chevron and Shell, which are already researching algae fuel, but a published scientific report on these fundamentals will be a major benefit to other researchers looking into algae Biofuel.

Research successes would also open the door to larger grants from agencies like the U.S. Department of Energy, and could be immediately applicable to the handful of pilot-scale algae biofuel facilities recently funded by Shell and start-up firms.

Several thousand miles to the east, University of Virginia researchers have announced development of commercial production models for growing algae more efficiently. They believe the proper balance of CO_2 and organic material can boost oil production by as much as 40 percent.

However a new research study from the University of Virginia researchers have found that the life cycle of algal biofuel produces high levels of greenhouse gas emissions -- much more than it sequesters.[29]

[29] http://www.algaeindustrymagazine.com/u-va-study-finds-complexity-in-algae-deployment/

Future plans

University of Virginia has announced plans to develop a commercial model to grow algae more efficiently.

University of Washington (UW), USA

Aim of the Project: Algae to transportation fuels

Year: August 2008

Collaboration

Allied Minds, a seed investment corporation specializing in early stage university business ventures, has partnered with the University of Washington to establish AXI, LLC to commercialize novel technology to develop and create commercially advantageous strains of algae for the production of biofuels.

Funding

The university received a Technology Gap Innovation Fund award from UW TechTransfer to support further research(2008)

In June 2012, a professor of chemical and biological engineering at the University has received a five-year grant worth $750,000 from the U.S. Department of Energy Office of Biological and Environmental Research to explore new possible ways to produce biofuels with algae.

Details of the project[30]

University of Washington is growing dozens of different kinds of algae at the lab to find the right ones for turning into different kinds of fuels that can power cars, trucks, airplanes and boats.

University of Washington is developing algal strains that will bridge the gap between the promise of clean energy generation and the reality of economical biofuel production systems. Of the many feedstocks that can be used for biodiesel, algae are emerging as the clear winner because significant biomass can be produced on non-arable lands (thus avoiding the food vs. fuel debate) and CO_2 (a greenhouse gas) supports their growth.

[30] http://depts.washington.edu/techtran/aboutus/Docs/AXIPressRelease.pdf

The proprietary methodology for developing specific growth and productivity traits will help any algal production system improve its output of inexpensive, oil-rich algae as the raw material for the generation of biofuel.

This technology will permit the economic use of clean algae as a viable replacement to petroleum-based fuels. The technology is superior that will now be in a better position to hit the ground running as the alternative energy market continues to mature.

UW startup was formed to commercialize her proprietary method for optimizing algae for the high-level production of specific types of oils (lipids).

Future plans

To provide the optimal strains and work with production companies to make bio-friendly fuel from algae for automobiles, jets, home heating, and many other uses.

Utah State University, USA

Aim of the Project: Algae to biofuel

Year: July 2008

Collaboration

Oak Ridge is in Cooperative research with UtahStateUniversity on discrete challenges in the production process (e.g., photosynthetic saturation, minimizing surface shading, “hydrophobic” materials to prevent biofouling in photobioreactors, and scalable photobioreactor design)

The university will team with MontanaStateUniversity to grow species of algae that thrive in geothermal vents and the Great Salt Lake in a test of their oil content.

A collaborative project between the Utah city and the Utah State University Research Foundation will use the ponds to grow algae, which might not only fix the phosphate problem for little money but produce energy

Funding

- UtahStateUniversity will share a $900,000 government research grant for biofuel production.
  (September 2008)
- USU was among several institutions to receive grant money of $19.9 million from the U.S. Department of Defense toresearch ways to convert algae into biofuels for military jets.
  (2008)

- UtahStateUniversity has received a $500,000 state grant to experiment with turning algae into methane that could ultimately fuel city vehicles. The state grant is given to begin converting the 460-acre lagoon complex into an algae farm as a small-scale pilot project
  (September 2009)
- The university received USTAR funds from the Oak Ridge National Laboratory.
  (2009)

Details of the project[31]

Professors at Utah State University are researching to use "pond scum" for a very useful purpose. They are developing commercial scale systems to grow algae to produce biofuel. Biofuel can be used to replace transportation fuels that are refined from petroleum products, decreasing our reliance on foreign oil and minimizing CO_2 emissions that cause global warming.

USU researchers are carefully screening different algae strains to find the perfect algae for making biofuels. The USU team is also working to design "bioreactors" to better distribute sunlight to grow algae faster and in more concentrated environments. In short, the team hopes to find a way to use the right algae in the right bioreactor for the optimal production of biofuels.

Since algae needs CO_2 to grow, the USU team is applying innovative strategies to build bioreactors that allow CO_2 from power plants or other sources to be captured or "sequestered" in the algae. In this way, algae can further slow global warming - first by replacing fossil fuels and second by trapping CO_2 produced when fossil fuels are burned.

The university invented a novel method of collecting and distributing sunlight through optical fibers to light the inside of buildings.

The university is trying to fast track algae as fuel and has shown that algae will produce 15 times more oil per acre than other plants already in the new fuels mix such as corn and switchgrass.

The University is currently studying 3,000 different algae species. It has 40,000 species to choose from. The military spent nearly $12 billion last year on research and development with hundreds of companies studying algae fuels. Scientists are in a race to be the first to produce the most oil and do it for less than $3 per gallon.

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[31] *http://www.usu.edu/ust/pdf/2009/july/itn071309304.pdf*
http://www.innovationutah.com/research/biofuel/biofuel.html

This research is part of the Utah Science, Technology and Research Initiative (USTAR) ongoing effort to develop an environmentally friendly, non-food source of secure, clean and sustainable alternative fuel.

In November 2011, researchers at the university moved their algal biofuels project from USU's Logan campus to Vernal, Utah, the heart of the state's oil and natural gas industry.

Future plans

- To develop a pilot project for growing and harvesting algae from wastewater lagoons west of Logan.
- To maximize the biomass production of oil-rich algae for use in alternative fuels.

Universities – Others

- Japan as an oil-exporting nation? Not in this universe -- unless the oil is derived from algae. Then it might just happen one day. - The idea of using algae as an energy resource dates back years. The Japanese government included studies on algae in its Sunshine Project after the first oil crisis in 1973. And the government-affiliated Research Institute of Innovative Technology for the Earth (RITE) tried its hand at research in the 1990s, but halted the project because it never reached economic viability. But now researchers are at it again, and the slogan this time is for Japan to become an oil exporter by 2025 - May 2008 [32]
- Washington State University biological engineering is working on algal fuels – Oct 2008

[32] http://www.nni.nikkei.co.jp/FR/TNKS/Nni20080520D20HH027.htm

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