Microalgae for production of bulk chemicals and biofuels

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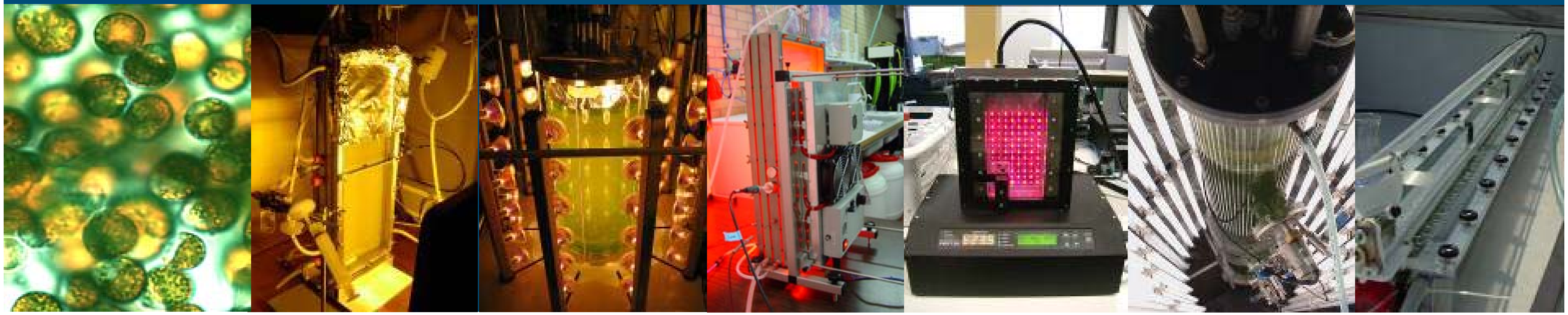

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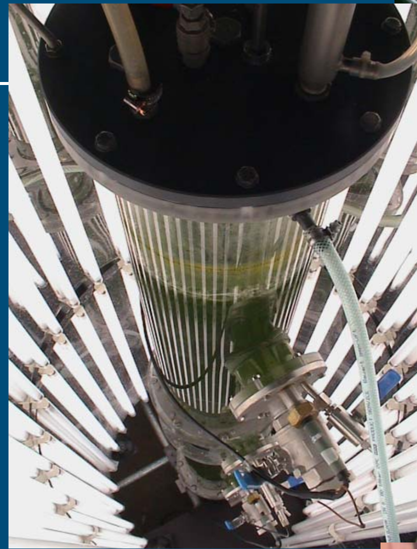

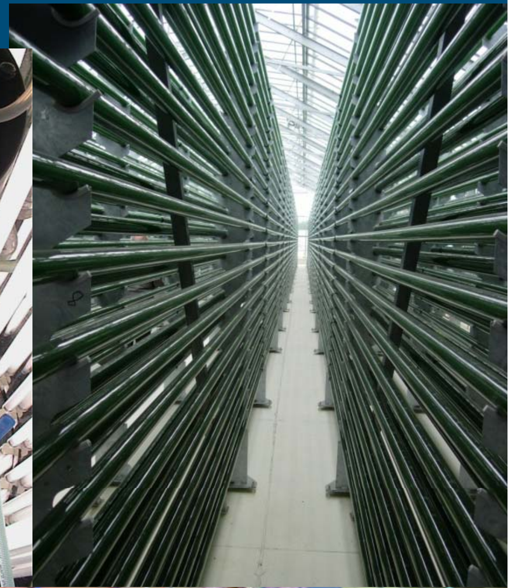

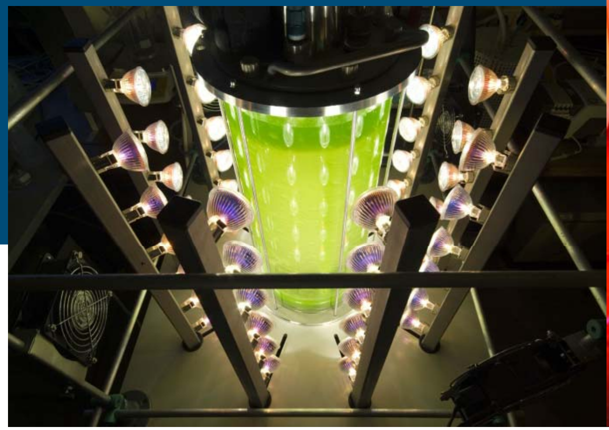

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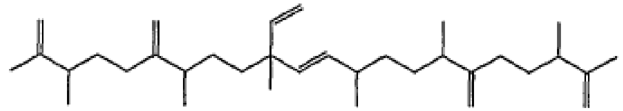
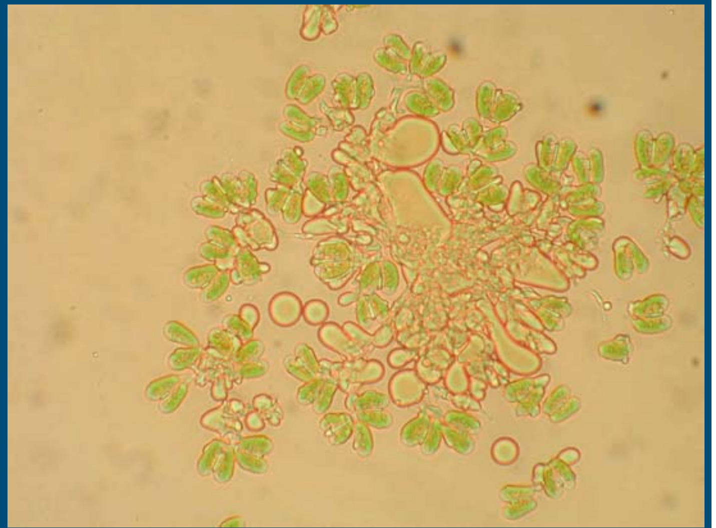
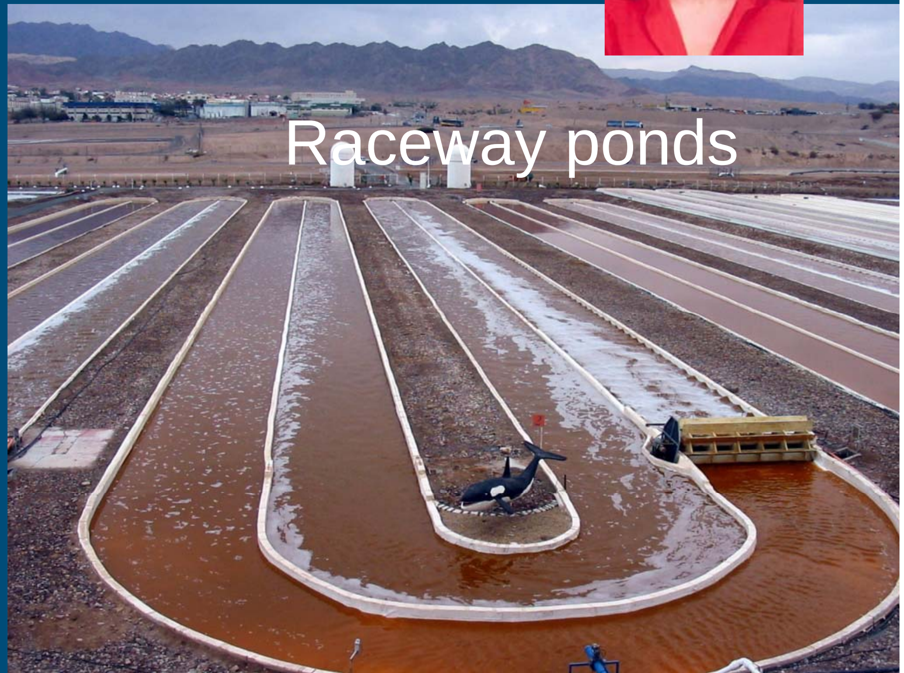
Biodiesel from microalgae



