Algae production systems

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

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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 ?

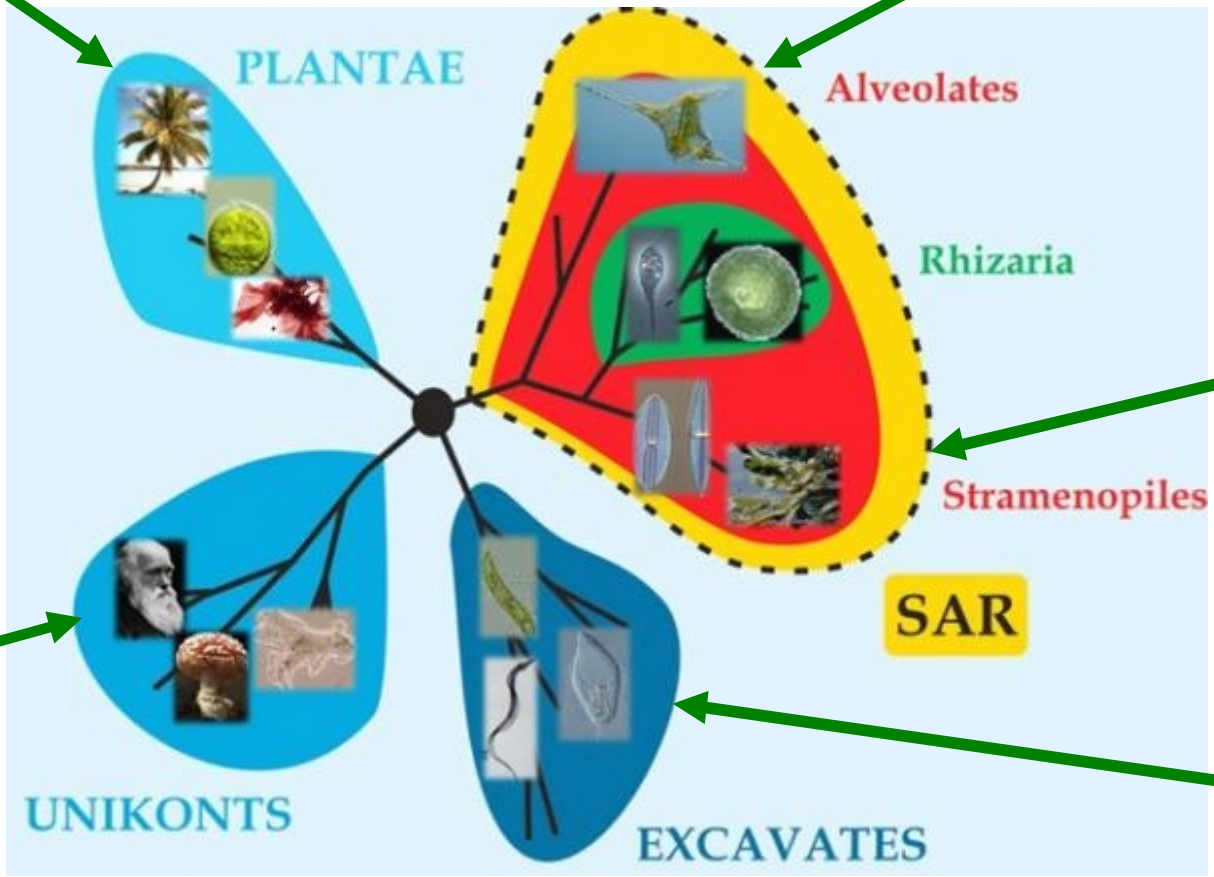
Division	Common Name	Habitat			
		Marine	Freshwater	Terrestrial	Symbiotic
Cyanophyta	Blue-green algae	Yes	Yes	Yes	Yes
Prochlorophyta	n.a.	Yes	n.d.	n.d.	Yes
Glaucophyta	n.a.	n.d.	Yes	Yes	Yes
Rhodophyta	Red algae	Yes	Yes	Yes	Yes
Heterokontophyta	Golden algae	Yes	Yes	Yes	Yes
	Yellow-green algae				
	Diatoms				
	Brown algae				
Haptophyta	Coccolithophorids	Yes	Yes	Yes	Yes
Cryptophyta	Cryptomonads	Yes	Yes	n.d.	Yes
Chlorarachniophyta	n.a.	Yes	n.d.	n.d.	Yes
Dinophyta	Dinoflagellates	Yes	Yes	n.d.	Yes
Euglenophyta	Euglenoids	Yes	Yes	Yes	Yes
Chlorophyta	Green algae	Yes	Yes	Yes	Yes

