FutureDirections international

INDEPENDENT STRATEGIC ANALYSIS OF AUSTRALIA'S GLOBAL INTERESTS

Associate Paper

21 May 2013

# Food and Fuel Forever

***Australia depends critically on imported fuels for its food security and economy. This study explores a new industry with scope to make this country 100% self-sufficient in transport fuels and food, forever.***

**Key Points**

- Australia has just 23 days' supply of fuel in the pipeline: a major oil crisis could cripple our economy within days.
- Algae culture has the potential to make Australia 100 per cent self-sufficient in transport fuels and food.
- It can create major new industries in aquaculture, plastics, textiles, health food, paper, industrial chemicals and pharmaceuticals.
- It can generate an estimated $50 billion in new revenue and create over 50,000 new jobs, mainly in regional Australia.
- Australia's endowment of sunlight makes it one of the world's richest oil provinces of the 21st Century.
- Australia needs an accelerated national R&D effort into algae culture and algal biofuels, coupled with a national investment plan to capture this opportunity.

**Author: Julian Cribb**

This discussion paper was written *pro bono publico* by science writer, Julian Cribb FTSE. His aim is to stimulate national public discussion about the scope for an algal biofuels, feed and industrial products industry, a much-expanded aquaculture industry and urban agriculture in Australia. The author has no financial interest in any of the companies or institutions mentioned in the report. His intention is to share his own impressions, gathered from a great many local and overseas experts, of this opportunity with fellow Australians.

**Foreword**

It is always a pleasure to be associated with innovation, particularly when the concepts and ideas expressed may well help in achieving a more sustainable planet.

Algal farming is one such concept and Julian Cribb's paper provides a thoughtful rationale as to why Australia should commit far more research dollars and expertise into harnessing the natural components of algal farming – sun, brackish water, nutrients and readily available space – to produce biofuels in particular, but also plastics, textiles, paper, fertiliser and food, free of environmental degradation.

I look forward to this paper generating maximum discussion, sound policy development and very possibly an exciting, environmentally clean and essential new industry.

**Michael Jeffery AC AO (Mil) CVO MC**
*Chairman*
*Future Directions International*

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***Oil: Australia's 'Fukushima'***

Transport fuel is the Achilles' heel of the Australian economy. Amid abundant energy from coal, gas, wind, solar, hydro, geothermal and other sources the one thing we lack is liquid transport fuel.[i] Currently, the nation imports 85 per cent of its transport fuels, either as crude oil or refined products. Reliance on imported fuels is growing as refineries close.

According to a Kokoda Foundation/NRMA study we have just 23 days' supply of fuel in the pipeline in the event of a crisis in the Middle East or Southeast Asia that disrupted delivery. Unlike most advanced nations, we have no national fuel reserve, our policy being to 'rely on the market'. In such an event food supplies would run out nationally in 7-10 days[ii], essential medical supplies and fuel for motorists within 3 days: "Essentially our society as we know it would cease to function," the study warns.[iii]

Furthermore Australia spends around $38-40 billion a year buying fuel from other countries – money which could otherwise be used to create new industries and regional jobs here and to build national infrastructure.

While debate rages over 'peak oil', a fact that has generally escaped public notice is that world vehicle production is expanding by around 7 per cent a year, whereas global oil production from all sources, conventional and unconventional, is only growing by 0.7 per cent a year. This mismatch between future demand and supply of fossil oil poses inherent price and supply risks.

While the risk of a global oil crisis disrupting our national fuel supplies is deemed by some as low[iv], its potential impact on Australia is very high. Transport by road, air and sea would quickly come to a halt, as there are no large-scale viable transport fuel alternatives available at short notice. While Australia is often characterised as 'food secure' [v], food delivery relies on 80,000 truck movements a week and food production is close to 100 per cent reliant on liquid fuels for farming and water pumping. An oil crisis may quickly become a food crisis.

***A New Energy Source***

Petroleum is primarily a biological product, produced over millions of years by the breakdown of organic matter (chiefly from algae) and its reprocessing by geological heat and pressure. Oil is also produced renewably every day by living plants, using sunlight as their main energy source, in forms that can be used in all the ways we now use petroleum – and many more.

The most productive source of 'fresh' oil is green algae, microscopic water plants, which capture sunlight and store it as oil. These produce over 100 times more oil than do land plants (such as canola, sunflowers or soybeans) because they do not have to divert energy to producing roots, stems, flowers, seeds and leaves.[vi] Yields of oil from different types of wild algae range from 28-77 per cent. Unlike our food crops, these algae have not yet been improved or specially bred for high production, so scope for future yield gains is large.[vii] Also, with 72,500 known algae species to choose from worldwide, scope for selecting the most productive and suitable types is also very large.