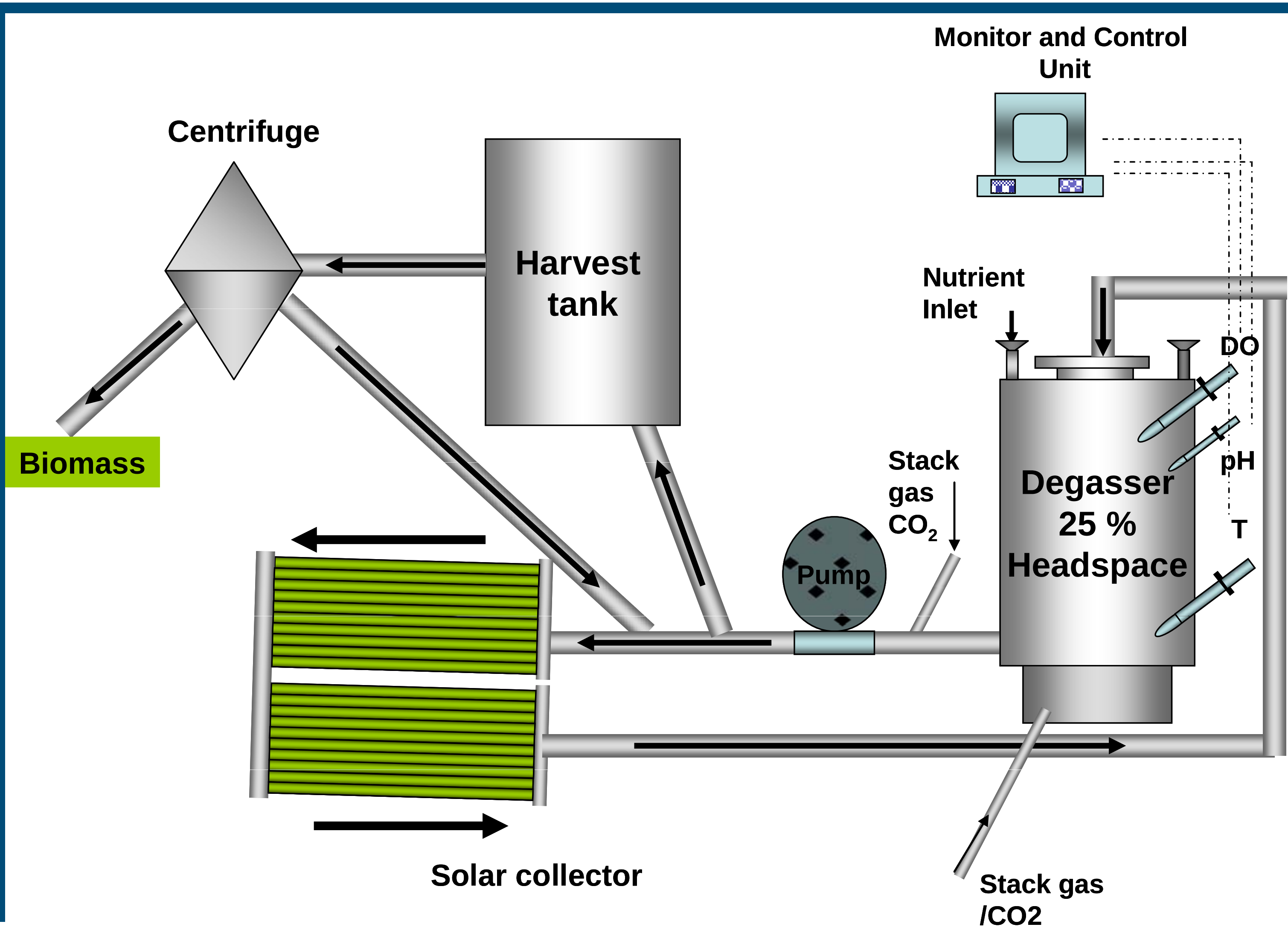
- *Botryococcus*
  - Alkanes (C34)
  - High concentrations (40-70%)
- Other algae
  - 20-60% lipids
- High productivity
  - Palm oil: 6,000 l/ha/year
  - Algae: 20,000-80,000 l/ha/year
  - No competition with food
  - Salt water



