

New types of bioenergy - algae in energy production

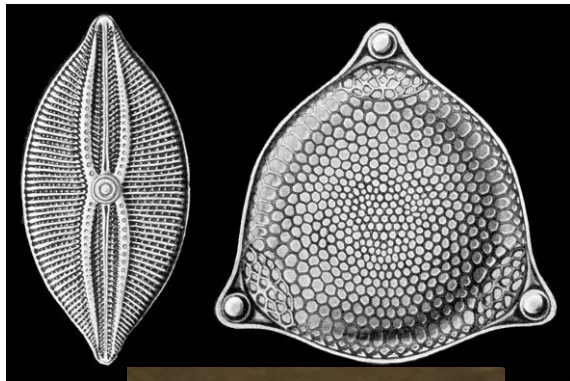
microalgae as raw-material for biofuels

Kristian Spilling

Finnish Environment Institute, SYKE

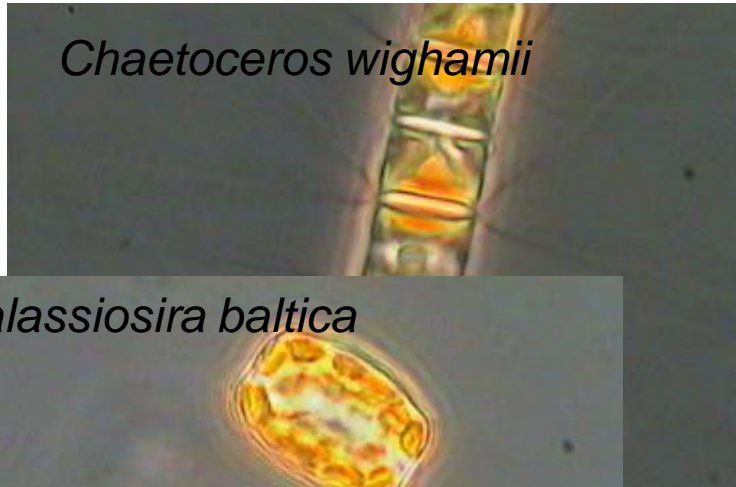
What is algae

- Simple plants (e.g. without roots)
- Macro and micro forms
- Very diverse



Baltic Sea species

Chaetoceros wighamii



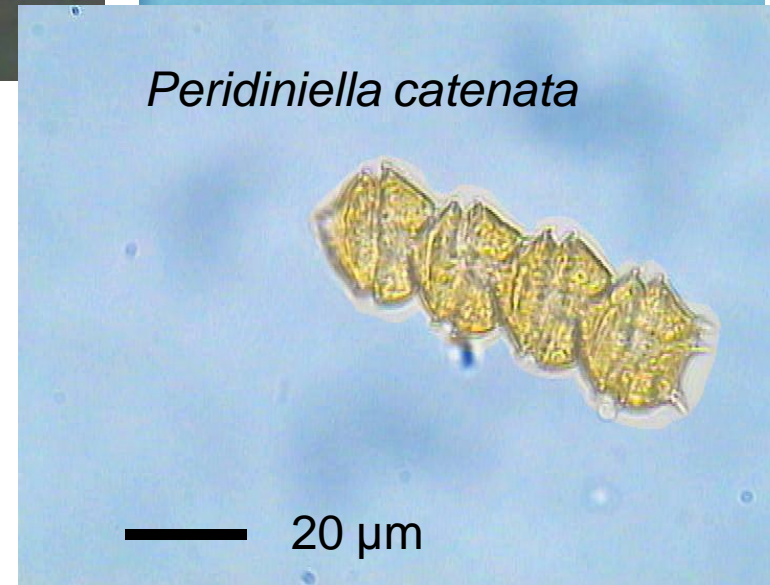
Scrippsiella hangoei



Thalassiosira baltica



Peridiniella catenata

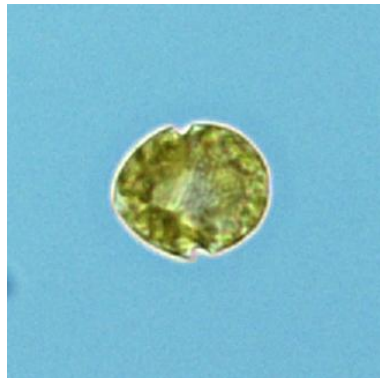
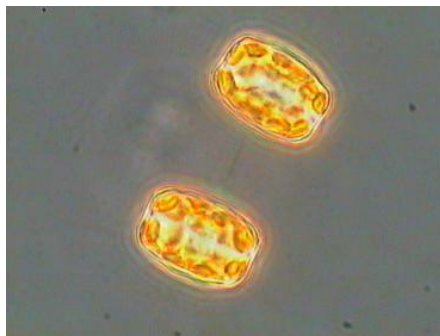


Pauliella taeniata



Micro-algae

- Aquatic, free-floating, unicellular or filamentous (phytoplankton)
- Can be very fast-growing
- Have minimal amounts of structural components