*Table 1: Yields of oil from various wild algae (% of dry weight)*

| | |
|---|---|
| • Ankistrodesmus | 28-40% |
| • Cyclotella | 42% |
| • Dunaliella | 36-42% |
| • Hantzschia | 66% |
| • Nannochloropsis | 25 - 46% |
| • Stichococcus | 33% |
| • Neochloris | 35-54% |
| • Schiochytrium | 50-77% |

Oil is typically recovered by filtering the algae to remove the water, and then by cycloning them to extract the oil[viii], or else by using a combination of heat and pressure in processes such as hydrothermal liquefaction (HTL). This leaves a high-value residue of protein-rich material that can be made into human food or fed to farm livestock and fish, as it is high in naturally-occurring omega-3s, vitamins and betacarotene, highly desirable in a healthy diet. It can also be used to manufacture fertilisers, chemicals, textiles, biodegradable plastics, paper and other industrial products. The protein content and oil can be used to make health foods and medical drugs.

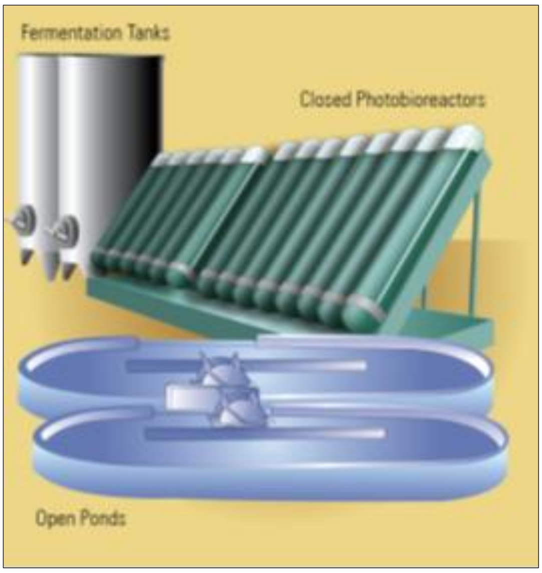
Processes for extracting fresh oil from algae are simpler, cleaner, safer, less polluting and potentially cheaper than extracting fossil oil from deep underground or beneath the ocean. Furthermore fresh algal oil is entirely renewable and, if well-designed, has little or no greenhouse impact.

***Green Fuels – Storing Sunshine***

Fresh algal oil is liquid solar energy. The main product of algae culture is a crude oil which can be fractioned into the same kinds of fuels and chemical compounds as fossil petroleum. Algal biofuels have been used to power jet aircraft as well as trucks, cars, ships and railway locomotives.

In 2012 President Obama made algal biofuels a pillar of America's energy policy, saying "We can't just rely on fossil fuels from the last century".[ix] The US Navy has for some years tested algal fuel mixes in both its ships and aircraft. Canada invests over $400m a year in biofuels research and conducted the world's first jet aircraft flight on 100% aviation biofuel.

Worldwide, countries actively engaged in algal biofuels development also include India and Israel, China, Thailand, Japan, Bulgaria, Germany, France, Spain, Portugal, Switzerland, Netherlands, Argentina, Saudi Arabia, New Zealand, Sri Lanka and Mexico.




Algae are generally grown in large ponds, tanks or raceways, or else by more intensive cultural methods (eg. photobioreactors) which offer higher yields per area of land.

Based upon current yield estimates from large pond operations it has been calculated that the world's entire transport fuel needs (1.1 billion tonnes of diesel equivalent) could be met from an area of algal ponds of 57.3 million hectares.[x]

Australia's entire transport liquid fuel needs – every car, truck, ship, plane and train – could be met from an area of 600,000 hectares (6000 sq kms) of ponds, equivalent in size to *a single large sheep station*. Or if intensive methods were used, an area of 60,000 hectares, equal to about five big Western Australian grain farms.[xi]

Similarly, the US Department of Energy has estimated America's entire transport fuel needs could be met by an area of ponds one seventh that occupied by the current corn crop – or about the size of Maryland. [xii]

***What Do Algal Biofuels Need?***

An Australian algal biofuels industry has four main requirements: an area in which to grow the algae, a source of water, a source of nutrients and a source of energy.

