Emerging views suggest that algae are seen as the great green hope of the biofuels sector. They have a minimal environmental footprint and don't need agricultural land to thrive – thereby avoiding the 'food versus fuel' debate. It is reported that Algae simply require plenty of sunlight, water, carbon dioxide (CO2) and certain nutrients in the appropriate conditions and they can be grown in open pond or closed system photo-bioreactors located near brackish or slat water, or use wastewater to process fuel with minimal energy demands.

It is also reported that Algae can be harvested year round and grow phenomenally fast, doubling their mass several times a day and can produce between 15 and 20 times more oil per hectare than alternative biofuels sources such as rape seed, palms soya or jatropha – and some claim yield will be far greater. Reports indicate that Algae require high concentrations of CO2 of sources; including power plants and chemical facilities and Algae farms can be more productive than conventional sources of biofuel. There are claims that Algae can generate about 5,500 gallons / year / acre compared to 500 g/y for palm oil, 90 g/y for soy and 350 for corn (ethanol).

Reports suggest that Algae can be grown in natural or man-made ponds. Although the open ponds may be cheaper, quality control is very challenging. However, raceway ponds (which are divided into a rectangular grid, with each rectangle containing one channel in the shape of an oval, life an automotive raceway circuit; each rectangle contains a paddle wheel to make the water flow continuously around the circuit) are apparently used as neutraceutical sources of algae which sell for several large sums of money.

Published articles report of open pond algae producers such as Aqua flow Bionomic Corporation, which harvests algae from settling ponds of wastes management systems in the dairy, meat and paper industries. It is also reported that a New Zealand-based company recently signed a memorandum of understanding (MoU) with UOP to licence its proprietary photo-bioreactor technology and a pilot plant is to be commissioned at Nelson, New Zealand, to produce green crude, with initial production of 60 l/d* and commercial scale-up planned in 2010.

'A beneficial by-product of the Aqua flow process is water remediation, with potential release of trillions of litres of clean water for use in recycling or irrigation,' says co-founder Nick Gerritsen. Aqua flow produces a crude oil analogue with three fractions – kerosene, aromatics and chemical. In conjunction with UOP, Aqua flow has made Jet A1 specification synthetic paraffinic kerosene (SPK) derived from wild algae. Gerritsen believes the company's algae system 'will be highly competitive with conventional crude, because we can sit right at the nexus of water and energy'.

There are reports that Israeli algae producer Seam biotic has located a modified open algae pond in direct contact with a coal-fired power plant to produce Omega 3 fatty acid products and biofuels. Seam biotic operates a 1,000 sq meter open pond within an Israel Electric Corporation power plant at Ashkelon, producing 20 grammes (dry)/sq meter/d, which is mostly used for neutaceuticals and downstream studies of biodiesel and bioethanol production, as well as by-product protein fir animal and human feed.

Fuel gas is fed direct from the power station chimney as a source of CO2, with seawater to cool the turbines. 'Microalgae is grown from three major classes – green, diatom and semi-green,' says Professor Ami Ben-Amotz, a renowned expert on marine-algae research. 'Our aim is not to produce biodiesel, but to develop the technology for economical production of algae. The cost of algae production today is about $15/kg, but this needs to be brought down to $0.5/kg, assuming there is a market for the by-products also.' It is reported that the system has been proved on a small scale and discussion are underway to build a production scale plant abroad, in collaboration with China, the US, Korea or Vietnam, within the next two years.

Meanwhile, the European Union (EU) is said to be investing 2.7 bn Euros in algae research. In the US, a major programme under the National Renewable Energy Laboratory (NREL)'s Aquatic Species Program, using two 1,000 sq meter open pond systems, was reported to be too expensive for large-scale production. However, in recent years, a new breed of algae producer is convinced that economic production is viable.

Pilot Plants

It is reported that Dr John Scott, Chairman of PetroAlgae, is running a pilot plant open pond system in Florida. The company has raised $50mn to date, and says it will be building commercial scale plants under licence round the would from the end of the year. Its first multi-unit licence deal is with GTBP in Taiwan and China for a series of 5,000 hectare open pond bioreactors. 'Each unit will be capable of producing 75mn g/y of renewable fuel and 121,000 t/y of protein,' he claims.

PetroAlgae's system manages sunlight to ensure optimum radiative transfer for micro-crop production. The biomass is harvested several times a day, using vacuum skimming; then the biomass and water enters a pressing operation, producing water and soluble protein which is separated. The water is recycled and high quality protein is used for animal feed or human supplements. 'The amount received for the protein largely underwrites the whole operation,' comments Scott. Lipids can then be refined as a drop-in material to produce diesel or gasoline.

Scott emphasizes: 'We produce a drop-in replacement fuel which need no adaptation and can be used in existing refining infrastructure. The new drop-in fuel can increase refinery profitability by reducing feedstock costs and entering the cooker directly, to produce a more profitable fuel mix.' However, Scott recognizes the capital intensive nature of the process. 'You need big customers to bear the cot of algae production.'

