Algae production systems

Open or Closed or ...
Lessons learned from the last 3 years

Marc Van Aken
CEO
SBAE Industries NV
The Company

- Founded in 2006
- Crossroads of engineering and applied science
- Four investment funds, including one of Europe’s largest cleantech investment funds
- Leading strategic IP
- Operational algae production facilities
## Anyone say algae?

<table>
<thead>
<tr>
<th>Division</th>
<th>Common Name</th>
<th>Marine</th>
<th>Freshwater</th>
<th>Terrestrial</th>
<th>Symbiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanophyta</td>
<td>Blue-green algae</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Prochlorophyta</td>
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<td>n.d.</td>
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<td>Rhodophyta</td>
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<td>Heterokontophyta</td>
<td>Golden algae</td>
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<td>Yes</td>
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<td></td>
<td>Yellow-green algae</td>
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<td>Yes</td>
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<tr>
<td></td>
<td>Diatoms</td>
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<td></td>
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<tr>
<td></td>
<td>Brown algae</td>
<td></td>
<td></td>
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<tr>
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<tr>
<td>Haptophyta</td>
<td>Coccolithophorids</td>
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<td>Cryptophyta</td>
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<td>Chlorarachniophyta</td>
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<tr>
<td>Dinophyta</td>
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<td>Euglenophyta</td>
<td>Euglenoids</td>
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<tr>
<td>Chlorophyta</td>
<td>Green algae</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tr>
</tbody>
</table>
The tree of life
Where do we find algae?

Here !

Here !

Here as well !

Not Here ....

And Here !
Differences in biology

“algae” are a very diverse group
this has implications for the production methods
Some common ground

- Light – highly efficient users
- Carbon source – mainly CO$_2$
- Water - OK
- Nutrients – NPK
“Founding father”

Martinus Willem Beijerinck
1890
Cultivation? Some books...

Cultiver L’océan
Maurice Aubert
1965

Microalgae
Wolfgang Becker
1994

Algal culturing techniques
Robert Andersen
2004
Cultiver l’océan

1965

• 3 methods of algae cultivation
  – “American” – closed circuit with circulating air
  – “German” – open circuit with circulating air
  – “Japanese” – open circuit with rotating arms
A common dichotomy

- Today’s agenda!
- Different PBRs
  - Horizontal
  - Vertical
  - Tubular
  - Flat panel
  - ....

ALGAE CULTIVATION

Planktonic
Free floating in the water

Open system
Ponds (HRAP)

Closed system
Photobioreactor
This is how we “do” it at SBAE ... 

A look inside
Cultivation – The big picture

- **Light**
- **Water & Nutrients**
- **Algae X inoculation**
- **CO₂**
- **Purified air**

Algae X Cultivation

- **Algae X Fluid**
Post processing
application dependent

Algae Fluid X → Centrifuging → Algae paste X

Algae paste X → Freeze Drying & post treatment → Algae powder X
The applications

- Why go through all this trouble?
  - There is a market!
- Currently sold in the aquaculture industry
  - Mixes of different algae
    - Greenwater
    - Rotifer food
  - Focus on hatcheries
    - Food for fish larvae
    - Critical path
- Can be used as well in nutraceuticals, cosmetics, ...
Does this “scale”? 

- You can put PBRs in different places
  - in a breeding room in a hall
  - in a hall
  - in a greenhouse
  - outdoor
- You can make them in glass or plastic
- Will impact the economic picture
- You have to maintain some control: contamination, temperature, stability, quality, ...
- Scaling: sure; to some extent
Indoor production at SBAE industries ...

Clearly not the answer to the bioenergy question
There is a different way

ALGAE CULTIVATION

Traditional
- Planktonic
  - Free floating in the water
  - Open system
    - Ponds (HRAP)
  - Closed system
    - Photobioreactor
  - Water re-circulates within the system
  - Algae float in the water

Eco-system
- ‘Peri-fyton’
  - Attached on rocks and plants
  - Open system
    - DIAFORCE
  - Water circulates through the system
  - Diatom algae remain fixed
SBAE DIAFORCE imitates nature

Ecosystem Approach
‘Mountain stream’
High hydro-dynamics
Poly-cultures
Fastest growers
Choice of species to grow

Diatom

Poly-Culture

• Growth rate
  – Diatoms need only 6.5% of the energy required by typical algae to build their silica cell wands
  – Diatoms use more of the spectrum of sunlight to produce biomass – more efficient light users
  – Indigenous Diatom Poly-Culture
    • a more stable culture
    • very resistant to invasion by other algae and since the culture is native to the locality, it poses no threat to the local ecosystem
    • is able to exploit all micro niches in the system
  – Diatoms can divide 2 to 4 times per day
Economical harvesting

Attached diatom-algae

Diatoms grow on carriers

Carriers lifted out of the water and algae removed

Less than 1% of total water volume to process
Separation

**Biofuel Feedstock**

- Centrifuge
  - Concentrates biomass
- In-Line extraction
  - Opens silica cell wall of diatoms to release oil in-line with centrifuge process
Conditioning for the right oil

• Poly-Modulation™
  – Uses well known principles in a unique way to induce the Diatoms to produce an additional 20% to 30% triglycerides, ideal for biofuels
  – These are in addition to the content of 5 – 10% phospholipids, typically not as useful for biofuels
Industrial scaling

Continuous and stable production

Ocean water and non agriculture lands

Temperate to tropical regions

Diatom “fuel” farms are an interesting option
Options, options, options

• Algae **industry** is very new, rooted in a long tradition
• Open or closed is not the real issue
• Solutions will have to address numerous challenges in an economical way: contamination/stability, nutrient depletion, photic inhibition, self shading, harvesting, ...
• DIAFORCE is an “out of the box” approach, addressing all of these issues
Food for thought

• What are the (real) issues?
  – Diatom composition: essential amino acids, essential fatty acids, fytosterols, anti-oxydants, probiotics, vitamins and “energy molecules”
  – Feed for people or for cars (or both)?

• What are the (real) problems?
  – GHG, global warming, peak oil, ...
  – Is there a sense of urgency?
Thank You

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