Feasibility study Delta nv



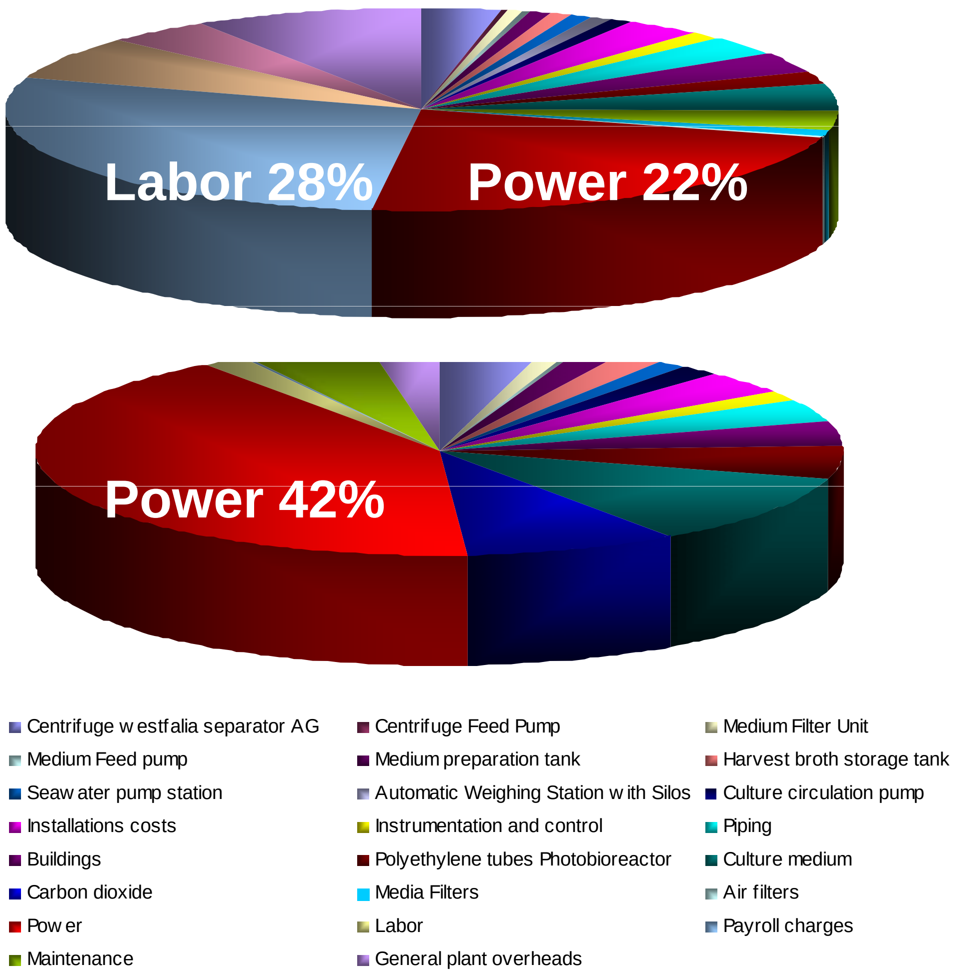
Tubular reactor



Biomass production cost

1 ha

10.62 € / kg biomass



100 ha

4.02 € / kg biomass

89% decrease

potential

0.4 € / kg biomass

15 €/GJ

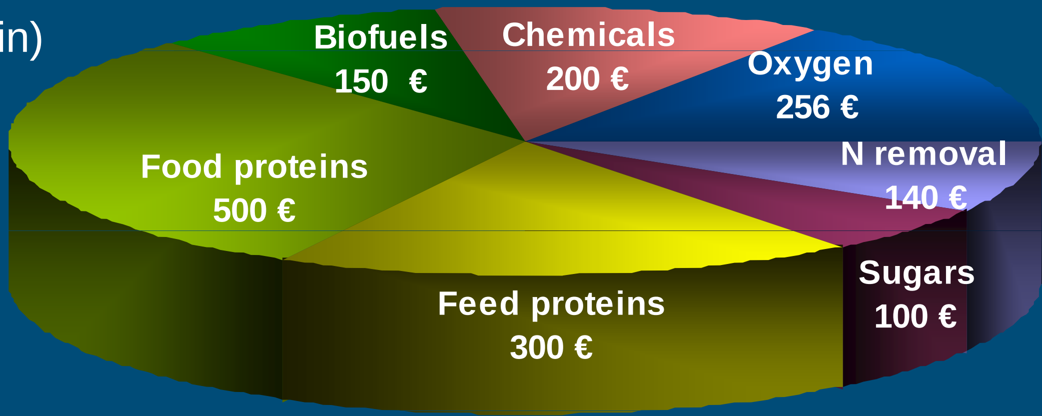
Conclusions Delta report: economical viability

- Power input is the main constrain in photobioreactors
- Sensitivity analysis show that biomass production costs can be further decreased from 4 to 0.4 €/kg
- Parameters that need improvement
  - Mixing system / efficiency
  - Photosynthetic efficiency
    - reactor design
    - cultivation conditions
    - strain improvement / screening
  - Integrate processes
- Positive energy balance still needs to be reached

Economical Viability: Process integration and valorisation

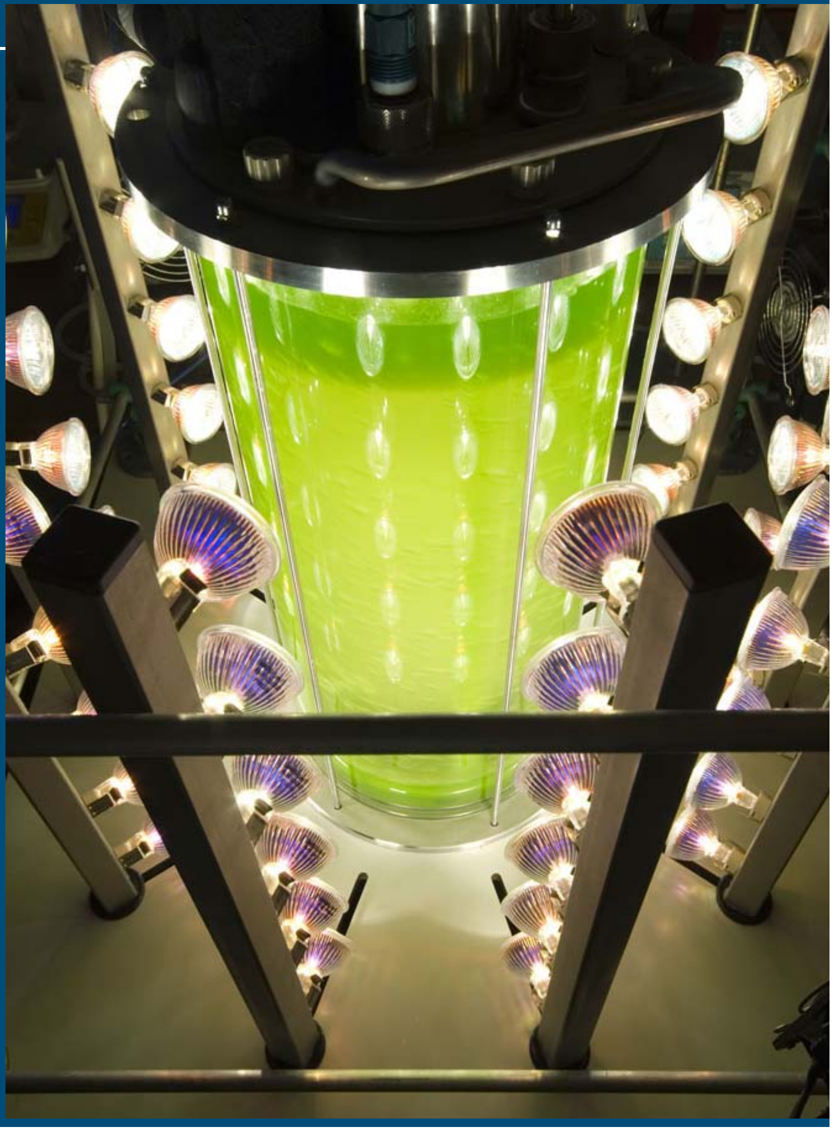
Bulk chemicals and biofuels in 1,000 kg microalgae

