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Program on Technology Innovation: Algae Biofuel, CO_2 Reuse, and Related Technologies Vendor Description

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PRODUCT DESCRIPTION

Interest has been growing over the last several years in the use of microalgae for production of various forms of bioenergy. These include transportation fuels, solid fuels for cofiring, digestion to natural gas, and other forms. Many of these applications involve electric utilities, either directly or indirectly. Due to rapid growth in this research field it can be difficult to keep abreast of the latest technology developments and field of vendors. Thus EPRI has compiled a database that contains brief descriptions of active algae vendors and their current activities.

Results and Findings

This report compiles information from more than 80 vendors in the area of algae biofuels, CO_2 reuse and related technologies in a single place as a starting point for review of activities in the field. Approximately 20 of the vendors included in the database provided additional information and review of their entries beyond what was originally compiled.

Challenges and Objectives

A number of technical challenges to full scale deployment of algal bioenergy systems exist, and few systems have progressed past the pilot or demonstration scale stages at this time. These challenges include low production rates for algae-derived oil, and potentially large requirements for necessary land, water, and other inputs. A variety of approaches to these challenges are being investigated through commercial vendors, research institutes, universities and government laboratories and other organizations. Many of these approaches are described in this database.

Applications, Values, and Use

The field of algal bioenergy is rapidly evolving, and the engineering and technical approaches to improving biomass productivity and the efficiency of the energy production processes will continue to be updated. Future updates to this database will be performed to keep it current, and the information within will be also used as a starting point for more in depth technology analyses at EPRI.

EPRI Perspective

EPRI is in a unique position in this field of research as electric utilities may play the roles of host facilities or development partners of algae bioenergy technologies. Thus continuing EPRI research is necessary to understand the full scope of potential and challenges, reduce utility investment risks in this area, and provide results in a transparent and public manner.

Approach

This report was compiled through review of publically available materials provided by vendors, available on the Internet, presented at conferences, or obtained through discussion with vendors. Individual company entries were sent to the appropriate vendors, who were provided the opportunity to provide comments before EPRI staff performed the final review and compilation.

Keywords

Microalgae, algae, algal, biofixation, carbon capture, carbon reuse, biofuel

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Introduction

Microalgae are microscopic plants that perform photosynthesis to reproduce and create new biomass. The lipid fraction of algal biomass is of great interest as a potential source for the production of energy, including gasoline, diesel, and jet fuel-like biofuels. Some algae can be used to produce ethanol, methane, or other chemicals for use as fuels, and the solid portion of the biomass may be used for co-firing at fossil fuel power plants. In addition, many other products of algal metabolism have other uses, such as for animal feed, fertilizer, nutriceuticals, and pharmaceuticals. Growth necessary to produce high biomass productivities requires enhanced levels of CO_2 above what the algae cells can extract directly from the atmosphere. Thus, concentrated sources of CO_2 such as the gas streams of power plants, cement plants, or other industrial processes have been proposed as appropriate sources of CO_2 for algae systems. The determination of net benefits or drawbacks to the host plant is currently being investigated by many researchers, including EPRI. A more detailed description of this research field can be found in an upcoming EPRI Technology Innovation Sci-Tech Brief titled “Algal Biotechnology for Energy Production & Carbon Capture”.

Vendor Descriptions

As a result of intensifying interest in these technologies, many companies, partnerships and collaborations, and initiatives have been created to perform research or provide consulting services on these topics over the past several years. More than 100 companies regularly appear in the media or at scientific conferences to discuss their work. The large variety of current technical knowledge gaps in this field means that a number of issues are being addressed by a number of organizations, each with their own approach.

In response to increasing interest in the linkages between algae systems and power plants, EPRI has initiated development of several assessment tools for technology evaluation. One tool is a compilation of vendors working in this area to be used as a single starting point for identification and basic facts about their technology. This compilation will aid in the understanding of the general types of technologies being investigated, the technology niche of individual companies, and major activities of which they are a part. No evaluation or judgment of the technologies is included, and no endorsement is intended. Rather the document is intended to be a summary of current activity.

Methodology of Compilation

The companies were chosen for inclusion in the database based primarily on the prevalence of information available in the pubic domain. Companies that solely refine algae oil were not included. The focus was intended to be on U.S. companies, but some international companies are included as the information was found. It is expected that this list is incomplete due to the rapid pace of the field, and the fact that much of this work is done outside of the public domain.

