# Biodiesel from microalgae

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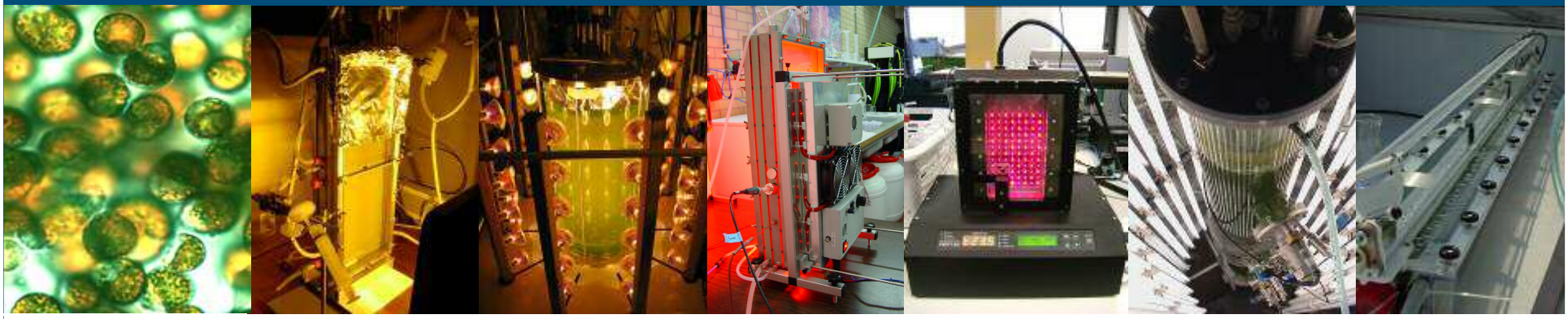

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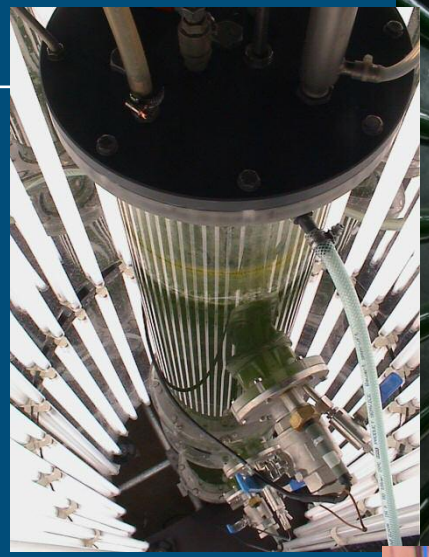