- 400 kg lipids
  - 100 kg as feedstock chemical industry (2 €/kg lipids)
  - 300 kg as transport fuel (0.50 €/kg lipids)
- 500 kg proteins
  - 100 kg for food (5 €/kg protein)
  - 400 kg for feed (0.75 €/kg protein)
- 100 kg polysaccharides
  - 1 €/kg polysaccharides
- 70 kg of N removed
  - 2 €/kg nitrogen
- 1,600 kg oxygen produced
  - 0.16 €/kg oxygen
- Production costs: 0.40 €/kg biomass
- Value: 1.65 €/kg biomass



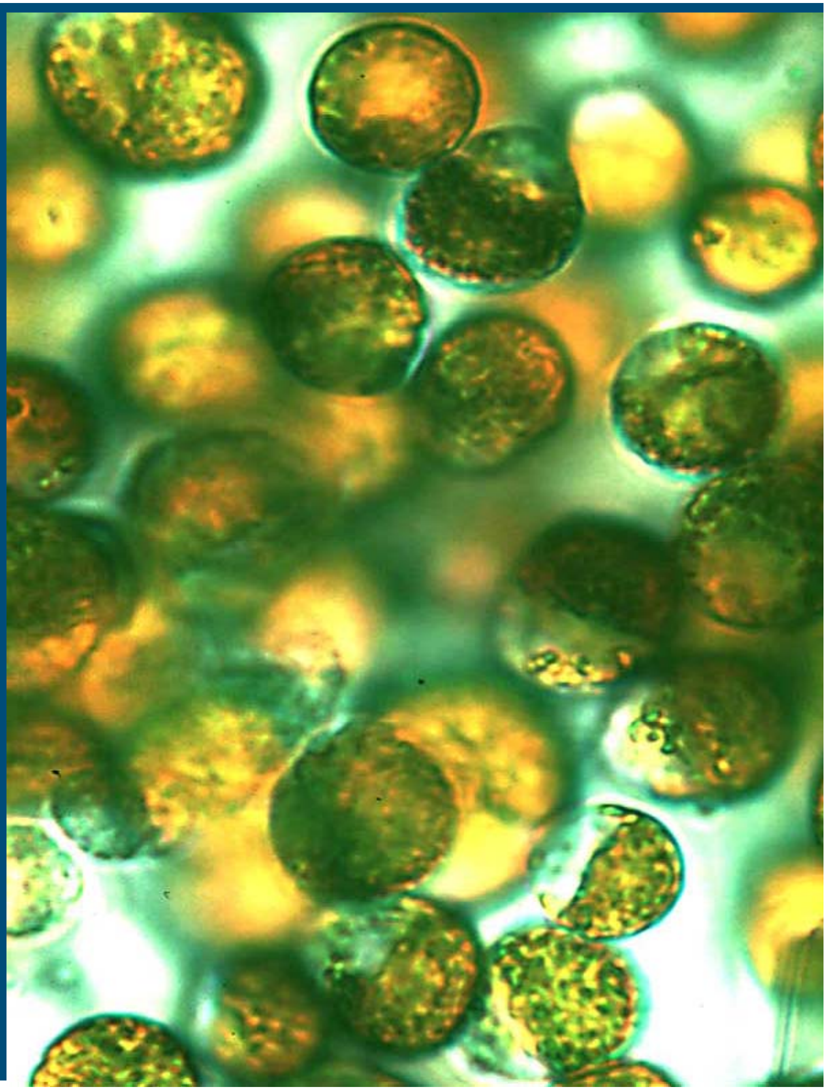
Research programs

- Photosynthetic Cell Factories (NWO)
- Solar-H and Solar-H2, SUNBIOPATH (EU)
- Sealand Sole (Min. Agriculture, province Sealand, companies)
- SUNLIGHT (University of Ghent)
- CO_2 fixation (TNO)
- Reactor design (Proviron, University Huelva, Wetsus)
- AlgiCoat (Akzo, Ingrepro, Essent)
- Wetsus (17 companies)
- AlgaePARC (15 companies)



