Biodiesel from Algae: challenges, opportunities and the way forward

Tom Beer, David Batten, John Volkman, Graeme Dunstan, Susan Blackburn
CSIRO Energy Transformed Flagship
23-25 January 2008
If the world airline fleet used 100% biojet fuel from soybeans, it would require 322 billion litres.

This would require 5,750 sq km of land (about the size of Europe)
To meet aviation’s fuel demand

If the world airline fleet used 100% biojet fuel from soybeans, it would require 322 billion litres.

This would require 35k sq km land (about the size of Belgium)

34,250 sq km (3.4 million hectares) algae ponds
World first: Flying high on pond scum

DENISE MCNABB

AIR New Zealand and airliner manufacturer Boeing are secretly working with Blenheim-based biofuel developer Aquaflow Bionomic Corporation to create the world’s first environmentally friendly aviation fuel, made of wild algae.

If the project pans out the small and relatively new Zealand company could lead the world in environmentally sustainable aviation fuel.

It’s understood Air NZ is undertaking risk analysis. If everything stacks up it will make an aircraft available on the Tasman to test the biofuel.

The fuel is essentially derived from bacterial pond scum created through the photosynthesis of sunlight and carbon dioxide on nutrient-rich water sources such as sewage ponds.

Air NZ would most likely test the fuel on one engine while normal aviation fuel would drive the other engine. Fuel is held in cells on the aircraft that can be directed to a specific engine.

None of the parties involved will talk about the joint venture development because of confidentiality agreements but whispers about the project were circulating at the roll-out of the Boeing 787 Dreamliner in Seattle in the US last week.

Local Marlborough media reported a visit by Boeing to Aquaflow earlier this year and Boeing has stated publicly since then that it believes algae is the airtime fuel of the future.

Virgin Fuels announced in April it was working with Boeing to demonstrate biofuel in a 747-400. The focus is on testing algae-derived jet fuel, especially its freezing point.

Boeing’s Dave Daggett was reported this year as saying algae ponds totalling 34,000 square kilometres could produce enough fuel to reduce the net CO2 footprint for all of aviation to zero.

Until now the relatively new Blenheim company’s focus has been on biodiesel for cars, trucks, buses and boats.

Environment Minister David Parker drew public attention to the company in December when he test drove a Land Rover around Parliament’s forecourt that was powered by Aquaflow’s blend of algae biofuel and diesel (5% algae fuel and 95% conventional fuel) just a year after it was developed.

Virgin Airline boss Richard Branson met Parker in January to discuss biofuel, including Aquaflow’s technology for wild algae.

Aquaflow director Vicki Buck said yesterday that she couldn’t talk about...
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Objective of the Presentation

- To seek partners to determine the amount and location of algal biomass in the ESCAP region that could be suitable for the production of biodiesel

- To offer the possibility of a sustainable, low GHG emissions feedstock that
  - grows rapidly
  - yields more biofuel per hectare than oil plants
  - contains no sulfur and is non-toxic
  - is highly biodegradable
  - does not compete with food, fibre or other uses
  - does not involve destruction of natural habitats
About Microalgae

- They contain lipids and fatty acids as
  - membrane components
  - storage products
  - metabolites and
  - sources of energy
- They contain up to 40% of lipids/oils by weight
- They need light, nutrients and warmth to grow
Sources of Microalgae

• Large-scale, natural sources:
  • Bogs, marshes and swamps
  • Salt marshes
  • Salt lakes

• Small-scale sources:
  • Wastewater treatment ponds
  • Animal waste
  • Other liquid wastes
Methodology

$T > 15^\circ C$ and availability of:
- water body or wastewater pond;
- flat, low cost land;
- infrastructure.

$\text{CO}_2$ resources
Suitable Climatic Areas

15°C or higher

Köppen's Climate Classification
by FAO - SDRN - Agrometeorology Group - 1997

CSIRO  Biodiesel from Algae
Dairy feedlot potential

[Map showing dairy feedlot potential around the world with color coding for different ton N per cell values]

CSIRO  Biodiesel from Algae
Pig feedlot potential

ton N per cell
- < 200
- 200 - 1000
- 1000 - 2000
- 2000 - 5000
- 5000 - 10000
- 10000 - 20000
- > 20000

CSIRO Biodiesel from Algae

Asian and Pacific Centre for Agricultural Engineering and Machinery
Municipal wastewater potential

ton N per cell
- < 500
- 500 - 1000
- 1000 - 2500
- 2500 - 5000
- 5000 - 10000
- 10000 - 15000
- > 15000