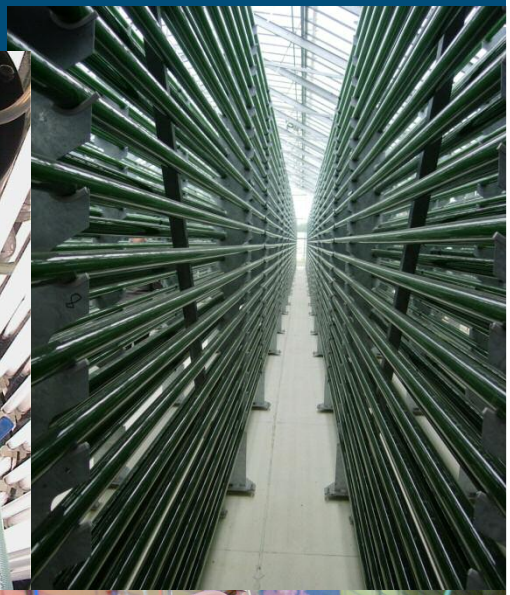

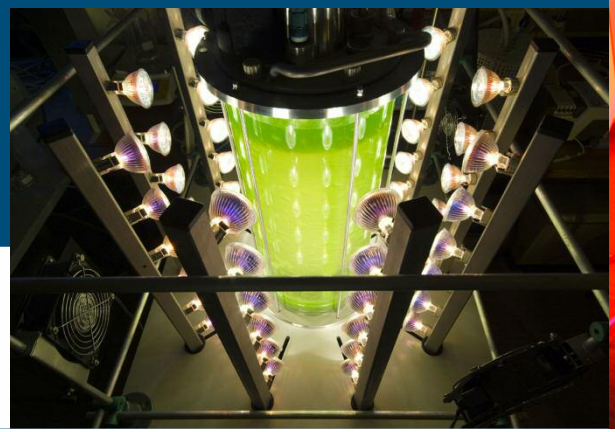

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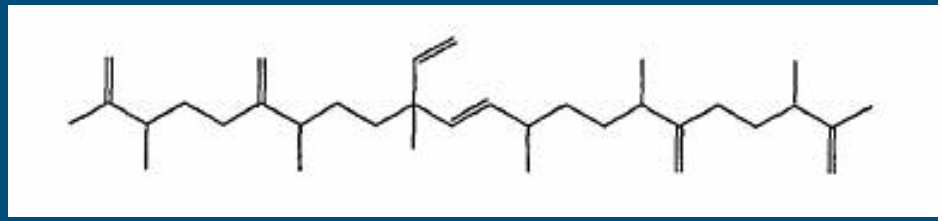
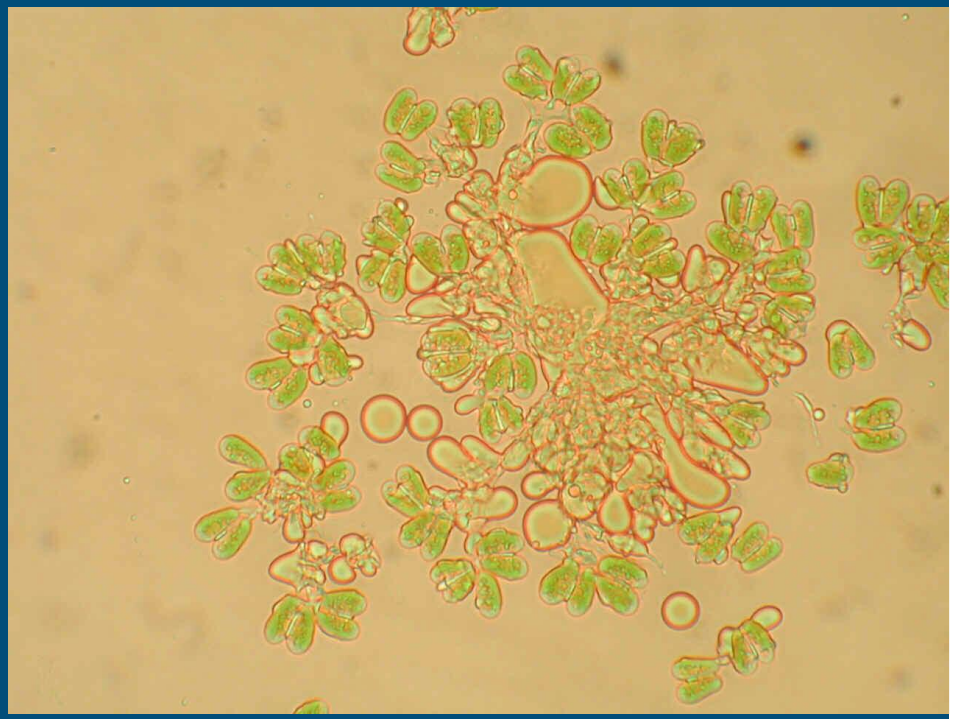
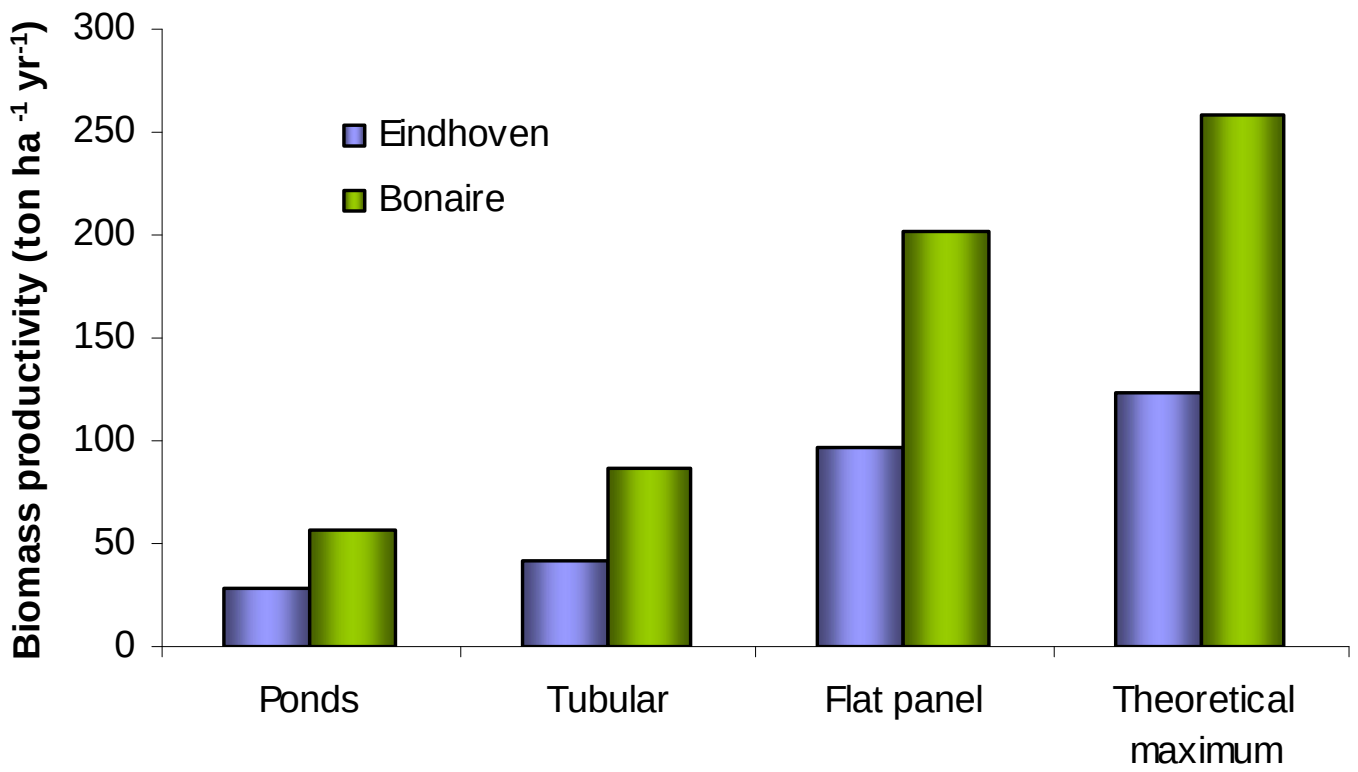
# Biofuels