1. **Area**

At current published oil yields it appears feasible to produce all Australia's fuel needs from 6000 square kilometres of ponds, roughly 0.07 per cent of our land surface area (for comparison, equivalent to one tenth of the urban area). However algae, being water plants, can also be grown at sea and in bays in floating tanks or plastic bags, so the actual area required for fuel self-sufficiency may be as low as 0.03 per cent of Australia's sovereign land and ocean territory. Intensive algal production may take as little as a tenth the land required for ponds, and can be carried out on individual farms, factories, mine sites, urban wasteland or industrial land, providing renewable local fuel right where industry most needs it. There is no reason for algae culture to compete for land area with food production or wilderness.

2. **Water**

Algal culture relies on significant amounts of water. However useful algae grow in marine, saline or brackish water which is not fit for drinking, for livestock or for industrial uses. With sound planning, there is no need for algae farming to compete with any other area of the economy, society or the natural environment for fresh water. Algae farms can be located in bays and bights, in tidal inlets and in salt flats and salt lakebeds, on abandoned farming or grazing lands, on contaminated industrial sites etc. Most algae farms recycle their water, so losses are mainly confined to evaporation. In intensive algae culture, most water used can be recycled. Algae farms can also make use of sewage effluent and other urban or industrial wastewaters, or groundwater released by mine dewatering or oil and gas production. The bioremediation of these sources is a significant opportunity to clean the water for reuse and offset the costs of fuel production as well as reducing costs to the polluting industry.

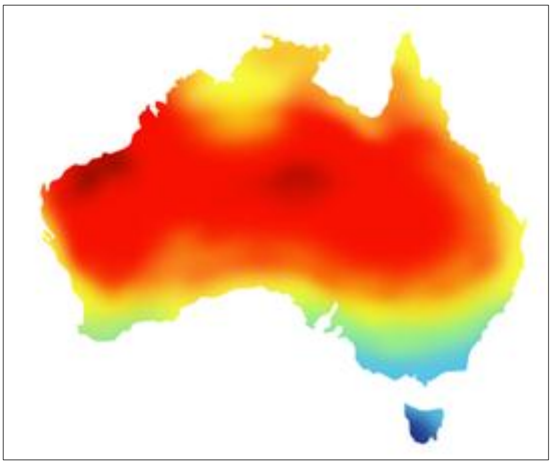
3. **Nutrients.**

Like all plants, algae require nourishment – but this need not take the form of expensive mineral fertilisers needed to grow food crops. Australia presently throws away $3-4 billion worth of food, beside organic waste from factories and abattoirs, garden and park clippings and most of the nutrients in its sewage system. It also removes nutrients from wastewater at high cost. All these nutrients can readily be recycled to nourish algae, which in turn will yield fuel, fertiliser and feed for animals and fish.

To underpin this development, Australia's cities will need to adopt organic waste recycling systems similar to those now operating in some European countries, and to recycle sewage biosolids and effluent. Algae farming, in other words, offers a cure for a major waste disposal headache for Australia by re-using nutrients currently considered too contaminated to use in food production. This will reduce the flow of material into landfill, and eliminate ocean and river pollution by effluent. Algae thus provide the 'missing link' in Australia's nutrient management chain, encourage recycling and reduce national exposure to imported fertilisers (from global sources as risky as oil.)

A large opportunity being pursued by several companies is to reuse waste $CO_2$ produced by power generation, as well as other industrial waste-streams, to feed algae.

4. **Energy.**



Algal fuel and food is 'bottled sunshine'. The energy from the sun is converted by tiny plants using photosynthesis and stored as oil, proteins and carbohydrates. Most of the energy and warmth they use for growth is derived from the sun – and growth occurs whenever the sun is in the sky.

Thanks to our mid-latitude location and relatively cloudless skies Australia receives more sunlight per square metre (known as 'photon density') than almost any country on Earth (left). We thus have a greater potential to grow algal fuels and other products more efficiently and cheaply than other, less sunny places.

Regions such as the north of South Australia, the Central Deserts, the western regions of NSW and Queensland and north western WA all offer exceptional potential for algae culture.

These also suffer from very high costs for conventional fuels due to long, fragile transport chains, making a local fuel source attractive.