Information was gathered from company websites, press releases, white papers, presentations at scientific or business conferences (such as the Algal Biomass Summit www.algalbiomass.org), and discussions with company staff. All information provided is publically available. No patent application or other documentation was reviewed.

Database entries include the following:

- **Company**. Name of company.
- **Company review?** Draft entries for each company were sent by email, along with a brief description of the database purpose and design, to company contacts to allow for their review and correction. If a company responded with changes within the two week time period allotted, this entry was 'Y'. The text of the letter sent is included in Appendix A.
- **Purpose/Revenue Stream**. In many case the intent of the technology's use was stated in company materials.
- **Company Links**. If a partnership, joint venture, or other relationship with other companies is known to exist it is included here.
- **Growth system**. Entry choices included open pond, photobioreactor (PBR), and hybrid systems. A hybrid system is one in which algae are grown in both open ponds and PBRs in some way. For example, the cultures grown in open ponds are used to periodically seed the PBR.
- **Species**. The organisms used by the company.
- **Niche**. The primary technology(ies) being developed by the company. What characteristics distinguish this company's offerings from those of others.
- **Notes**. Other relevant information, such as if the oil produced has been ASTM certified, oil from their process been tested in a major project (e.g. Continental Airlines flight powered by biofuel), etc.

As business and research plans in the field of algal biofuels and related technologies are evolving at a fast rate, we can not guarantee the exact accuracy of the entries in the database months after publication. However, future updates are planned. Furthermore, the intent of the database is rather intended as a guide or starting point for further inquiry.

Algal Biofuel, CO_2 Reuse, and Related Technology Vendor Descriptions

Company	Company Review?	Purpose/Revenue Stream	Company Links	Growth System	Species	Niche	Notes
A2BE Carbon Capture	Y	Technology licensing	Raytheon; Accelergy; UND-EERD; MSU; UC Riverside; Sapphire Energy	PBR	Almost any green algae, diatom, or cyanobacterial species	Rollers pass over PBR made of plastic film to mix system and expel waste gases. Low water consumption, rigorous gas control.	Company suggests their system works well with oxyfuel generation. Led several webinars for Electric Utility Consultants, Inc.
Advanced Lab Group	Y	Biofuels, renewable electricity		PBR	Various	Low cost PBRs, potentially using polyethylene film. Capital and energy efficient thermal management.	
Algae Biofuels		Biofuel	PetroSun subsidiary				
Algaedyne Corporation				PBR		LED patterns for optimum artificial light absorbtion	
Algae Floating Systems	Y	Algal oil, biofuels, animal feed, wastewater treatment, engineering		PBR	Native	Inexpensive PBR of simple construction and operation and expected long lifetime. Low energy gravity-based harvesting system. Wet biomass oil extraction with catalyst and ultrasonic cell disruption.	Plan to deploy soon a commercial system in non-arable lands, and eventually in open sea.
AlgaeLab		Nonprofit teaching and research				Lab for algae research that is open to the community.	
AlgaeLink		PBR systems	KLM	PBR		Prefabricated or custom PBRs with automated operation and cleaning. Solar dryer for biomass.	
Algaewheel		Wastewater treatment				Algae replace aeration blowers for more efficient wastewater treatment. Algae grown on wheel fins with bacteria in wheel center. Gasify algae to power the process.	
Algafuel		CO_2 capture, biofuels	spinout of Necton SA				
Algatechnologies	Y	Astaxanthin-based products and sulfated-polysaccharides; PUFA; other products		PBR; semi-closed systems	*Haematococcus spluvialis, Porphiridium sp.,* others	Up to two stage growth in reactors of column and sleeve designs.	Mature and operating production plant at Ketura Kibbutz in Israel accredited as GMP, HACCP, ISO, and Kosher.
Algenol		Biofuel, plastic feedstocks, O_2 for coal combustion	Multiple partnerships - Dow Chemical (plastic PBR); Georgia Tech and Membrane Technology & Research (O_2, H_2O, ethanol separation); NREL (CO_2 source impact on algae)	PBR	Genetically engineered cyanobacteria; saltwater species	Photosynthetically-derived sugars converted to ethanol which is excreted. Cells engineered to live in high ethanol levels. PBR troughs lined with plastic bags. Fuel ethanol produced from reactor condensate with energy efficient membranes & separations.	Plan to replacing natural gas a feedstock for plastics. Have 40 bioreactors in FL and plans on a demo project at Dow's Freeport TX site.
Algosource		Recycling of industrial effluents	Partnerships/co-managment with Alpha Biotech, and GEPEA			AlgaeSIM process simulator for mass & energy balances. Consulting services for algae. Selective filtration of solar radiation; low-cost fiber optics.	
Aquaflow Bionomic Corporation		Water treatment, biofuel, crude		Open pond	Harvested from effluent management systems	Harvesting and concentration of wild-type algae from open pond municipal waste facilities with low energy requirement. Produced synthetic paraffinic kerosene meeting Jet A-1 specification from their wild algae.	Several demo projects with up to two years of year-round operations. Pilot at the Blenheim WWTP. A sample converted to jet fuel by UOP (Honeywell) and used in Air New Zealand flight.

