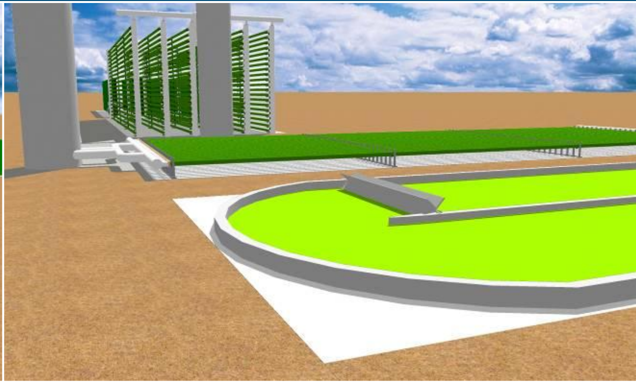
# Microalgae in a biobased economy

Dr.ir. Packo P. Lamers
*Assistant Professor in Bioprocess Engineering*
*Wageningen University, the Netherlands*

PAN, Lublin, 4 Nov. 2011





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# Towards a biobased economy

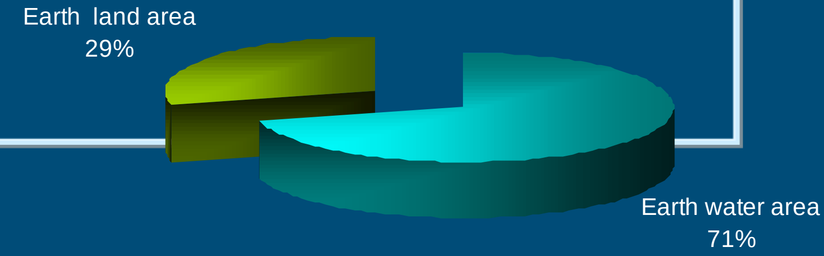
*Ma*

*"Production of fuels, food, feed, bulk and fine chemicals using waste streams, renewable resources and biological processes"*

# Drivers for aquatic Biomass

## Biobased Economy

- World population growth and increase in prosperity -> higher energy demand
- High energy prices
- Security of energy supply
- Climate change due to greenhouse gasses
- Rural development




## Specific aquatic biomass

- Increased competition for land for the production of food, chemicals and energy
- Limitations of land for agriculture
- Impacts of global climate change on agricultural productivity

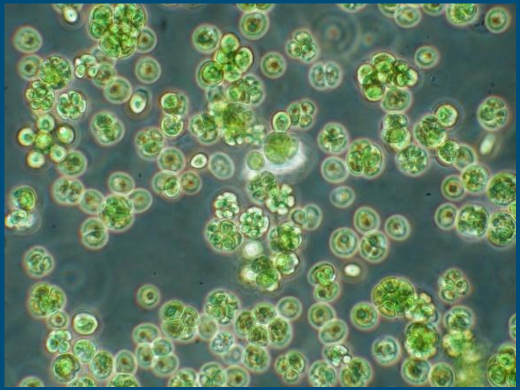
# Why microalgae?

| Feedstock | Oil Productivities<br>L / ha /year |
|---|---|
| Corn | 172 |
| Soybeans | 446 |
| Sunflower | 386 |
| Rapeseed | 1 250 |
| Oil palm | 5 950 |
| Jatropha | 1 892 |
| Microalgae | |
| **PE 3%; 30% lipids; NL** | 12 300 |
| **PE 3% ; 30% lipids; Bonaire** | 25 800 |
| **PE 6% ; 30% lipids; Bonaire** | 52 000 |