The tree of life

Where do we find algae ?

Here !

Here !



Here as wel

Not Here ….

And Here !

Differences in biology

"algae" are a very diverse group
this has implications for the production methods

Some common ground

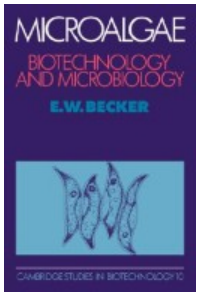
- Light – highly efficient users
- Carbon source – mainly CO_2
- Water - OK
- Nutrients – NPK

“Founding father”

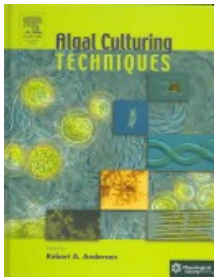
Martinus Willem Beijerinck
1890

Cultivation ? Some books…

Cultiver L'océan
Maurice Aubert
1965



Microalgae
Wolfgang Becker
1994

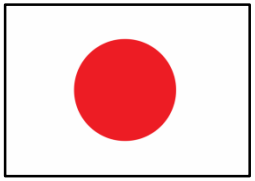


Algal culturing techniques
Robert Andersen
2004

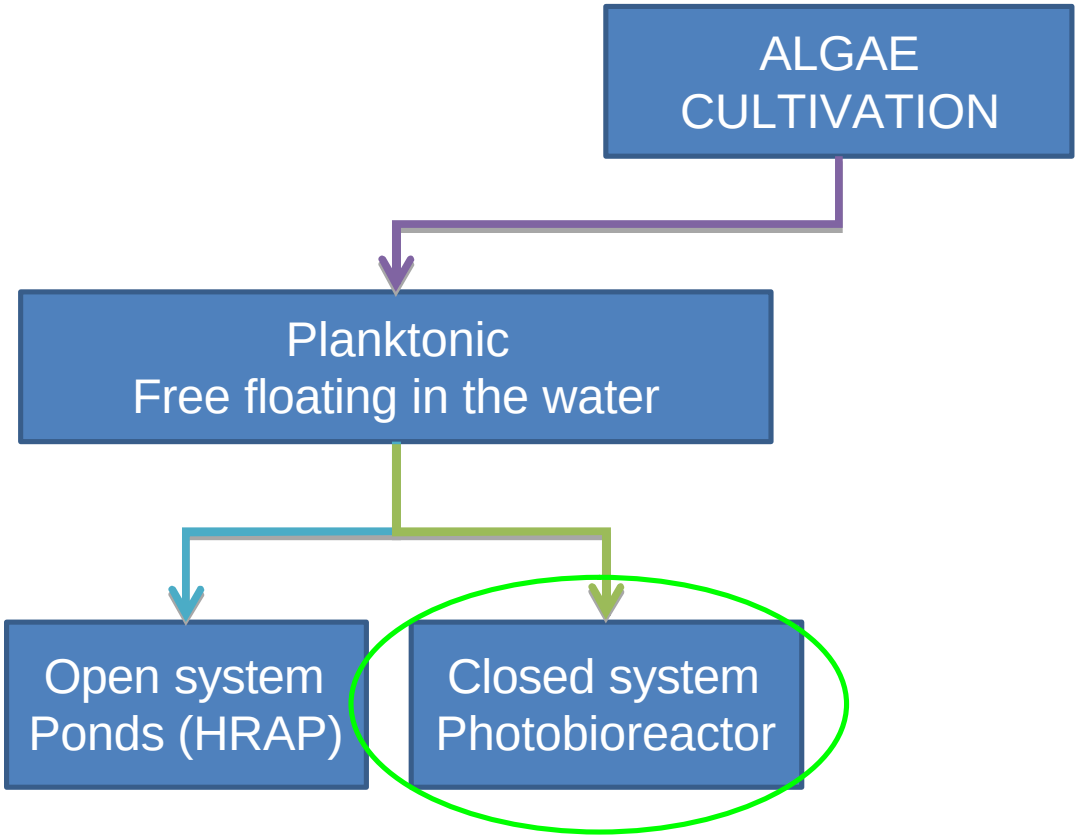
Cultiver l'océan

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

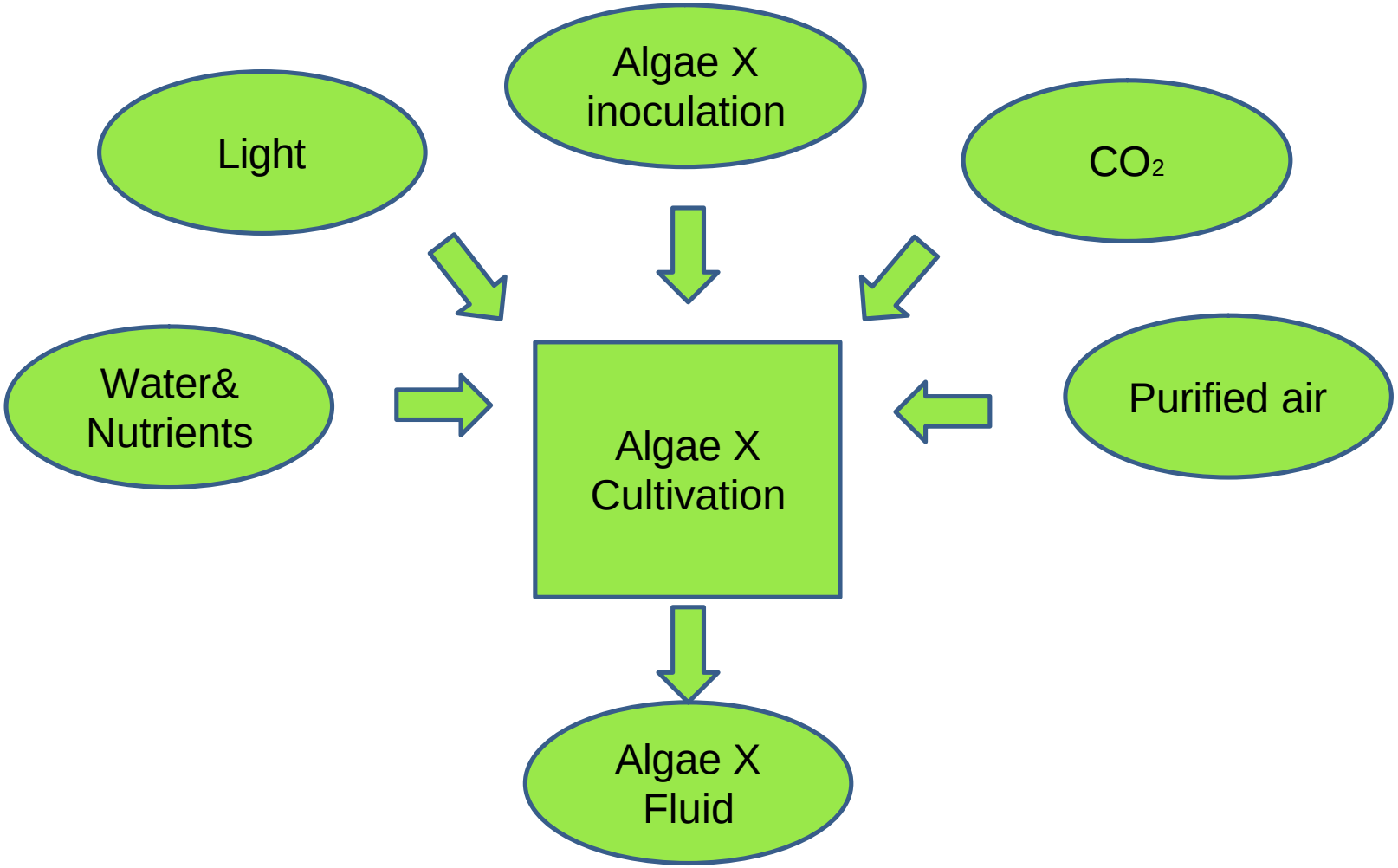


- Today's agenda !
- Different PBRs
  - Horizontal
  - Vertical
  - Tubular
  - Flat panel
  - ....