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Aquatic Energy		Biofuel, animal feed, nutritional supplement	University of Louisiana at Lafayette, Louisiana State University and LSU Agricultural Center	Open pond		Working on algae growth, harvesting, and extraction techniques.	Three pilot-scale algae farms in Louisiana.
Aurora Biofuels	Y	Biofuel, CO_2 capture, animal feed, oleochemicals		Open pond	Using transgenic organisms in lab work; non-transgenic organisms for outdoor work; marine	Using high throughput screening and directed evolution related to photoinhibition. Optimized hydrodynamic pond design of pond systems for CO2-rich environment. Looking for strains with outdoor stability first, then high oil content and quality .	Business plan won the Global Intel+UC Berkeley Technology Entrepreneurship Challenge at the Haas School at Berkeley in 2006. ASTM certified biodiesel at pilot scale. Operated a pilot plant (coastal FL) since Aug. 2007.
Bioalgene	Y	CO_2 capture, biofuels, air and water remediation, energy production, other products	Washington State University; Seattle University; Boeing; Portland General Electric; City of Everett; City of Moxee	PBR; pond	*Chlorella sp., Botryococcus sp., Scenedesmus sp.*	High rate open ponds.	Test sites in Washington, Oregon, and Missouri.
Bionavitas		Biomass, biofuel		PBR		Light Immersion Technology: LEDs provide artificial light at maximum wavelength for chlorophyll absorption (e.g. 432nm).	
BioProcess Algae		Biofuel, feed, CO_2 capture	Green Plains Renewable Energy	PBR		Light and heat addition to PBR. Water, heat, CO_2 will be recycled from ethanol manufacturing process for algae growth.	Plans to build pilot project at Green Plains Ethanol plant in Shenandoah, Iowa.
Blue Marble Energy		Water treatment, biogas, high value biochemicals	Washington Department of Ecology		Harvested from wastewater and ocean	Generate algal blooms in wastewater facilities and feed them to other microbes to produce high-value industrial chemicals (organics, anhydrous ammonia, and CH_4) through anaerobic fermentation. No need for drying biomass, and can use other biomass.	Cone-shaped coffee-filter-like device works with current clarifier tanks and lagoons; harvested by raising device.
Bodega Algae	Y	Biomass for feed, high value by-products, long-term CO_2 capture, wastewater, PBR sales	NASA Ames Research Center	PBR		Passive solar light-guided optics allow for larger, more efficient tank volumes. Collects light over large area and delivers to vertical lenses in pulses to optimize photosynthesis.	Funding from National Science Foundation starting in 2010.
Canadian Pacific Algae		Biomass, high value products			Diatoms, esp. *Skeletonema* , *Thalassiosira* , and *Chaetoceros*	Grow marine algae in six one million gallon tanks, located 3-km inland. Operations are in a batch reaction.	
Canrex Biofuels							
Carbon Capture Corporation		Biofuels (diesel,JP8, methane), fish feed, butanol, biomethane, CO_2 capture	Algal Biomass Consortium (led by Sandia National Lab); partnerships for other projects	Open pond	*Spirulina sp., Dunaliella sp.,Nanochloropsis sp.*, other diatoms	Conditional use permit to build 50MW peak power plant; awaiting utility contract. Can be run standalone. Will be used to test algae systems. Working on electrocoagulation, ultrasound, and micro fluidizer processor technology for cell lysis.	Testing with Capstone C330 propane microturbines to simulate natural gas power plant CO_2 source.
Carbon2Algae		CO_2 capture	Partnership of inVentures Technologies, Aquasea Group International, Renewable Algal Energy (RAE)			Combine Aquasea Group's high yield algae growth systems, inVentures' ultra efficient gas infusion technology for CO_2 transfer into liquids, and RAE's algae biomass preconditioning, harvesting, extraction and refining processes.	
Cellana		Biofuel	Joint project with HR Bioproduction (see below) and Shell	Open ponds, lined	Non-GMO algae; strains indigenous to Hawaii		2.2 Ha pond facility contructed on the big island of Hawaii at the Natural Energy Laboratory of Hawaii Authority (NELHA). Operates on ocean water.