- *Botryococcus*
  - Alkanes (C34)
  - High concentrations (40-70%)
- Other algae
  - 20-60% lipids
- High productivity
  - Palm oil: 6,000 l/ha/year
  - Algae: 20,000-150,000 l/ha/jaar
  - No competition with food
  - Salt water
- Investmens in US: US$ 2.4 billion ***(NYTimes)***





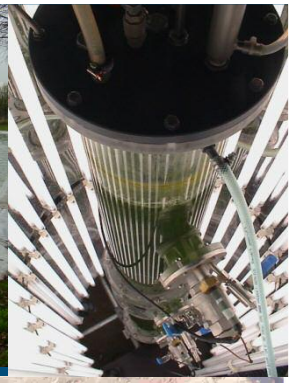
# Truth about algae

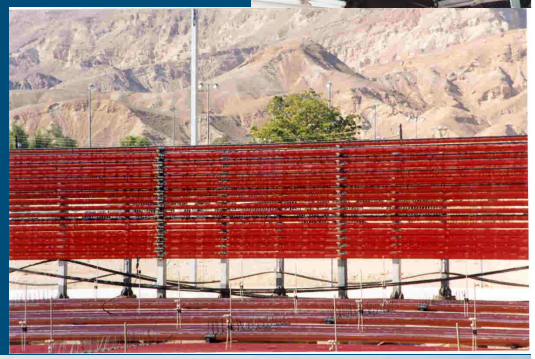



Lipid content algae is 20-60%

# Production methods of algae

- Open systems
  - Raceway
  - Cheap?
- Closed systems
  - Bubble column
  - Tubular reactors
  - Flat panels
  - Expensive?





