Microalgae biotechnology

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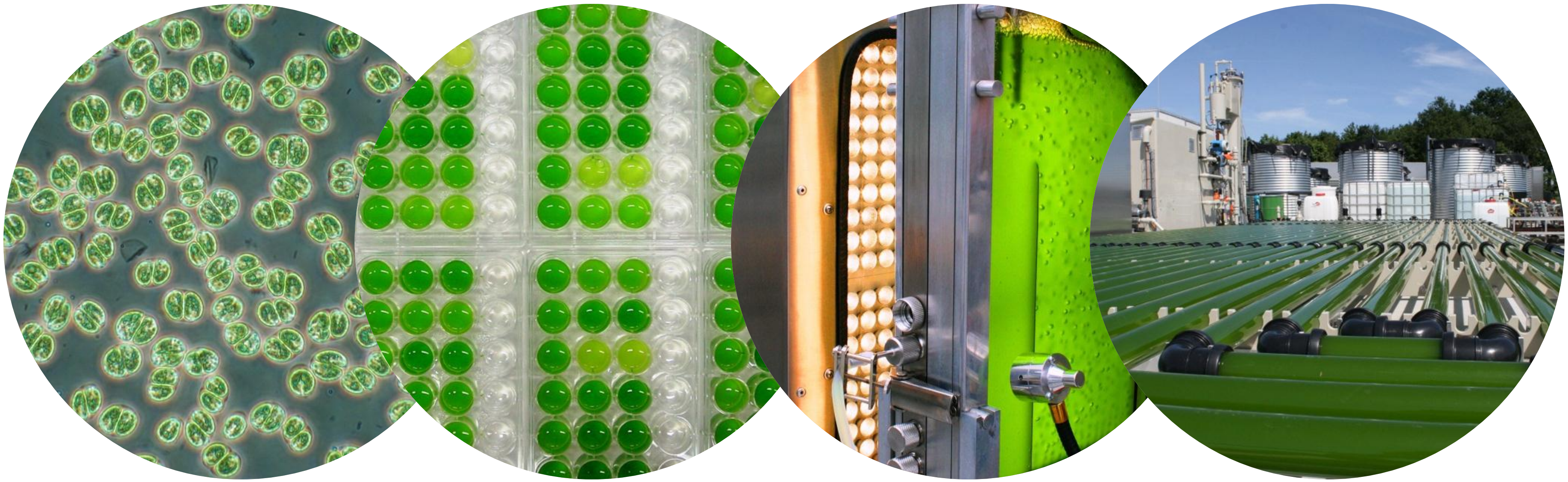

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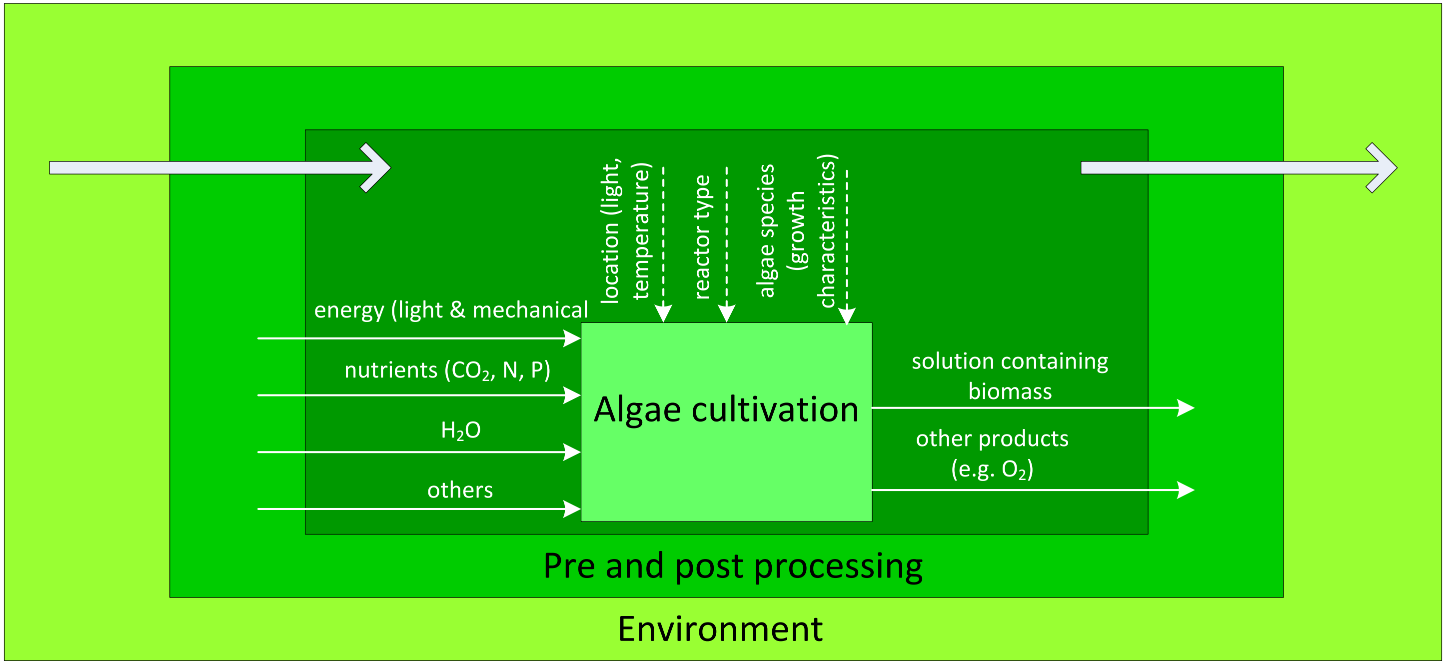
Research strategy