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Cequesta Algae		Fishmeal substitute, wastewater treatment, biofuel later	Cequesta Water	Open pond		Originally targeting low cost PBR using Richmond vertical flat design. Moved to open pond. Targeting collaborations with solar thermal or landfill methane collection sites as CO_2 sources, or integrated fishfeed manufacturing.	New joint venture with Irish company to use ocean kelp as ethanol feedstock.
Columbia Energy Partners		Biofuels, livestock feed, CO_2 capture	PGE; BioAlgene (providing algal strains)	Open pond	Natural species	Small-scale proof-of-concept tests conducted on a slip-stream of flue gas from Portland General Electric's Boardman coal-fired power plant.	
Community Fuels		Biodiesel, glycerin				Extraction, purification, and conversion of algae oils	
Culturing Solutions		CO_2 capture, pond care products and consulting	Varicon Aqua Solutions group	PBR		BioFence tubular reactor with self-cleaning beads that circulate with the algae. Ultrasonic cavitation for lipid extraction. Dark reservoir tank for protein building phase. Ultrasonic cavitation for oil extraction.	Technology is bench-scale in 2008.
Cyanotech		Nutriceuticals, foodstuffs		Open pond	*Haematococcus,* Spirulina Pacifica™ bred from *S. platensis*	Use $NaHCO_3$ for carbon source, salt water for nutrients, combine with fresh water.	Samples converted to jet fuel by UOP (Honeywell) for Continental flight in January 2009.
Diversified Energy		Biofuel, nutriceuticals	XL Renewables	Open pond or PBR		Low cost open or closed polyethylene trough with aeration and O_2 release vents. License Centia refining system from NCSU. Converts triglyceride to fatty acids, then to paraffins, then desired biofuel. Burn glycerol byproduct for energy.	Demonstration at Withrow Dairy in Casa Grande Az providing 100-200 dry tons algae/acre.
Enhanced Biofuels & Technologies		Waste CO2/Biofuel, animal feed	Concensus Business Group, Alchemie Technology, Green World Biotech	Open pond		Based in London, UK.	Not to be confused with "Enhanced Biofuels", a Houson, TX based company
General Atomics		Biofuel, particularly jet fuel	Many partners	Open pond	"Brine algae"	Process improvements for growth efficiency, cellular oil concentration, nutrient utilization, reactor design, CO_2 delivery, separation technology.	Started experimental lab work 2007 & 2008 started larger pilot ponds. Second facility in Pecos, Texas (A&M University)
Genifuel Corporation	Y	License and royalties from natural gas or electricity	Pacific Northwest National Laboratory	Open pond or wastewater systems	Larger algal cells; no monoculture requirement	Wet catalytic hydrothermal gasification license from PNNL. 5-25% biomass enters fixed bed with ruthenium/carbon pellets. Converts 99% of biomass. CO_2 recycled to ponds. 400x faster & higher yield than other biomass gasification. Can use any wet organic material as feedstock, including wastewater solids and other wastes.	Different from thermal pyrolysis gasification, which produces syngas ($CO + H_2$) and requires expensive drying. This process instead produces natural gas (mostly CH_4).
Global Green Solutions	Y	Straight vegetable oil, biofuel feedstocks, animal feed, CO_2 capture, various high-value products	Joint venture with Valcent	PBR	Indigenous and transgenic controlled algae communities	Vertical plastic PBRs with horizontal flow; potentially housed in greenhouse. Continuous system.	
Greenfuel (Closed 2009)		Biofuel		PBR		Original PBR design used multiple parallel triangular growth chambers. Second PBR was an inclined tube. By 2007 a third design (3D Matrix) was used inside a greenhouse. Diluted light levels increased photosynthetic active area per areal footprint.	
Green Star Products		Biofuel, ethanol, biogas, fertilizers, chemicals	ECOAlgae USA partners	Hybrid		Partial light cover on the growth system to diffuse light; no evaporation because closed system. Have license from Biotech Research, Inc. (BTR) for process that extracts oil and separates different carbon chain carbohydrates, proteins and other constituents.	Demonstration facility in Montana, 40,000L.

