



Asia Pacific Partnership on Clean Development and Climate
Renewable Energy and Distributed Generation Task Force

PROJECT PROPOSAL

Application for AP6 Project Endorsement and Inclusion in the REDGTF Action Plan

Key Information

Project Title: A fully Integrated Process for Biodiesel Production from Microalgae in Saline Water
Lead Country: Australia

Project Contact Details

Organisation: Murdoch University
Project Manager:
Title: Professor
First Name: Michael
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Project Description

Project Purpose: *Please provide a clear statement of the purpose or aim of the Project.*

The aim of the project is to demonstrate unequivocally the technical and economic feasibility of an integrated process for the production of microalgal oils that are suitable as a feedstock for biodiesel production. The project will cover the whole process of microalgae oil production including species selection, culture system design, construction and operation, optimal growth conditions and culture management for sustainable high oil yields, harvesting, media recycle, oil extraction and biomass disposal and/or reuse. It integrates existing technologies with new advances and developments at all stages of the process. The project builds on the extensive experience in commercial large-scale algae

production, engineering and biofuels of the key participants. As part of the first stage of the project a preliminary economic feasibility study and assessment of total greenhouse gas emissions will be carried out based on the results of the small-scale studies. These preliminary economic and GHG emission assessments will be used as a decision-making point on whether to continue to the large-scale phase of the project. The project will be guided throughout by an ongoing analysis of the economic feasibility. The second stage will integrate all the steps at the pilot scale and optimise the process over a long-enough period which will allow detailed assessment of the economics and GHG emissions.

Background and Project Description:

Describe the opportunity or the problem that is driving the need for this Project. You may wish to provide some background and any other information to demonstrate 'why' this Project is important (1 page maximum).

The production of biodiesel is ultimately limited by the available supplies of oil feedstock. Many species of microalgae algae contain high levels of lipids/oils in the range of 25 – 60% of dry weight can grow over a wide range of salinities ranging from freshwater to saturated brines (about 12x seawater concentration). The areal productivity of shallow algal cultures is about 5-10x higher than higher plants such as sugarcane. Commercial production of microalgae for high-value products is a well developed industry with the largest algae production plants, growing *Dunaliella salina* for β -carotene located in Australia and which has been in operation since 1984. Open pond-based technology is used as all comparative studies to date indicate that the capital cost of closed photo-bioreactors is not sufficiently offset by the slightly increased productivity achieved in these systems.

The high productivity, as well as the ability to grow in saline water, makes microalgae very attractive for biological CO₂ fixation and the production of oil for biodiesel. However, despite extensive research in the last 30 years, the current cost of commercial algae production presently is too high *for these applications*. Analysis of current commercial production costs of microalgae show that the cost of algae oil (assuming 40% oil in the biomass) is at least 5x higher than current alternative oil feedstocks for biodiesel. In order to develop an economical production system it will be necessary to use highly productive algal strains, grown reliably at high annual productivities in a low-cost continuous culture system under optimal climatic conditions. It is also essential to optimize the whole process (i.e. algal culture, harvesting, dewatering, lipid extraction, utilization of remaining biomass) in order to have an economical and reliable production system. For example, the commercial process of β -carotene production from *D. salina* in Western Australia, the lowest cost algal production in the world, uses an efficient, reliable and low cost culture process (low pond construction costs & minimal energy and labour requirements for culture maintenance). The productivity of the ponds is low, but the plant can be operated all year, and the low productivity is offset by a very efficient harvesting and extraction process.

Australia, especially Western Australia, has some of the best climatic conditions for algal culture, large areas of cheap land and large amounts of saline water available either from the ocean or saline groundwater. Other potentially suitable areas have been identified in India and China. This project builds on the experience in commercial microalgae production of Prof M. Borowitzka and on the work done in his laboratory at Murdoch University on lipid-producing algae since 1990. This work has resulted in the isolation and characterisation of 3 new elite strains of microalgae (at a cost of about \$250,000), selected for their properties suited to oil production in continuous culture outdoors and low-cost harvesting. Similarly, Parry Nutraceutical Ltd, India, the largest microalgae producer in India brings expertise in algae culturing, harvesting and extraction to the project. This project will be the fully integrated development and optimization of the algae oil for biodiesel process carried out at a scale and timeframe required to clearly demonstrate its technical and economic feasibility. Before commencing large-scale pilot studies further small-scale work in outdoor cultures is required to select the best of these strain(s) for all year production, optimise the culture protocol and determine the most suitable harvesting and extraction processes. These strains, combined with improved, innovative and lower-cost methods of pond construction and operation and culture management, harvesting and extraction, and based on our experience in

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commercial microalgae culture, should lead to significant improvements in productivity and lower capital costs compared to previous attempts, making the process economically viable.

