SOLVENT RESCUE LTD

David Painter Consulting [DPC] Ltd

Algae for Fuel

What source of energy will <u>you</u> use for your transport in 10 years?

Chris Bathurst and David Painter

Royal Forest and Bird Society,

North Canterbury Branch

14 November 2007

In about 45 minutes …

- Poor and promising options for biofuels
- A short history of algae and fuel:
  - Megayears BCE to 1999
  - 2000 to 2007
- The whole algae for fuel process
- Algae, oil, New Zealand, …
- Where to from here?

Poor and Promising Biofuel Options [for NZ]

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Poor Options Give Good Biofuels a Bad Name

What source of energy will you use for your transport in 10 years?

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ESR/IPENZ June 2007

Poor Options for New Zealand 1

Maize ethanol:

- Insufficient land available
- Land location competition with food
- Low energy out: energy in ratio
- Maize has better uses
- Ethanol drawbacks as fuel extender
- Dairy factory waste ethanol better

Poor Options for New Zealand 2

Rapeseed biodiesel:

- **Insufficient land available**
- **Land location competition with food**
- **Low energy out: energy in ratio**
- **Rapeseed oil has better uses**
- **Possible interference with brassica seed production industry**

Poor Options for New Zealand 3

Palm oil biodiesel:

- Has to be imported
- Competing with producer countries
- Possible impacts on deforestation
- Palm oil has better uses
- Suspect energy out: energy in ratios

Poor Options for New Zealand 4

Ethanol from sugar crops:

- Insufficient land available
- Land location competition with food
- Ethanol drawbacks as fuel extender
- Sugar crops have better uses
- Suspect energy out: energy in ratios

Promising Options for NZ 1

Ethanol from whey:

- Existing technology
- Under-utilised capacity
- Provides dairy industry cleanup
- By-product of a major, growing NZ industry

Promising Options for NZ 2

Oil from algae:

- High areal productivity
- High energy out: energy in ratio
- Beneficial carbon balance
- Provides wastewater cleanup
- Provides a wide-spectrum oil
- Extendable to other growing media

Promising Options for NZ 3

Biodiesel from algae:

- High areal productivity
- Beneficial carbon balance
- Provides wastewater cleanup
- Extendable to other growing media

Promising Options for NZ 4

Bioethanol from woody crops:

- Waste wood available now
- Woody crops can use non-food land
- Provides soil and water cleanup
- Possible useful byproducts

The Most Significant Immediate Option for NZ 1

CONSERVATION:

- Upgrading fuel-efficiency of vehicles
- Down-powering the vehicle fleet
- Sustainable urban design
- Provision of effective public transport
- Incentives to use public transport
- Moving further to full-cost pricing of fuel
- Education and incentives for sustainable living

The Most Significant Immediate Option for NZ 2

Oil from algae:

- High areal productivity
- High energy out: energy in ratio
- Beneficial carbon balance
- Provides wastewater cleanup
- Provides a wide-spectrum oil
- Extendable to other growing media

The Most Significant Immediate Option for NZ: Oil from algae

So, what are we doing about it?

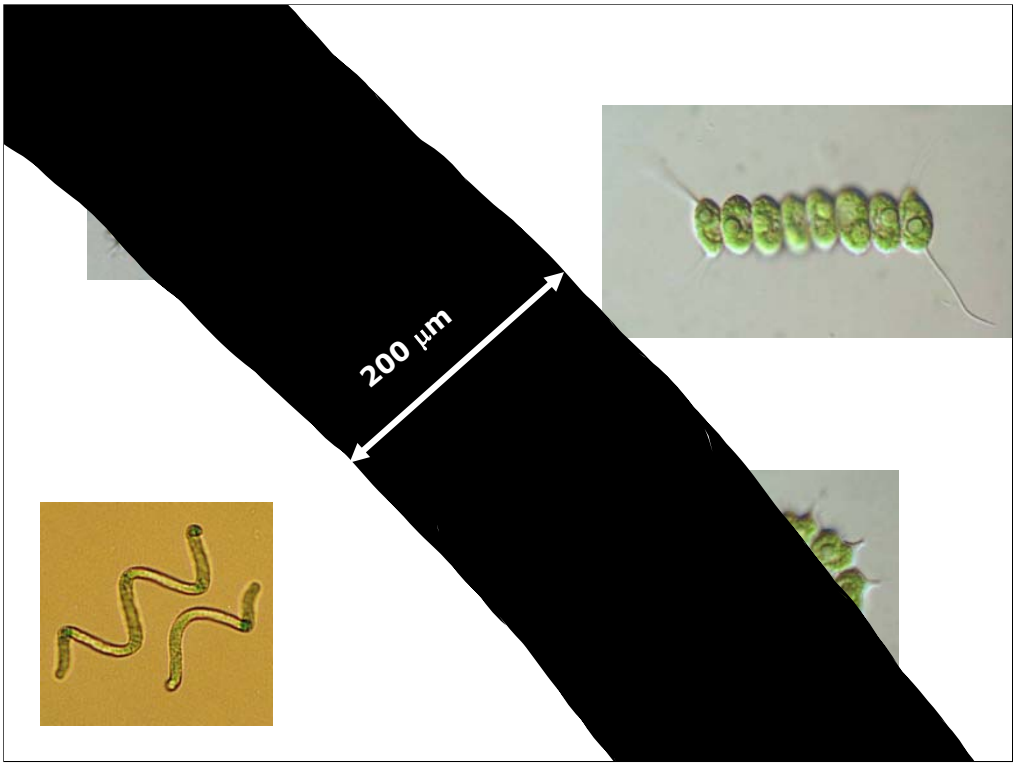
Quite a lot, quite quickly!

