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Efficient algae – the next biofuel?

Robin Taylor

Microalgae are grown in Australia to produce high-value dietary supplements. Now, they are being touted as a source of renewable energy to replace fossil fuels.

Credit: CSIRO

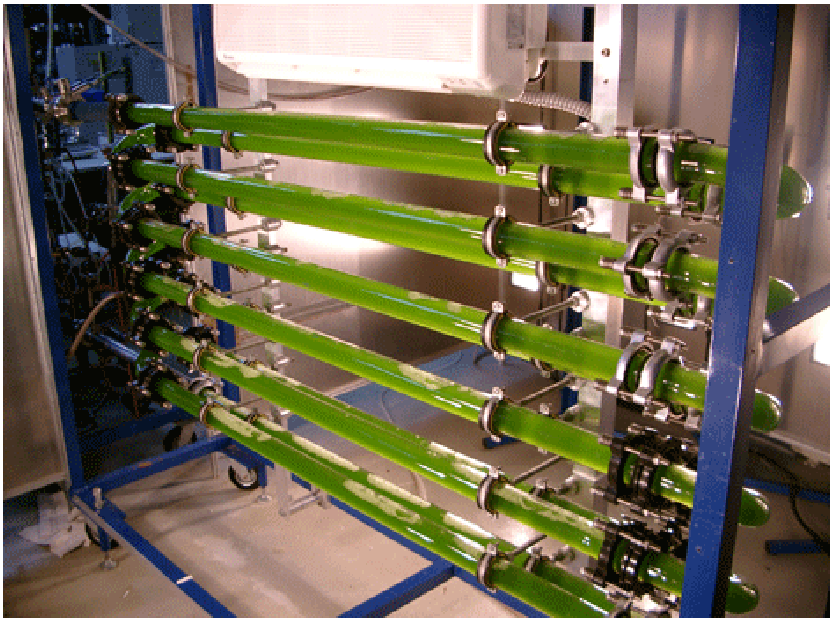
Plant-based sources of biofuels, such as soybeans, canola and palm oil, compete with food crops for land, water and nutrients. In contrast, microalgae production does not require arable land; it can be grown in saline or waste water. Grown on an industrial scale, microalgae has the potential to produce the same amount of biofuel as current plant-based sources, using significantly less land area.

Like plants, algae use photosynthesis to turn carbon dioxide into carbohydrates, some of which are transformed into complex organic molecules such as lipids (fats and oils). Lipids can be used as feedstock for biofuels. Several Australian groups are already investigating ways to produce biofuels such as biodiesel, biomethane and bio-hydrogen from microalgae. The next step in the commercialisation process will be pilot plants to test the performance of algal strains and reactors.

Producing algal biodiesel

Algal biodiesel is produced in a similar way to biodiesel from other sources. Algal biomass is grown using an appropriate algal strain and growth conditions, and oil is extracted from the algal biomass in a chemical process known as transesterification. Compounds called triglycerides in the extracted oil have the potential properties of fossil diesel. In a detailed lifecycle analysis, CSIRO scientists have shown that it is theoretically possible to produce algal biodiesel with significantly lower greenhouse gas emissions than fossil diesel.

The cost of producing algal biodiesel is not yet competitive with mineral diesel. Research into lower cost technologies, combined with higher future diesel prices, may allow algal biodiesel to be produced at a competitive cost. However, considerable R&D is needed before these models become a reality.



Credit: Clemens Posten, Karlsruhe Institute of Technology

Dr Tom Beer, of CSIRO's Energy Transformed Flagship, estimates that based on Australia's annual transport fuel consumption of 30 billion litres – and assuming high algal growth rates of 110 t/ha/year and 30 per cent oil content – 100 km^2 of algal ponds could provide all of Australia's fuel needs.