The pilot culture facility will incorporate several novel aspects in pond design, construction and operation aimed at reducing capital expenditure and operating costs. It will provide the biomass necessary for the development of the downstream processes. The large volumes of water (and quantities of nutrients) required also mean that the growth medium must be recycled after harvesting of the algae as it still contains significant amounts of nutrients, thus excluding some methods of harvesting. The preferred harvesting method would be settling followed by further dewatering but, where this is not possible, flocculation and flotation (or settling) would be required. The method of harvesting will depend on the properties of the species of alga cultured. Little work has been done on large-scale oil extraction from microalgal biomass, a critical step in the whole process. It is therefore essential to provide sufficient culture/biomass for the harvesting and extraction trials and also for testing of the oils in the production of biodiesel. The biomass remaining after extraction (~ 50% of the biomass harvested) can be potentially used as an animal feed additive or be fermented to produce methane to generate energy on-site combined with partial recovery of nutrients (N, P) to be reused in the algal culture process.

The project will provide the necessary data on productivities and culture management methods over at least a full annual cycle at an appropriate scale. As key environmental factors (light, temperature, rainfall, and possibly water quality) change over the year it is essential that productivities are determined over at least one full annual cycle at a site with climatic conditions very similar to where a production plant would be situated. Similarly, the culture monitoring and management protocols must be able to handle changing climatic conditions and be able to cope with unpredictable events such as storms. The project also will develop and optimise integrated harvesting and extraction processes.

The information produced by this project will allow an accurate evaluation of the economic viability of the process and will provide the basis for commercialisation of the process in Australia and elsewhere.

Appropriateness for the AP6 Programme:

Please answer the following questions:

How will this Project increase access to or uptake of affordable and reliable renewable energy or distributed generation across Partner countries?

Before algae oil production for biodiesel can be established it is necessary to develop, optimise and fully integrate all the steps (algae production, harvesting, extraction etc.) in the process, and to demonstrate the economic feasibility of the process in Australia and several of the Partner countries. This requires significant capital and intellectual investment.

This project will identify key algal strain(s) chosen from the elite strains isolated and characterised at Murdoch University, the various system design and engineering required, and the necessary process control and management needed. Effective algal culture is climate-dependent; however we have identified suitable regions with optimal climate for large-scale algal culture in Australia, India (the Rann of Kutch) and China (Hainan Island). Possible other sites will be examined as part of the project. The parallel trials in India and China will provide the necessary data on the performance of the strains under their conditions and how the process may have to be modified to suit local conditions. It also allows for important technical input by the Indian and Chinese Scientists, and is part of the strategy for effective technology transfer.

A key part of the project will be the ongoing interaction and collaboration between all parties. An initial week-long meeting/workshop of all participants will be held in Perth at the earliest opportunity following commencement of the project.

What is the potential for the Project to deliver permanent greenhouse gas emission reductions? If relevant, provide details on the amount of CO₂ equivalent reduced over time.

Biodiesel is currently produced from a range of feedstocks including tallow, recycled cooking oil and canola and palm oil. The life cycle CO₂-equivalent emissions from biodiesel produced via these feedstocks are approximately half of those from mineral diesel. Thus, the displacement of mineral diesel by biodiesel can lead to significant reductions in greenhouse gas emissions. In fact, complete substitution of current mineral diesel usage (~15,000 ML p.a.) in Australia by biodiesel produced from either tallow or canola oil would lead to a reduction in greenhouse gas emissions of approx. 25 Mt CO₂-eq p.a.

Sufficient quantities of these biodiesel feedstocks, at low enough prices, are unlikely to ever be available to meet such a high demand for biodiesel. In the case of canola oil, areal productivities are so low that the area of arable farming land required to meet this demand is not feasible. On the other hand, microalgae have significantly higher areal productivities and their growth in saline media at large scale does not compete with agriculture for the very limited land and fresh water resources. While current production costs of microalgae are uncompetitive for lipid production for biodiesel, the proposed project has the potential to deliver microalgal lipids as an abundant and cheap biodiesel feedstock. This feedstock could feasibly be grown in Australia at sufficient scale to supply enough biodiesel to displace at least 30% of current mineral diesel consumption – some 4500 ML p.a. – within a 10-20 year time frame.

The life cycle CO₂-equivalent emissions from algal biodiesel are currently not known. These will depend largely on the embedded energy due to harvesting and nutrient addition and on the fate of the algae biomass co-product which are not known at this stage. A preliminary assessment of life cycle greenhouse gas emissions will be undertaken at an early stage during this project. This assessment will rely, in part, on data obtained from small scale testing of the culturing, harvesting and extraction processes. At the completion of the project a detailed life cycle assessment of the final proposed process will be undertaken. Nevertheless, a conservative estimate may be made by assuming that the life cycle CO₂ emissions for biodiesel from algal lipids are similar to those for biodiesel from canola oil, i.e. 0.043 kg-CO₂-eq/MJ. Thus, the displacement of 4500 ML p.a. of mineral diesel (0.086 kg-CO₂-eq/MJ) by biodiesel would lead to the abatement of at least 7.5 Mt CO₂-eq p.a. Therefore, assuming a 10-year commercialisation timeframe, with compound growth in production up to 4500 ML in year 20, it is possible that this project could instigate a total reduction in CO₂ emissions in Australia by 2027 in the order of 20 Mt CO₂-eq. Benefits on a similar scale are expected in other countries in which suitable conditions exist for the large-scale production of microalgae, such as in the partner countries India and China.