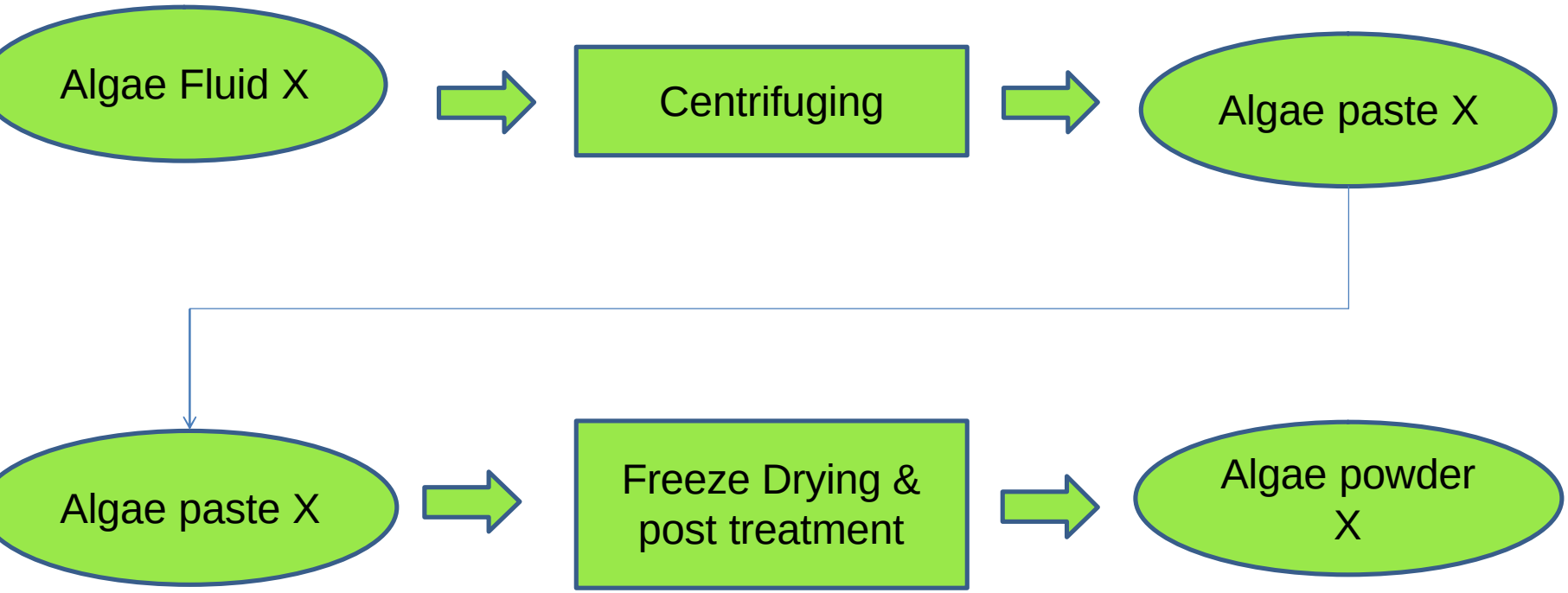
This is how we “do” it at SBAE …

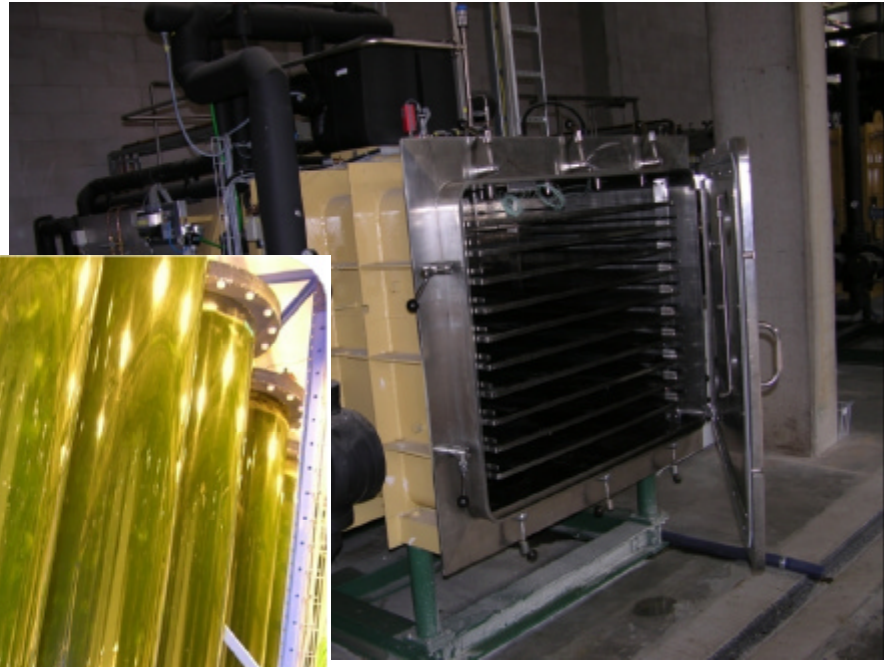
A look inside

Cultivation – The big picture



Post processing
application dependent





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, ...