Why planktonic algae? - biology and biochemistry

■ Harvest cycle

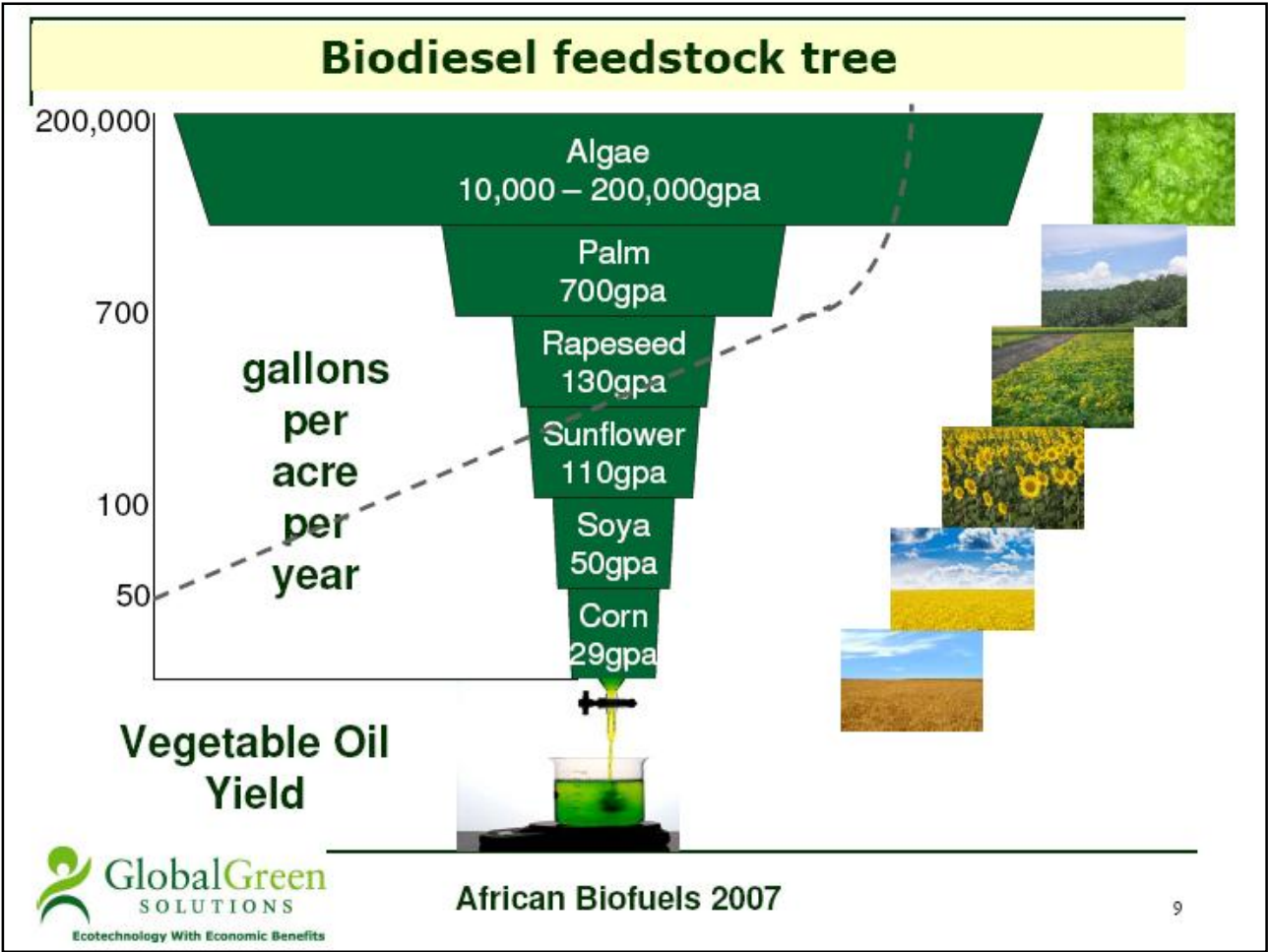
- Forest biomass: years to decades
- Field biomass: months
- Microalgae: days, even hours

■ Biomass composition

- Oil compounds (lipids) can be very high (even 40-60%)

■ Production per area

- Higher to very much higher (2-10 times), compared with the best terrestrial crops



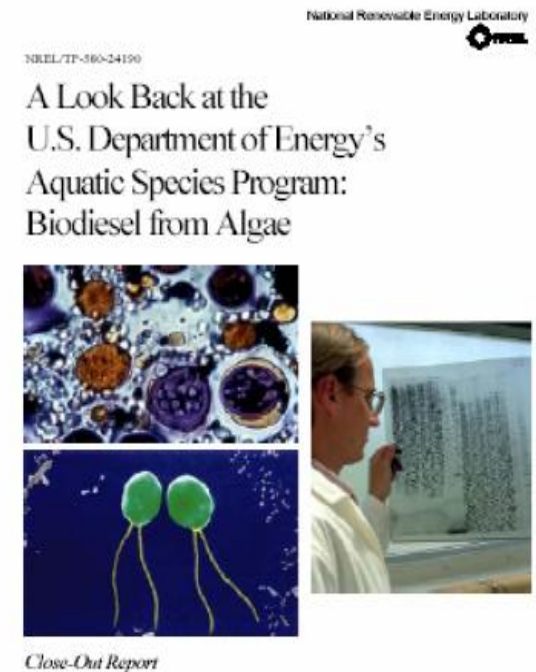
Additional benefits of algae

- Do not compete for fertile land
- Salt or wastewater can be used
- Potentially very positive energy / carbon balance
- Can be coupled with CO₂ producing industry