# Feasibility study

Delta nv

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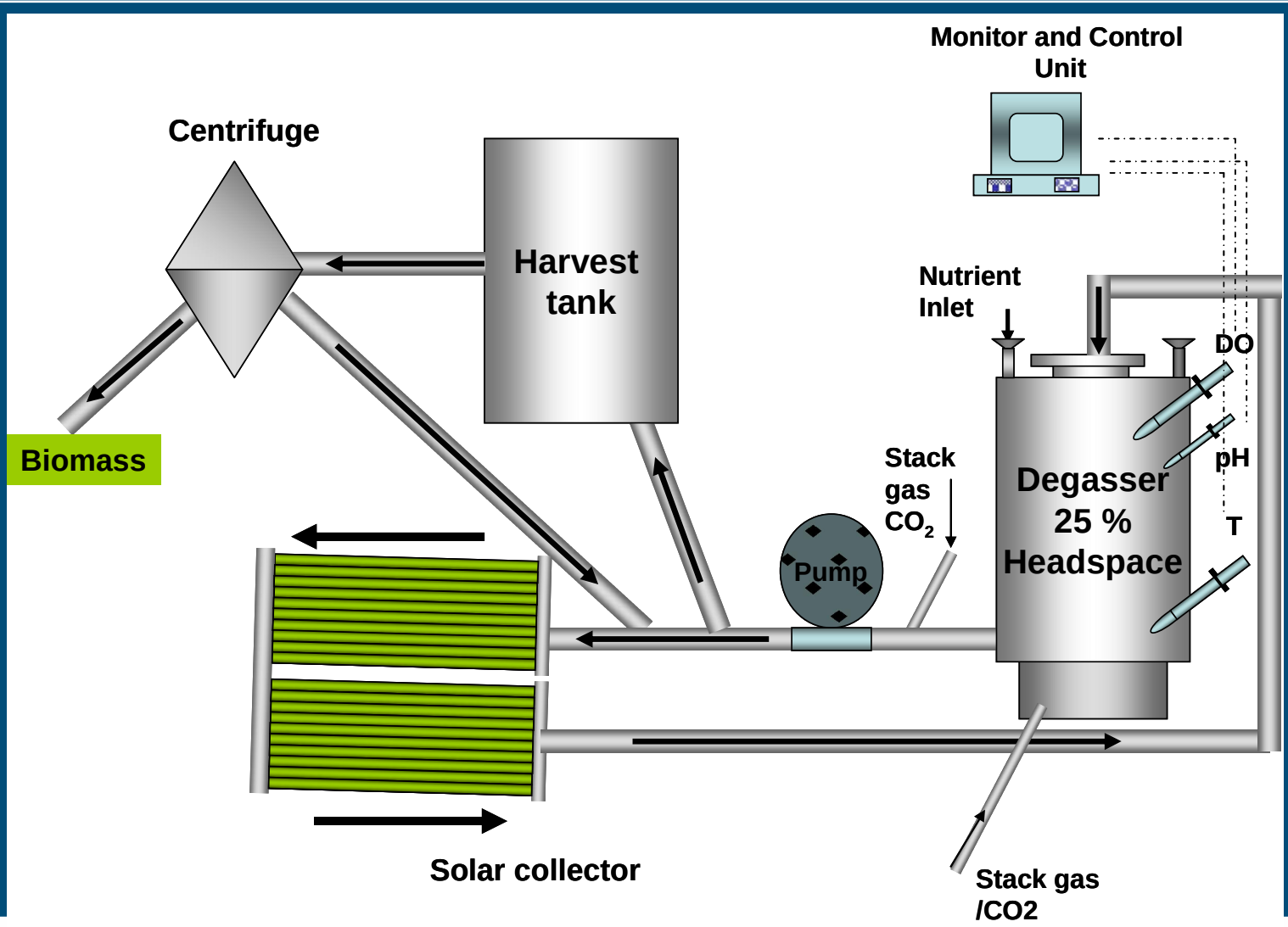
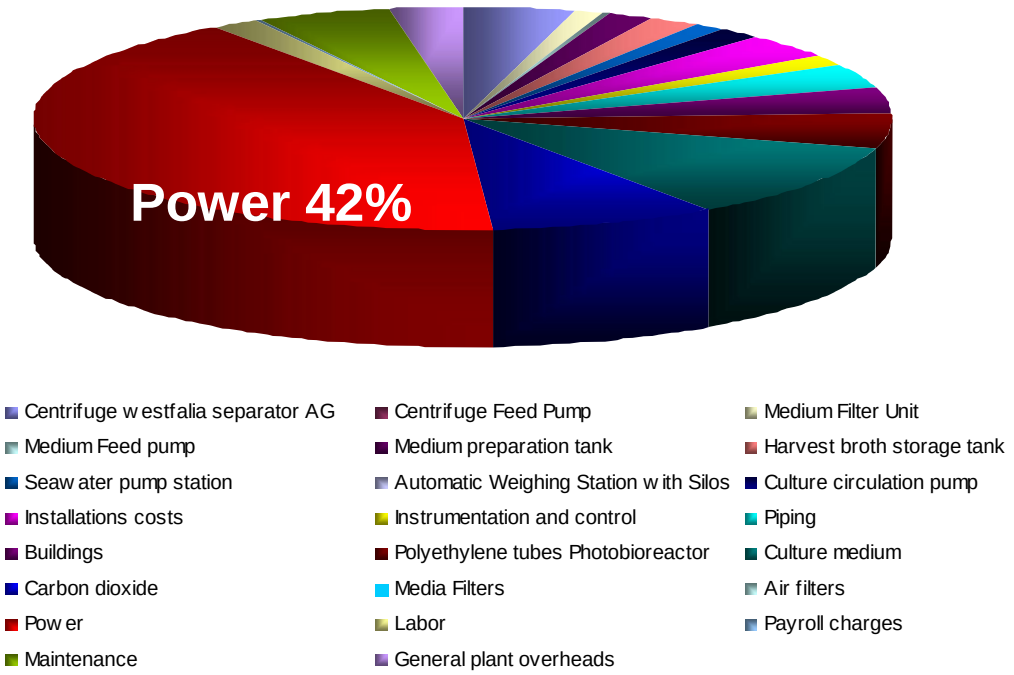
# Tubular reactor