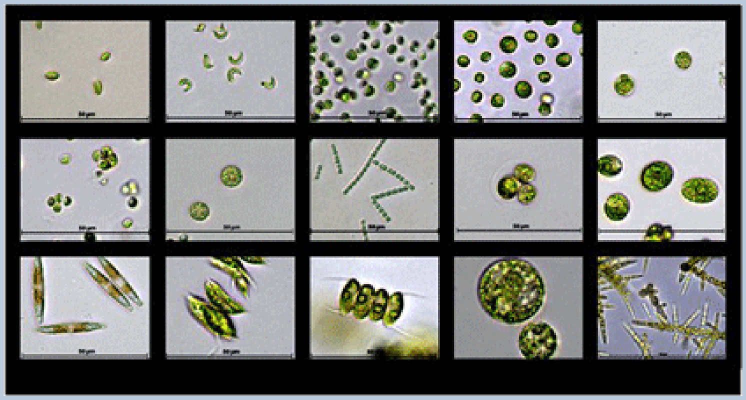
Chair of the Algal Fuels Consortium, Associate Professor Rob Thomas, believes that algal fuels could provide ~10 per cent of Australia's diesel fuel needs. The consortium, made up of CSIRO, Flinders University, the South Australian Research and Development Institute (SARDI) and Flinders Partners, is developing a pilot scale production unit using seawater ponds on Torrens Island, next to a gas-fired power station. The consortium, which is looking for a new industry partner following the withdrawal of their investor, won a $2.7 million research grant from the Department of Resources Energy and Tourism in 2009.

Assoc. Prof. Thomas says the pilot facility will be ~1 ha in size, and will operate for two years before scaling up to a 10-ha pre-commercial facility. The consortium aims to produce 10,000 to 20,000 L per year of algal oil: enough to test the oil as a suitable biofuel feedstock.

As well as the planned project on Torrens Island, SARDI has also recently opened a $5 million photo-bioreactor facility at its Aquatic Sciences laboratories at West Beach.[1]

Growing algae

Algae can be grown in either open (ponds or raceways) or closed systems (known as photobioreactors). A photobioreactor is a sealed aquaculture system that optimises the availability of light to provide the energy algae need to grow.



Local algal species from marine, brackish and freshwater environments are isolated and grown under a variety of conditions and then screened for properties desirable for biofuel production. Ben Hankamer

Photobioreactors have advantages over algal ponds, in terms of efficiency and the ability to provide controlled conditions. However, they have higher capital costs. Assoc. Prof. Ben Hankamer, Director of the Solar Biofuels Consortium, says economic analysis shows that both cheap lower-efficiency systems and more expensive higher-efficiency systems have the potential to be equally profitable.

'The market will ultimately decide which systems will be adopted, and it is also possible that hybrid systems will emerge,' he says. 'With the photobioreactors, it is about designing systems to give the best light distribution throughout the system, while keeping the cost down.'

Biodiesel properties of different strains

Researchers at the National Algae Culture Collection have been studying oils in microalgae since the 1980s, initially for the developing aquaculture industry: microalgae are the source of the omega-3 oils extracted from fish that are sold as fish oil supplements.

Head of the Collection, Dr Susan Blackburn, says one of the reasons for the interest in algae for biofuel and other bio-applications is that they are such an easily renewable source, given the right temperature conditions, light and nutrients. But, until recently, the focus has been on the engineering side of how to grow algae, with little surveying of the best strains for the particular job.

'There are tens of thousands of micro-algal species in the world, of which only a few thousand have been cultured and only a handful developed commercially,' she says.

Credit: CSIRO

However, researchers internationally – including the US Department of Energy – are now recognising that strain selection is one of the key issues facing the development of biofuel based on microalgae.

Dr Blackburn's team now identify, grow and compare different microalgal strains to investigate potential biodiesel profiles. They have identified strains that produce oils with better biodiesel profiles than current biodiesel sources, such as palm oil.

'These microalgae can then be selected for the environment of choice, eg saline, hypersaline or waste water,' she says.

The Algal Production Group at SARDI Aquatic Sciences is also optimising algal strains for biofuel production. Assoc. Prof. Thomas says that several strains have already been selected, giving good production levels of 25 g/m^2/day (25 t/ha/year) with oil yields of ~30 per cent, in small-scale production trials. Their challenge is to maintain these yields consistently on a commercial scale.

At the University of Queensland, researchers associated with the Solar Biofuels Consortium have found significant differences in performance between different algal strains. Director of the Consortium, Associate Professor Ben Hankamer, and his team, have conducted extensive industrial feasibility studies to optimise microalgal strains, growth conditions and photo-bioreactor design for biofuel production. Over the next three years, they will refine the design and scale up production from 10 to 50 m^2, aiming to reach commercial scale in 5–10 years.