But first …

A short history of algae 1: some taxonomy

- 'Alga' and 'algae' come from the Latin for 'seaweed'
- 'Alga' and 'algae' are not formal taxonomic terms
- Algae result from several unrelated evolutionary lineages
- They were once [other than cyanobacteria] in the kingdom Protista; but others at other times have regarded them all as plants
- They are organisms [or, only the eukaryotic ones], other than plants, which employ oxygenic photosynthesis
- They range in size from picoalgae, less than 1 μm in diameter, up to giant kelp with fronds up to 60 m long
- Yes, Didymo mosphenia is a diatom and a microalga; like other microalga, when present in huge numbers it can form visible clumps
- We are referring in this talk mostly to

  freshwater microalgae



The black thing is a human hair!

A short history of algae 2: Megayears BCE to 1999

Millions of years BCE:

Fossil bio-oil, or petroleum, is thought to have been formed by the action of temperature pressure, time and catalysis on submarine sedimentary deposits of biomass, mainly phytoplankton [including marine algae].

This is the 'biogenic' view of the origin of oil, largely accepted by most scientists.

An alternative, the 'abiotic' or 'chemical' view, is espoused by a few scientists and said to be quite widely accepted in some areas of the former Soviet Union.

A short history of algae 3: Megayears BCE to 1999

Microalgae have been used **for food**:

Mainly Spirulina and Chlorella, others under study

This site is in Hawaii.

A short history of algae 3: Megayears BCE to 1999

Microalgae have been used for pharmaceuticals:

Table 7-6. *Published studies and unpublished experiments on potential therapeutic applications of Spirulina*

Application	Subject	Reference
External wounds	Humans	Clément, Rebeller, & Zarrouk 1967; Yoshida 1977
Infection (antibiotic action)	Microbial cells	Martinez Nadal 1970; Jorjani & Amirani 1978
Pesticide poisoning	Human cells	Matsueda et al. 1976
Hypothyroidism	Poultry	Babaev et al. 1979, 1980
Infection (immune stimulation)	Rabbits	Besednova et al. 1979
Hypercholesterolemia	Rats	Chen et al. 1981; Devi & Venkataraman 1983b; Kato et al. 1984
Obesity	Humans	Nakaya et al. 1986
Oral cancer	Humans	Becker et al. 1986
Hypochromic anemia	Human cells	Schwartz and Shklar 1986
Diabetes	Humans	Takeuchi 1978[a]
Hepatitis, cirrhosis	Humans	Takeuchi 1979[a]
Pancreatitis	Humans	Takeuchi 1979; Miyairi 1982[a]
Cataracts	Humans	Tanaka 1980[a]
Constipation	Humans	Yamazaki 1980[a]
Liver cancer (immune stimulation)	Humans	Sakai 1981[a]
	Mice	Iijima 1982[a]
Iron-deficient anemia	Rats	Takemoto 1982[a]
Stress ulcer	Rats	Takemoto 1982[a]
Allergy	Humans	Watanabe 1982[a]
Hypertension	Rats	Iwata 1984[a]

Lembi & Waaland [Ed] 1988

BUT

"… the scarcity of warranted information does not preclude the possibility that certain microalgal species may possess properties that are of distinct therapeutic value."

Becker 1994

A short history of algae 3: Megayears BCE to 1999

Microalgae have been suggested for:

- heavy metal cleanup from wastewater
- protein production [cf soya beans]
- hydrogen production
- human life support in space
- etc.

Chris's 20 minutes

Algae for biofuel, 2000-2007

Solvent Rescue 1999

Multinat enquiry 2000

Kelly Anderson 2002

Colleen McGlone and Elizabeth Peate 2003

SCWR development

A2B 2005; mini-HRAPs and Waihi algae

Striking oil!