San Diego-based Sapphire Energy is also pioneering green crude production using an open pond system, to produce a drop-in replacement fuel. Some $100mn have been invested to date. Key investors include Bill Gates' Cascade Investment and the Welcome Trust. CEO John Pyle insists that Sapphire Energy's system is 'highly evolved, combining a pond-to-pond system'.

Sapphire has developed a commercial strain of algae using sophisticated agricultural and pharmaceutical know how. He suggests: 'Closed bioreactor systems can be 100 times more expensive than open pond systems.'

Sapphire currently operates small test and development sites in Texas and New Mexico, and plans to team up with a major coal-fired electric utility for CO2 supply in New Mexico. Jet fuel tests have been run with Continental and JAL. 'We believe it will be feasible to build a 10,000 b/d green crude facility within five years and are aiming for 100mn g/y of diesel and jet fuel by 2018,' says Pyle.

Aurora Biofuels is building a 20-acre, semi-closed pilot project in Florida, due to come on-stream in 2010, with full commercial production by 2012. 'the VC-funded company will be able to provide biodiesel competitive with petroleum –based fuels,' says Matt Caspari, Vice President of Business Development. 'At full scale, our process will be capable of producing fuel at $55 to $60/b.'

Aurora is operating a pilot operation, with ponds in Florida and extraction in California, and plans to run an eight-acre site by the end of the year. Fluor is partnering development on the engineering side. The ponds feature a jet mixing system which injects CO2 into the pond. Instead of using energy –hungry centrifuges to extract the oil and biomass, Arurora uses a classic waste water treatment system with air floatation to float out the algae, followed by solvent extraction.

‘We reckon we can produce buifuel at $2/g on a 2,000 acre site. Commercial scale production is anticipated by 2013’, states Caspari.
‘The biggest challenge for most algae producers is to keep the algae alive and productive,’ he admits. Indeed, some competitors, like GreenFuel Technologies Corporation, are already understood to have ceased business, despite ambitious plans to develop a large-scale algae farming plant in partnership with Aurantia near the Holcim cement plant near Jerez, Spain. GreenFuel installed field assessment unit using Holcim flue gases, and had commenced building a 100sq meter prototype vertical thin-film algae-solar bioreactor. GreenFuel’s closed photo-bioreactor (PBR) apparently proved difficult to clean in-situ. Consequently, the company collapsed. ‘GreenFuel is entertaining offers for the sale of its intellectual property,’ says Holly Flesh, Vice President Business Operations, GreenFuel Technologies.

Patents Filed

Meanwhile, OriginOil has filed seven patents for a low cost, closed algal oil extraction system. Riggs Eckleberry, President and CEO, argues that the big problem with open pond systems is low productivity. ‘An open pond will typically produce 1 gramme (dry) wt/l/d compared to 5 gramme (dry) wt/l/d from an industrial bioreactor.’ Until early this year, OriginOil was pursuing an end-to-end pilot system. ‘We found there were distinct challenges at every point. However, we made a big break-through in extraction.’
originOil has managed to extract and separate the oil without dewatering, using a one-step quantum fracturing process which combines with electro-magnetism and pH modification to break down cell walls. Algae rises to the top for skimming and refining, while the remaining biomass settles to the bottom for further processing as fuel and other valuable products.
The company has teamed up with Desmet Ballestra to commercialize the single step extraction technology in commercial scale plants. Work is underway to develop a compact extraction system which will fit in a 20-ft still container, with field trials planned in 2010. ‘We consider that the algae industry offers fundamentally the most efficient biofuel available,’ says Eckleberry.
More recently in the US, ExxonMobil has announced an alliance with leading biotech company Synthetic Genomics (SGI) to research and develop next generation biofuels from photosynthetic algae. Under the progamme, if research and development milestones are successfully met, ExxonMobil expects to spend more than $600mn, which includes $300mn in initial costs and potentially more than $300 to SGI.

Commercial Production

Meanwhile, Solazyme claims to be the only commercial scale algal fuel producer today. ‘But it will still be a couple of years till we reach economic parity of years till we reach economic parity with fossil based fuel,’ remarks President Harrison Dillon. Solazyme takes cellulosic materials such as corn Stover, switch grass, wood chips and sugar cane and feeds them to algae in a large dark fermenter, which converts the biomass to crude oil very efficiently.
‘It’s about 1,000 times cheaper per gallon to use a fermentation process rather than sunlight. Our process takes a few days whereas growing algae in a pond takes months,’ says Dillon. Furthermore, over 75% of the dry weight of the algae is oil, whereas pond algae contains between 10% and 15% oil by dry weight. Solazyme tailors the algae for particular products, with shorter carbon chain links for ASTM D975 standard biodiesel. ‘We have made our technology compatible with existing infrastructure at every step. You can come up with a new molecule, but if it is not compatible with existing infrastructure you’ll never commercialize it,’ says Dillon.

What's bugging producers?

Reducing process costs and finding the right synergistic partners is what really bugs algae producers today. However, all the algae producers anticipate making a fundamental dent in oil imports in the near to medium-term future.