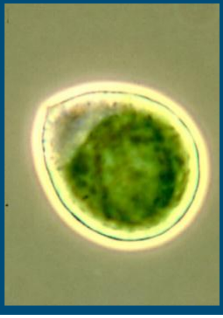
Where we are

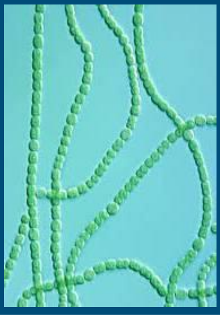
Potential

# Why microalgae?



- High areal productivities
- Can grow in seawater
- No competition for arable land
- Lower water footprint than agricultural crops
- Great variety in species -> variety in products!
- Ability to accumulate large amount of oils
- Offer possibility to steer metabolism to production of specific compound
- $CO_2$ mitigation
- Recycling nutrients (N & P)

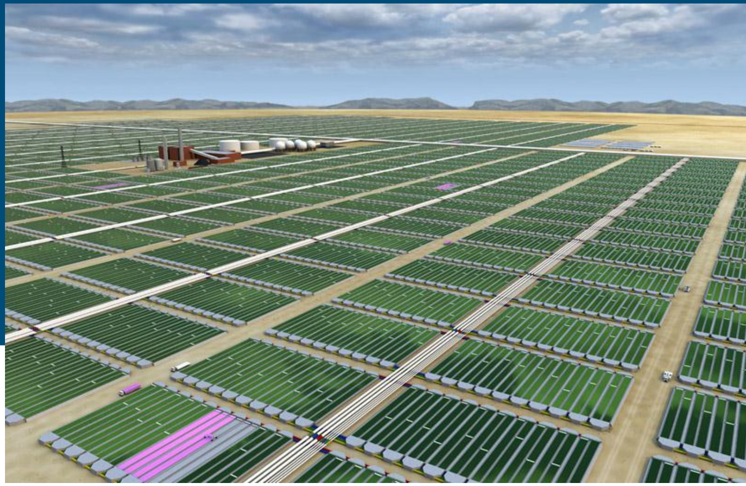



# What can be produced?

- Biofuels
- Industrial biochemicals (biopolymers, lipids, …)
- Pharmaceuticals
- Ingredients for food/feed
- ‘Sink’ for $CO_2$
- Integration with other processes
  - Biogas installation
  - Waste water treatment
  - Aquaculture systems (fish /shellfish, shrimps)

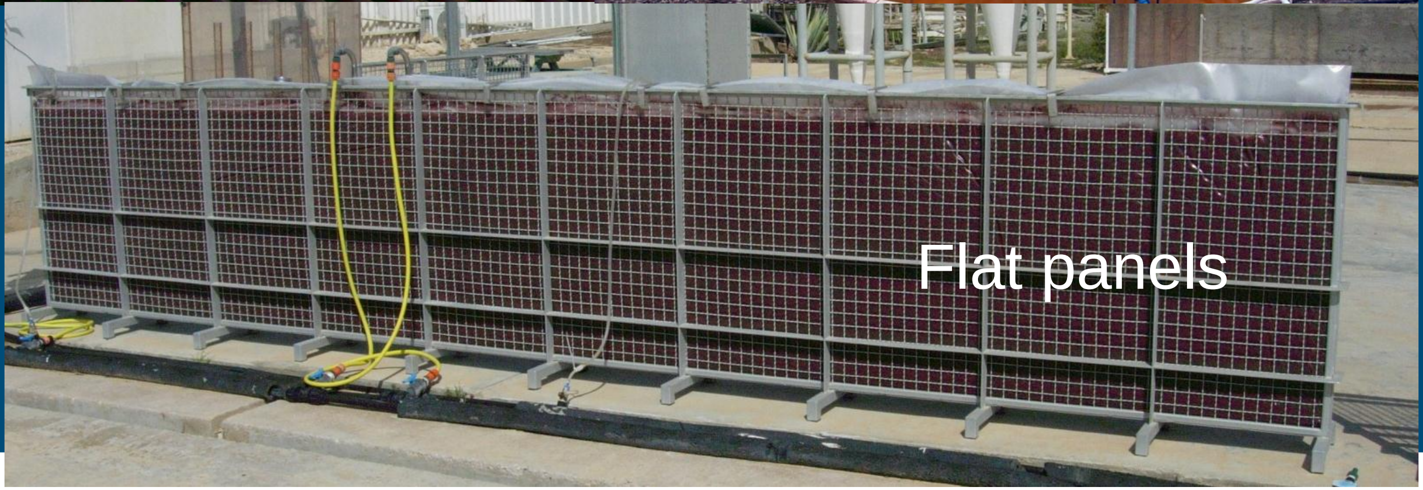
# From a craft to an industrial process…