Project Details

1. Timing:

Estimated Project Start Date: 1/7/ 2007

Estimated Project End Date: 30/5/2011

Project Duration: ~ 4 years

2. Project Location:

Please list Project locations and key activities to be undertaken at each site.

Location (site, city/region, country)	Activity at Site
Murdoch University, Perth, Western Australia, Australia	Project management & coordination, Small scale algae trials, pilot-scale plant design, economic modelling, analytical work
University of Adelaide, Adelaide, South Australia, Australia	Small-scale harvesting and extraction trials, pilot-scale plant design and engineering, analytical work, , life-cycle GHG emissions analysis
Site to be determined, Western Australia, Australia	Pilot-scale plant construction & commissioning, algae production and harvesting trials & oil extraction from biomass
Oonaiyur, Tamil Nadu, (Parry Neutraceuticals), India	Small & Pilot-scale algae production, harvesting trials and extraction trials and participation in economic modelling for Indian conditions
South China University of Technology, Guangzhou, South China, China	Small and Pilot-scale algal culture, harvesting and extraction trials, plant design and engineering, analytical work and participation in economic modelling for Chinese conditions
Site to be determined, Australia (Agri-Energy Ltd)	Testing of algal oils in biodiesel production

3. Project Methodology:

Please explain the Project methodology and provide details of each Project step and estimated timing, in the table below.

Project Steps		Estimated Date for Achievement
No.	Description	
NOTE: This table should be read in conjunction with the Gantt Chart below.		
1	<p><i>Small-scale algae culture and strain optimisation</i> At least 2 of the most promising algal strains isolated by the Murdoch University group will be grown in Perth using the extensive algae culture facilities (ALGATRON) including existing outdoor 1m² raceway ponds and 2 x 2m² raceway ponds in continuous culture for extended periods (> 6 months), and the lipid productivity optimised. The outdoor trials will be supplemented with laboratory studies to determine the key limiting factors to productivity. These trials will also establish the best culture monitoring and management processes.</p> <p>Similar small-scale trials will also be undertaken in India and China to examine the algal performance under the local conditions and to familiarise the Indian & Chinese partners with the properties of the species used. These trials are essential to allow for inter-site comparison, to optimise strains and culture conditions for each location and for the economic analysis.</p> <p>These cultures will also provide the inoculum for the later, larger cultures.</p>	21 months from commencement of project
2	<p><i>Small-scale Harvesting Trials</i> Small-scale harvesting experiments will be undertaken using algae cultured in a 2m² algal raceway pond located at the University of Adelaide. It may also be possible to use the facilities being constructed</p>	21 months from commencement of project