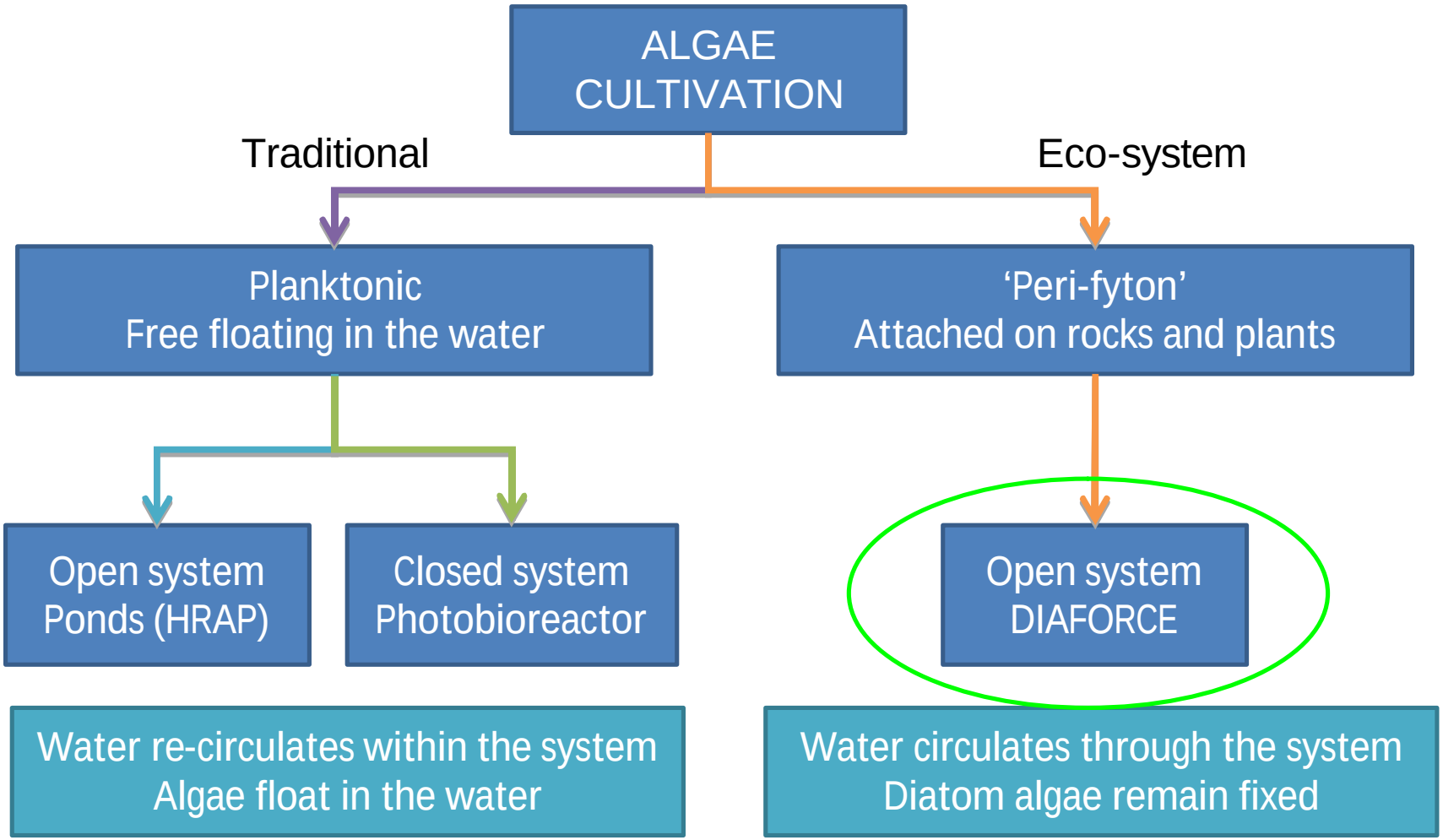
Does this “scale” ?

- 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