Wageningen research agenda

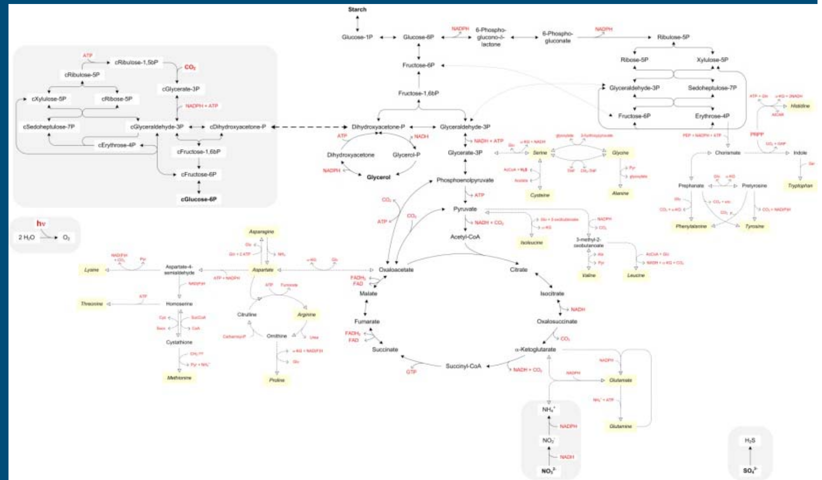
- Control of primary metabolism
- Photobioreactor design
- O_2 removal and CO_2 supply
- Biofilms for post-treatment wastewater
- Harvesting and Oil extraction
- Biorefinery
- Design scenarios
- AlgaePARC

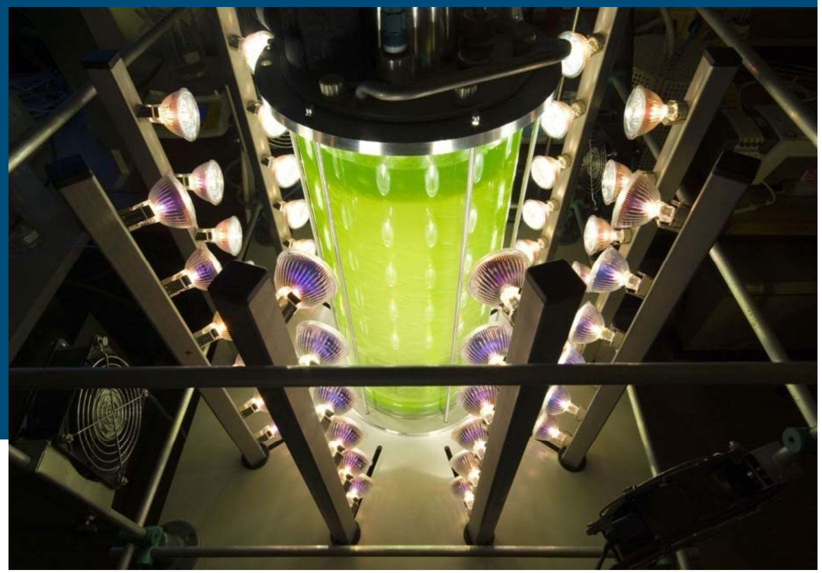


Control primary metabolism

– Annette Kliphuis, Anne Klok, Packo Lamers

- Research reactor to apply wide range of cultivation conditions
- On-line monitoring of production and consumption rates (CO_2, O_2, N, biomass)
- Metabolic network model and flux calculations to predict rates in primary metabolism
- Objective: control metabolism





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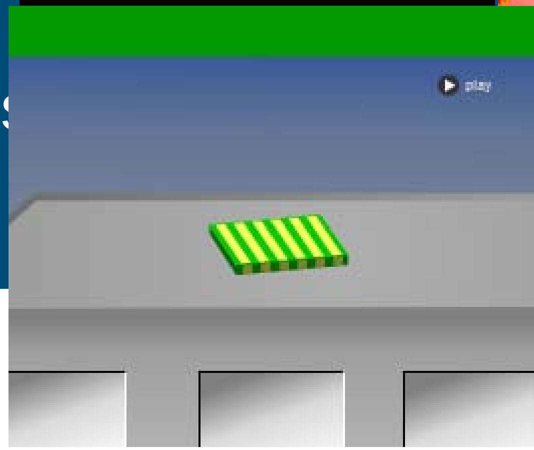
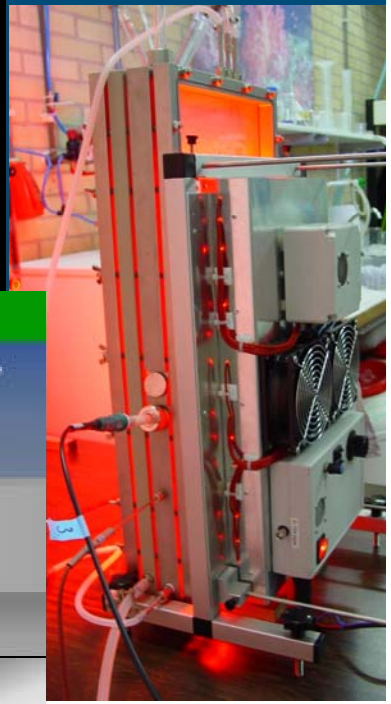
Photobioreactor design

Maria Cuaresma, Lenneke de Winter, Jan-Willem Zijffers, Rouke Bosma, Niels Henrik Norsker, Carsten Vejrazka

- Translate laboratory experiments to
  practice, study daily variations:
  - day to day changes in light
  - day/night changes in light
  - Temperature
- Development of control strategie
  - Mixing
  - Biomass density - harvesting





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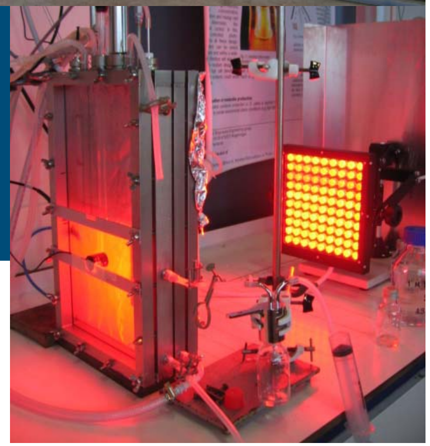
O_2 removal and CO_2 supply