Overseas corporate

November 2007

Growing Algae

Use sewage water output

(scaled version)

Encourage further algae growth in racetrack ponds

Picture here of algae harvest from another source (need to get their permission for this one.)

Harvest Algae

Discharge Clean Water

Algae Oil Extraction Process

Harvested Algae

Any suggestions on pictures we could put here?

Confidential

Water Extraction Process

Confidential

Oil Separation Process

Biocrude Oil

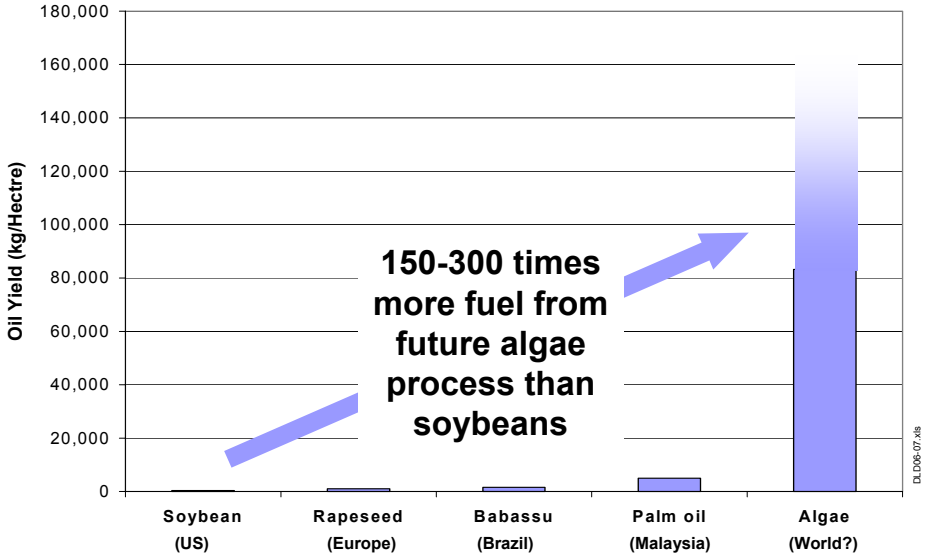
Biojet fuel production process

Biocrude Oil

Refining Process

Biojet Fuel

Other future oil-yielding feedstocks may hold more promise for large scale biofuel production



Using Algae feedstock, the WORLD's airline fleet biofuel needs might be more easily met

If the world airline fleet used 100% biojet fuel from algae, it would require 85B gallons

World Fleet in 2004

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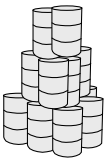
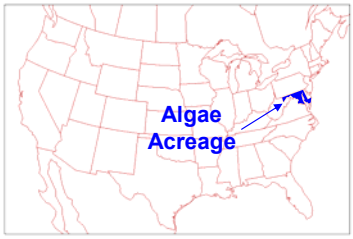


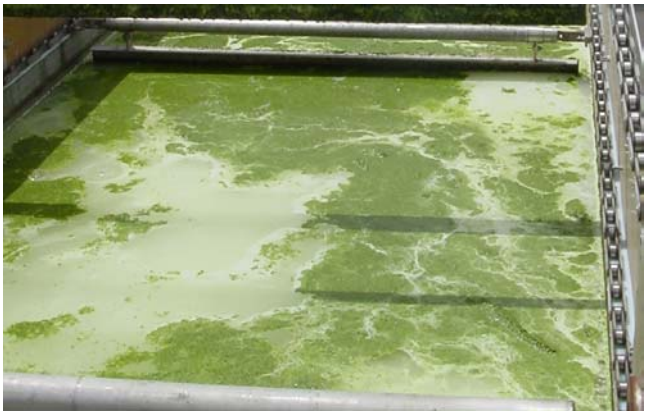
85B Gallons
(322B Ltr) Bio-jet

This would require 8.5M acres of land (about the size of Maryland)



8.5M acres
(3.4M Hectares)
algae
(@ 10,000 US gal/acre)