***Algae for a Better Life***

Any new form of energy is accompanied by vigorous debate over its environmental and social impact, and algae farming will be no different. However algal biofuels offer a number of benefits which alternative and traditional fuels do not:

- Since the modern food chain depends on liquid fuels for production and transport, algal biofuels offer the (only) prospect of complete food security for Australia regardless of external shocks.
- They can potentially be produced in ways that yield few or no net greenhouse gas emissions, thus making a major contribution to national climate policy goals.
- They offer the prospect of tens of thousands of new jobs and enterprises in a decentralised industry that will regenerate regional and rural Australia. This is equivalent to a doubling in size of the farming economy.
- They offer a dependable, decentralised source of transport fuel for the Australian Defence Forces, emergency services, hospitals, remote communities, farms and other essential users that is proof against overseas crises and shortages, and most climate impacts.
- They can be used to clean up pollution in our water supplies, if so required – especially nutrient pollution likely to cause wild algal blooms and eutrophication of water bodies, but also heavy metals, pesticides and organic contaminants.
- They can be used to consume the waste-streams of polluting industries, such as CO2 emissions from coal-fired power stations or wastes from food processing, abattoirs, pulp and paper making, pulp mills etc.
- While the footprint of an algal fuels industry is large (the equivalent of half the size of Sydney), it is no larger than mining overall and can be confined to areas of land or sea of low economic, social and environmental value – including abandoned surface mines.
- Its impact can also be diluted by having numerous small algae farms spread across the continent and its ocean zone, especially in desert regions, growing fuel close to where it is used, and making the national fuel supply proof against major climate impacts.
- Algae can be used to make biodegradable polymers that break down naturally, to replace the current fossil oil-based plastics which are contaminating the planet and killing wildlife.
- They can be used to recycle urban organic waste, waste water and runoff.
- Algae offer a renewable source of organic fertiliser for farming, horticulture, forestry and revegetation.
- Half of the output of algae production can potentially be used as a high-value stockfeed, leading to a doubling in the size of Australia's fish and livestock sector.
- They are a viable use for saline groundwaters released by the dewatering of mines or by coal-seam gas production, which would otherwise go to waste, have undesirable environmental impacts or high disposal costs.

- Their byproducts can be used as a replacement for wood in certain uses, including paper and cardboard, and as a green solid fuel replacing coke for fires, barbecues etc.
- There are many suitable algae species native to Australia which, unlike food crops, avoid the risk of adverse environmental impacts from foreign introductions.

***What Can We Make From Algae?***

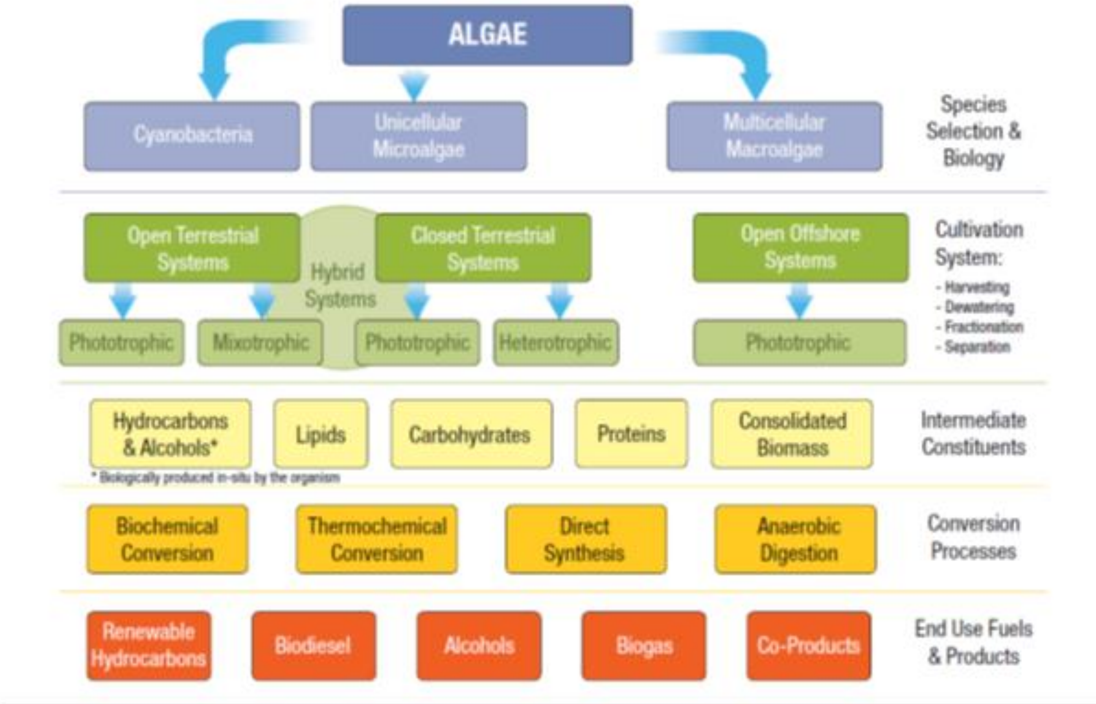
The products and byproducts of algae are limited only by the human imagination. In this paper algal biofuels are discussed as the primary product because governments, investors and citizens generally appreciate the value of transport fuels and their importance to almost every aspect of our society. Clean, renewable oil production and national fuel and food security present the most compelling arguments for establishing a national algal biofuels industry.