- Current worldwide microalgal manufacturing infrastructure ~5000 tons of dry algal biomass
- High value products such as carotenoids and ω-3 fatty acids used for food and feed ingredients.
- Total market volume is €1.25 billion (average market price of €250/kg dry biomass)
- World production of palm oil is nearly 40 million tons, with a market value of ~0.50 €/kg



# 2007: Delta Feasibility Study



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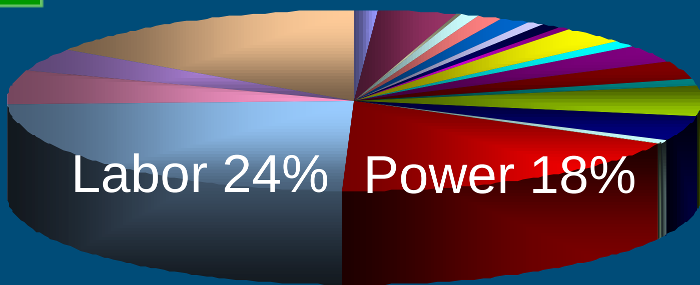
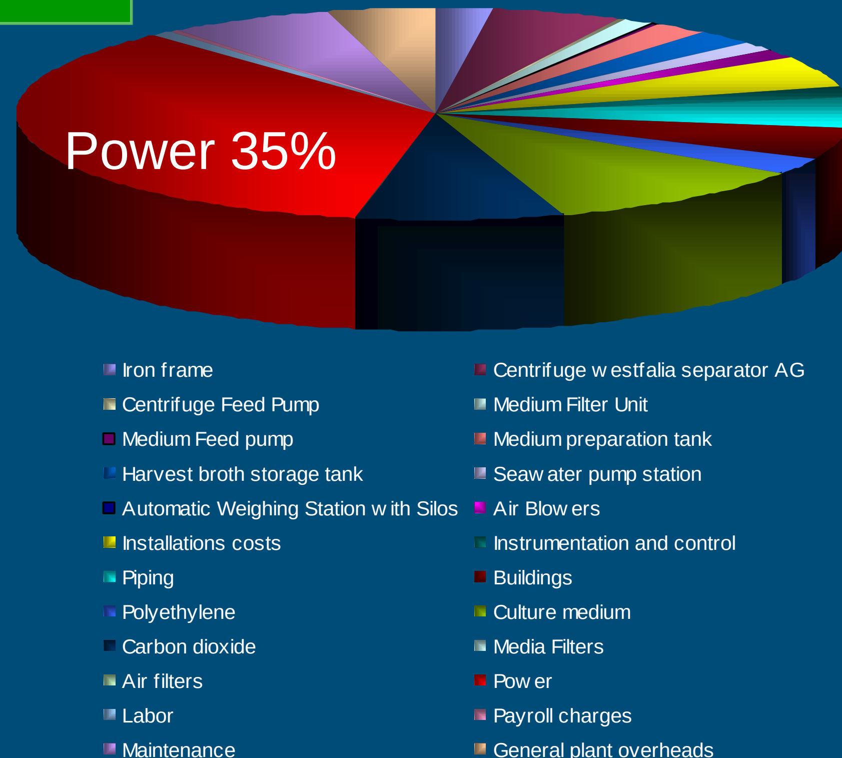
# Delta feasibility study: production costs

1 ha




100 ha




- At 1 ha scale today: 10 €/kg
- At 100 ha scale today: 4 €/kg
- What will be possible: 0.70 €/kg