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GreenShift Corp.		CO_2 capture at corn ethanol and other fermentation processes	GS Cleantech	PBR	Thermophilic cyanobacteria	Parabolic mirrors and fiber optic cables direct solar energy to acrylic panels. The panels diffuse light over vertical polyester sheets on which the algae grow. Algae fall off into a collection duct when mass becomes large. Have a mobile pilot PBR.	Based on work done at the University of Ohio.
GreenWater Energy							No information available yet.
Hawaii Bio Energy			Established by: Kamehameha schools, grove farm co & Maui land & pineapple co. / Vinod Khosla, Pierre Omidyar & Finistere ventures				
HR BioPetroleum	**Y**	Biofuels, animal or aquaculture feed, biofuels, electricity generation	Joint effort with Shell called Cellana; Hawaiian Electric Company; Maui Electric Company	Hybrid	Indigenous community	Two step hybrid system - grow in PBR under nutrient deprivation, then move to open saltwater pond for a few days to produce oil.	Building a commerical plant in Maui with two electric utilities.
HydroMentia	**Y**	Water treatment, CO2 capture, biobutanol, organic fertilizer, animal feed, high-value products		Open surface flowway	Periphyton, including filamentous green algae	Thin layer of pulsed water on a HDPE liner and film to which algae attach for growth. Harvest by scraping with a tractor (Algal Turf Scrubber) and flowing water. Lower lipid content (e.g. 2-4%) so investigating biobutanol, gasification, other products. Effective at low nutrient conditions.	Developed as a water treatment system and can be used for point and nonpoint source applications such as stormwater runof and river systems. Testing at a 30 MGD facility in Okeechobee, FL.
Institut fuer Getreideverarbeitung GmbH (IGV)	**Y**	PBR design; high-value products; consulting		PBR	Freshwater and saltwater microalgal strains	Development of new concepts for biomass growth and processing, harvesting, drying and extraction techniques and technologies. Research in uses of remaining biomass after extraction.	Over 100 PBRs sold worldwide. 4000L system to be installed at Arizona Public Service's Red Hawk Plant.
Independence Bio Products	**Y**	Biodiesel feedstock, industrial CO_2 capture, nutritional ingredients		Open pond	Wild-type proprietary	Low-cost Algamaxx system. Technologies to control species stability in ponds (manage invasive strains) and harvest at low cost.	Operating system in place at a utility. Growing algae on one acre with scrubbed flue gas as a CO_2 source.
Infinifuel Biodiesel / AG Energy Corporation		Biodiesel				Biomass gasifier attached to a Sierra Pacific coal plant.	
Innoventures Canada		Biofuels, nutriceuticals, chemicals, fertilizers, methane	Numerous industry and government partner	Hybrid		Stage II - solar collectors on top on pond to take light deeper into pond.	
Inventure Chemical		Biodiesel, glucose, plastics, other, high value products (amino acid for fish/animal feed, lactic acid)	Arizona Public Service; Seambiotic; Imperium Renewables		Algae	Direct catalytic esterification/alcoholysis and integrated distillation for multiple products, including biodiesel, esters, ethanol, organic acids, 1,3 propanediol, others. Remaining cellulose, starch and protein is converted to amino acid and glucose derivatives.	Partner w/Seambiotic to build a pilot commercial biofuel plant in Israel (2008).
Joule Biotechnologies			Biofuel	PBR	GMO; brackish water microbes; "not algae"	HelioCulture system - produces ethanol or hydrocarbons (called SolarFuel) from photosynthesis, and fuels are excreted from the cells. PBR design is a 8' x4' flat sheet.	Requires removal of Hg and potentially other materials from power plant flue gas if that is CO_2 source.
Kai BioEnergy	**Y**	Algae crude oil; Transportation fuel		Open pond	Indigenous monoculture; marine diatoms; green algae species	Continuous system that reduces the risk of algae contamination in open systems and allows for high yield growth of a dominant species. Developed finely harmonized disruptive technologies for extraction and separation of biomass fractions (e.g. lipids). Enhanced nutrient and CO2 mix in recycle stream.	Convert to transportation fuel through strategic partner's proprietary process.
Kegotank BioFuels						Use wind and solar to power algae facility	

