ALGAE, A NEW GOLD RUSH?

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NEWSPAPER HEADLINES

Kweekvijver van algen op Chemie Park
Toepassingen in vervaardiging en biobrandstof

Algen zijn het groene goud

KLM vliegt in 2010 op algen
Dure vliegtuigbrandstof en CO2-uitstootrechten maken algenkerosine zeer lucratief

Ook Unilever denkt na over algen

Bankiers geloven in algengekte
Oil versus Algae

Algae, some facts

Algae, the business

Algae and applied research
Crude oil, gas and coal are formed 100 to 300 million years ago from plants, microbes and algae, resulting in a complex liquid consisting out of 10,000 compounds.

Main compounds

Alkanens $C_x H_y$
Cycloalkanes
Aromates
The refinery of crude oil

- 100% crude oil
  - 70% diesel and fuel oil
  - 20% gasoline & nafta
  - 10% other compounds
    - 13% transport fuel car
    - 7% commodities for the chemical industry
      - 4% polymers
      - 3% chemicals
PRODUCTS FROM CRUDE OIL

benzine, diesel, kerosine, antivries, schoonmaakmiddelen, medicijnen, aspirine, verf, autolak, luiervloeistof, insecticiden, kunstmest, oplosmiddelen, remvloeistof, verpakkingsmateriaal, kogelvrijevesten, textiel, cd/dvd, flessen, airbags, computerkasten, buizen, leidingen, boten, auto-onderdelen, sportartikelen, zuignappen, (auto)banden transport fuel, cleaning agents, pharmaceuticals, paint, solvents, packaging materials, textiles, CD/DVD, Bleu ray, bottles, tubes, car parts, boats, computer housing, furniture, tires
### Turnover of the world largest companies

<table>
<thead>
<tr>
<th>nr</th>
<th>COMPANY</th>
<th>turnover 2010 (billion $)</th>
<th>turnover 2009 (billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wal-Mart</td>
<td>408</td>
<td>415</td>
</tr>
<tr>
<td>2</td>
<td>Shell</td>
<td>285</td>
<td>458</td>
</tr>
<tr>
<td>3</td>
<td>ExxonMobil</td>
<td>284</td>
<td>442</td>
</tr>
<tr>
<td>4</td>
<td>BP</td>
<td>246</td>
<td>367</td>
</tr>
<tr>
<td>5</td>
<td>Toyota</td>
<td>204</td>
<td></td>
</tr>
</tbody>
</table>

Figures from Fortune 500, CNN)
Algae are a large and diverse group of simple, typically autotrophic organism, ranging from uni-cellular to multicellular forms, typically 2 to 20 microns. They are photosynthetic like plants and simple because their tissues are not organized into many distinct organs.
ALGAE AND CRUDE OIL

Photo synthesis

$$6 \text{CO}_2 + 6 \text{H}_2\text{O} \rightarrow C_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$$
# Compounds within algae

<table>
<thead>
<tr>
<th>Alga</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Lipids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anabaena cylindrica</td>
<td>43–56</td>
<td>25–30</td>
<td>4–7</td>
</tr>
<tr>
<td>Aphanizomenon flos-aquae</td>
<td>62</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>Chlamydomonas rheinhardii</td>
<td>48</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Chlorella pyrenoidosa</td>
<td>57</td>
<td>26</td>
<td>2</td>
</tr>
<tr>
<td>Chlorella vulgaris</td>
<td>51–58</td>
<td>12–17</td>
<td>14–22</td>
</tr>
<tr>
<td>Dunaliella salina</td>
<td>57</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>Euglena gracilis</td>
<td>39–61</td>
<td>14–18</td>
<td>14–20</td>
</tr>
<tr>
<td>Porphyridium cruentum</td>
<td>28–39</td>
<td>40–57</td>
<td>9–14</td>
</tr>
<tr>
<td>Scenedesmus obliquus</td>
<td>50–56</td>
<td>10–17</td>
<td>12–14</td>
</tr>
<tr>
<td>Scenedesmus dimorphus</td>
<td>8–18</td>
<td>21–52</td>
<td>16–40</td>
</tr>
<tr>
<td>Spirogyra sp.</td>
<td>6–20</td>
<td>33–64</td>
<td>11–21</td>
</tr>
<tr>
<td>Arthrospira maxima</td>
<td>60–71</td>
<td>13–16</td>
<td>6–7</td>
</tr>
<tr>
<td>Spirulina platensis</td>
<td>46–63</td>
<td>8–14</td>
<td>4–9</td>
</tr>
<tr>
<td>Synechococcus sp</td>
<td>63</td>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>
# Algae biomass in comparison with other crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>ton/ha/jr (dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>20-100</td>
</tr>
<tr>
<td>Palmoil</td>
<td>10</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>3</td>
</tr>
<tr>
<td>Soya</td>
<td>1 – 2,5</td>
</tr>
<tr>
<td>Jathropha</td>
<td>7-10</td>
</tr>
<tr>
<td>Sunflower</td>
<td>3-5</td>
</tr>
</tbody>
</table>