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Norsker N-.H., et al (2010) Microalgal production – a close look at the economics. ***Biotechnology Advances***

# Efficiency in supply and use of nutrients and resources

Sunlight

Water

$CO_2$, Nitrogen and Phosphorus

# Efficiency in supply and use of nutrients and resources

**Sunlight**

Water

$CO_2$, Nitrogen and Phosphorus

# Production costs

## Increasing Photosynthetic Efficiency – what margin do we have?

PE 9.0 %

↓ Reflection on PBR

8.6 %

↓ Night biomass loss

7.8 %

↓ Maintenance

What's left ?... 7.4%

Light saturation?

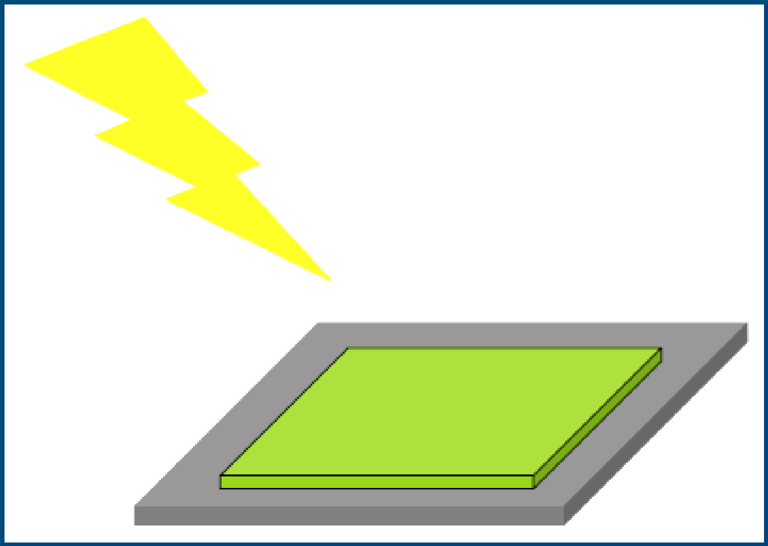
Nutrient limitations? $CO_2$