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Kent Bioenergy		Biofuels, water treatment, methane, fertilizer, animal feeds, CO_2 capture	Spinoff of Kent Biosciences; sibling of Kent SeaTech (striped bass farming); prior partnerships	Open pond	Indigenous community	License Clemson University technology. Multi-stage sequential ponds separately optimized for growth, concentration, and harvest. Stabilization of cultures by fish (tilapia) and tilapia enhanced sedimentation. Bioflocculation. Anaerobic digestion for CH_4, CO_2, and nutrients.	Project with Salton Sea Authority and Clemson Univeristy to remediate Salton Sea.
Kuehnle AgroSystems		Biofuel, animal feed, CO_2 capture				Tailor algae strains to specific customer needs	
Kwikpower		Biofuel			*Botryococcus*	Licensing species from U.C. Berkeley	
LiveFuels		Omega-3s, aminal feed, nutriceuticals, biofuel, CO_2 credits	Algal Biomass Consortium (led by Sandia National Laboratories)	Open pond	Saltwater algae	Minimize contamination by ensuring that all the nutrients are converted to forms the algae can easily use. Use tiny filter-feeding fish to gather algae and then fish oils are harvested.	9 testing ponds in Brownsville TX. Plan to develop commercial facilities to harness agricultural pollution flowing from the Mississippi River, which can be used as nutrients. Goal to move offshore.
Mana Fuels		Biodiesel					
Martek Biosciences		Biofuel	British Petroleum		GMO microbes	Improving fermentative metabolism pathways through genetic engineering.	Martek develop technology and BP bring it to scale.
MicroBio Engineering	**Y**	Consulting, wastewater treatment, biofuel, high value products, CO_2 reuse	California Polytechnic State University; many others	Open pond	General microalgae; not genetically engineered	Integrated wastewater treatment-algae biofuels technology. Consulting services on most aspects of algal technologies based on 30 years of experience in the field.	20 years of full scale facility engineering design experience.
Mighty Algae Biofuels		Oil		PBR		Algae farming, with low-cost manufacturing methods and a proprietary PBR design.	
OriginOil	**Y**	Biofuels		PBR		Rotating helical shaft with low energy lights. Use high pressure to create slurry of micron size bubbles of H_2O, CO_2, and nutrients for better delivery. Ultrasonic bursts weaken the cell walls and bubble slurry applied for extraction.	Plan to have product available late 2010.
PetroAlgae (XL Tech Group)		Biofuel, high value by-products, CO_2 capture	NREL; Arizona State University	Open pond	Microcrops; lemna, microalgae	Fuel functionally identical to fossil diesel. Optimizing algal light exposure.	
PetroSun		Wastewater treatment	Algae Biofuels is a subsidiary	Open pond		Use saltwater.	Wastewater pilot program at Neely wastewater reclamation facility in Gilbert, AZ.
Phycosource		High value by-products (cosmetics, nutrients)				Produce biomass and perform biofuel lipid analysis. Own line of PBRs.	
QuantumSphere						Nanocatalyst for biomass conversion to methane or hydrogen.	
Round River Technologies		Wastewater treatment, energy, CO_2 capture		PBR		Algacore PBR design; produces acetate and O2, which can be used in fossil-fuel power generation.	Suggest IGCC as CO_2 source.
Sapphire Energy	**Y**	Biofuels (gasoline, diesel, jet fuel)	Southwestern Biofuels Association; San Diego Center for Algae Biotechnology	Open pond	Photosynthetic marine algae; GMO and non-GMO varieties	"Drop in" fuel chemically consistent with today's conventional fuels.	2% blend in a larger biofuel mix was run on Continental Airlines January 2009 and in another blend on Japan Airlines. Algaeus plug-in hybrid run on algal gasoline.
SarTec		Biofuel, animal feed, high value product, CO_2 capture		Open pond	Indigenous freshwater community	Developing the McGyan continuous process for biodiesel refinementwhich uses multiple feedstocks, including algae, by combining with ethanol and exposing to a zirconia catalyst.	