![Bar chart showing liter olie per hectare](chart.png)

- **Koolzaad**: Green bar
- **Palmolie**: Blue bar
- **Algen**: Purple bar
CO₂ SEQUESTRATION

Grow of 1kg algae sequesters 2 kg CO₂

1 ha sequesters between 100 en 150 ton CO₂

This is much more effective than all other crops

The Earth

Total natural algae population sequesters 450 billion tons CO₂ (estimate) and is responsible for 50% of the total oxygen production, the other half is produced by trees and green plants.
De value pyramide
## Algae market

<table>
<thead>
<tr>
<th>Algae products</th>
<th>Value (€ / ton)</th>
<th>Size World market / jaar (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutraceuticals</td>
<td>10.000-100.000</td>
<td>60 – 100 milion</td>
</tr>
<tr>
<td>Fish- and feed</td>
<td>500 - 5000</td>
<td>3 - 4 billion</td>
</tr>
<tr>
<td>Bulk materials</td>
<td>500 - 1200</td>
<td>10- 50 billion</td>
</tr>
<tr>
<td>Transport fuels Energy</td>
<td>&lt; 500</td>
<td>&gt; triljard</td>
</tr>
<tr>
<td>CO₂ credits</td>
<td>In development</td>
<td></td>
</tr>
</tbody>
</table>
One big difference
oil and algae business

Crude oil / natural gas
was and still is available in large quantities

Algae (and other biomass) have to be produced
Start of applied research

Oil crisis 1970
Rise of the Aquatic Species Program in the US
Biodiesel from algae (1978-1996)

Several European countries developed expertise in several laboratories

Japan concentrated on offshore bio-reactors

In the Netherlands
2000 - 2003 EET (Energie, Ecologie en Technologie) project,
expertise within different institutes WUR/ECN/ UvA
The yields are disappointing regarding the theoretical expectations.

The costs are higher than expected.

The growing of algae is possible in open ponds and the optimal climate conditions are known.

3000 algae species have been evaluated and the top 300 has been stored in an algae databank hosted by the University of Hawaii and is still available.
US and Europa
same knowledge background

Different approaches to develop the algae business
THE AMERICAN DREAM

Solix Biofuels
An area as big/small as Idaho can supply all algae to replace the crude oil demand of the US.

An area as big/small as Portugal is able to supply the demands of Europe.

3% of the total ocean area is able to provide the crude oil demand of the whole world.
EUROPEAN DREAM

More divers

Pharmaceutical products
Cosmetics
Fish feed / feed
Bio plastics
Water treatment
Cradle to cradle

Bio diesel, Kerosine
Green Gas
Ethanol
Production Process

Algae Selection

Grow

Harvesting

Final product

Drying

Refinery

Final product

Final product

Final product
Process

Algenkweek
- Open vijver
- Hybride systeem
- Foto bioreactor
  - A
  - B
  - C (D, E...)