Most things that can be made from petroleum can be made from fresh algal oil. These include diesel, avgas and jet fuel, petrol, marine diesel, high-performance fuels, lubricants, methane, hydrogen and a host of industrial chemicals. Many of these products are currently imported, opening the way for large savings on the trade account by import replacement. Algal biofuels will thus ‘import’ jobs into Australia from overseas, in contrast to many industries – including the oil refining sector, textiles and plastics – which are presently off-shoring their workforces and exporting jobs.

Algal oil and carbohydrate byproducts include plastics, synthetic and natural textiles and paper, which are also largely imported into Australia, paving the way for a revival of manufacturing activity and employment in these areas – and potentially even exports. Biodegradable plastics made from algae can potentially replace the 100 million tonnes of petro-plastics produced worldwide each year and now posing one of humanity’s biggest waste disposal problems and global environmental threats.

Because they can be produced in carefully-controlled and hygienic conditions, algae offer prospects for human food, either in their own right, or as healthy ingredients in processed foods or special diets. They are naturally high in vitamins, essential amino acids, omega-3 oils and antioxidants all of which are desirable to help address the current epidemic of diet-related disease and death caused by the modern Australian diet and its overconsumption, and so restrain national health and aged care costs. They can be used to manufacture novel medical products, drugs, vaccines, grafts and other treatments.

Meat and fish are a major part of the Australian diet and also of the rising middle class of Asia. Demand for these products is likely to more double the worldwide demand for livestock feed over the next few decades. As grain production becomes less reliable due to a changing climate and more grain is required for human food, the potential to feed the world’s meat animals, poultry and fish on a diet based on algae will grow dramatically. Up to half the byproduct of algae grown for oil consists of vegetable protein and carbohydrates highly suitable as animal and fish feeds. This in turn holds major benefits for Australia’s livestock and aquaculture sectors.




*Source: US Algal Biofuels Roadmap 2010.*

***Aquaculture – A Major New Food Industry***

Despite having the world's second largest ocean zone and a strong aquaculture sector, Australia imports three quarters of the fish it consumes, mainly from Asia, at an annual cost of $1.5 billion. Aquaculture is the fastest-growing food industry in the world, and a recent CSIRO spatial analysis identified 1.5 million hectares of land in northern WA, the Northern Territory and north Queensland suitable for fish farms. Today the average Australian fish farm produces 7 tonnes of prawns and 11 tonnes of barramundi per hectare per year. This indicates the potential for a very large new livestock industry producing hundreds of thousands of tonnes of fish and seafood every year on land and sea, and worth billions of dollars domestically and in exports. Potentially this could one day exceed in scale all our other livestock industries combined, for the simple reason that fish turn plants into human food more efficiently than do cattle, sheep, pigs or poultry.

A major barrier to aquaculture development is the availability of sufficient high quality feed to nourish all these fish and sea creatures. Algae are the natural plant food eaten by fishes, especially when they are small, and an algal biofuels industry will produce as a byproduct several million tonnes a year of edible protein and carbohydrate. Furthermore, being pond culture, it will probably occur in areas close to, if not as an actual part of, fish farms. (Feeding grain to fish is unsound from a number of perspectives, including land degradation and the likely future price of grain.)

Algal biofuels are thus the springboard that makes exponential growth in Australian aquaculture possible, leading to major import replacement, an entire new export sector, new regional enterprises and jobs and a much healthier national diet that will save many lives and reduce the burden of chronic disease in the community.

Algal protein is also a major feed additive for beef cattle, sheep, dairying, pig and poultry production, adding significant value and growth potential to this existing $10bn sector. The culture of macro algae ('seaweeds') also offers significant low-cost opportunity as human food, stockfeed and for the production of industrial raw materials like gums, thickeners and other food additives.

An important aspect of a widely-dispersed algal feed production is that yields are less likely to be adversely affected by climate extremes than broadacre grain production, especially the closed intensive algal systems. Algae therefore represent a far more climate-stable and reliable source of feed (and food) at a time of growing climatic instability, and hence a genuine national response to climate change adaptation.