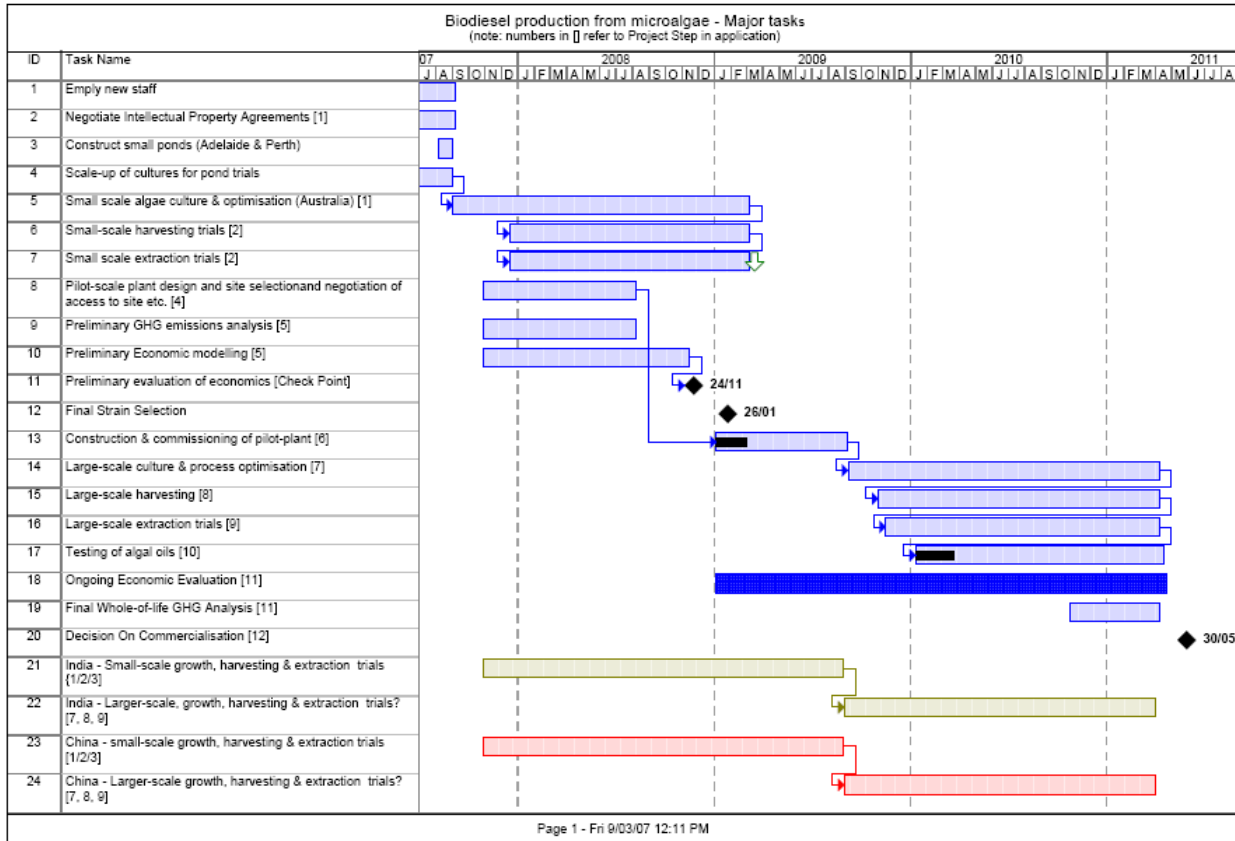
	<p>by SARDI for the production of the algal biomass. The operation of the pond will be based on optimal conditions recommended from the Murdoch trials.</p> <p>Small-scale harvesting trials will also be carried out in India and China.</p> <p>The outcome of Stage 1 is to design a scalable low-cost high efficient harvesting unit processes. These will be scaled up and used for Stage 2 at the pilot scale site.</p>	
3	<p><i>Small-scale Extraction Trials</i> Initially algae harvested from the small-scale raceway ponds will be utilised to study the optimal extraction of lipids. It is expected that the optimal harvesting technique will be strongly dependent on the extraction methods; i.e. aiming to reduce the number of unit processes (steps) from pond to fuel!</p> <p>Small-scale extraction trials will also be carried out in India and China.</p> <p>Initially algal biomass harvested at Murdoch would be shipped to Adelaide for extraction experiments.</p>	21 months from commencement of project
4	<p><i>Pilot-scale plant design, site selection and negotiation for access to site</i> The pilot-scale plant will be constructed at a site yet to be selected. The site will be located at, or north, of Carnarvon, WA, to provide the best climatic conditions necessary for maximum annual algal production all year round. The general geographical regions required have been identified from climatic data (ie. maximum sunshine, low rainfall, low number of cloudy days, temperature). Specific site selection will include the following criteria:</p> <ul style="list-style-type: none"> • Availability of adequate water sources (preferably saline ranging from 0.5x seawater to 1.5x seawater) • Availability of infrastructure incl. nearby accommodation for staff, tradespeople, transport, power, phone etc. • Preferably there will be adequate land available in the general region where one could construct a full-scale production plant. • Preferably the site will have existing building space and related infrastructure already available for the basic laboratory and maintenance facilities. <p>Several potential sites have been identified and are being more fully evaluated. Discussions with land owners and government agencies have commenced.</p> <p>The pilot-scale plant needs to be of sufficient size so that any data obtained can be scaled to full production size. It also needs to be able to provide adequate biomass for the development of downstream processes i.e. harvesting, oil extraction etc.</p> <p>Suggested pond configuration: 2 x 250 m² lined raceway ponds (= approx ¼ full scale or ~75,000L)</p>	12 months from commencement of project

	<p>1 x 250 m² unlined raceway pond 2 x 50 m² lined raceway ponds (for production of inoculum and smaller-scale optimisation trials).</p> <p>Lined and unlined ponds are necessary to determine whether unlined ponds (which are much cheaper to construct) can be used for reliable long-term, high productivity culture.</p> <p>The design of the plant will incorporate several new and innovative features (including new materials) which will reduce capital costs, lower energy requirements and enable better control of the cultures resulting in improved productivities.</p> <p>The design and engineering of the culture system can commence immediately, whereas the design and engineering of the harvesting and extraction systems requires the results of the small-scale trials before commencement. The design will incorporate a number of novel improvements over current systems in the area of materials, construction methods, and in energy conservation.</p> <p>One of the methods of harvesting to be trialled is a device recently invented by Z Filter Pty Ltd which has the advantage of low energy costs, and which has the potential to significantly reduce harvesting costs.</p>	
5	<p><i>Preliminary Economic Modelling and Life-Cycle GHG Emissions</i> The economic model for the whole process will be developed from the beginning of the project, and a detailed preliminary economic assessment will be undertaken at the conclusion of the small-scale trials.</p> <p>Whole of life-cycle greenhouse gas emissions for the production and use of bio-diesel from microalgal lipids will be undertaken based on existing knowledge of large-scale algae production and using data obtained during small-scale trials.</p> <p>The results of these models and analyses it will be used to decide <u>whether to proceed to the large-scale trials</u>.</p>	<p>~ 15 months from commencement of project (GO/NO GO point for rest of project)</p>
6	<p><i>Construction and commissioning of pilot plant</i> Construction time is estimated at between 6 to 9 months, depending in part on the availability of contractors. Commissioning should take about 3 months.</p>	<p>~24 months from commencement of project</p>
7	<p><i>Large-scale culture trials and process optimisation</i> The large-scale culture trials will take at least 18 months so as to obtain the necessary reliable data on annual productivities and on the reliability of the culture process.</p> <p>Parallel culture trials will be undertaken in India by Parry Nutraceutical Ltd, a commercial algae producer at their plant in India, and by the South China University of Technology in Guandong to obtain data on algae productivity under Indian and Chinese conditions. They will be trialling the strains supplied by Murdoch University, but may also include locally developed strains.</p> <p>The exact scale of the Indian and Chinese trials will be determined at a</p>	<p>46 months from commencement of project</p>