Claudia de Sousa, Ana Santos,
Sayam Raso, Michiel Michels



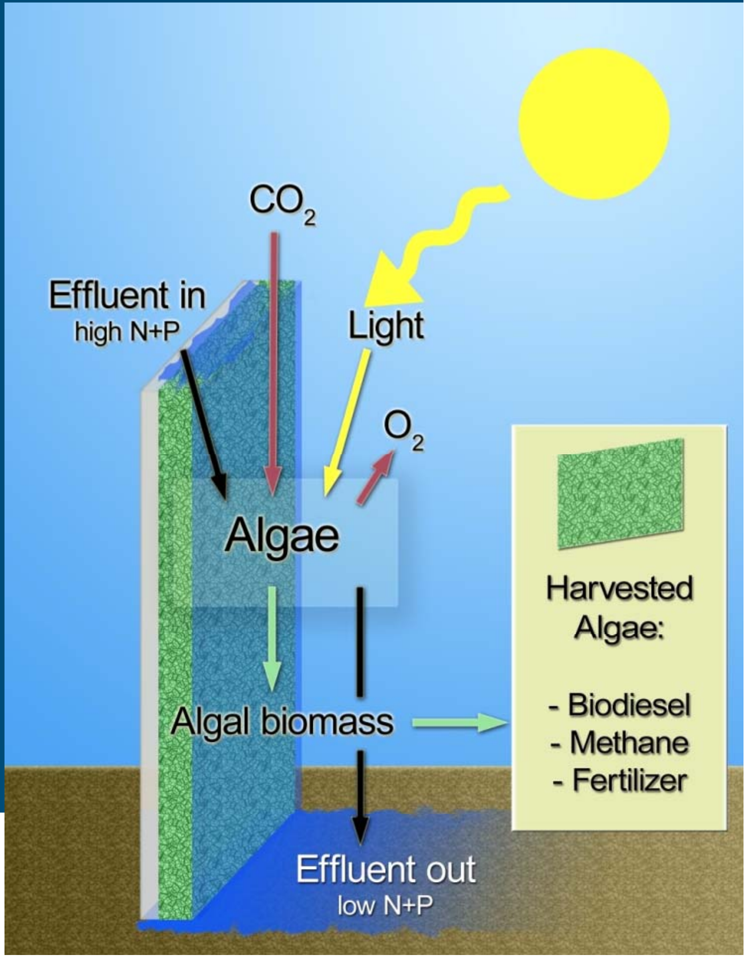

- High Oxygen partial pressure inhibits photosynthesis
  - Maximal tolerable O_2 partial pressure
  - Strains more resistant to O_2
  - Develop new technology to remove O_2
- Energy efficient CO_2 supply
  - Conditions: high pH, high salt
  - Selection of lipid accumulating strains

Biofilms for post-treatment wastewater

– Nadine Boelee, Kanjana Tuantet

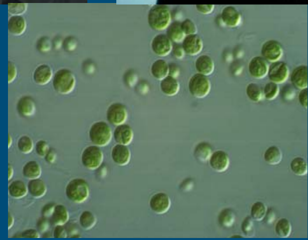
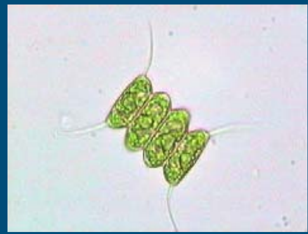
- biomass is easier to harvest
- no suspended matter in effluent
- low energy requirement (no mixing)
- vertical placement is possible (giving higher photosynthetic efficiency due to light dilution)

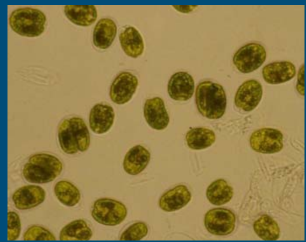


Harvesting and oil extraction

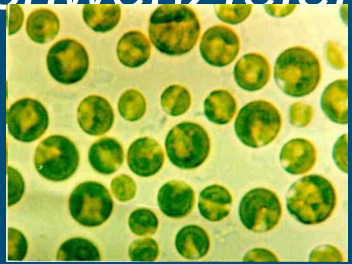
Sina Salim, Dorinde Kleinegris


- Reduction of cost & energy demands
  - No additional chemicals
  - Ensure medium reuse
- Bio- & auto-flocculation
  - Microalgae with high lipid content
  - Characterization of algae
  - Mechanistic study
  - Kinetics of harvesting
- Milking of microalgae




Biorefinery: Make value from protein – *Anja Schwenzfeier*



Isolation of pure and native protein from microalgae for food applications

Characterization and fractionation of the isolated protein

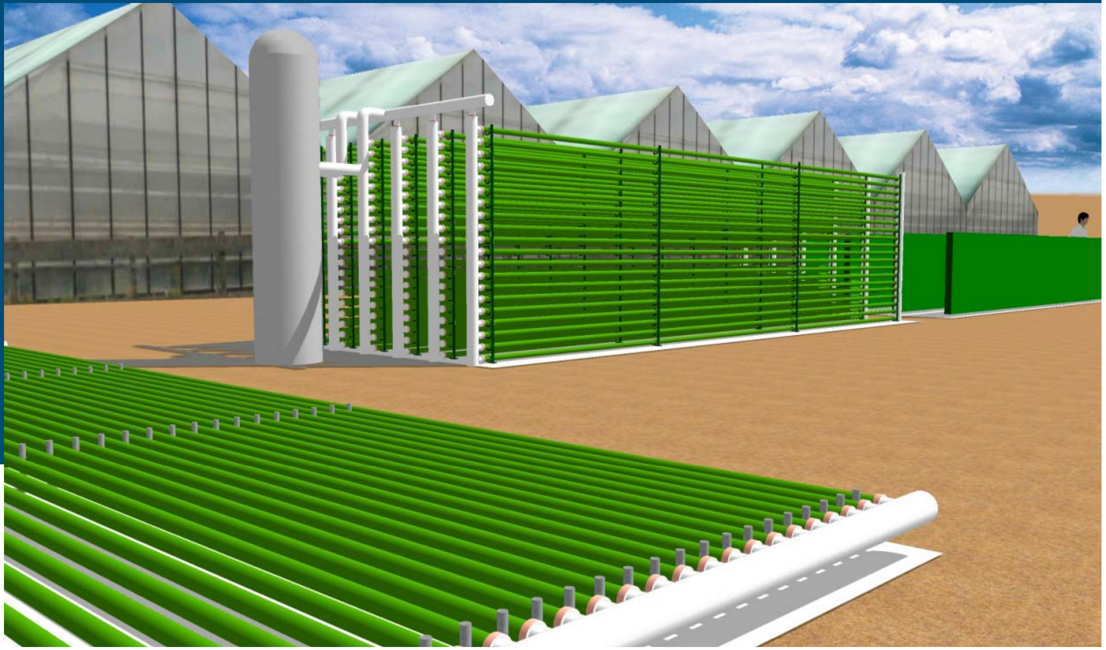
Test techno-functional properties of isolated protein fractions and its possible applications as a food ingredient