# Biomass production costs horizontal tubular reactor

- 1 ha plant
  - 10.62 €/ kg biomass
- 100 ha plant
  - 4.02 €/ kg biomass
  - 150 €/GJ
- Present value
  - 10 €/GJ

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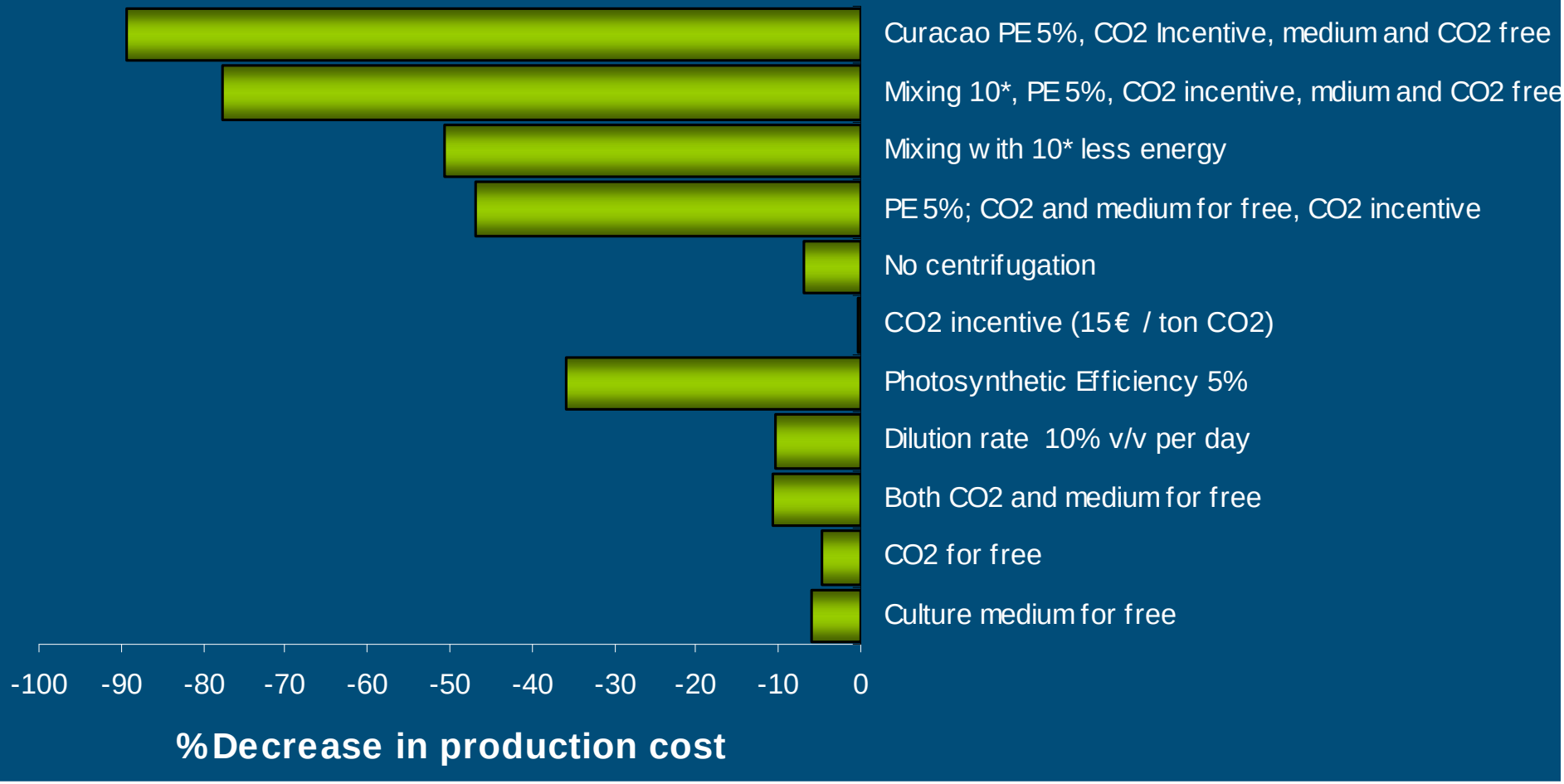
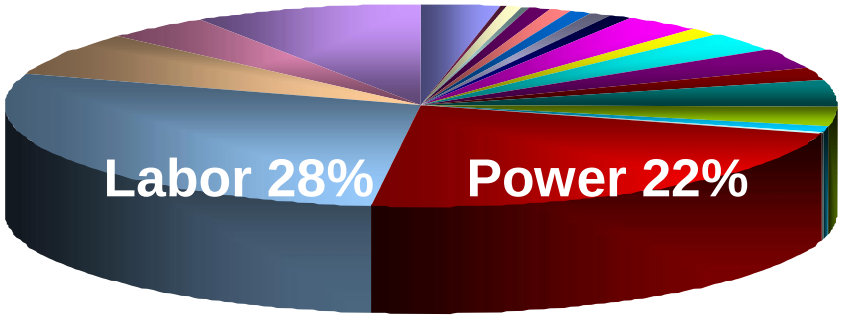
# Sensitivity analysis