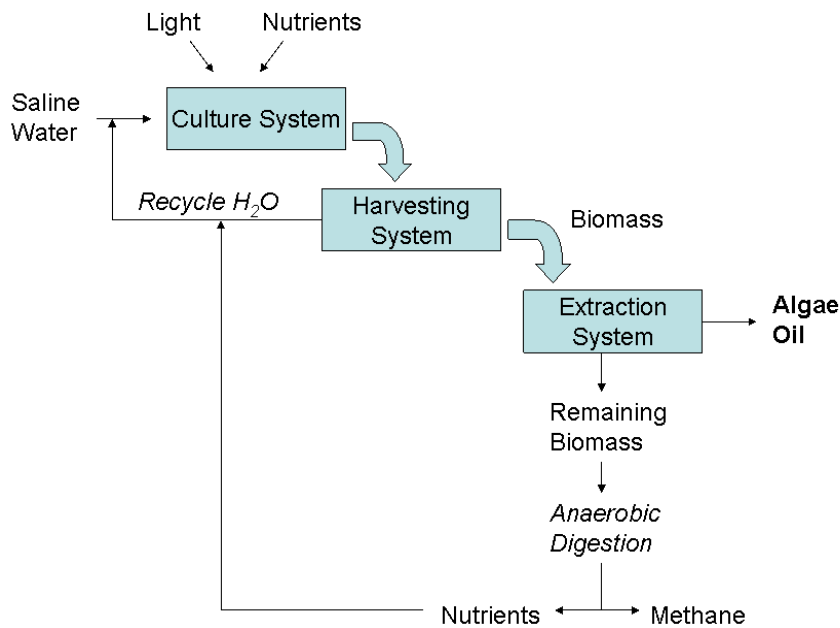
	<p>alter time and will depend, in part, on the funding available to the Indian and Chinese partners for pond construction and operation. However, pilot-scale trials identical in scale to the trials in Australia are not essential for effective evaluation of the economics of the process in these countries. Long-term smaller-scale culture trials would provide sufficient data on local productivities. Experience in the large-scale culture, harvesting and extraction required for efficient technology transfer also can be obtained by Indian and Chinese researchers spending time at the Australian facility.</p>	
8	<p>Large-scale harvesting The harvesting system will be built on-site at the pilot scale plant and operated continuously to determine the optimal operating situation. This will enable the best possible synergistic operating conditions of the ponds and harvesting process to be determined. Harvesting trials will also be undertaken in India and China.</p>	46 months from commencement of project
9	<p>Larger-scale extraction and production of algal oils for testing by biodiesel producers. The biomass harvested from the pilot plant will be extracted either on site or in Adelaide (depends on extraction process developed) and the oils produced will be supplied to biodiesel producers for testing. Extraction trials will also be undertaken in India and China.</p>	46 months from commencement of project
10	<p>Algae oil for biodiesel trials The algae oils produced will be tested by Agri-Energy for their suitability for biodiesel production.</p>	
11	<p>Economic Evaluation and Life-cycle GHG emissions This will be an ongoing process with both the economic model and the life-cycle analysis being refined as new data become available. Separate economic evaluations will be made for the process in Australia, India and China. The economic model and LCA will be a key parts of the decision making process throughout the project.</p>	Ongoing, completed 46 months from commencement of project
12	<p>Final decision on commercialisation The results of the economic analyses and the GHG emissions analyses will be used to develop a suggested commercialisation strategy.</p>	~ 47 months from beginning of project

Additional information on Project methodology (if applicable):

Project Stages & Timeline



OIL FROM MICROALGAE - PROCESS



Capability statements of key researchers

Professor Michael A. Borowitzka B.Sc (Hons), PhD, FAICD Dip.–

Michael is professor of Phycology at Murdoch University. He has worked in commercial microalgae production for over 30 years. As Head of Biology at The Roche Research Institute of Marine Pharmacology he began work on the production of β -carotene from the alga *Dunaliella salina*, This project continued with Roche Algal Biotechnology resulting in the construction of a pilot plant at Hutt Lagoon Western Australia. Michael joined Murdoch University, but continued as principal Consultant to Westfarmers Algal Biotechnology on the *Dunaliella* process and also worked on astaxanthin production from *Haematococcus*. The project was eventually commercialised by Western Biotechnology Ltd where Michael was also Principal Consultant. This is now the largest algal production facility in the world owned and operated by Cognis Nutrition & Health.