Oogsten
- Floculatie
- Centrifugatie
- Micro-filtratie
- Decanteren

Drogen
- Trommel drogen
- Vriesdrogen
- Droogmolen
- Sproei drogen
- Zon drogen

Raffineren
- Mechanische pers
- Oplosmiddel extractie
- Enzymatisch
- Sonicatie
- Super kritisch CO2

Producten
- droge algenmassa
- olie
- residu
- eiwitten
- koolhydraten
- diesel
- mest
- food
- Ω vetzuren
- feed
- aminozuren
- ethanol
Growing systems

Open Systems

“Raceway ponds”

Closed Systems

State of the art
Companies

Profitable

Mera farmaceuticals, Hawaii, specific patented process, β carotene, divers.

Earthrise VS, spirulina, food supplements

Algatech, Israel, asthaxathin

Cognis, Australia, β carotene

Seambiotic, Israël, asthaxathin, β carotene

BleuBioTech GmbH, production location China, products spirulina, food supplements, cosmetics.
## Overview Companies I

<table>
<thead>
<tr>
<th>Company</th>
<th>Grow system</th>
<th>Weast streams</th>
<th>Dessert</th>
<th>Water</th>
<th>Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2BE Carbon Capture</td>
<td>reactors</td>
<td>+</td>
<td>+</td>
<td>sweet/salt</td>
<td></td>
</tr>
<tr>
<td>Algaewheel</td>
<td>ponds</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XL Renewables</td>
<td>ponds</td>
<td>+</td>
<td>+</td>
<td>salt</td>
<td>Union of farmers Venture</td>
</tr>
<tr>
<td>Algenol Biofuels</td>
<td>reactors</td>
<td></td>
<td></td>
<td></td>
<td>Venture</td>
</tr>
<tr>
<td>Cellana</td>
<td>hybride</td>
<td></td>
<td></td>
<td>salt</td>
<td>o.a. Shell for sale</td>
</tr>
<tr>
<td>Petrosun</td>
<td>ponds</td>
<td></td>
<td>+</td>
<td>salt</td>
<td>Bedrijf</td>
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<tr>
<td>Greenfuel Technology</td>
<td>reactors</td>
<td>+</td>
<td>±</td>
<td>±</td>
<td>Early venture bankrupt cy</td>
</tr>
<tr>
<td>Company</td>
<td>Grow system</td>
<td>Waste stream</td>
<td>Dessert</td>
<td>Water</td>
<td>Capital</td>
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<td>------------------</td>
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<td>----------------------</td>
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<tr>
<td>Solix Biofuels</td>
<td>Reactors in water</td>
<td>±</td>
<td>sweet</td>
<td></td>
<td>venture</td>
</tr>
<tr>
<td>Greenstar</td>
<td>divers</td>
<td></td>
<td></td>
<td>salt</td>
<td>venture</td>
</tr>
<tr>
<td>Sapphire Energy</td>
<td>Special reactor</td>
<td>+</td>
<td></td>
<td></td>
<td>Venture Bill Gates</td>
</tr>
<tr>
<td>Solazyme</td>
<td>dark reactor, sugar input</td>
<td>sweet</td>
<td></td>
<td></td>
<td>large (oil) companies</td>
</tr>
<tr>
<td>Martek</td>
<td>dark reactor, sugar input</td>
<td></td>
<td></td>
<td></td>
<td>Sold to DSM</td>
</tr>
<tr>
<td>Aurora Biofuels</td>
<td>hybride</td>
<td></td>
<td></td>
<td>sweet</td>
<td>Venture, DARPA</td>
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<tr>
<td>Blue Marble Energy</td>
<td>harvesting the sea</td>
<td>+</td>
<td></td>
<td>salt</td>
<td>Venture</td>
</tr>
</tbody>
</table>
## The Netherlands

**Netherlands**
- AlgaeLink B.V. reactors
- Aquaphyto B.V. ponds
- Ingrepro B.V. ponds
- Lgem B.V. reactors
- AFF B.V. reactors
- Procede B.V. research
- Algaecom VOF reactors