Inhibition? $O_2$, light

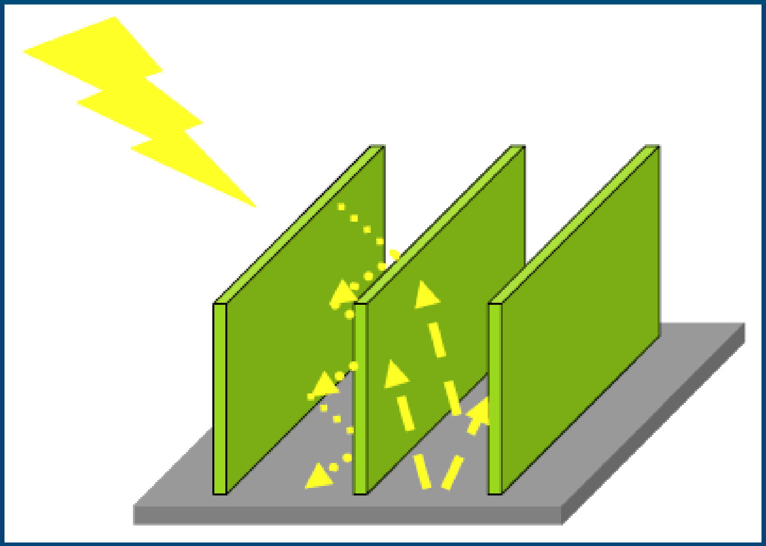
**ca 50% reduction in production cost**

Practice?... 3 - 4%

# The principle of light dilution – go vertical!

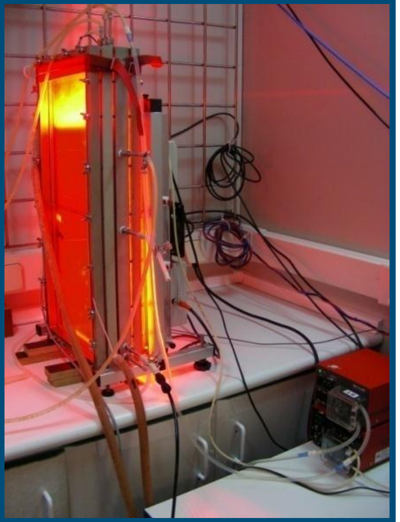


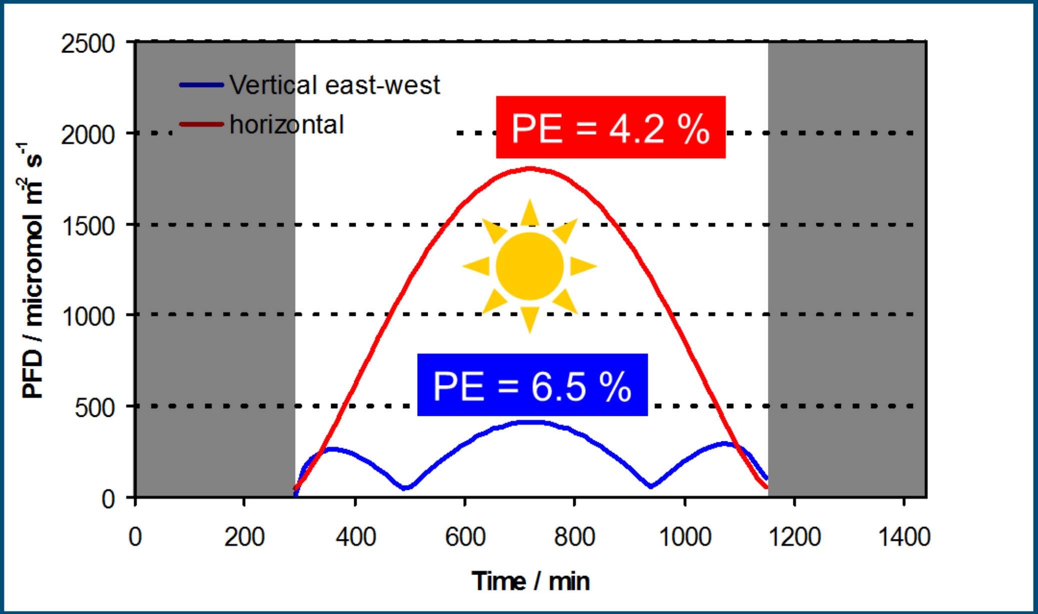
$I_{max}$: 1800 µmol photons $m^{-2}$ $s^{-1}$
(direct sunlight)



$I_{max}$: 400 µmol photons $m^{-2}$ $s^{-1}$
(diluting effect)

# Production costs: Photosynthetic Efficiency






At lab scale a photosynthetic efficiency of 6% is within reach

What about

- Pilot scale 10 – 100 $m^2$
- Extended time > 1 yr



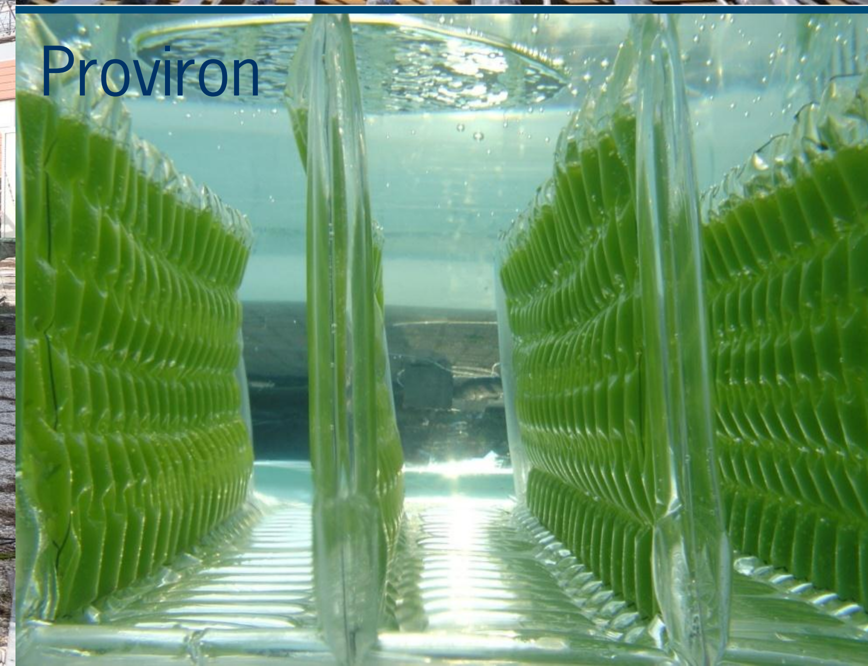
*Cuaresma et al. (2011) Bioresource Technology*