- Research in the context of a complete process
- Identification of bottlenecks
- In depth research on these bottlenecks
- Integration for complete process



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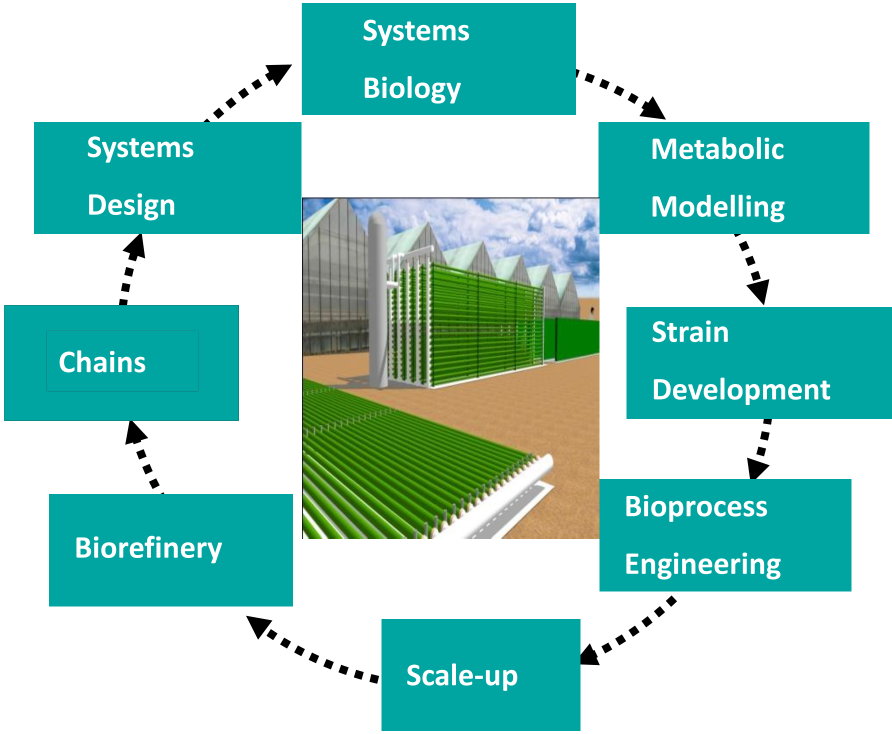
Wijffels & Barbosa (2010) An outlook on microalgal biofuels. Science 329: 796-799

Wageningen UR algae research

- Interaction between basic research and pilots
- Multidisciplinary approach
- Research topics
  - Efficient use of sunlight
  - Reduction of energy input
  - Use of residual nutrients
  - Lipid accumulation
  - Strain improvement
  - Scale-up
  - Biorefinery
  - Design scenarios/LCA’s



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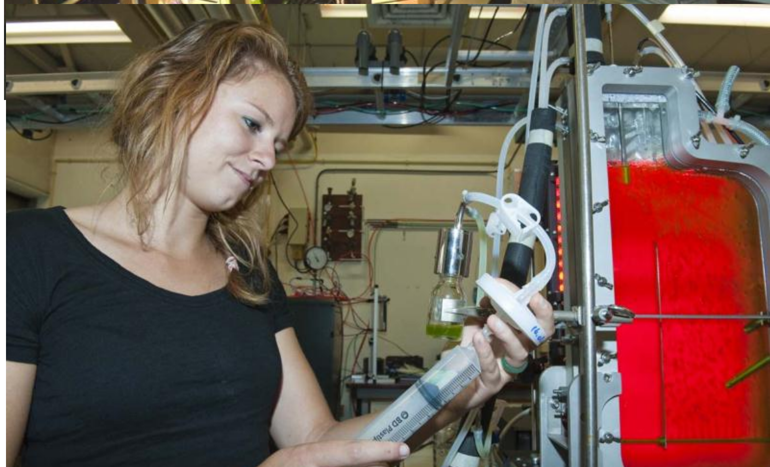
Research programs