Municipal

CSIRO Biodiesel from Algae
Waste/water Potentials

- ESCAP countries with large wastewater or animal waste potentials:
  - Southern China (wastewater, pig wastes)
  - Thailand (wastewater, pig wastes)
  - Indonesia (wastewater)
  - Malaysia (wastewater)
  - Philippines (wastewater, pig wastes)
## Theoretical resource potentials by 2020

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<td>Africa</td>
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<td>Middle East</td>
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<td>1</td>
<td>0</td>
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<td>Oceania</td>
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<td>2</td>
<td>2</td>
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<td><strong>Total</strong></td>
<td><strong>142</strong></td>
<td><strong>137</strong></td>
<td><strong>87</strong></td>
<td><strong>366</strong></td>
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</table>

Algae to Biodiesel Pathway

Selection of micro algae species → Growth of micro algae → Harvesting of micro algae → Extraction of oil from micro algae → Oil for processing into biofuel → BIODIESEL

Further treatment to recover other valuable material?

Waste liquor

Residual micro algae → Dewatering and extrusion

Extraction of protein

High protein content (up to 35%)

- Aquafeed
- Animal feed
- Pet feed

Incorporate into human foods

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- Aquafeed
- Animal feed
- Pet feed

Incorporate into human foods
### Algal biomass yields

<table>
<thead>
<tr>
<th>Project</th>
<th>Date</th>
<th>Algae species</th>
<th>Stable?</th>
<th>Sustained growth</th>
<th>Average yield (g/m²/day)</th>
<th>Annual yield (MT/ha/yr)</th>
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<tr>
<td>&quot;Species control&quot;</td>
<td>1976</td>
<td>Spirulina</td>
<td>no</td>
<td>NA</td>
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<tr>
<td>Larger scale</td>
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<td>Hawaii 1960-97</td>
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<td>California 1981-80</td>
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<td>Ben-Amotz,Israel</td>
<td>1984-85</td>
<td>L. gracile N. atomos</td>
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<td>46</td>
<td>20</td>
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<td>Technion, Univ.Israel</td>
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<td>L. gibbus</td>
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<td>Summer, optimal</td>
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<td>18</td>
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<td>OTF, New Mexico</td>
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<td>C. sorokinii</td>
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<td>30</td>
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<td>December</td>
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<td>M. minutum</td>
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<td>1990</td>
<td>M. minutum</td>
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<td>1 tear</td>
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<td>no summer months</td>
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37.5 g/m²/day
137 T/ha/yr
Bioreactors or Ponds

CSIRO Biodiesel from Algae

United Nations ESCAP
Asian and Pacific Centre for Agricultural Engineering and Machinery
Bioreactors or Ponds

*Spirulina* and *Haematococcus* Cultivation at Cyanotech Corp., Hawaii.
*Spirulina*: blue-green ponds; *Haematococcus*: orange-red ponds

CSIRO Biodiesel from Algae
Peel Inlet, Western Australia
Peel Inlet, Western Australia
Peel Inlet, Western Australia
Biodiesel manufacture in WA (Picton)
Biodiesel manufacture in Darwin (NT)
Biodiesel from various feedstocks

- B100 Tallow
- B25
- Canola
- B10 Tallow
### Fatty acid composition

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>BDF from</th>
<th>Lipids from</th>
<th>Lipids from</th>
<th>Lipids from</th>
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<tr>
<td></td>
<td>Crude palm oil</td>
<td>Crude coconut oil</td>
<td>Dunia maritina</td>
<td>Dunia salina</td>
<td>Chlorella vulgaris</td>
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<td>0.18</td>
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<td><strong>Sum of Saturated FA</strong></td>
<td>49.83</td>
<td>93.13</td>
<td>12.6</td>
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<td>25.7</td>
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<td>-</td>
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<td>8.8</td>
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<td>5.53</td>
<td>2.5</td>
<td>3.4</td>
<td>7.3</td>
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<td>Linoleic acid, C18:2</td>
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<td>1.26</td>
<td>4.1</td>
<td>6.1</td>
<td>11.8</td>
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<td>Linolenic acid, C18:3</td>
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<td><strong>Sum of Unsaturated FA</strong></td>
<td>50.18</td>
<td>6.86</td>
<td>87.4</td>
<td>80.3</td>
<td>74.3</td>
</tr>
</tbody>
</table>

Sums for algae include other fatty acids
Energy Transformed Flagship
Tom Beer
Leader, Transport Biofuels

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Thank you

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