Research history

- Aquatic Species Program (ASP)
 - USA, 1978-1996
 - Focus on open algal cultivation systems for bio-diesel
- Research for Innovative Technology of the Earth program (RITE)
 - Japan, 1990-2000
 - Focus on closed photobioreactors, CO₂ mitigation and higher value products
- After 2000, renewed focus



Renewed focus on microalgae

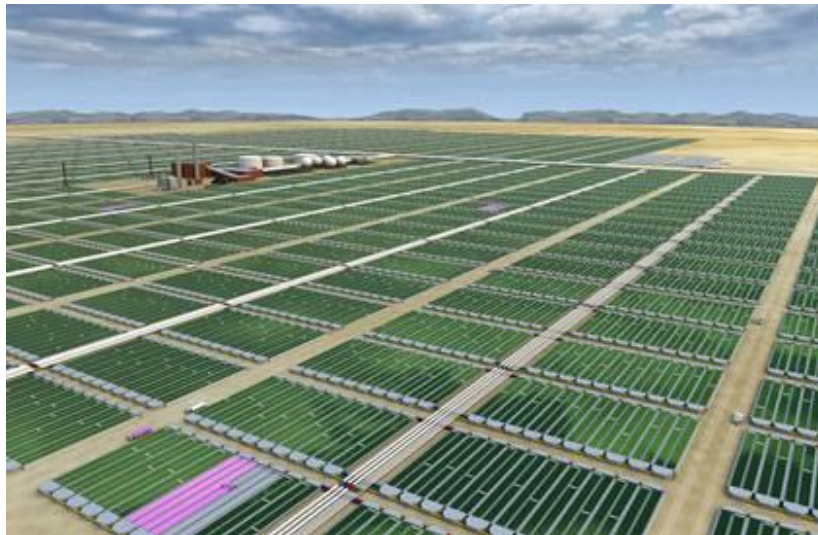
- Political focus on biofuel
 - Climate change
 - Energy independence (high oil price)
 - Biofuel can be used with present infrastructure
- Problems with traditional energy crop
 - Energy vs. food production
 - Biodiversity (e.g. cutting down rain forest)
 - Energy / carbon balance
- Projected raw-material shortage
(EU's target is 10 % biofuels by 2020)

Why biofuels?

- Climate change (CO₂)
 - Biofuels offer a closed carbon loop (in theory)
 - Can be used now (with small modifications)
- What about hydrogen or electric vehicles
 - No-emission-fuel is environmentally the best option (NB! whole life cycle must be taken into account)
 - But it requires full change of infrastructure (takes time)
- What are the alternatives
 - As price of crude oil ticks upwards several alternatives becomes economical viable
 - Most are more polluting than fuels refined from crude oil, e.g. fuel from coal or tar sand

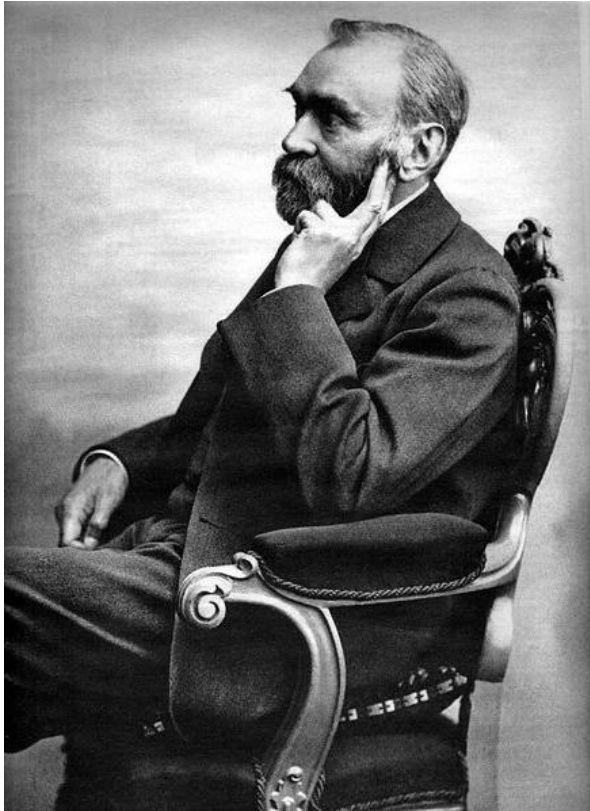
Any bioethical concerns of algal biofuels?

- Need for CO₂ in higher concentration than in air
- Dependence on fossil fuels?
- A lot of CO₂ also from other sources
- More energy output per CO₂ emitted