- Photosynthetic Cell Factories, SmartSep, Biocement, FOM (NWO)
- Solar-H2, SUNBIOPATH, Aquafuels, Algadisk (EU-FP7)
- Sealand Sole (Min. EL&I, province Zeeland)
- SUNLIGHT (SBO, University of Ghent)
- Food and Nutrition Delta (Feyencon, Algaebiotec)
- AlgiCoat (Akzo, Ingrepro, Essent)
- Wetsus (15 companies)
- Biosolar Cells (min EL&I)
- AlgaePARC (18 companies)
- Emerald Oil (Unilever)
- Cradle to Cradle (NIOO)
- Feasibility study (Suriname Staatsolie)
- Microalgae biorefinery (climate KIC, ISPT)
- Systems analysis for large scale biofuel production (NSF)
- SPLASH (EU)



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Industrial consortia

- <u>Technology platforms:</u>

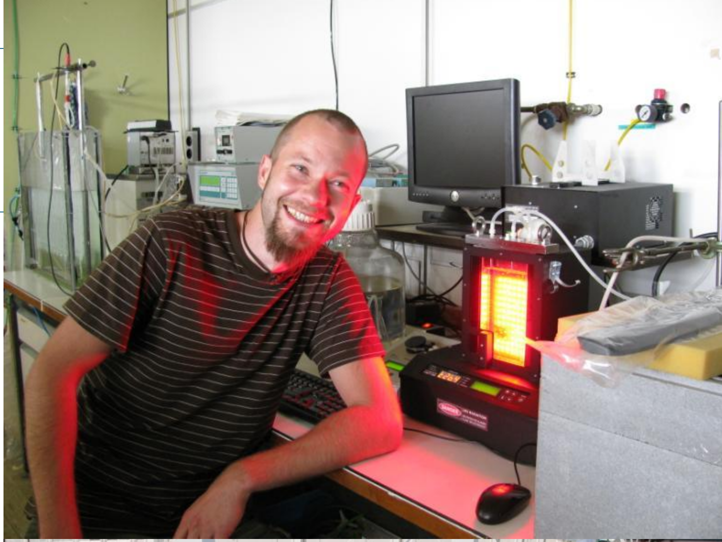
  Large industrial consortia

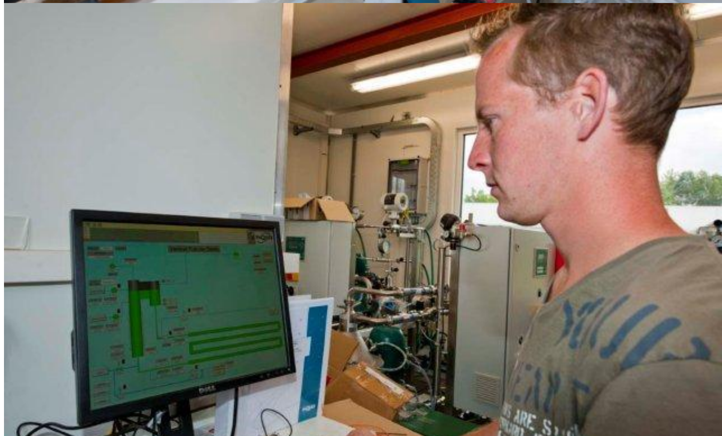
  - Production: Wetsus
  - Scale-up: AlgaePARC
  - Biorefinery: ISPT

- <u>Production platforms:</u>

  - Products of specific interest to individual companies
  - Demonstration projects:

    climate KIC





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Collaboration Wageningen UR with industry

- Large consortia

wetsus ISPT BioSolar Cells

AlgaePARC

- Collaboration with industry

BASF The Chemical Company · DSM Bright Science. Brighter Living. · Drie Wilgen Development · ExxonMobil · GEA Westfalia Separator Group · heliae

Neste Oil · nijhuis Water Technology · Paques · pdx Exceptional Efficiencies · Proviron · Roquette Offering the best of nature

sabic · Simris Alg Food & Fuel from the Sea · Staatsolie · Synthetic Genomics · Total · Unilever

FrieslandCampina · Delta the multi-utility company · Dow · syngenta · ingrepro · FeyeCon

AkzoNobel Tomorrow's Answers Today · desah · Eneco · essent · alliander · Infors HT