**Belgium**
- Proviron B.V. developing reactors
- SBAE Industrie Bankruptcy 2011 (venture)
### Rest of the world

<table>
<thead>
<tr>
<th>Country</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Large projects, 80 ha</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Aquaflow Bionomic Corporation</td>
</tr>
<tr>
<td>Germany</td>
<td>Novagreen GmbH</td>
</tr>
<tr>
<td></td>
<td>Subitec GmbH, Frauenhofer</td>
</tr>
<tr>
<td></td>
<td>Phytololutions GmbH, Jacobs Universiteit Bremen</td>
</tr>
<tr>
<td>Italy, Spain, Portugal, Tsjechië</td>
<td>University spin offs</td>
</tr>
<tr>
<td>Asia</td>
<td>China, aqua culture, production spirulina</td>
</tr>
<tr>
<td></td>
<td>Japan, research</td>
</tr>
<tr>
<td></td>
<td>India, start of many different activities, bio diesel</td>
</tr>
</tbody>
</table>
Project “Algen voor een schoner wad”
Largest pilotplant in the Netherlands in symbiose with a chemical plant
Cooperation Zeolyst NV, Waterbedrijf Groningen, Algaecom and BN Algen

- Low cost reactor
- Outdoor
- Innovative harvesting system
- Waste streams
- Testing the process in winter conditions
Algaecom specializes in world wide knowledge about available algae technology

Algaecom develops a protein algae market focusing on the Netherlands and Germany

Algaecom develops state of the art pilot projects based on waste streams
Contribution of applied universities to the green gold

Depends on the vision how innovation works and how “praktijkgericht” research is interpreted
soort activiteit
verlopen tijd
fundamenteel onderzoek
toegepast onderzoek
technologie ontwikkeling
product ontwikkeling
product op de markt

universiteiten
instituten grote bedrijven starters
grote bedrijven starters

benodigde investeringen

Private bijdrage
Durfkapitaal
Banken
Fiscale bijdragen

25% subsidie
Private bijdrage
Durfkapitaal

50% subsidie
Private bijdrage

Onderzoekssubsidie
Onderwijsgeld
Private bijdrage

www.hanzehogeschool.nl/lectoraten

Private bijdrage
Durfkapitaal
Banken
Fiscale bijdragen

soort activiteit
verlopen tijd
PLATINUM TRI ANGLE

INVESTMENTS

ACTIVITY

TIME

fundamenteel onderzoek

toegepast onderzoek

technologie ontwikkeling

product ontwikkeling

product op de markt

product development

technology development

SME
## NEW BUSINESS DEVELOPMENT

<table>
<thead>
<tr>
<th>Phase</th>
<th>technologie</th>
<th>product ontwikkeling</th>
<th>markt</th>
<th>organisatie</th>
<th>financiën</th>
<th>netwerk</th>
<th>regelgeving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea phase</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
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<tr>
<td>Development Phase</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Demonstration Phase</td>
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<td>✔</td>
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<td>Market Introduction</td>
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<td>✔</td>
<td>✔</td>
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</tr>
<tr>
<td>Promotion Phase</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Stable situation</td>
<td></td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>
ROLE OF APPLIED UNIVERSITIES

- idea generation
- literature searches
- technology development
- market analysis
- business models
- facilities

Publications
Knowledge transfer
Implementation higher education
New companies

Regular business
The Conversation
The Art of Listening, Learning, and Sharing

Brigitte Boeck and JESS3
“ALGAE BUSINESS” OPPORTUNITIES

Waste management

Sequestering CO₂
- Carbon credits
- Green image

Water treatment
- Reduction of nitrates and fosfates
- Reduction of heavy metals

Production of valuable compounds

Bulk products
- bio fuel
- feed/fish feed
- proteïnes

Fine chemicals
- Carotenoids
- Omega fatty acids
- Amino acids
Final Conclusion or Message,

There are so many interesting subjects to develop regarding the bio based economy
So, just start and cooperate in open innovation programs to transfer algae, but also other biomass, into green gold

Aiming for a new generation people thinking “green”