Solix Biofuels

Applications of algae - dynamite

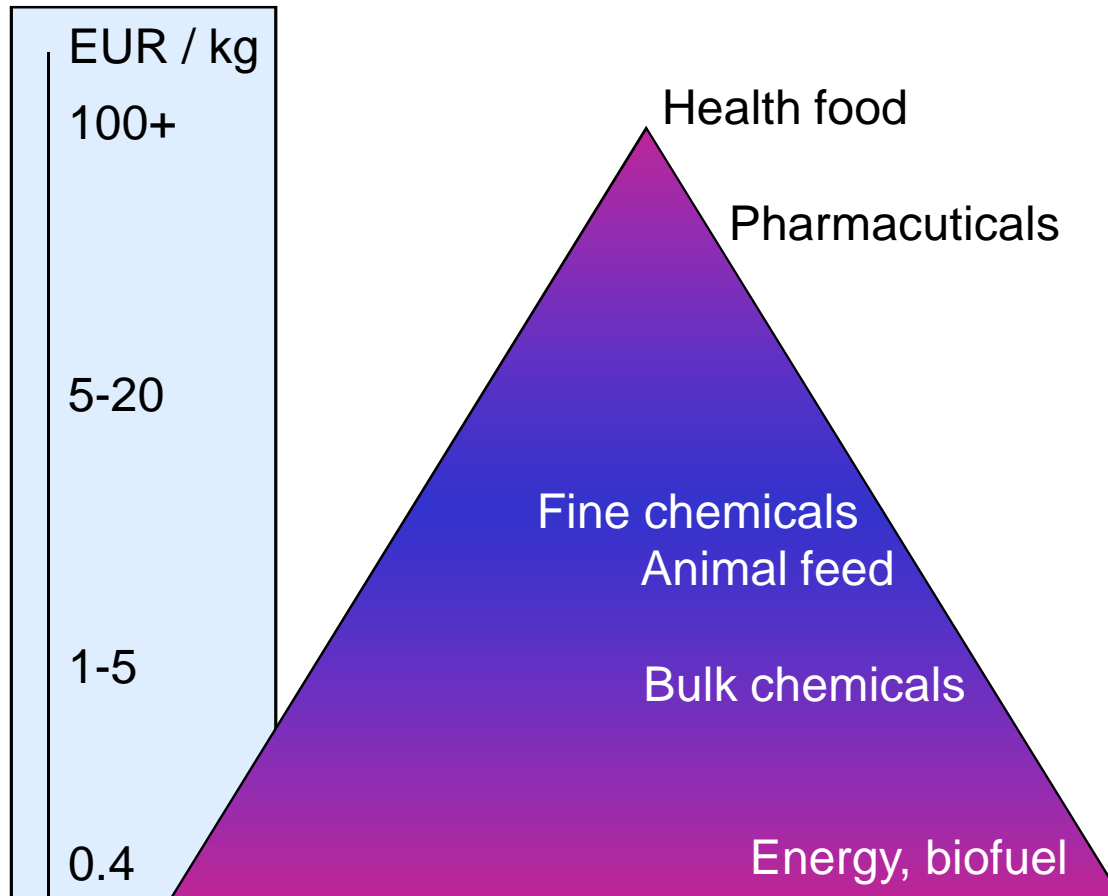


Dynamite = nitroclcyerin + kieselguhr (diatoms)

Applications of algae

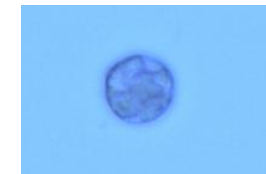
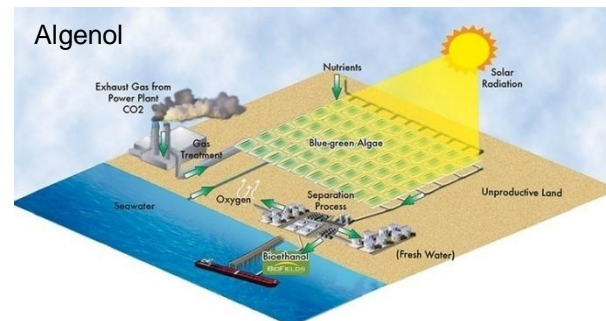
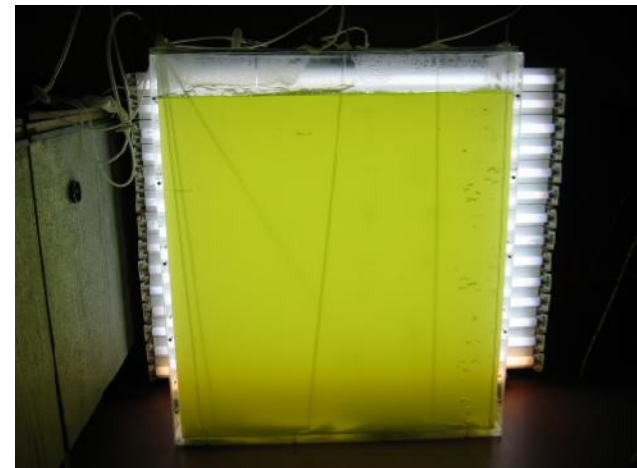


Applications of algae



Technology (product and production method)

- Liquids vs. gas (biogas /methane vs. hydrogen)
- Biodiesel vs. bioalcohol (ethanol) or both
- Closed vs. open systems (or hybrid)
 - Closed - GreenFuel
 - Hybrid - (Shell)
 - Open - Most existing plants today
- Harvesting vs. 'milking'
 - Harvesting - GreenFuel
 - Milking - Algenol