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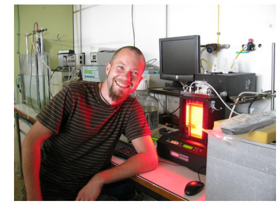
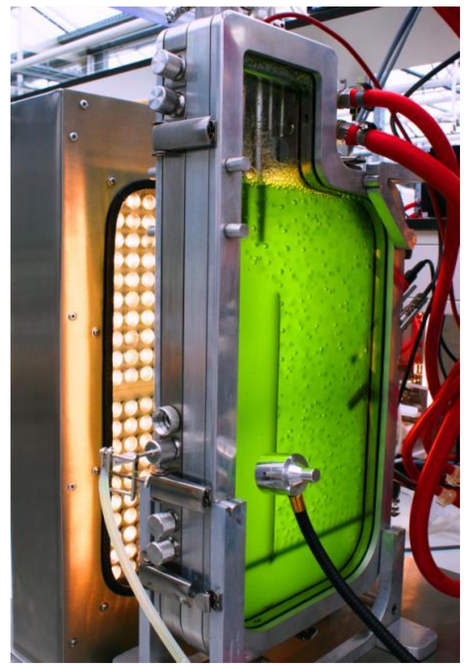
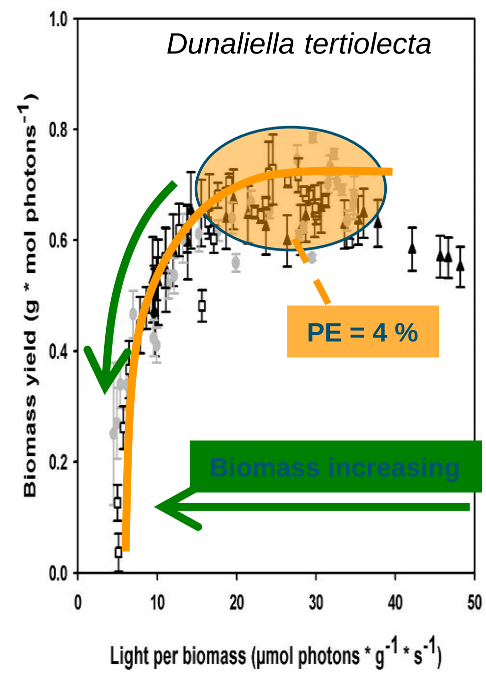
Efficient use of sunlight

Carsten Vejrazka
Lenneke de Winter
Tim de Mooij
Maria Barbosa
Marcel Janssen

- What is the best combination of light intensity, light path and biomass density?
- Does a flashing light effect exist? Does mixing help?
- What is the effect of truncated antennae on the reactor productivity?



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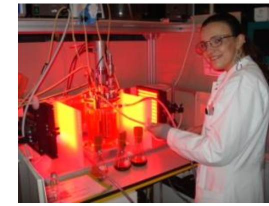
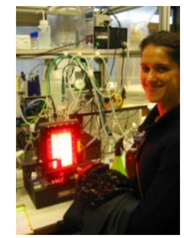
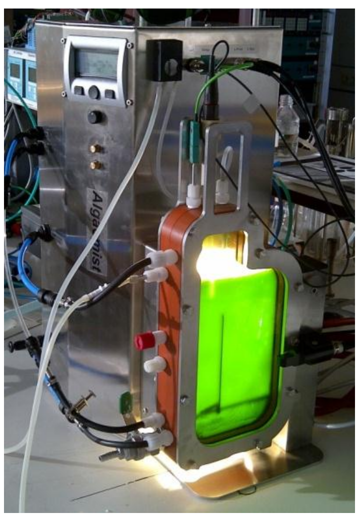
Vejrazka et al. (2011) Photosynthetic efficiency of *Chlamydomonas reinhardtii* in flashing light. Biotechnol. Bioeng.108: 2905-2913 Cuaresma et al. (2011) Horizontal or vertical photobioreactors? How to improve photosynthetic efficiency. Bioresource Technology 102: 5129-5137
Zijffers et al.(2010) Maximum photosynthetic yield of green microalgae in photobioreactors. Mar. Biotechnol. 12: 708-718

Reduction of energy input

Claudia Sousa
Ana Santos
Sayam Raso
Packo Lamers

- Development of an energy efficient and economically feasible process for O_2 and CO_2 transfer in highly productive lipid-rich microalgae
- Growth at high O_2 partial pressure and high CO_2 concentrations
- Growth under alkaline-saline conditions

	Content (% w/w)							
Fatty acid	pH 8.1 N+	$\%_{rel}$	pH 8.1 N-	$\%_{rel}$	pH 10.0 N+	$\%_{rel}$	pH 10.0 N-	$\%_{rel}$
C16:0	2.41	31.1	3.92	29.6	2.74	23.8	7.79	22.3
C16:1	0.22	2.8	-	-	0.31	2.7	0.14	0.4
C18:0	0.17	2.2	0.35	2.6	0.39	3.4	0.76	2.2
C18:1	1.00	12.9	4.00	30.2	3.34	29.0	15.22	43.6
C18:2	2.14	27.6	3.08	23.3	3.23	28.0	9.25	26.5
C18:3	1.80	23.6	1.88	14.2	1.51	13.1	1.72	4.9
Total	***7.74***		***13.23***		***11.52***		***34.88***	