Michael has consulted on and led commercial algae projects in Australia, China, Chile, Cuba, USA, UK and Europe for FAO, World Bank and many private companies in Australia and overseas. He is an acknowledged international authority on commercial algae culture. He is the past President of the Asia Pacific Society for Applied Phycology, the President of the International Society of Applied Phycology, a member of the Executive of the International Seaweed Association, past chair of the WA Branch of the Australian Biotechnology Association, member of the committee of the WA Branch of Ausbiotech, Editor-in-chief of the Journal of Applied Phycology. He is the coordination of the ‘Biotechnological and Environmental Applications of Microalgae (BEAM)’ Research network (<http://wwwscieng.murdoch.edu.au/centres/algae/BEAM-Net/BEAMHOME.html>).

He has published extensively on algal biotechnology and algal ecology (see <http://wwwscieng.murdoch.edu.au/centres/others/algaelab/MABpublications.htm> for list of publications) and co-edited one of the key books in the area, ‘Micro-algal Biotechnology’. Michael regularly presents keynote lectures at international conferences in the field.

The Algae Research laboratory at Murdoch University has extensive algal culture facilities including several small raceway ponds, 2 1000L pilot-scale tubular photobioreactors, several smaller photobioreactors (tubular, plate and airlift), controlled temperature rooms and growth cabinets including the ALGATRON, an extensive culture collection of algae with commercial potential, analytical facilities, microscopes, fluorescence devices etc.

David Lewis PhD BE(Chem) – Capability statement

David Lewis is a lecturer in the School of Chemical Engineering at the University of Adelaide. He enrolled at the university as a mature-age undergraduate in 1993, completing a Bachelor of Engineering (Chemical) Honours Degree in 1998. In 1999 David commenced a PhD in the School of Civil and Environmental Engineering. His PhD project was focussed on the control of cyanobacteria (blue-green algae) in drinking supply reservoirs, which was funded by the CRC for Water Quality and Treatment. David became a lecturer in 2002 and setup the Microalgal Engineering Research Group (MERG) with a research focus on water and wastewater quality, commercial and environmental applications for microalgae.

From 2002 to 2005 MERG undertook research to optimise media and physical growth conditions for heterotrophic production of specific microalgae for aquaculture feed. This work was undertaken at the laboratory scale to optimise the bio-composition of the microalgae. In 2006 the process was successfully scaled up for commercialisation and in 2007 will be trialled at the SA Oyster Hatchery in Port Lincoln. An important component to this work was to apply Life Cycle Assessment (LCA) to ensure the commercial competitiveness of the novel process compared with existing large-scale culturing processes used in the aquaculture industry. MERG has also applied LCA’s to winery wastewater treatment processes to assist the wine industry in optimising process operations and ultimately reduce their carbon footprint.

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A key research project within MERG is the optimisation of microalgal removal from secondary treated wastewater for agricultural applications. This project has direct relevance to the challenge of harvesting microalgae from open ponds and the skills developed in this area will be of immeasurable use to the proposed REDGTF project. Additionally MERG is involved with extraction of compounds from microalgae for commercial application which also has direct relevance to extraction of lipids from microalgae.

As a Chemical Engineer with a trade (Electrical Fitter/Mechanic) background, David is well equipped to undertake commercial and industrial scale research and development. His engineering background provides the necessary skills to be able to conceptualise and scale-up processes that are economically and environmentally sustainable.

MERG operates two fully-equipped research laboratories, one for microalgal culturing, harvesting and extraction purposes; and the other a jointly owned analytical laboratory. The key equipment in these two laboratories includes:

- Atomic Adsorption Spectrophotometer
- Dissolved Air Flootation Jar Tester
- Gas Chromatograph
- Microscope (Inverted Phase) plus colour video camera and particle visualisation and enumeration software
- UV Visible Spectrophotometer
- HPLC
- Specialised glassware for column extraction experimentation
- Fume hoods and laminar flow cabinets

Peter Ashman PhD, Grad.Cert.Ed., ME, BE(Chem)

Peter Ashman is a Senior Lecturer in the School of Chemical Engineering at the University of Adelaide. A chemical engineer with over 15 years of research experience, he was appointed to the University of Adelaide in 1999 as a lecturer with a joint appointment to the Cooperative Research Centre (CRC) for Clean Power from Lignite as a Key Researcher and Project Leader. In his role with the CRC he was responsible for managing research programmes with an annual budget of approx. \$0.75M p.a., involving the equivalent of approx. 8 full-time research staff and students during the period 1999-2006. These programmes were focussed on the delivery of new technologies for generating electricity from Victorian and South Australian low-rank coals with high efficiency, and thus with low greenhouse gas emissions.