Design scenarios - *Ellen Slegers*

- Objective
  - Develop scenarios for production of energy carriers at very large scale
- Why
  - Logistics: complexity and energy use of supply of materials
- Research issues
  - Which scale is most economic? 1-10-100-…>10,000 ha?
  - Logistics of a large scale facility are very complex
  - Energy
  - Mixing, degassing, CO_2 supply, harvesting, materials
  - Industrialized areas, desert, floating, local
  - Day/night/summer/winter
  - Storage

AlgaePARC: Algae Production and Research Center

- 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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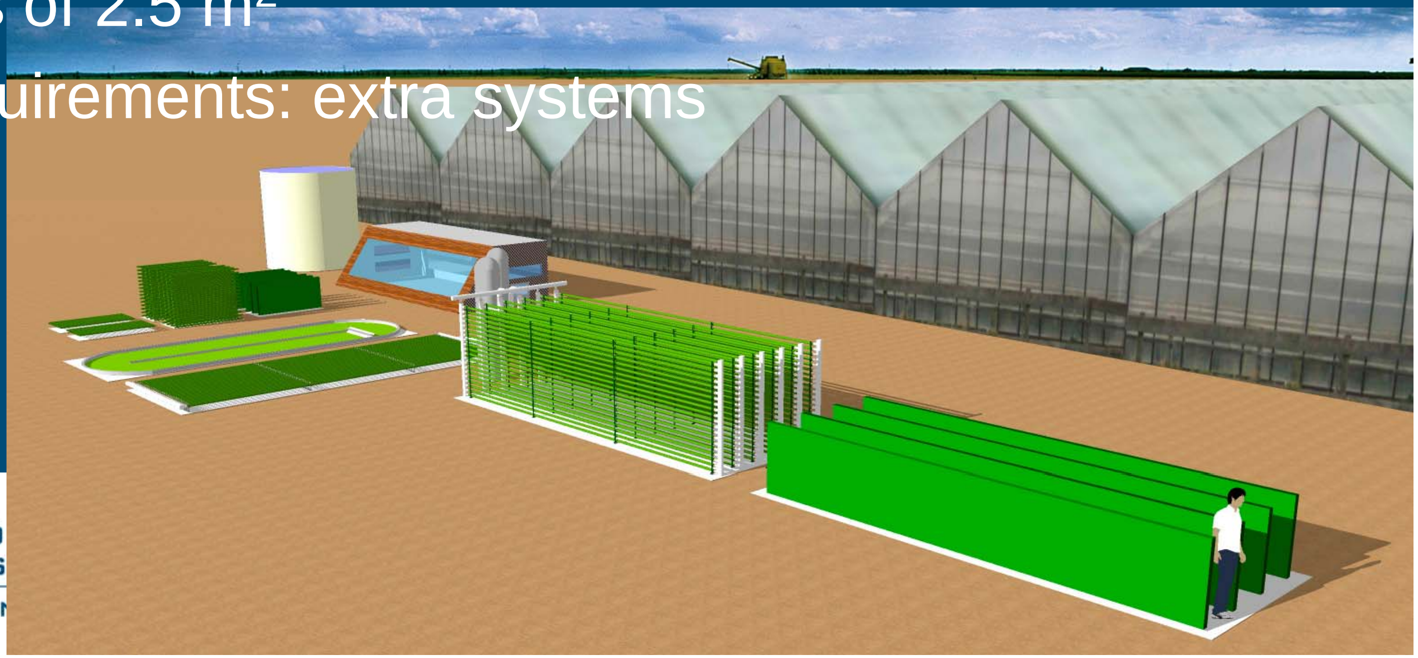
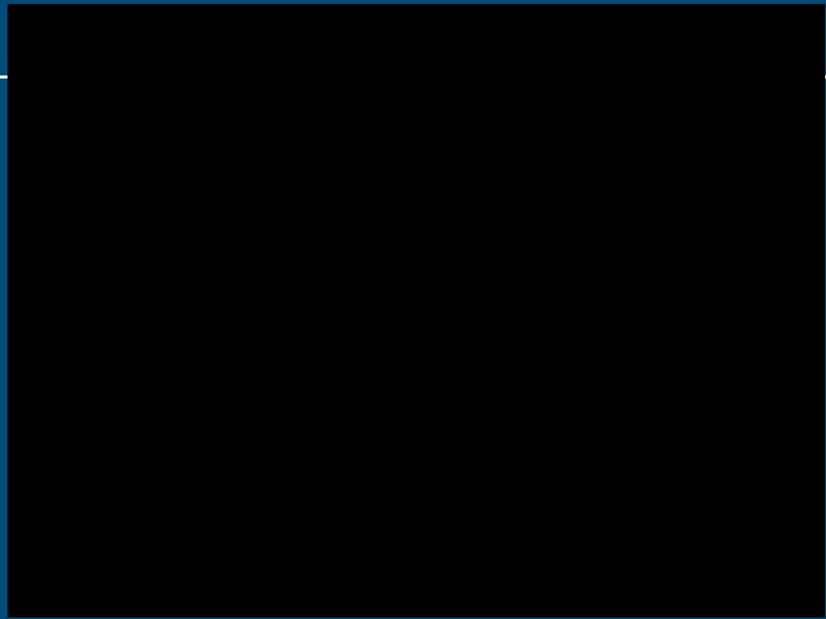
AlgaePARC

- Research plan
- 4 outdoor systems of 25 m^2 each
  - Open pond: reference
  - Horizontal tubular system: high light intensity, oxygen accumulation
  - Vertical tubular system: low light intensity, oxygen accumulation
  - Flat panel system: low light intensity, no oxygen accumulation
- 4-8 systems of 2.5 m^2
- Specific requirements: extra systems