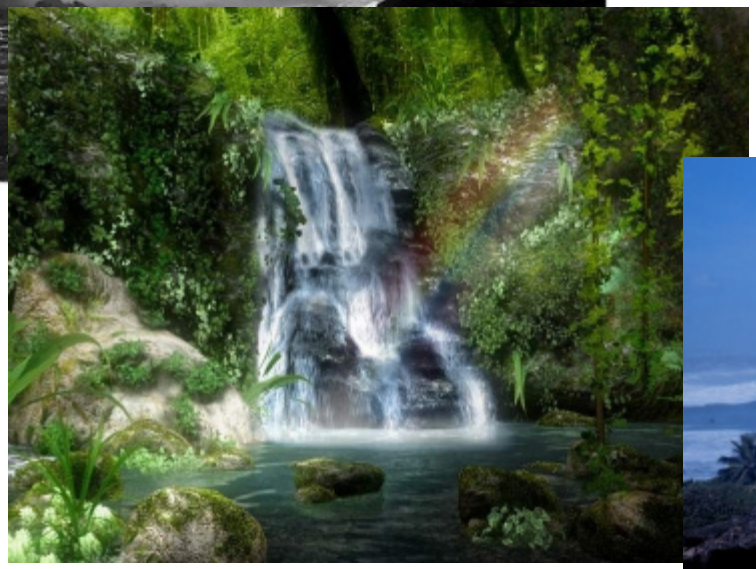
Indoor production at SBAE industries ...