# Light dilution in practice

Challenges

- Material lifetime
- Cleanability
- Reduced energy input (e.g reflect IR)





# Efficiency in supply and use of nutrients and resources

Sunlight

**Water**

$CO_2$, Nitrogen and Phosphorus

# Main inputs in the process: Water

Photosynthesis : ~0.75 liter of water / kg of biomass
1.5 liters of water / liter of oil ( 50 % lipid content)

$$CO_2 + 0.93\ H_2O + 0.15\ NO_3^- \rightarrow CH_{1.72}O_{0.4}N_{0.15} + 1.42\ O2 + 0.15\ OH^-$$

In practice consumption is much larger:

- cooling closed systems
- fresh water needs to be added to open ponds to compensate for evaporation.

- Cooling with large saltwater buffer
- Seawater species
- Growth on large water surfaces (lakes and seas)

# Efficiency in supply and use of nutrients and resources

Sunlight

Water

**$CO_2$, Nitrogen and Phosphorus**

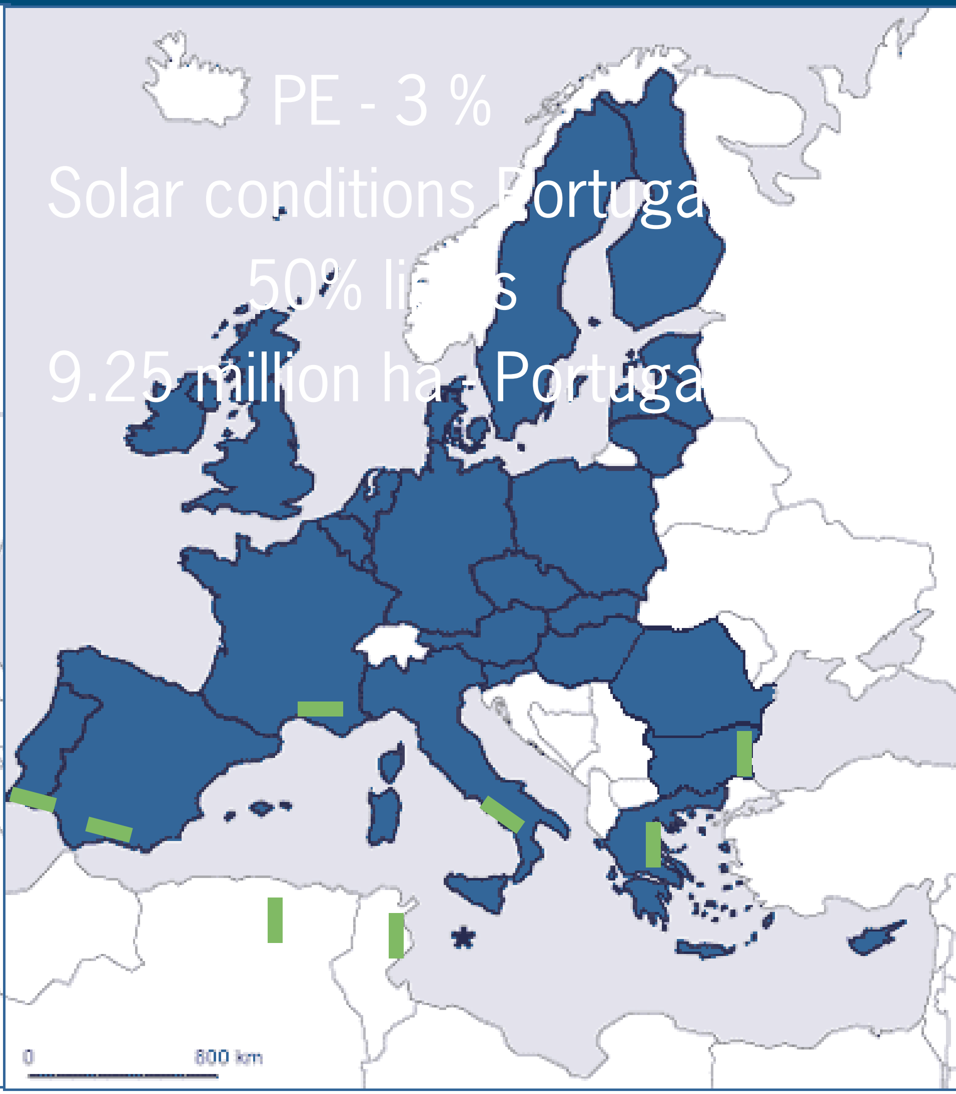
# Transport Fuels in Europe - 0.4 billion m3