***Algae and the Carbon Cycle***

Algae are a vital part of the Earth's natural carbon cycle, using photosynthesis and carbon dioxide for growth. They remove carbon from the atmosphere and deposit it as organic matter on the ocean floor when they die, forming the origin of fossil oil. This organic detritus, carried into the crust by tectonics, is then slowly transformed by geological heat and pressure over tens of millions of years into petroleum, coal, tar sands and gas. Science has recently established a fast-track way to do the same thing in minutes.[xiii]

Algae farmed for biofuels take up carbon when they grow, and then release it again when they are burned. This has a neutral impact on the amount of carbon in the earth's atmosphere meaning that, unlike fossil fuels, algal fuels do not add to global warming, provided other elements in the production chain are also carbon neutral (eg pond construction, water pumping, oil extraction and transport etc).

If Australia were to replace all its fossil transport fuels with algal biofuels, it would reduce national greenhouse emissions by 15-20 per cent.

***Algae and 'Green Cities'***

Algae farming can play a key role in the greening of Australia's cities. It can be used to clean up all the organic wastes from food, industry, homes, gardens and public amenities, sewage systems and urban stormwater – making our cities cleaner, healthier and more liveable. Industry experience suggests that bioremediation will provide a significant economic driver for the development of algae farming generally.

Around the world, cities are already producing more of their own food locally using techniques such as hydroponics, aquaponics and rooftop urban farming, for reasons of food security, reducing 'food miles', freshness and minimising climate impacts.[xiv] Algae (both micro and macro) can be integrated in many creative ways with the production of vegetables, fish, fruits, healthfoods and small livestock as part of the emerging urban agriculture, both to recycle wastes and to create new products.

***Who Is Into Algae?***

Worldwide hundreds of companies, large and small, are investing in algal biofuels and their research. Prominent among them are major aviation corporations such as Boeing, Honeywell, General Electric, Continental Airlines, Qantas, Virgin Airlines, Lufthansa, Japan Airlines and Air New Zealand.[xv] These companies recognise the economic and climate risks which continued reliance on fossil fuels now pose to their business.

Australian institutions with active research programs in algae and algal biofuels include: James Cook University; Wollongong University; The University of Queensland; The University of Adelaide; Murdoch University; the South Australian R&D Institute (SARDI); Flinders University; and CSIRO, which holds the national algae culture collection.

Companies reported as having active research, development and commercialisation programs in algae products in Australia include (alphabetically):

- Algae.Tec Ltd. Offers a sustainable and renewable advanced algae-to-biofuels technology. Its enclosed modular high-yield algae-to-biofuels bioreactor system uses waste C02 and sunlight to produce aviation fuel. Facility at Nowra, NSW. http://algaetec.com.au/
- Aurora Algae develops performance, sustainable algae-based alternatives yielding cost effective, high value products addressing a variety of markets. Headquartered in Perth, major facility at Karratha, WA. http://www.aurorainc.com/
- Cognis, a subsidiary of BASF, is the world's largest producer of algal beta-carotene and carotenoids. http://www.australiannaturalhealthcare.com/fullpage.php?ckey=177
- MBD Energy. MBD's advanced algal bioremediation systems transform costly industrial waste $CO_2$ into saleable nutritious feed and food as well as solid and liquid fuels. Based in Townsville. http://www.mbdenergy.com/index.php
- Muradel PL. An Australian company specialising in the development of renewable fuels from microalgae. Based in Adelaide, with a pilot plant in Karratha, WA, and a new demonstration plant to be built in Whyalla, SA. http://www.muradel.com/
- Plentex Ltd produces algae-based raw materials for the renewable fuel and energy, livestock feed and nutraceutical industries. http://www.plentex.com.au/IRM/content/default.aspx
- Qponics PL, a Brisbane-based company specialising in production of omega-3 oils and nutrients from algae and fish grown in aquaponic, photobioreactor and integrated systems. www.qponics.com
- SQC PL. South Australia-based SQC develops solutions and commercial applications of innovative technologies involving turning micro algae into renewable hydrocarbon products, especially fuels. http://sqcaustralia.com.au/about_us.php
- Solazyme Inc. A US renewable oil and bioproducts company that transforms a range of low-cost plant-based sugars into high-value oils. http://solazyme.com/

***What Do Algal Biofuels Cost?***

The estimated cost of producing algal biofuels varies widely, from three or four times the price of crude oil, to less than half. This reflects the early stage in the evolution of the industry, the multiplicity of technological approaches to production being trialled and the many different kinds of algae being tested.