Santos et al (2011) Growth of oil accumulating microalga *Neochloris oleoabundans* under alkaline-saline conditions. Bioresource Technol. doi:10.1016/j.biortech.2011.10.084
Sousa et al. (2011) Growth of the microalgae *Neochloris oleoabundans* at high partial oxygen pressures and sub-saturating light intensity. Bioresource Techn. dx.doi.org/10.1016/j.biortech.2011.10.048
Raso et al. (2011) Effect of oxygen concentration on th growth of Nannochloropsis sp. At low light intensity. J. Appl. Phycol. DOI 10.1007/s10811-011-9706-z

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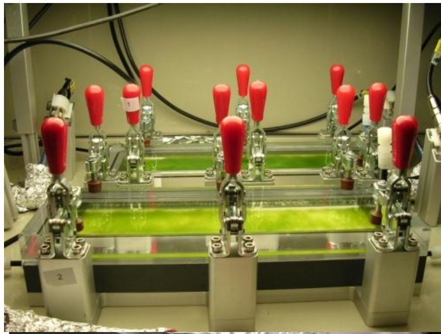
Use of residual nutrients

Nadine Boelee
Kanjana Tuantet
Hardy Temmink
Marcel Janssen
Tania Fernandes
Nadia Inderfurth
Packo Lamers

- Effluent polishing
  - Reduction and recovery of N and P
  - Cultivation with cell retention → biofilms
  - Optimal uptake at loading:
    1.0 g N/m2/d and 0.13 g P/m2/d
  - Target values 2.2 mg/L N and 0.15 mg/L P reached
- Urine as nutrient source
  - 6 g-N·L^{-1} and ± 0.5 g-P· L^{-1}
  - Thin photobioreactors with high light input



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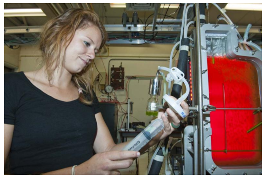
Boelee et al (2011) Nitrogen and phosphorus removal from municipal wastewater effluent using microalgal biofilms. Water Research 45: 5925-5933

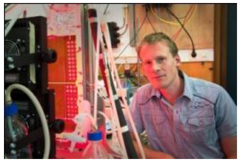
Lipid accumulation

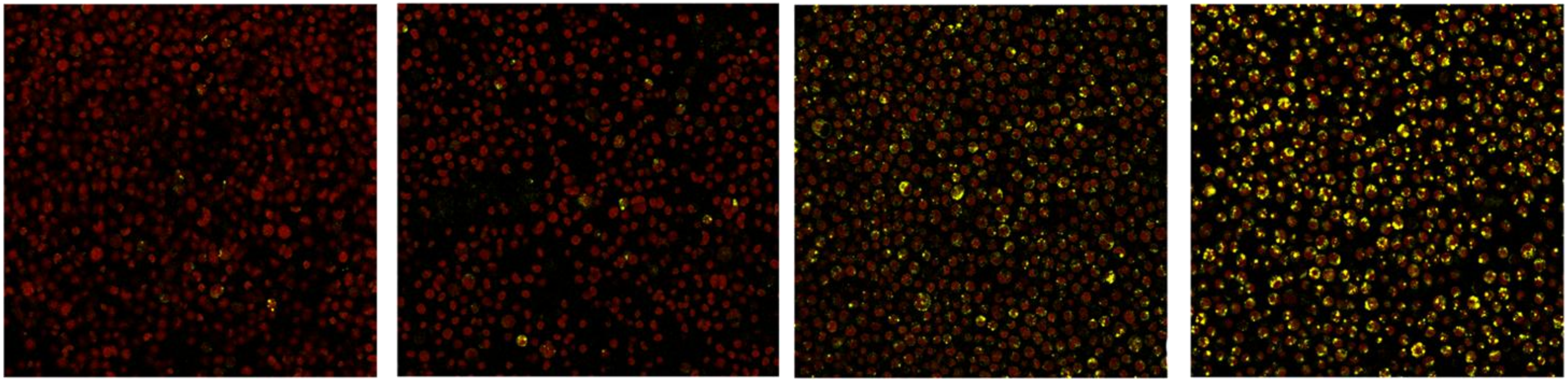
Anne Klok
Marjon van Es
Guido Breuer
Kim Mulders
Packo Lamers
Dirk Martens