Clearly not the answer to the bioenergy question

There is a different way



SBAE DIAFORCE imitates nature



Ecosystem Approach

‘Mountain stream’

High hydro-dynamics

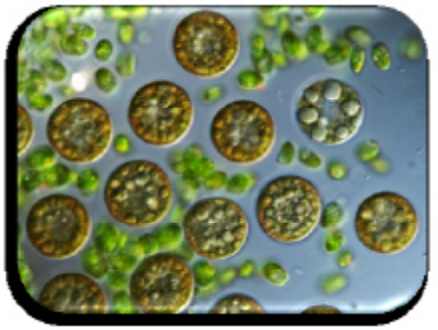
Poly-cultures

Fastest growers

Choice of species to grow

Diatom

Poly-Culture

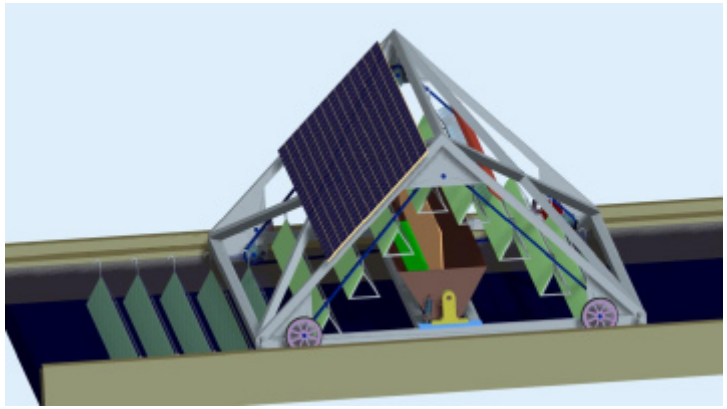


- Growth rate
  - Diatoms need only 6.5% of the energy required by typical algae to build their silica cell wands
  - Diatoms use more of the spectrum of sunlight to produce biomass – more efficient light users
  - Indigenous Diatom Poly-Culture
    - a more stable culture
    - very resistant to invasion 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

Diatoms are the Golden algae

Economical harvesting

Attached diatom-algae



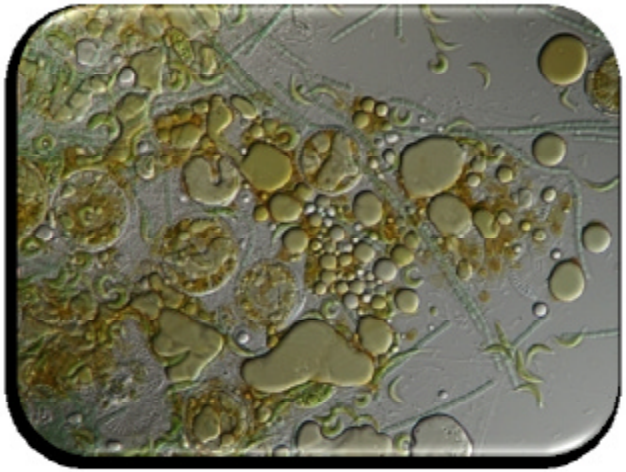
Diatoms grow on carriers

Carriers lifted out of the water and algae removed

Less than 1% of total water volume to process

Separation

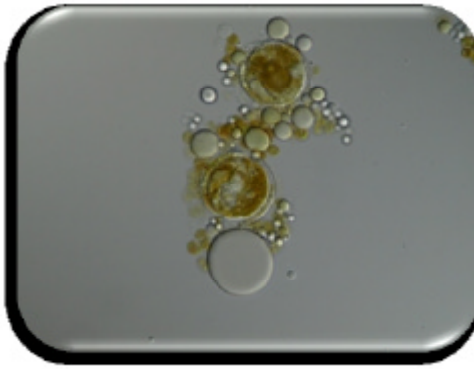
Biofuel Feedstock / Biomass



- 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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