CSIRO says its research shows "it should be possible to produce algal biodiesel at a lower cost and with less greenhouse gas emissions than fossil fuels".[xvi] Pilot studies by Algae Tec indicate its intensive system may deliver oil for around $42 a barrel – less than half current world crude prices. [xvii] OriginOil has estimated it could produce a blended algal fuel for 60 cents a litre and pure algal oil for $1.44. However, most reports indicate that algal biofuels are still more expensive than fossil oil.

Other commercial benefits such as reduced greenhouse emissions, production of food, feed and high-value chemical byproducts, environmental remediation and carbon trading are therefore expected to play an important role in achieving a commercially viable algae industry. In a recent survey of US algal fuels producers, 90 per cent were confident algal oil would be price competitive with crude oil by 2020.[xviii] The pessimists are saying 2040 – but much depends on the price of crude oil, and also the rate of progress in worldwide R&D.

As a young industry, with multi-million dollar research investments being made around the world and a huge array of wild algal species to choose among, the prospects for step-gains in algal productivity and efficiency are greater than for more mature energy technologies.[xix]

For Australia especially, even algal biofuel *above world oil prices* may offer a viable transport fuel solution to remote communities, mining and farms which face heavy trucking costs on conventional fuels. This will give us the opportunity to 'road test' early systems on a fully commercial footing while those in other countries are unable to compete against fossil fuels.

***Research Challenges***

Although algae have been eaten as food in many cultures for thousands of years, they are only now being domesticated as an industrial crop. This means that there are numerous research challenges to be overcome in adapting them for high-production farming and intensive cultural systems. This makes the industry both risky and exciting – much like petroleum in the 19th and early 20th century. The reasons for investing early are exactly the same, with the added spur of combatting climate change, cleaning up society's wastes and generating an inexhaustible source of liquid fuels.

Key research challenges lie in:

- Assessing different species and mixes of algae for optimal production of different products
- Nutrient sources for algae, especially waste from other industries
- Optimising oil and other yields by controlling the growth process

- Optimising output of fuels, feed, food and industrial products to meet market demand.
- Improving the overall energy balance of algae relative to other fuels.
- Scaling up lab-sized operations to industrial and commercial scales
- Bio-enhancement of algae
- Understanding and controlling the light demands of algae
- Fine-tuning algae as a feed source for livestock and fish
- Improving the environmental performance of algae culture, including greenhouse emissions
- Control of algal parasites.

Australia currently invests around $15m a year in algal biofuels research through the Australian Renewable Energy Agency (ARENA) plus an unknown amount of private and other research funding. Given the large potential scale of the future industry, this falls far short of what is required if Australia is to become a serious player in this emerging global industry.

***What Are The Likely Economic Benefits?***

The likely economic benefits of an algal biodiesel, food, feed and products industry include:

- Import replacement of up to 100% of Australia's fossil oil and transport fuel imports, currently worth $38.5 billion a year.
- An aquaculture sector capable of totally replacing $1.5 billion in imports and earning even more from exports, worth an estimated $4-5 billion year
- A new livestock feed sector capable of replacing imports worth $700 million a year and generating exports worth $2 billion or more.
- Regional job and enterprise creation: possibly as many as 50,000 new jobs across all the different enterprises flowing from an algal biofuels industry with economic multipliers of 1:3 or more across the entire economy.
- Spinoff import-replacement industries in textiles ($2.5bn), plastics ($3bn), paper ($2.5bn), medications, fertiliser, health foods, fine chemicals, and environmental clean-up.
- Knowledge and technology exports to other countries wishing to establish algal biofuels industries.

Among various potential new energies, algal biofuels received one of the most encouraging assessments in the Federal Government's Advanced Biofuels Study (2011). [xx]

***Conclusion***

Algae are not a 'silver bullet' – there is no such thing in the energy and food industries. They are a new, highly promising option for Australian farmers, resources companies, investors, governments and young people to consider as we plan a more prosperous, sustainable and secure future in an insecure and fast-changing world.

There are inherent risks in any new agricultural or aquacultural venture – but these have not prevented the development of other advanced and highly sophisticated farming and food industries in recent decades.

Where algae have an advantage over existing industries is in their ability to provide enduring solutions to real threats to national security, both of food and fuel, and their particular suitability to the climate and geography of Australia, the technical skills and positive outlook of its people.

Importantly they offer a chance to develop a home-grown industry, largely owned and run by Australians, and independent of the power of transnational energy giants – an industry that re-invests its returns in Australia, rather than off-shoring them. They hold great scope for import replacement of manufactured and processed goods across the board. They constitute a major new knowledge, technology and services export opportunity.