Algal Biofuel Companies

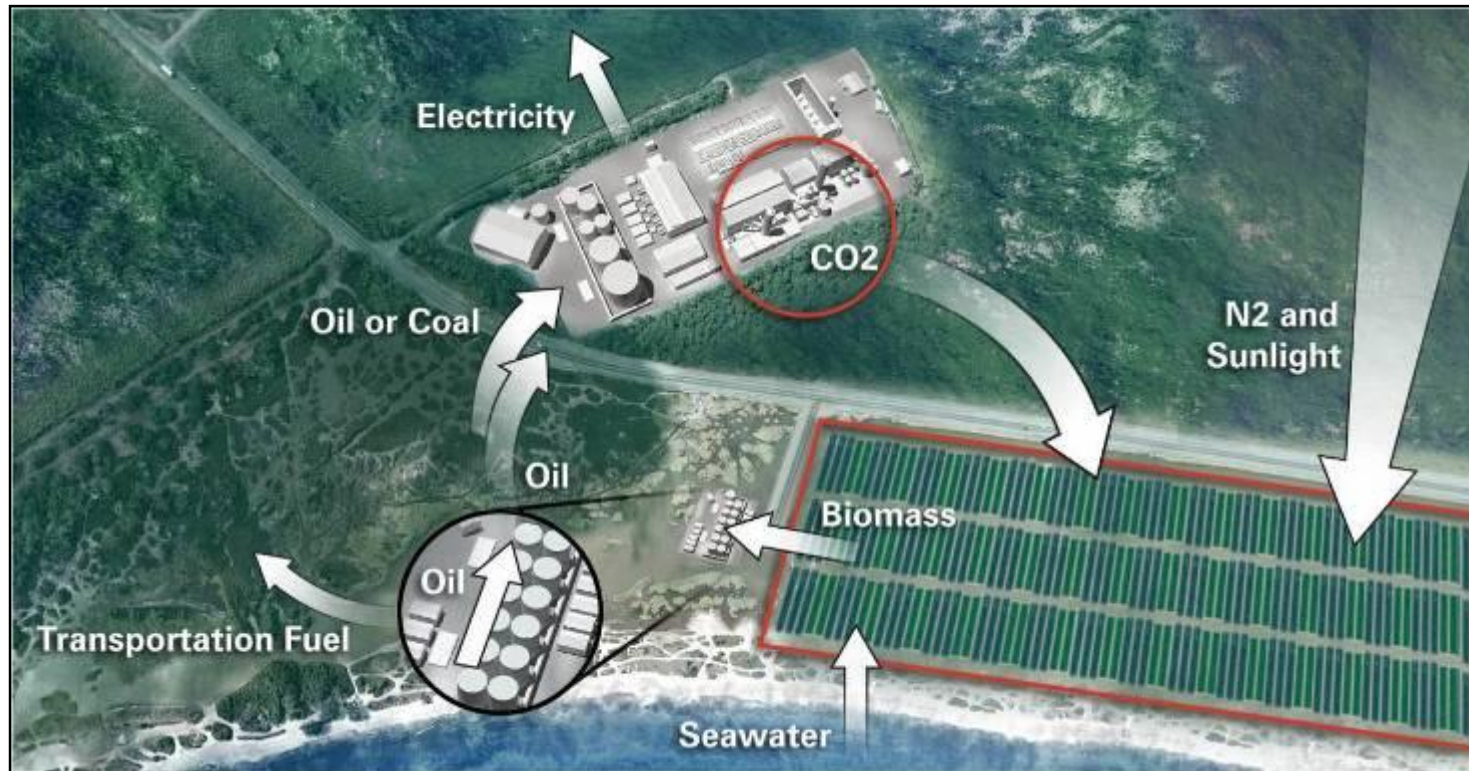
A2BE Carbon Capture LLC
Algae Biofuels
Algae Floating Systems
Algae Fuel
Algae Fuel Systems
Algae Link
AlgalOilDiesel
Algenol
Algodynne
Algoil
Aquaflow Bionomic
Aquatic Energy
Aurora BioFuels Inc.
Bionavitas
BioFuel Systems
Blue Biofuels
Blue Marble Energy
Bodega Algae
Cellena
Cequesta
Chevron
Circle Biodiesel & Ethanol
Community Fuels
Diversified Energy
EnBW
E.ON Hanse
Energy Farms
Enhanced Biofuels & Technologies
General Atomics
Global Green Solutions

Green Star
Greener BioEnergy
GreenFuel Technologies Corp
GreenShift
Growdiesel
GS Cleantech
HR Biopetroleum/Shell
IGV
Imperium Renewables
InfinfuelBiodiesel
Inventure Chemical
Kai BioEnergy
KAS
Kent SeaTech Copr.
Kwikpower
LiveFuels Inc.
Mighty Algae Biofuels
Oilfox
Organic Fuels
OriginOil
PetroAlgae
PetroSun
Phycal
Revolution Biofuels
RWE AG
Sapphire Energy
Seamibiotic
SeaAg Inc.
Shell