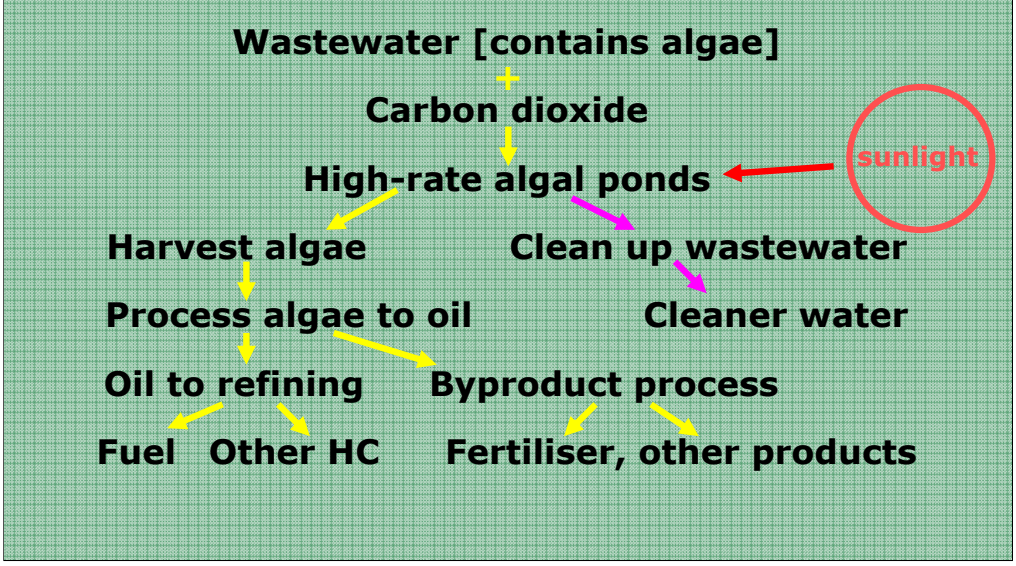
Oil from algae

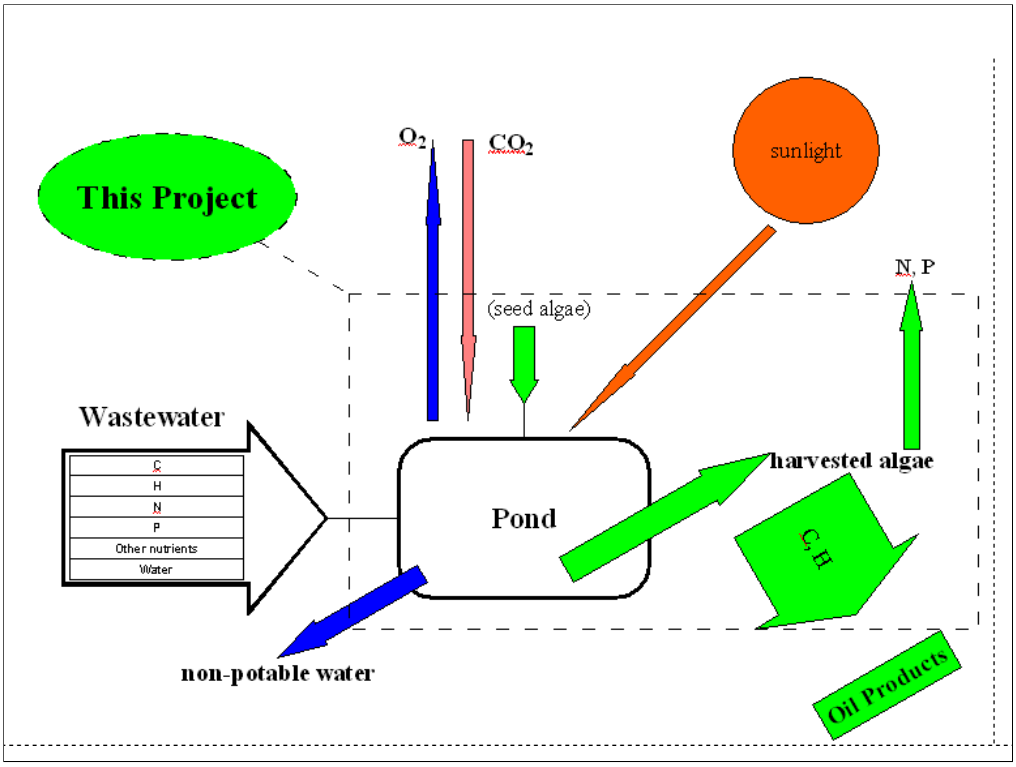


Acknowledgement:
Hauraki District Council

Feedstock: algae grown on wastewater

The whole algae for fuel process




This Project
O_2
CO_2
sunlight
N, P
(seed algae)
Wastewater
C
H
N
P
Other nutrients
Water
Pond
harvested algae
C, H
non-potable water
Oil Products

Dexcel APS, Hamilton

Oil from algae

Image acknowledgement: Duncan Shaw-Brown, UC

Feedstock: algae grown on wastewater [or …]

Preliminary growing and processing trials under way

Chris's 5 minutes

Algae, Oil, Christchurch and NZ

Where to from here?

In conclusion

- This is no time for conclusion!
- We are right in the thick of it now
- Progress is very promising
- We have science, engineering and commercial challenges and opportunities
- **Watch this space!**

{and thanks for listening}

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