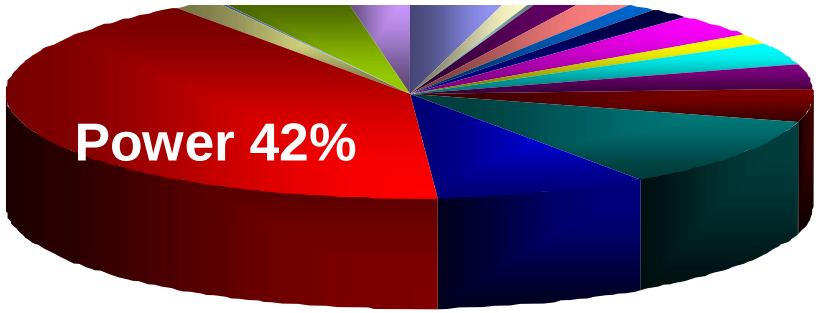
# Biomass production cost

1 ha




10.62 € / kg biomass

100 ha




4.02 € / kg biomass

89% decrease

potential

Centrifuge w estfalia separator AG
Centrifuge Feed Pump
Medium Filter Unit
Medium Feed pump
Medium preparation tank
Harvest broth storage tank
Seaw ater pump station
Automatic Weighing Station w ith Silos
Culture circulation pump
Installations costs
Instrumentation and control
Piping
Buildings
Polyethylene tubes Photobioreactor
Culture medium
Carbon dioxide
Media Filters
Air filters
Pow er
Labor
Payroll charges
Maintenance
General plant overheads

0.4 € / kg biomass
15 €/GJ

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# Comparison of systems (100ha)