- Metabolic flux modelling
- How to produce lipids in continuous bioreactors: turbidostat
- *Neochloris oleoabundans, Phaeodactylum tricornutum, Botryococcus braunii* and others





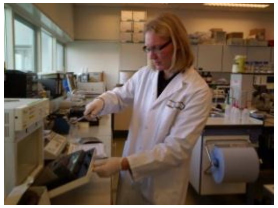




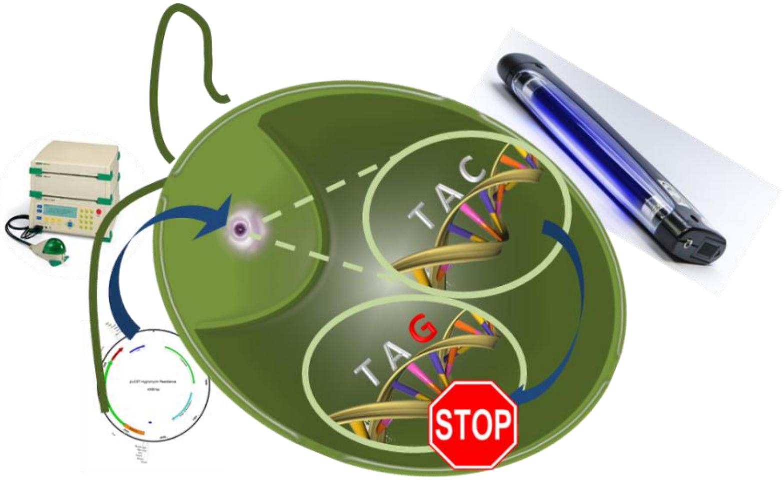
Kliphuis & Klok et al. (2011) Metabolic modeling of Chlamydomonas reinhardtii: energy requirements for photoautotrophic growth and maintenance. J. Appl. Phycol. DOI 10.1007/s10811-011-9674-3

Strain improvement

Lenny de Jaeger
Stefan Aanstoot
Jan Springer
Gerrit Eggink



- Lipids
  - Strain improvement towards a desired fatty acid profile
  - Substitute for vegetable oil directly applicable in the current edible oil infrastructure
- Hydrocarbons
- Mutagenesis and direct gene targeting approaches

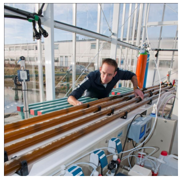


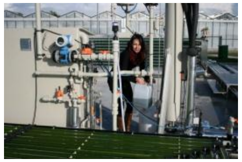
Scale-up

Rouke Bosma
Maria Barbosa
Giulia Benvenuti
Dorinde Kleinegris
Maria Cuaresma
Jeroen de Vree
Niels-Henrik Norsker
Michiel Michels

- AlgaePARC
  - International centre of applied research
  - Intermediate between basic research and applications
  - Development of competitive technology (economics, sustainability)
- Demonstration farm aquaculture
- Demonstration project Spain