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Seambiotic	Y	Omega-3s, essential amino acids, nutriceuticals, and other high-value products, biodiesel, bioethanol	Israel Electric Corporation; Inventure Chemical & others; NASA Glenn Research Center	Open pond	Marine algae: *Tetraselmis, N annochloropsis, Nannochloris* , *Chlorococcum* , diatoms	Pumping CO_2 from Ashkelon power plant, and seawater from Mediterranean, to algae ponds. Currently selling product. Cell growth enhanced on flue gas effluent due to special mineral content.	Collaboration with NASA center for large scale computational modeling, combined with Seambiotic's biological process modeling, to make advances in biomass process cost reduction. Collaboration with Inventure and others for oil refining.
Sequesco		Biofuels			GMO bacteria	Heterotrophic bacteria grow faster than algae, and don't need light, but are limited by volume. Developing GMO species with more lipid- and carbohydrate-rich biomass.	
Solazyme, Inc.	Y	Biofuels, nutriceuticals, high value products, animal feed		Heterotrophic reactor	Marine algae; GMO & directed evolution	Use fermentation pathways rather than photosynthesis for high oil yields. Oil is secreted into medium. Grown in dark in standard commercial fermentation tanks. Requires added sugar, but currently cost effective. Selling nutriceutical product currently.	Signed agreements to provide 35,000 gallons of ship and jet fuel.
Solena Group		Combustion of biomass		PBR		High temperatures to gasify algae and other organics for energy (synthetic natural gas). Recycle combustion CO_2 to algae. Algae grown in thousands of plastic cylinders (3'x10') and fed $NaHCO_3$ biproduct of coal plant.	
Solix Biofuels	Y	Biofuel and other algae products, technology licensing	Southern Ute Alternative Energy; Valero	PBR		Vertical plastic bag panel reactors in a shallow water bath. Centrifugal harvest and dynamic nutrient control.	Demonstration facility in Southern Colorado using processed water and industrial CO2 produced by methane-scrubbing plant.
Solray		Wastewater treatment, algae crude oil					Batch operations began in 2008 at the Bromley WWTP in Christchurch, New Zealand.
SunEco Energy		Biofuel, animal feed, CO_2 capture			Natural species (no GMO)	Licensing Global ReNergy Systems' process to produce straight vegetable oil.	
Sunrise Ridge Algae	Y	Petroleum substitute, animal feed, CO_2 credits, wastewater credits	University of Texas; University of Houston	PBR; open pond	Mixed freshwater green algae and cyanobacteria; freshwater *Lemnaceae* (duckweed)	PBR system of horizontal helical design and mixed symbiotic algae species used for CO_2 reduction. Open unstirred ponds with *Lemnaceae* (duckweed) for biomass production. Catalytic thermolysis method for converting low lipid, low cellulose biomass to petroleum substitute.	Test facility at Hornsby Bend wastewater treatment plant in Austin TX, and other test facilities.
Synthetic Genomics		Biofuels	ExxonMobil		Photosynthetic algae	Manipulating carbon partitioning between lipid, protein, and carbohydrate fractions.	
Targeted Growth	Y	Biofuels	Solix Biofuels; Washington State University		Photosynthetic bacteria	Metabolic engineering. Developed way to increase lipid content of cyanobacteria by 400%.	
Ternion Bio Industries		CO_2 capture, high-value products, oxygen, nutriceuticals, biofuel		PBR	Photosynthetic algae	Solar tubes, mirrors & high-powered LEDs provide light to algae; can also run solely on solar power. 250 gallon BioBlade inserts form the BioBloc. Testing mini-hydroelectric generators for taller units - use falling water to spin turbines for power.	
Texas Clean Fuels		Biofuel		PBR		Algal Growth Units (AGU) with high surface area and light transmission in center; Micro Organism Production System (MOPS).	