2.5 m^2 systems

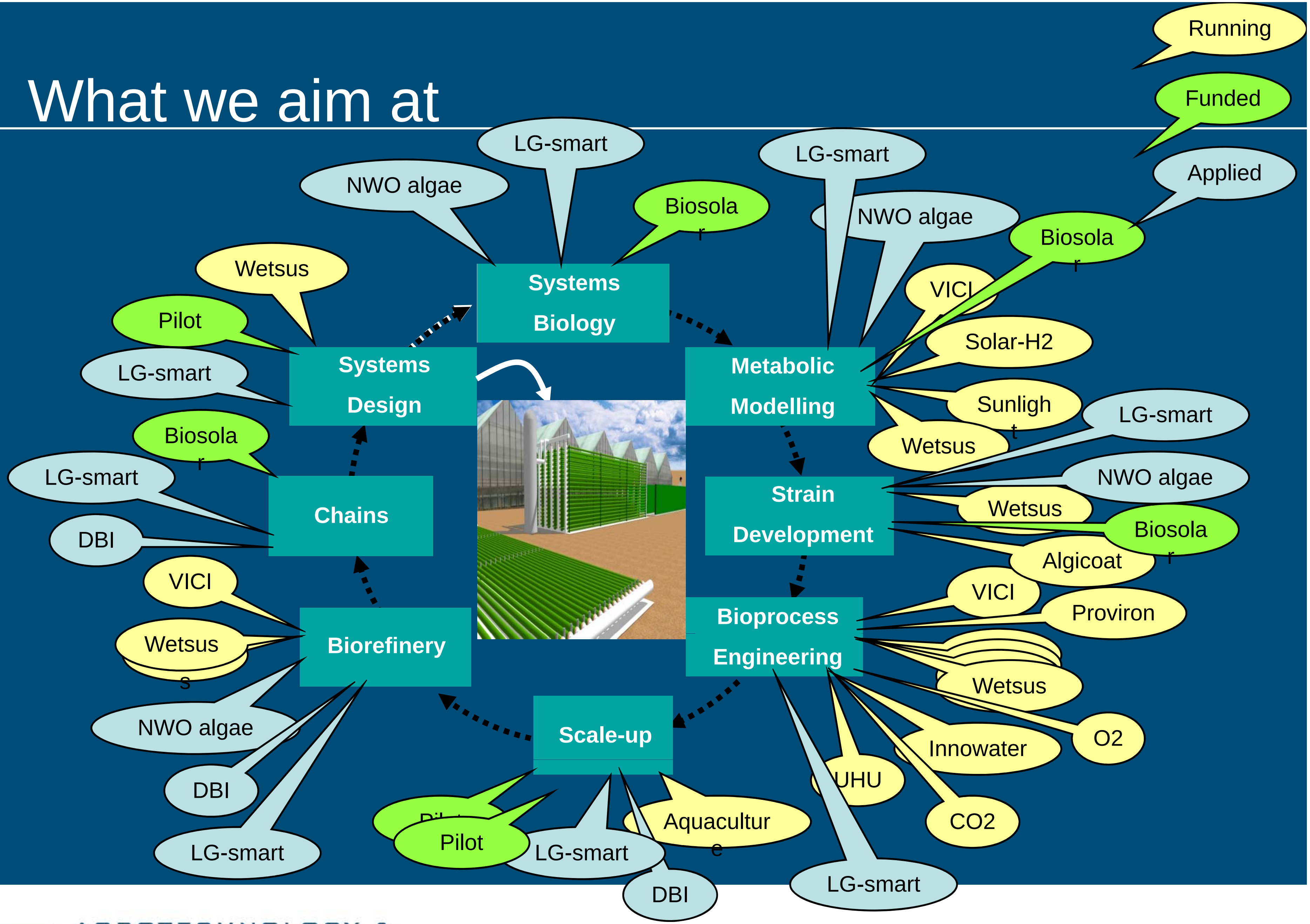


- Phase between lab and pilot
- Test things where you are not sure of
- Different strains
- Different feed stocks
- Adaptations in design
- New systems
- If successful
  - To 25 m^2 scale
- If not successful
  - More experiments
  - Reject

Conclusions

- Microalgae are promising for production of bulk chemicals and biofuels
- Microalgae technology is immature
- Development of technology requires large research programs
- Combination with biorefinery important
- Join forces

What we aim at



Collaborative research programs

- Wetsus
  - AF&F, Dow Chemicals, Delta, Eneco Energie, Essent, Friesland Campina, De Alg (Hednesford), Hubert, Ingrepro, Neste Oil, Liandon (Nuon), Rosendaal Energy, STOWA, Syngenta, Unilever
- AlgaePARC
  - LOI of 15 companies, Ministry of Agriculture, Biosolar program, province of Gelderland
- Biorefinery
  - Combination of end users (for the different biomass fractions) and technology suppliers

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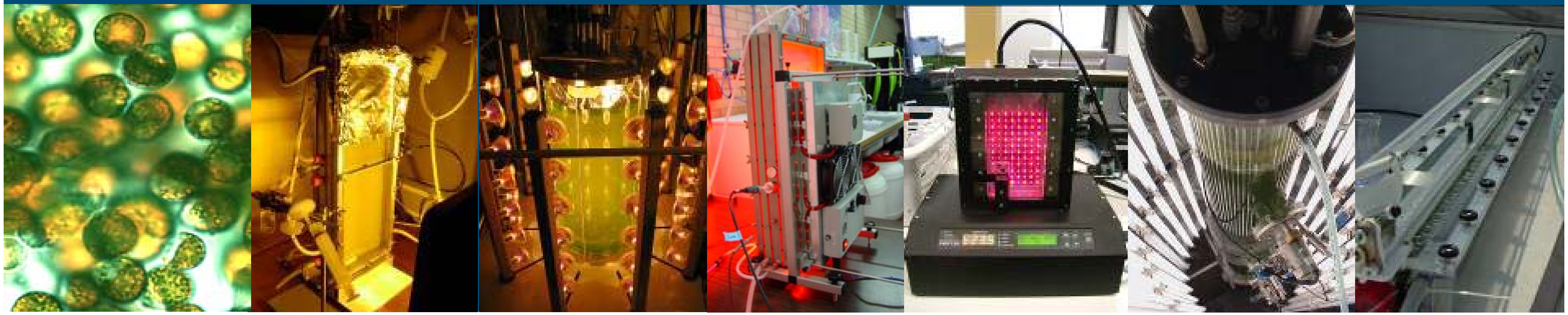
- Program coordinators:
  - Marcel Janssen: photobioreactors and CO_2 transfer
  - Marian Vermue: harvesting, biorefinery and O_2 effects
  - Dirk Martens: metabolic flux modelling
  - Maria Barbosa: AlgaePARC



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