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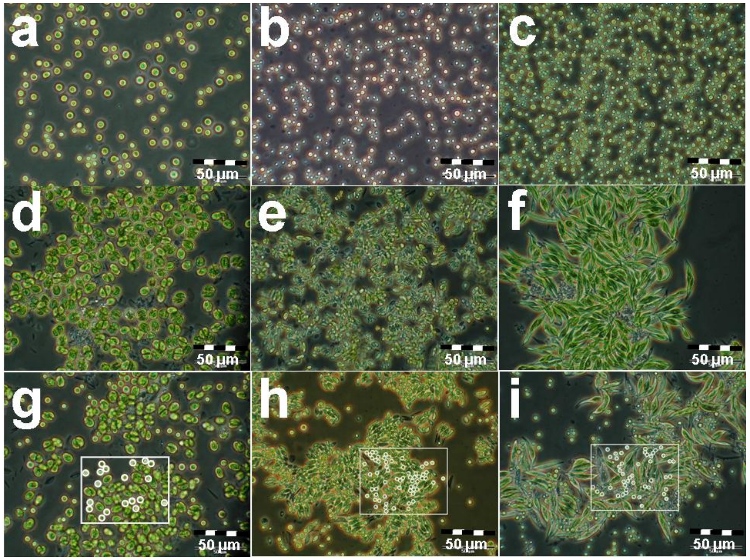
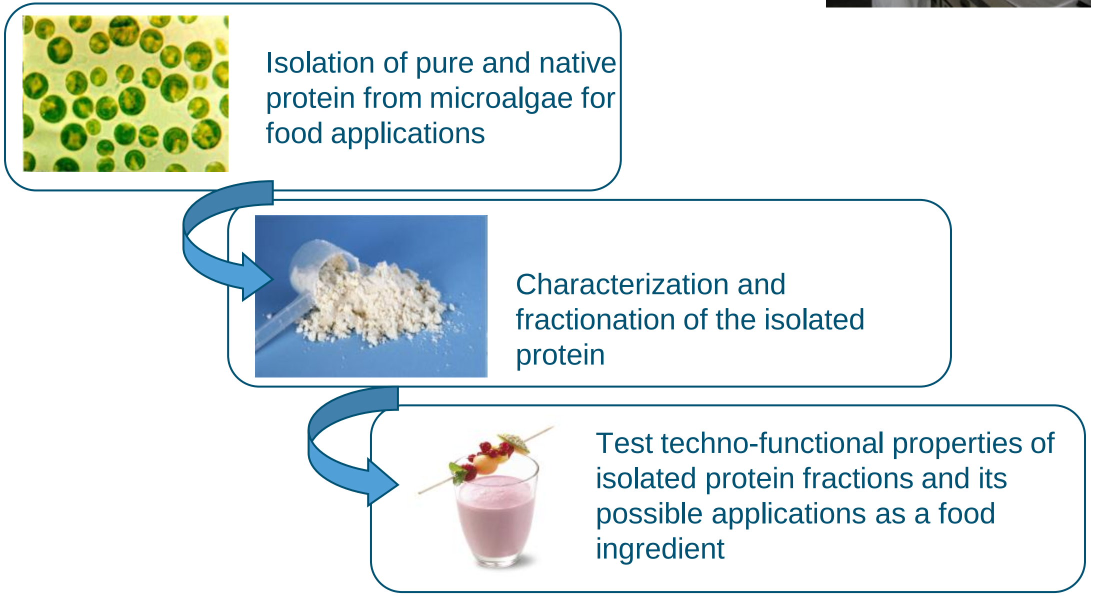
Biorefinery

Anja Schwenzfeier
Sina Salim
David Habeych
Rupali Desai
Emre Gunerken
Marian Vermuë
Michel Eppink

- Bioflocculation before harvesting
- Disruption of cell walls under mild conditions
- Extraction of lipids and functional proteins
- Fractionation of proteins





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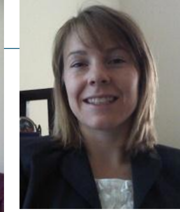
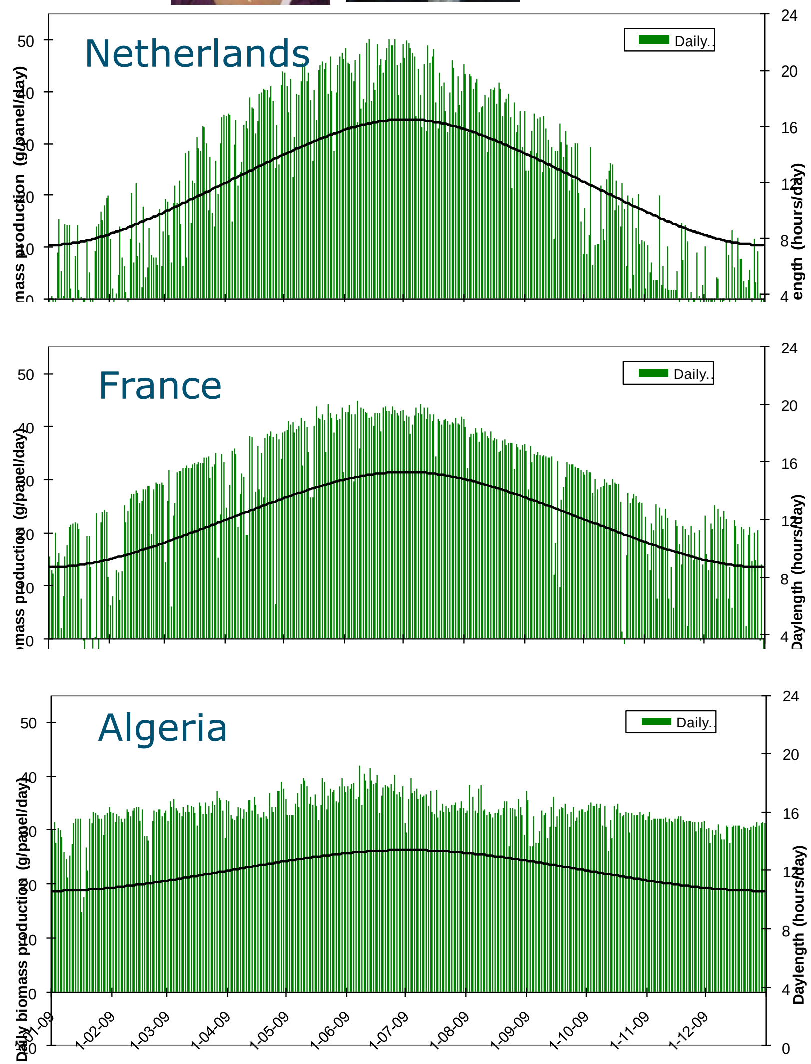
Salim et al. (2011) Harvesting of microalgae by bioflocculation. J. Appl. Phycol. 23: 849-855
Schwenzfeier et al (2011) Isolation and characterization of soluble protein from the green microalgae *Tetraselmis* sp. Bioresource Technol. 102: 9121-9127
Wijffels et al (2010) Microalgae for production of bulk chemicals and biofuels. Biofuels, Bioproducts and Biorefining 4: 287-296