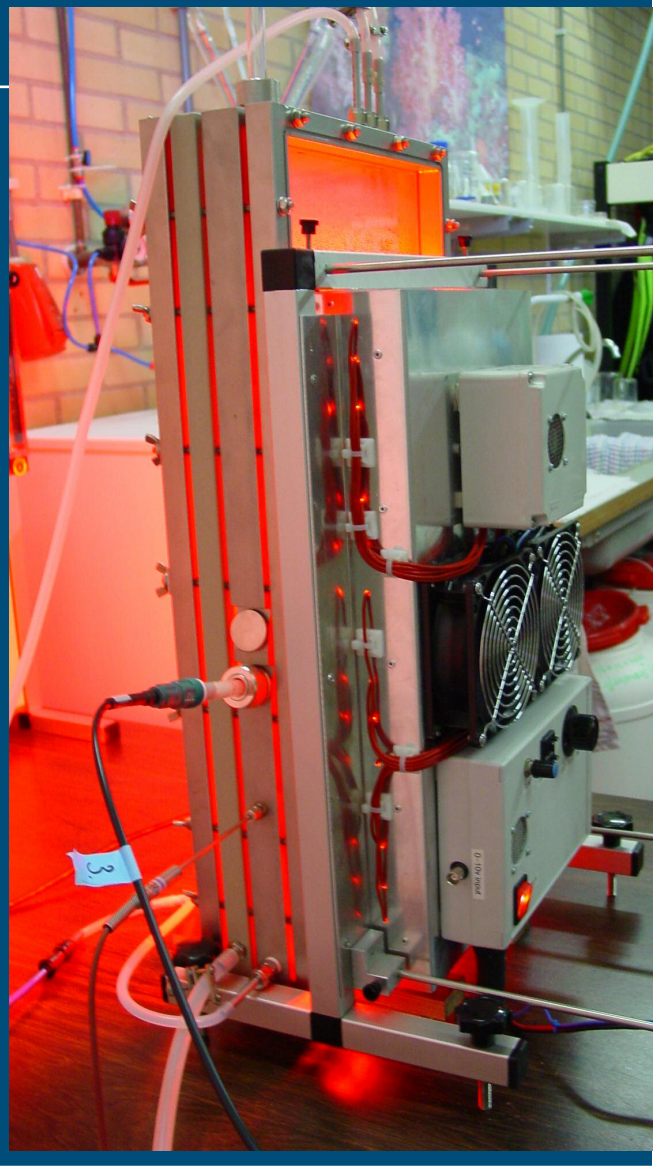
| | Units | Raceway pond | Flat panel reactor | Horizontal tubular reactor |
|---|---|---|---|---|
| Biomass Production | ton /year | 2071 | 6363 | 4141 |
| Photosynthetic Efficiency | % | 1.5 | 5 | 3 |
| Light path | m | 0.2 | 0.03 | 0.034 |
| Daily dilution rate | % | 10 | 30 | 30 |
| Culture volume | $m^3$ | 180180 | 57692 | 29671 |
| Investment | M€ /ha | 647 | 938 | 341 |
| Biomass production cost | € / kg DW | 5.70 | 4.03 | 4.02 |
| Main contributor to biomass production cost | % | Centrifuge 15 % | Air blowers 24% | Circulation pump 46% |

# Research programs

- Photosynthetic Cell Factories (NWO)
- Solar-H and Solar-H2 (EU)
- Sealand Sole (Min. Agriculture, province Sealand, companies)
- IWT: collaboration with University of Ghent
- Proviron
- EOS-LT (Akzo, Ingrepro, Essent)
- Wetsus (13 companies)

# WETSUS research project

- Feasibility study as basis
- Aim: reduction of production costs
- Biofuel is not the only product
- Several breakthroughs needed to realize economical feasibility
- Joining forces
- Basis for demonstration projects
- Technological Top Institute; funding
  - 25% university (Wageningen University)
  - 25% companies
  - 50% government
- 13 companies
- 5 million €



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# Participating companies

- AF&F
- Dow Chemicals
- Delta
- Eneco Energie
- Essent
- Friesland Foods
- Hednesford
- Ingrepro
- Landustrie
- Neste Oil
- Nuon
- Rosendaal Energy
- Syngenta


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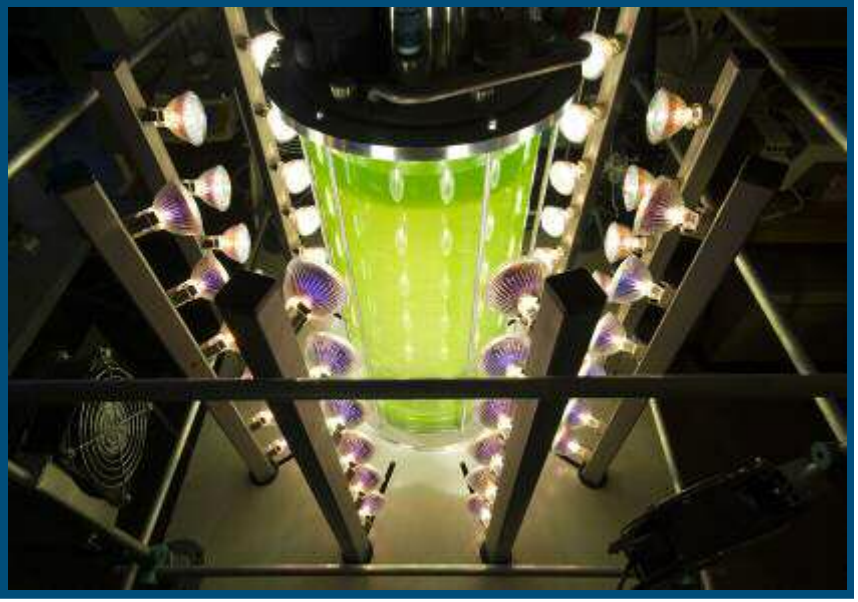
# Research topics