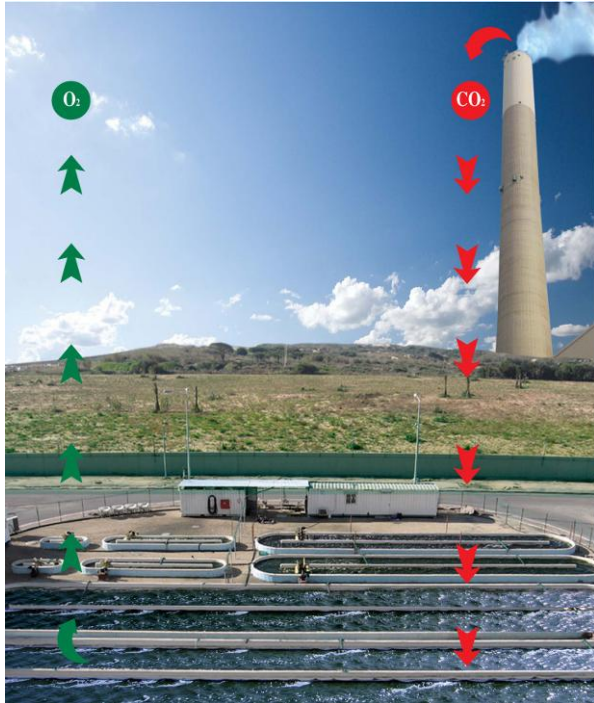
Solazyme
Solena
Solix Biofuels Inc.
Sunx Energy
Susquehanna Biotech
Texas Clean Fuel
Trident Exploration/Menova
Valcent Products
Vattenfall
Vertigo
W2 Energy
XL Renewables



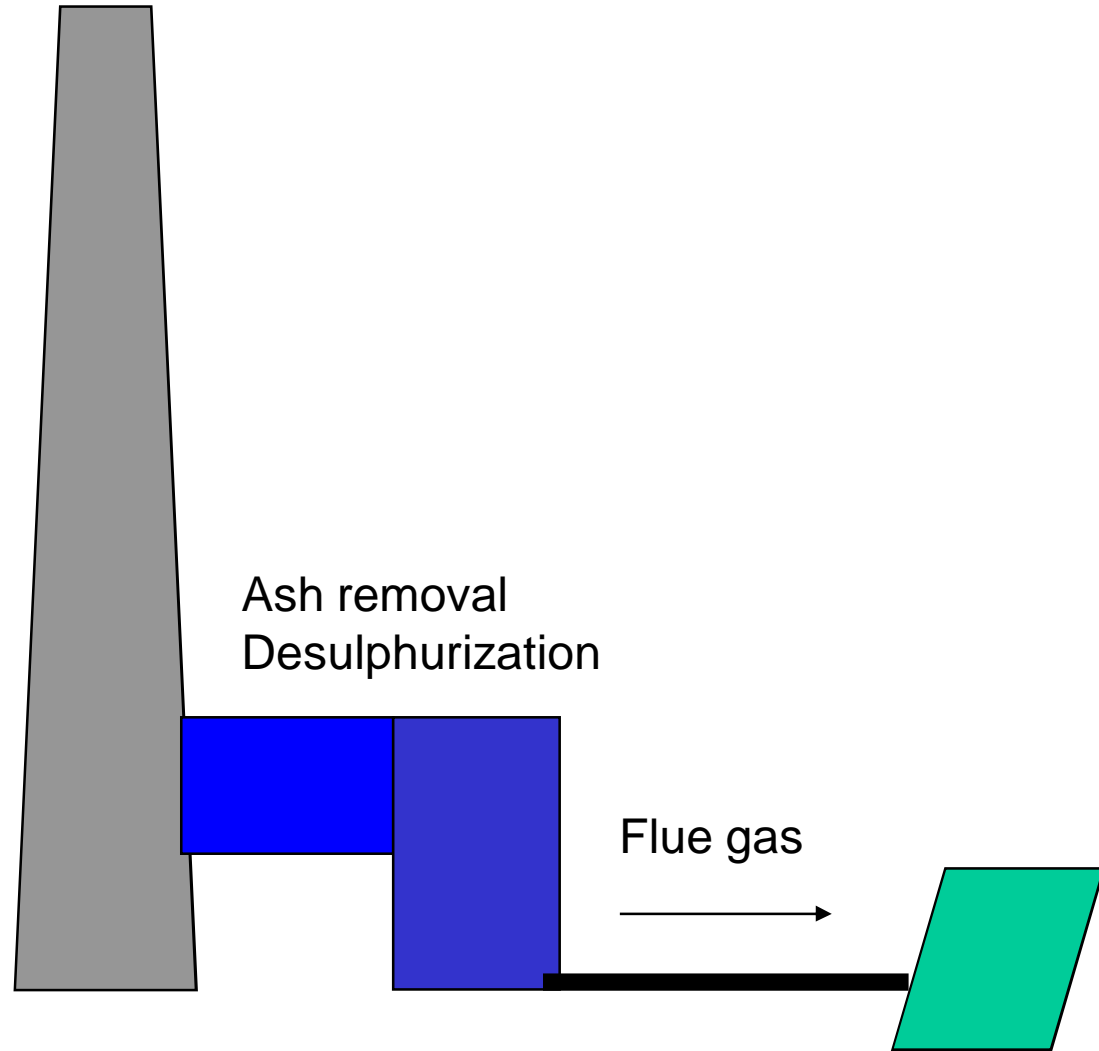
Visions - Shell + HR Biopetroleum (building pilot plant)