Since the unsuccessful re-bid of the CRC in 2005, Dr Ashman has been developing new research interests in the area of bio-energy, including biodiesel production, to complement his ongoing work in clean coal research. Accordingly, he has recently joined Dr Lewis' Microalgal Engineering Research Group (MERG) to enhance the capability of this group in the area of biofuels research. With a proven track record of managing large, commercially-focussed energy research projects, he is a key member of the proposed research team.

4. Project Outputs:

The Project will deliver: *(Please list the outputs to be delivered by this Project.)*

- A new technology taken to scale-up demonstration stage, including detailed analyses of economics and life-cycle GHG emissions
- Design and engineering plans for an algae production system
- Optimised and integrated algae harvesting process and oil extraction process
- Process manuals for algae production, harvesting and extraction
- Detailed criteria for site selection for algae production plants and identification of key sites in Australia, India and China.
- Plans for commercialisation in Australia, India & China

Examples: capacity of newly-deployed REDG systems; number of people trained for operation and maintenance; a report; a new technology taken to proof-of-concept, prototype or scale-up demonstration stage; a new mechanism for local financing of REDG systems, etc.

5. Additional Information (optional)

Please provide any additional information that you would like to bring to the attention of the Task Force (e.g. intellectual property issues, risk management).

This project is a medium risk project. One potential outcome may be that oil production from microalgae is not economically viable. However, the ongoing economic analysis is a key part of the risk management process and an important tool for the identification of key steps in the process affecting the economics and thus needing special attention. An early key check point has been included in the project at which time it will be decided whether to proceed to the major pilot-scale stage, based on the results of the preliminary small-scale studies and economic and GHG emissions studies.

The project will generate significant intellectual property. Where possible this intellectual property will be protected by patents, the rest will be covered by agreements between all parties associated with the project. Legal contracts and agreements on ownership of the intellectual property and licensing of any proprietary intellectual property (e.g. the new harvesting device invented and owned by Z Filter Pty Ltd and the Murdoch University algae strains) will be negotiated and agreements entered into during the first 3 months of the project.

Partnerships

List all Partners participating in the Project and describe their role in Project delivery.

Organisation / Agency	Country	Role in Project	Partnership Status (expected or approved)
Murdoch University	Australia	Project management; all aspects of algae culture, culture system design, waste biomass processing, economic analysis	Approved
University of Adelaide	Australia	Algae harvesting and oil extraction; engineering; life-cycle GHG emissions.	Approved
Parry Nutraceuticals Ltd	India	Pilot-scale culture studies in India. Harvesting.	Approved
South China University of Technology	China	Small scale algal culture, harvesting and extraction trials, plant design and engineering, analytical work	Approved
Agri Energy Ltd	Australia	Oil for biodiesel specifications; oil testing; economic analysis and commercialisation.	Approved
Z Filter Pty Ltd	Australia	Provision of proprietary harvesting device for testing, economic analyses and commercialisation.	Approved
SARDI	Australia	Small-scale culture facilities	Tentative

Resources

Please provide the estimated total cost of the Project and specify details of funding contributions (cash and/or in-kind) from various sources (including contributions from the applicant). Examples of in-kind resources: provision of people's time, access to facilities or land.

The conversion used is 1 \$AUS = 0.77 \$US

Funding Source: Agency/Organisation	Country	Cash (US\$ '000s)	In-kind (US\$ '000s)	Total Contribution (US\$ '000s)	Funding Status (expected or approved*)
Government Agency / Organisation					
REDGTF	AUSTRALIA	1458.0	0	1458.0	expected
Murdoch University	AUSTRALIA	171.4	282.9	454.3	approved
University of Adelaide	AUSTRALIA	240.5	286.1	526.6	approved
South China University of Technology	CHINA	203.0	237.0	440.0	Expected (requires funding from Chinese Government agencies)
Private Sector / Industry					
Agri Energy Ltd	AUSTRALIA	154.0	101.7	255.7	approved
Z Filter Pty Ltd	AUSTRALIA	0	100.0	100	approved
Parry Nutraceuticals Ltd	INDIA	50.0	80.0	130.0	Expected (requires funding from Indian Government agencies)
Non-Government Organisation (NGO)					
Other					
Total Project Funding		2276.6	987.6	3264.2	

*If funding has been approved, please attach documentary evidence to this application.