Systems design



Ellen Slegers
Laura Brentner
Ton van Boxtel

- Design scenarios
  - Location
  - Scale
  - Technology
  - Logistics
- Extrapolation to other locations
  - Calculation
  - Experimental
- Life Cycle Assessment
  - Complete production chains
  - Compare with alternatives



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Slegers et al (2011) Design scenarios for flat panel photobioreactors. Applied Energy 88: 3342-3353
Brentner et al (2011) Combinatorial Life Cycle Assessment to Inform Process Design of Industrial Production of Algal Biodiesel. Environ. Sci. Technol. 45, 7060–7067

Young Algaeneers
a green generation with energy for the future

- Need for professionals
  - 1,000 new professionals/year
  - 5% of students knows ‘biobased economy’
  - Upon explanation 80% favours a biobased economy -> career

- *High schools*
- *University: BSc/MSc*
- *Graduate courses*

Young Algaeneers

Symposium for young scientists only
14th-16th of June, 2012 Wageningen, NL
young.algaeneers@wur.nl

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Conclusions

- Development of scalable technology
- Sustainable production of bulk products
  - Biofuels (biodiesel)
  - Food (protein, oil)
  - Feed (protein, oil)
  - Chemistry (amino acids, oil)
  - Materials (silica, polysaccharides)
- Educate

Research facility in Matalascañas, Spain

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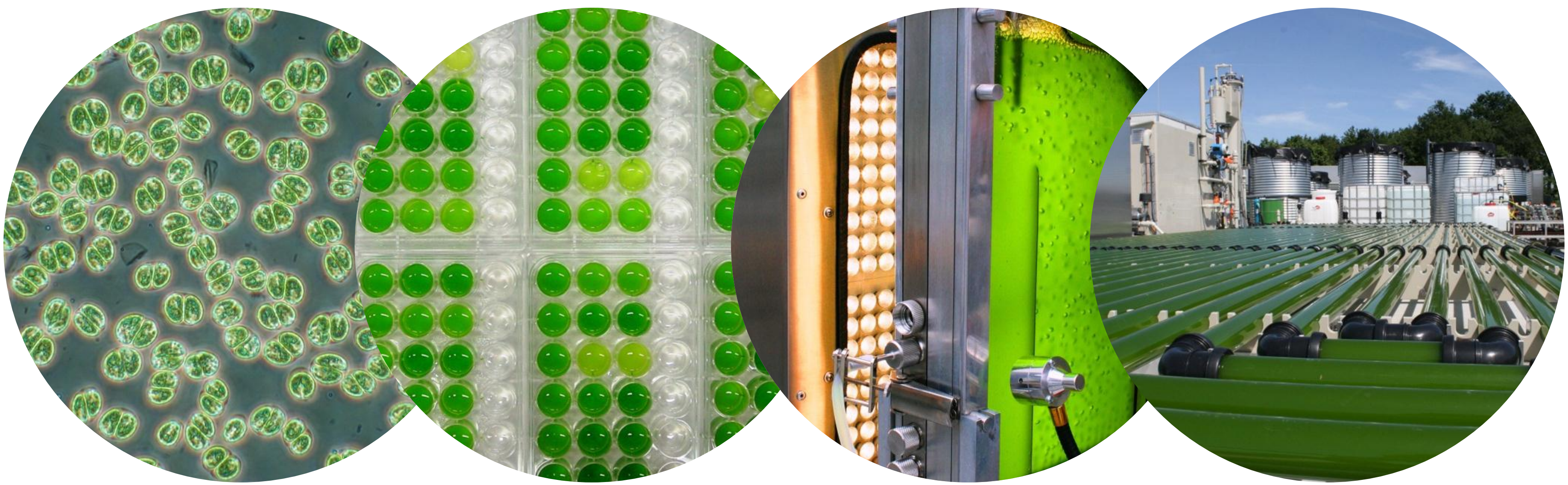
2 PostDoc vacancies (2-3 yrs) for experienced microalgae biotechnologists
Contact me when interested



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