- Energy for mixing
- Productivity/photosynthetic efficiency
- Lipid productivity
- $CO_2$ fixation
- $O_2$ production
- Make use of residual nutrients
- Harvesting
- Extraction
- Production scenarios



# Biorefinery of microalgae

- Assumption: 1,000 kg of microalgae
- Production costs: 400 €
- Production plant
  - CO2 fixation: 1,800 kg: -35 €
  - Nutrient removal from waste: - 65 €
  - Use of waste heat: -
  - Production of pure O2: 1,600 kg
- Product isolation
  - Lipids for chemistry: 100 kg 200 €
  - Lipids for fuel: 300 kg 150 €
  - Proteins for food: 100 kg 500 €
  - Proteins for feed: 400 kg 300 €
  - Polysaccharide fractions: 100 kg
- Summary
  - Total costs:
  - Total income: 1,300 €

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# Development plans

- Fundamental research is taking place
- We look for further expansion of that
- We wish to demonstrate feasibility
  - Production
  - Product isolation: protein, lipid and polysaccharide fractions
- Supply of biomass for product isolation

# Objectives of pilot/demo plant phase

- Development of a process chain
- Experience with systems
- Information for design of full scale plants
- Comparison of systems
- Comparison of strains
- Comparison of feeds (nutrients, $CO_2$, sunlight…
- Supply of biomass for further processing
- Further processing

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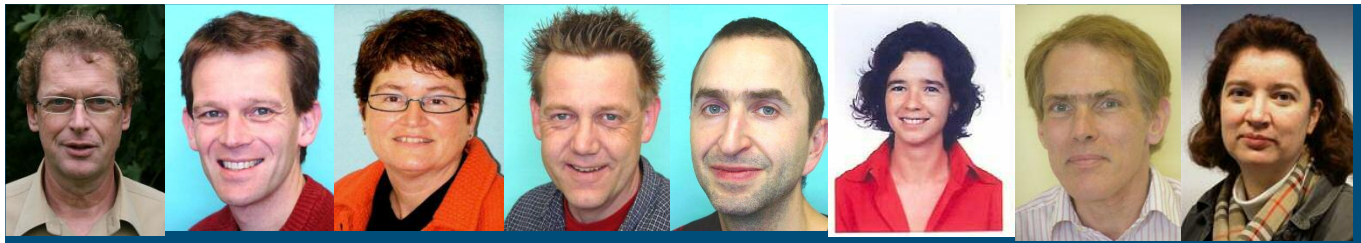
# Conclusions

- Production of chemicals and biofuels feasible
- Productivity high and no competition with food production
- Technology not ready
- Join forces
- Combination of applications



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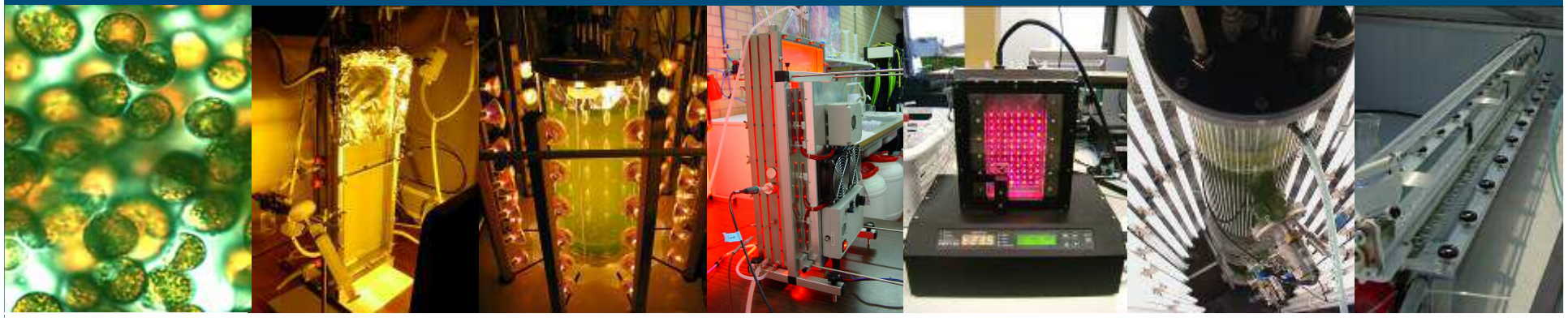

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