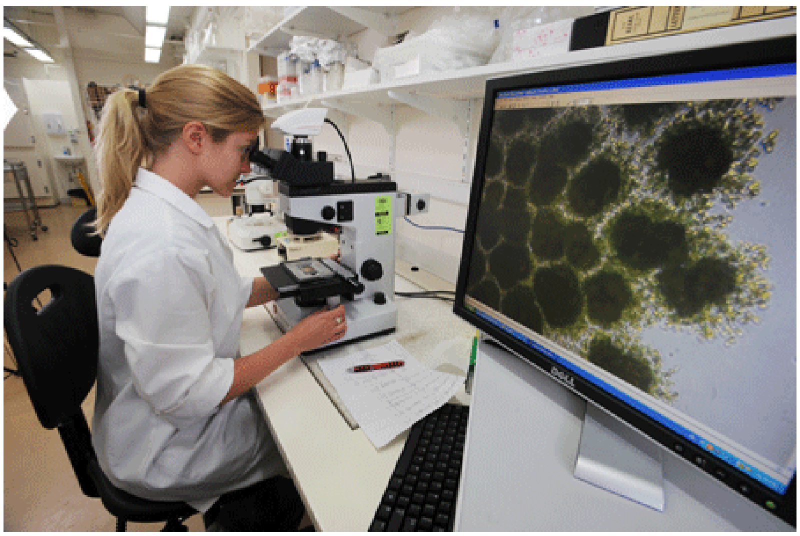
Commercial interest in algal biofuels

Commercial interest in biofuels produced from algae is growing. For example, the Solar Biofuels Consortium includes commercial partners Kellogg Brown & Root, Neste Oil, and Incitec Pivot. In Victoria, Smorgon Fuels recently ran a two-year pilot algal biodiesel project involving a closed reactor system and the use of CO_2 from the Hazelwood power station's flue gas to grow the algae and produce oil. Smorgon Fuels currently produces more than two million litres of biodiesel a year, from used cooking oil, tallow and canola oil, under its BioMax brand.

Business Development Manager for the Smorgon Group, Mr Stanley Sack, says while they have demonstrated that they can grow algae from coal-fired flue gas and tested several algal strains, commercialisation is still some years away. The pilot plant has now been decommissioned, and the company is now working with researchers at the University of Melbourne and Monash University on improving oil extraction.

The Smorgon Group's project engineer, Mr Ian Olmstead, ran the pilot plant. He says their experience has highlighted the lack of downstream technology to process algae to biofuel. Although the pilot plant used closed reactors, he says that on a large scale, they would probably move to open ponds because of the prohibitive costs of an enclosed system. He also says that the carbon capture benefits of the algal production are a minor factor. 'If we were to grow 1000 ha of algae in ponds at the growth rates we think are reasonable, we would only be using up about one per cent of Hazelwood's emissions a year,' he explains.

Another Australian company, CubicQED, is also focusing on large-scale pond production until closed-reactor systems become more cost effective. In partnership with Moree Plains Shire Council, the company plans to build a water treatment and biodiesel plant using water waste from the district's mineral spa industry.



Credit: CSIRO.

CubicQED CEO, Mr David McMurran, says the minimum-scale commercial plant will initially cover three hectares, with 15 ponds containing 15 megalitres of water producing a minimum of 1.2 t of algae per day. More than 100 ha of ponds are planned over a five year period. The company is in advanced stages of negotiation with a UK investment fund to provide the capital for the construction phase of the plant, and has also won an industry and innovation grant from the NSW Government.

Mr McMurran says the company's water demineralisation technology is also ideally suited for providing high-quality water for Australia's regional areas and treating inland saline waterways. Eventually, the company plans to feed the algae with CO_2 from the production process (biodiesel pumps), and possibly other industry.

CubicQED will supply its algal oil to a Queensland company to manufacture biodiesel. After oil pressing, the remaining algal residue will be dried and supplied as a 'cake' to stockfeed manufacturers, who pelletise and market it as a high-nutrient animal feed supplement. About eighty per cent of the processed water will also be sold back to the Moree shire for industrial and other uses.

More information

www.solarbiofuels.org
www.cubicqed.com.au
www.csiro.au/science/Sustainable-transport-fuels.html
www.csiro.au/places/Australian-National-Algae-Culture-Collection.html

1 The SARDI photo-bioreactor is a National Collaborative Research Infrastructure Strategy (NCRIS) facility.