Furthermore, algae are also the brightest new opportunity for rural and regional Australia in terms of enterprise and job creation in over a century, offering scope to reverse the ongoing drain of rural financial and human capital into the cities and restoring optimism, resilience and opportunity to regional towns and communities across the continent.

Algae farming represents a major environmental opportunity. It is green, renewable and climate friendly. It can enhance the natural carbon cycle. It need not compete with wilderness or displace native species. Indeed the algae of choice are Australian native plants, which have at long last found major economic uses. They can be used to clean up polluted water, eliminate organic waste and re-use carbon emissions.

These opportunities will only be realised with investment in algal production and research by Australians of sufficient vision and courage to see an opportunity with trans-generational benefits.

## *Recommendations*

The following recommendations are offered:

1. The Australian Government form a joint scientific/business task force to report on the opportunities and constraints to an algal biofuels, feed and products industry in Australia.
2. The leading Australian banks and superannuation funds form a fund for investment in an algal fuels industry in Australia, to ensure high local ownership from the outset.
3. Treasury and the ADF report on the risks to the nation of over-dependence on imported transports fuels. An industry panel report independently on food security.
4. The Federal Government establish a national Algae R&D Corporation, matching industry investment in research to public investment on a $2-for-$1 basis to fast-track research.
5. That the States and Territories identify suitable land and sea areas for large-scale algae farm development and zone them, based on the availability of sun, water, nutrients, access to markets, social benefits and low environmental impact.

6. The rural industries conduct large-scale training, education and extension to ensure the availability of a skilled, keen and committed workforce for the new industries, especially among young Australians with a bent for sustainable high technology.

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*Any opinions or views expressed in this paper are those of the individual author, unless stated to be those of Future Directions International.*

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[i] Energy White Paper 2012.
http://www.ret.gov.au/energy/Documents/ewp/2012/Energy_%20White_Paper_2012.pdf

[ii] During the Sunshine Coast floods of 2011, shop food supplies ran out in 2-3 days due to panic buying.

[iii] Blackburn J, Australia's Liquid Fuel Security, NRMA/ Kokoda Foundation, March 2013
http://www.mynrma.com.au/media/Fuel_Security_Report.pdf

[iv] The Energy White Paper rates Australian liquid fuel security 'high to moderate'.

[v] Eg. "Australia has a strong, safe and stable food system and Australians enjoy high levels of food security." National Food Plan Green Paper 2012.
http://www.daff.gov.au/__data/assets/pdf_file/0009/2175156/national-food-plan-green-paper-072012.pdf

[vi] Green Algae Strategy, Mark Edwards, 2009 http://www.fao.org/uploads/media/Green_Algae_Strategy.pdf
[vii] Algal Oil Yields, 2013 http://www.oilgae.com/algae/oil/yield/yield.html
[viii] Other extraction methods include use of mechanical presses, ultrasound, chemical solvents, enzymes, osmotic shock and supercritical fluid extraction.
[ix] http://www.whitehouse.gov/the-press-office/2012/02/23/remarks-president-energy
[x] Life cycle energy and greenhouse gas analysis for algae-derived biodiesel: Tara Shirvani, Xiaoyu Yan, Oliver R. Inderwildi, Peter P. Edwards and David A. King. http://www.smithschool.ox.ac.uk/wp-content/uploads/2011/08/TShirvani-EES-Manuscript-2011-web.pdf
[xi] Cribb JHJ, Peak Oil and Global Food Security, ANU Nov 2012.
[xii] http://www.washingtonpost.com/wp-dyn/content/article/2008/01/03/AR2008010303907.html
[xiii] http://www.ns.umich.edu/new/releases/20947-biofuel-breakthrough-quick-cook-method-turns-algae-into-oil
[xiv] Hodgson K et al, Urban Agriculture, 2011, http://www.planning.org/apastore/Search/Default.aspx?p=4146&a=1003
[xv] http://en.wikipedia.org/wiki/List_of_algal_fuel_producers
[xvi] http://www.csiro.au/en/Outcomes/Energy/Powering-Transport/biofuel/Algal-biofuel.aspx
[xvii] http://algaetec.com.au/in-den-news/?lang=de
[xviii] http://www.biofuelsdigest.com/bdigest/2013/03/08/answers-to-your-questions-about-parity-priced-algae-based-fuels/
[xix] See, for example, http://www.ns.umich.edu/new/releases/20947-biofuel-breakthrough-quick-cook-method-turns-algae-into-oil
[xx] LEK Consulting. Advanced Biofuels Study: Strategic Directions for Australia, 2011. http://www.arena.gov.au/_documents/abir/advanced-biofuels-study-appendix.doc