The economics of micro-algae production

and processing into biofuel

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Key Message

The Research and Development (R&D) of micro-algae is in it's early stages. The production of micro-algae for high value products like nutritional products is established and Australia is hosting some of the bigger algae plants due to the favourable climatic and investment conditions it has to offer.

Nevertheless low value algal products for biofuel, need a massive boost in R&D to overcome technical difficulties to overcome the large cost advantage of other biofuel feedstocks. Micro-algae need carbon dioxide to grow. The inclusion of the current price for carbon credits on the revenue side of an algae-biofuel business does not change the economically unfeasibility of the business.

Introduction

Constant increases in the price of fossil fuels over the last few years have brought micro-algaes as alternative biofuel source back into the Research & Development (R&D) limelight. Much of the current work is based on previous R&D programs like the Aquatic Species Program (ASP) from the United States Department of Energy. This program finished in 1994 and concluded that one of the main obstacles for algae production were the high oil production cost. What has changed in the economics of algae production particular in an environment of higher mineral oil cost?

Micro-algae – the plant

Micro-algae are primitive organism with a simple cellular structure and a large surface to volume body ratio which gives them the possibility of large uptakes of nutrients. They live in a water suspended environment which gives them ample access to water, CO_2 and nutrients. They are fast growing and efficient converter of solar energy capable of producing many times the biomass per unit area of land compared to terrestrial plants.

An ACIL study in 2002 found that in Australia around 3000 freshwater algae are currently described as species. The total number of algae species in Australia was estimated at between 10,000 and 100,000 assuming that one tenth of algae occur here. This leaves a large number of algae species to be researched.

The Algal dry biomass composition contains up to 46 per cent Carbon (C), 10 per cent Nitrogen (N) and 1 per cent Phosphates (P). One kilogram of dry algal biomass utilises up to 1.7 kg carbon dioxide (CO_2) but generally a relationship of 1kg of algae biomass to 1kg of CO_2 is used for calculations. Generally speaking low rainfall, high temperatures and sunshine hours are positive for algae growth. This means that areas in the northern part of Australia have favourable conditions.

Micro-algae – research and development

R&D on the use of micro-algae has been carried out for many decades. One research focus is on bio-fixation of CO_2 through micro-algae. Mass cultures of micro-algae are supplied by the means of sumps and diffusers with CO_2 and reuse it to produce biofuels or higher value products. The possibility of increasing the revenue from micro-algae via carbon credits is probably the main attraction for investors. One of the main technical issues seems to be the selection of stable algae strains which can be maintained in large open ponds. Algal species dominance can be challenged from invasion by ‘weed’ algal strain, grazing by zooplankton or other, often unknown, factors resulting into a pond crash. Current techniques require the development of inoculum production in case the ponds are contaminated. Current commercial technologies are based on ‘extremophiles’; species that thrive in extreme environments for example Spirulina grows in highly alkaline waters. This extreme environment avoids algal pond contamination but leads also to low productivities (50 tonne per hectare per annum).

Harvesting by bio-flocculation is probably a low cost harvesting technique but has been not tested on a large scale. Current harvest techniques such as centrifugation or chemical flocculation are expensive (>$500 per tonne biomass).

Pilot plant studies suggest that micro-algae cultures could achieve productivities of some 100 tonnes per hectare per annum biomass. These productivities have not been achieved in open ponds and hence have to be proven.

Micro-algae as a business

Currently the algae industry is growing fast, although from a small base. Annually over 10,000 dry tonnes of micro-algal biomass is currently worldwide produced. Species like Spirulina, Haematococcus, Chlorella and Dunaliella, are cultivated in open ponds for the production of high value nutritional products, speciality animal feed, etc. Micro-algae are also successfully used in the treatment of wastewaters (municipal, agriculture, mining, etc.).

The production of biofuels through micro-algae has enormous commercial potential due to the growth rates of micro-algae. Successful micro-algae production depends on the following parameters:

- Land (availability, suitability, cost)
- The algae itself (type, production, harvesting, processing)
- Value of the algae product

The use of algae oil as biofuel depends mainly on the price of the commonly used mineral oil derivatives and other biofuel feedstocks. Current estimates for the production of algae oil vary widely but none of the price estimates is even close to become competitive with other transportation fuel substitutes in the near future.

Table one below is taken from a report by van Harmelen and Oonk and the figures are converted into Australian Dollars. It shows that even with the inclusion of carbon credits ($3000 per annum or A$27 per tonne CO_2) the expected revenue (A$20,600) is considerably lower than the low cost scenario ($35,000). Note that the key assumptions are a 50 per cent+ increase of current annual productivity of biomass per hectare and the development of cheap mass harvesting technology. Michael Borowitzka from Murdoch University estimates the current production cost of a litre of algae oil at around A$5. That is a long way from the current price of 50 cents for a litre of mineral oil.

Table 1: ***Indicative Cost/Revenue Structure for a standalone micro-algae system with Biofuel and Greenhouse Gas (GHG) abatement the only revenue***

Assumption / Revenue (ha/pa)			**Cost (ha/pa)**	
Algae Growth	~30 grams day/sqm	*Cost Item (ha/pa)*	High Cost	Low Cost
Price t/CO2	$ 27	*Land (5% pa)*	A$ 8,000	A$ 0
Oil per ha	220 barrel or ~35,000 per litre	*Pond investment (capital charge from 15% to 25% over 20 years)*	A$ 42,000	A$ 27,000
Oil price	A$ 80	*Operation & M*	A$ 16,000	A$ 8,000
Oil $$	A$ 17,600	*CO2 compression & transport*	A$ 6,400	A$ 0
Carbon $$	A$ 3,000	*Risk premium*	A$ 7,200	A$ 0
Revenue	**A$ 20,600**	**Cost**	**A$ 79,600**	**A$ 35,000**

Conclusion:

Major R&D has to be done before the production of micro-algae as a stand alone biofuel project can play a competitive role in the fuel industry. One requirement to achieve the potential of the micro-algae industry is the development of long-term large scale demonstration projects so it can be shown that it is commercially viable to produce biofuels through micro-algae. The cost of these projects will be very high. Hence, the initial application of micro-algae mass cultures for renewable energy production and Greenhouse gas abatement are in the area of human, animal and industrial wastes which contain enough nutrients for algal growth. Nevertheless if algae oil can be produced as a by-product of higher valued algal products and carbon credits can be used to increase the revenue side of these businesses algae oil can play much earlier a role in the future transportation fuel mix.

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