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Office use only (not to be filled out by applicant):

Project Type	Endorsement	Actionable	
Category	Deployment	Market Enabling	R&D and Demonstration
Timeframe	Short-Term	Medium-Term	Long-Term
Ready for review by REDGTF:		February 2007	Later

Attachments to this Project Proposal:

Description	Name
Letter of intent – Murdoch University	Attach A
Letter of intent – University of Adelaide	Attach B
Copy of email on participation in project & support from South China University of Technology	Attach C
Copy of emails on participation in project & support from Parry Nutraceuticals	Attach D

Division of Research and Development



South Street, Murdoch
Western Australia 6150
Telephone: (08) 9360 2452
Facsimile: (08) 9360 6686
University PABX: (08) 9360 6000
<http://wwwadmin.murdoch.edu.au/research/>
Registered Provider Code: 00125J
A.B.N. 61 616 369 313

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To whom it may concern

Collaborative Research Project: *A Fully Integrated process for biodiesel production from microalgae in saline water (REDGTF project proposal)*

This letter is to confirm the commitment from Murdoch University to the above research project.

The project will be led and managed by Professor Michael Borowitzka, School of Biological Sciences and Biotechnology, who will also lead the research on algae culture, culture system design, and the economic analysis aspects of the project.

If the application is successful Murdoch University will commit \$1,200,000 of both cash and in-kind support over four years as well as one PhD scholarship in support of the research. Murdoch University will also make available the facilities (ponds, bioreactors etc) of the large scale microalgae culture facility (ALGATRON) and the elite algae strains isolated and characterised in Professor Borowitzka's laboratory.

Yours sincerely

Timothy Morrison
Director, Research & Development

Attachment B

06 Mar 2007 4:57PM

School of Chem Eng

+61 8 8303 4373

p. 1



FACULTY OF ENGINEERING, COMPUTER AND
MATHEMATICAL SCIENCES

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Executive Dean

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CRIQ06 Provider Code 001234

5 March 2007

Professor Michael Borowitzka
Professor of Marine Phycology
School of Biological Sciences & Biotechnology
Murdoch University
Murdoch
WA 6150

Dear Professor Borowitzka

Re: Letter of Intent: Collaborative research project
A fully integrated process for biodiesel production from microalgae in saline water

I am writing to confirm a commitment from The University of Adelaide to the above research project. If the project proposal is accepted, Dr Peter Ashman and Dr David Lewis, in the School of Chemical Engineering, will undertake a number of activities at the University of Adelaide in support of the overall project objectives. These will include small-scale harvesting and extraction trials, design and construction of pilot-scale harvesting and extraction facilities, and life-cycle analysis of GHG emissions. If successful, the University of Adelaide intends to commit A\$100k over the next four years (\$25k p.a.) in support of this research.

The University of Adelaide expects that activities at both the University of Adelaide and Murdoch University may develop valuable intellectual property. The parties agree that no IP will automatically transfer from one partner to the other as a result of this alliance and that property constituted IP agreements will be made, prior to commencement of the project, should the funding bid be successful.

The University of Adelaide looks forward to collaborating with Murdoch University in this important research alliance.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'P A Dowd'.

Professor P A Dowd, FEng, FTSE

Project ID: RDG-07-26

Attachment C

From: fewd304 [fewd304@scut.edu.cn]
Sent: Wednesday, 7 March 2007 11:40 AM
To: Michael Borowitzka
Subject: For the REDGTF Application

Dear Prof. Borowitzka,

I am pleased to be a partner in the REDGTF project as outlined in the Project proposal. It is depending on my obtaining funding support from China or other sources.

Best regards,

WEI Dong

WEI Dong, PhD
Associate Professor
Assistant Dean
College of Light Industry and Food Sciences
South China University of Technology
Guangzhou 510640
P.R. China
Tel & Fax:20-87113849
Mobile Phone: 13544599067
Email: fewd304@scut.edu.cn

Project ID: RDG-07-26

Attachment D

From: Sebastian.Thomas-Chief Executive-PNL-HO-PAI [SebastianT@pai.murugappa.com]
Sent: Wednesday, 7 February 2007 5:35 PM
To: Michael Borowitzka
Subject: RE: Algal Oil project

Michael,

Thanks.

Yes, we would like to get involved in this project.

Regards,

Sebastian

From: Sebastian.Thomas-Chief Executive-PNL-HO-PAI
[mailto:SebastianT@pai.murugappa.com]
Sent: Thursday, 25 January 2007 7:07 PM
To: Michael Borowitzka
Subject: FW: Algal Oil project

Michael,

The cost towards construction of ponds (as indicated in your Project proposal for 'Small scale' and 'Pilot scale'), paddle wheels, piping & valves, electricals etc come to around USD 41,000.00

No idea how this reflects with costing estimate in Australia.

Regards,

Sebastian

From: Sebastian.Thomas-Chief Executive-PNL-HO-PAI [SebastianT@pai.murugappa.com]
Sent: Monday, 26 February 2007 1:46 PM
To: Michael Borowitzka
Subject: RE: Algal Oil project

Michael,

Have gone thru the proposal. Looks good.

Correction/comments:

Page 9: Parry Nutraceuticals instead Neutraceuticals

Page 18: Parry Nutraceuticals' scope: 'Pilot-scale culture studies in India. Harvesting'.

If required, you can include us also for the extraction studies. We already have a commercial extraction facility for EPA/DHA oil extraction from algae and also for Mixed Carotenoids and Astaxanthin.

Regards,
Sebastian