Vision - Seamiotic (have a pilot plant using flue gas)



www.seamiotic.com

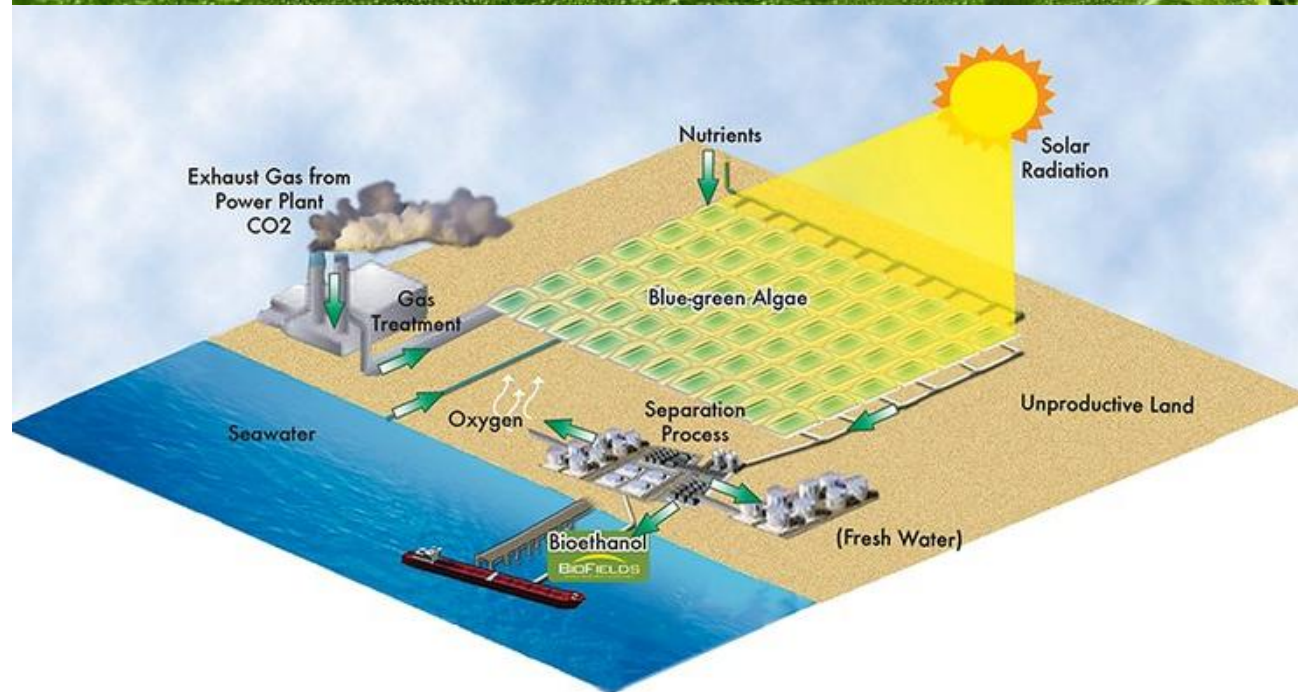


Vision - Algenol (building plant)

ALGENOL
B I O F U E L S

HARNESSING THE SUN TO FUEL THE WORLD™

Biofuels are poised
to transform the world...



Production cost

- Should be <0.5 \$ per kg dry biomass
- Lowest present production cost: 5-20 \$ / kg biomass

Main cost:

- 1) Manpower
- 2) Energy (harvesting)
- 3) Water
- 4) Fertilizer / CO₂
- 6) Tax



Algae for biofuel, SYKE & VTT projects

Participants:

SYKE
VTT

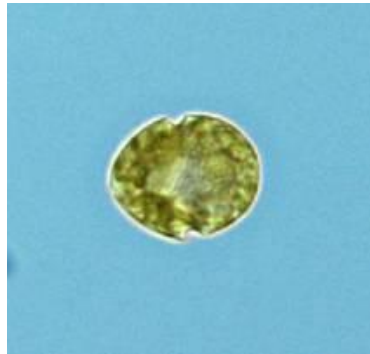
Projects:

ALGIESEL
(SA, 2012)
LIPIDO
(SA, 2011)
MICROFUEL
(Tekes, 2009)

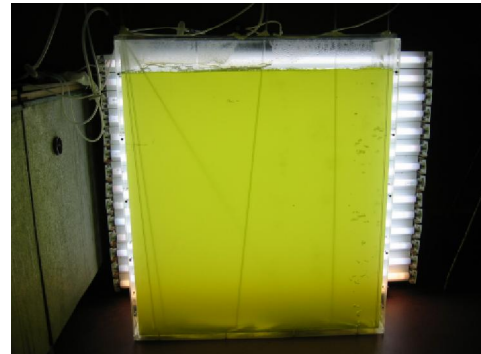
Overall aim:

Investigate the potential of microalgae as
a raw-material for biodiesel

Targeted through investigations of:



- * Sp. selection
- * Lipid profile

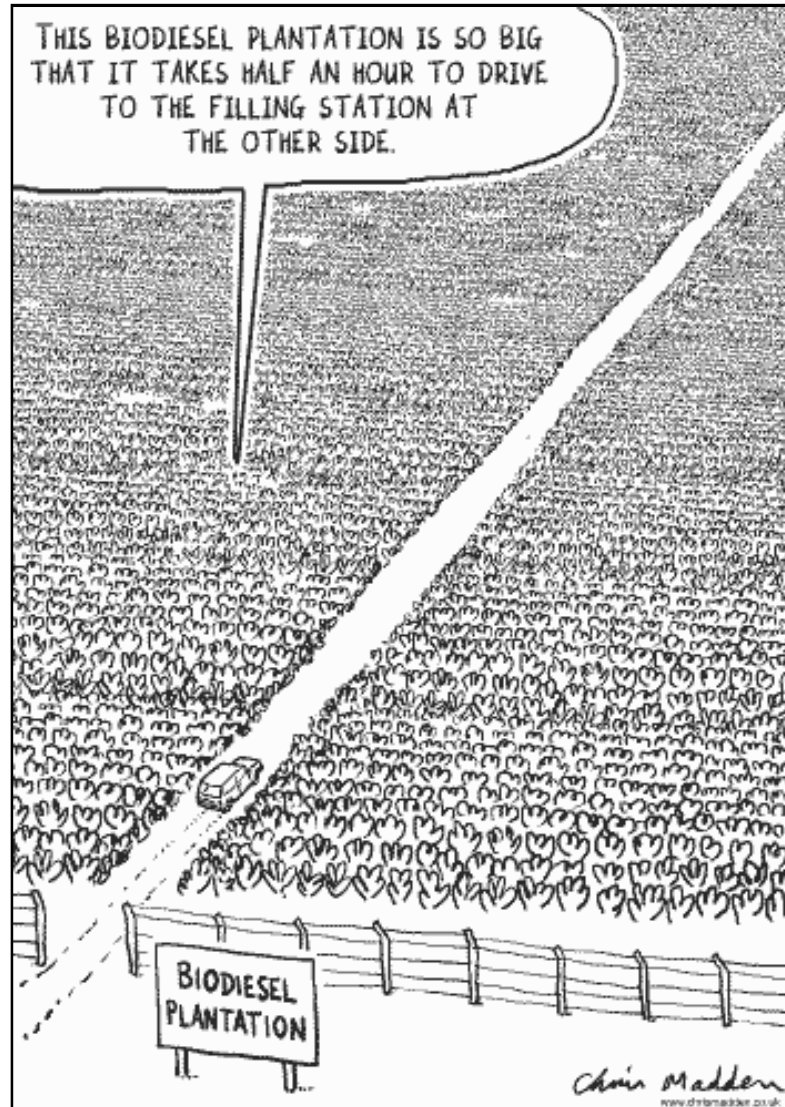


- * Growth control
and yield



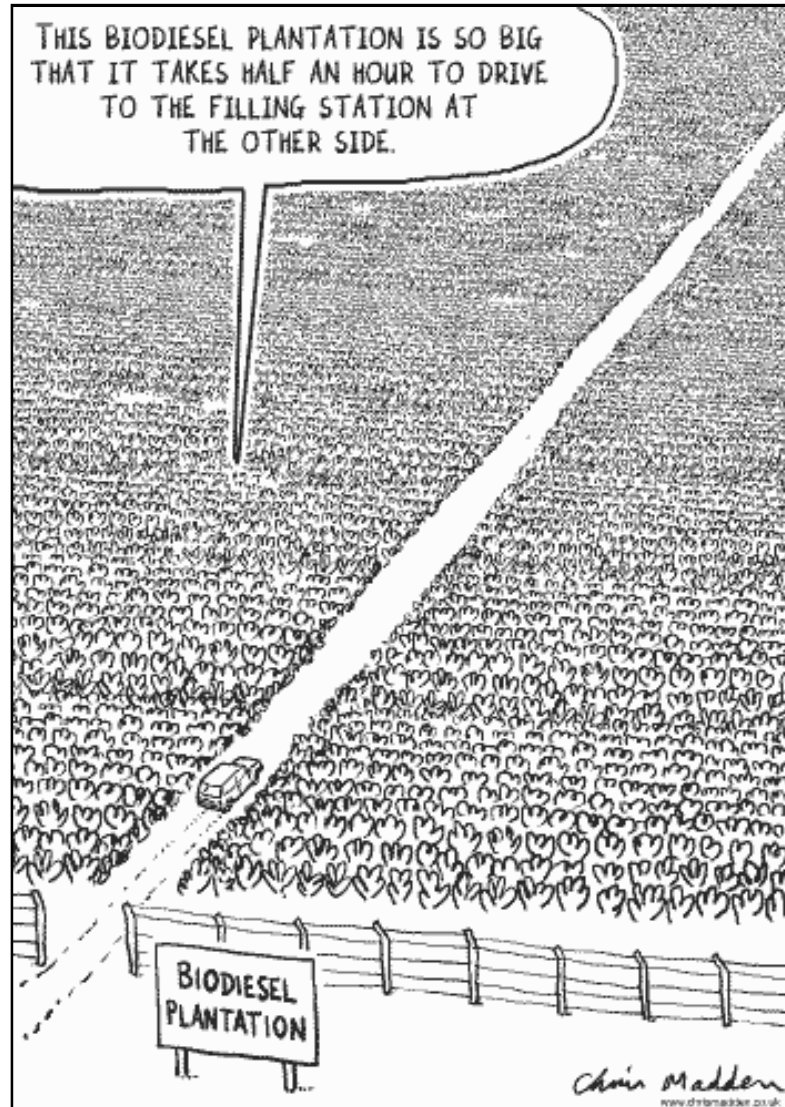
- * Harvesting
- * Biomass handling

Three important elements for development



- Obtaining high growth efficiency
- Low energy harvesting
- Downstream processing (e.g. getting lipids out)

Road ahead



- Reduce production cost
- Policy change e.g. taxing fuels based on their carbon footprint
- Added value, e.g. wastewater treatment and CO₂ uptake