Algal Biofuel, CO_2 Reuse, and Related Technology Vendor Descriptions

Company	Company Review?	Purpose/Revenue Stream	Company Links	Growth System	Species	Niche	Notes
Trident Exploration Corporation/Menova Energy			Menova Energy	PBR		Menova's light capture technologies with Trident's waste stream gas capture technology.	
Tomorrow Biofuels		CO_2 capture, biofuels, animal feed, ethanol				FALCON feeding process; flue gas transfer system with no pressurization.	
Univenture		Livestock/industrial/municipal wastewater	About 20 partners in government labs, universities, and industry	Hybrid		AlgaeCrop PBR - replicates of 11' x 200' growth chamber of an open pond with a cover. Siting tied to wastewater providers.	
Valcent Products			Moved to Valcent E.U./ Global Green Solutions Inc.	PBR		VertiCrop PBR -vertical plastic bags hanging from a turning rod that are constantly moving slowly to allow light to get in from every angle.	
XL Renewables		Biofuel, protein (esp. omega-3 human supplements)	Joint venture with Diversified Energy	Open pond and PBR		SuperTrough system can operate as both an open pond and PBR. Uses plastic film called BioTape as a cover. Built 6" deep and use soil as an insulating device. Developed Simgae Production system.	

A
APPENDIX

Text of Letter sent to Algae Vendors

Algae Technology Vendor Survey

Hello,

The Electric Power Research Institute (EPRI) is a non-profit research and development organization that performs public interest research that relates to all aspects of electric power. Utility companies that are members of EPRI represent more than 90% of the electricity generated in U.S. As a result of increasing interest in algal biofuels, carbon capture, and related technologies, EPRI has initiated development of several assessment tools.

One tool is a database that will be used as a starting point for our utility members to identify companies working in this area and some basic facts about their technology. This database is a table of approximately 90 companies that will be accompanied by a 3 page general description of the current interest in these issues. The database is not meant to reflect an endorsement, but to be a listing in one place of current activities and technology niches available.

We would like to include your company in the database. The table below contains the description that we have compiled from publicly available information provided on your website, in white papers or press releases created by your company, or from presentations at scientific conferences (such as the Algal Biomass Summit).

Your review of this entry for accuracy and your suggestions for additions will strengthen the quality of this database and provide exposure for your company to EPRI's utility members. Please reply with your response by Tuesday, November 24, 2009. Please note that (1) these descriptions are intended to be short - only several lines in a spreadsheet table format, (2) no detailed research results will be included, and (3) this database will be publicly available through EPRI's website and thus no confidential information should be included. The 'notes' column could include notable projects or results (e.g. ASTM certification of oil, awards such as the Clean Tech Open, or oil used in aircraft or vehicle testing). Finally, a link to information on how to self-identify your Technology Readiness Level is included in the TRL cell in table below.

We hope you are interested in participating to improve our algal technology database. If you have any questions, please contact either Stephanie Shaw (650-855-2353) or Brice Freeman (650-855-1050).

Sincerely,
Stephanie Shaw
Brice Freeman

B
APPENDIX

Acronym and Chemical Compound List

ASTM	American Society for Testing and Materials
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
DARPA	Defense Advanced Research Projects Agency
DOE	Department of Energy
GMO	Genetically Modified Organism
GMP	Good Manufacturing Practices (Israel Ministry of Health)
HACCP	Hazard Analysis and Critical Control Point
HDPE	High Density Polyethylene
H_2O	Water
IGCC	Integrated Gasification Combined Cycle
ISO	International Organization for Standardization
JP8	Jet Propellant 8
KLM	Koninklijke Luchtvaart Maatschappij (Royal Dutch Airlines)
LED	Light Emitting Diode
MGD	Million Gallons per Day
MRI	Midwest Research Institute
MSU	Montana State University
MW	Megawatt
$NaHCO_3$	Sodium bicarbonate
NASA	National Aeronautics and Space Administration
NCSU	North Carolina State University
NISTAC	National Institute for Strategic Technology Acquisition and Commercialization
NREL	National Renewable Energy Laboratory
O_2	Oxygen
PBR	PhotoBioReactor
PGE	Portland General Electric
PNNL	Pacific Northwest National Laboratory
PUFA	PolyUnsaturated Fatty Acids
UND-EERC	University of North Dakota Energy and Environmental Research Center
UOP	Universal Oil Products
WWTP	WasteWater Treatment Plant

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The Electric Power Research Institute Inc., (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together…Shaping the Future of Electricity

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