PE - 3 %

Solar conditions Portugal

50% lipids

9.25 million ha - Portugal

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Wijffels R.H., Barbosa M.J. (2010) An outlook on microalgal biofuels. ***Science*** 329: 796-799

# Main inputs in the process $CO_2$

- 1.8 tons of CO2 is needed to produce 1 ton of algal biomass


- 1.3 billion tons of $CO_2$ for 0.4 billion m3 of biodiesel
- EU $CO_2$ production 4 billion tons of CO2

Logistics?

# Main inputs in the process N & P


Biomass: 7% N

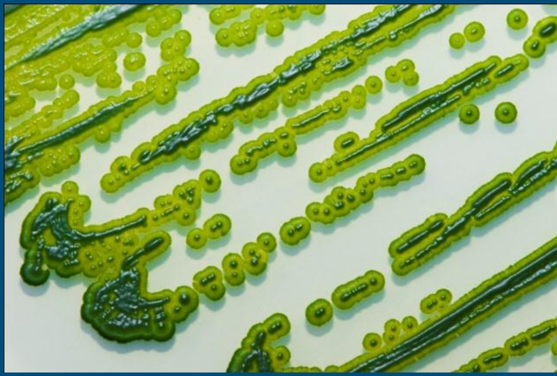
1 % P

- ~25 million tons of nitrogen
- 4 million tons of phosphorus

Twice the amount that is presently produced as fertilizer in Europe

- Use residual nutrient sources (ca 8 million ton N in Europe)
- Recycle nutrients

# How ?



- Increasing photosynthetic efficiency
- Integrate processes (free nutrients)
- Decreasing mixing
- Developing cheaper and less energy consuming harvesting technologies
- Choosing locations with higher irradiations

Scale-up

Production costs

Energy requirement

# AlgaePARC

## Algae Production And Research Center

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# AlgaePARC

The main focus of AlgaePARC is to develop knowledge, technology and processes strategies to ***scale up*** microalgae facilities ***under industrial settings*** and to optimise product productivities under stress and controlled conditions outdoors.

# Cultivations systems (24 m$^2$)

Open pond
- Reference

Horizontal tubes
- high light intensity
- oxygen accumulation

Vertical stacked hor. tubes
- light dilution
- oxygen accumulation

Flat panels (Proviapt)
- light dilution
- no oxygen accumulation

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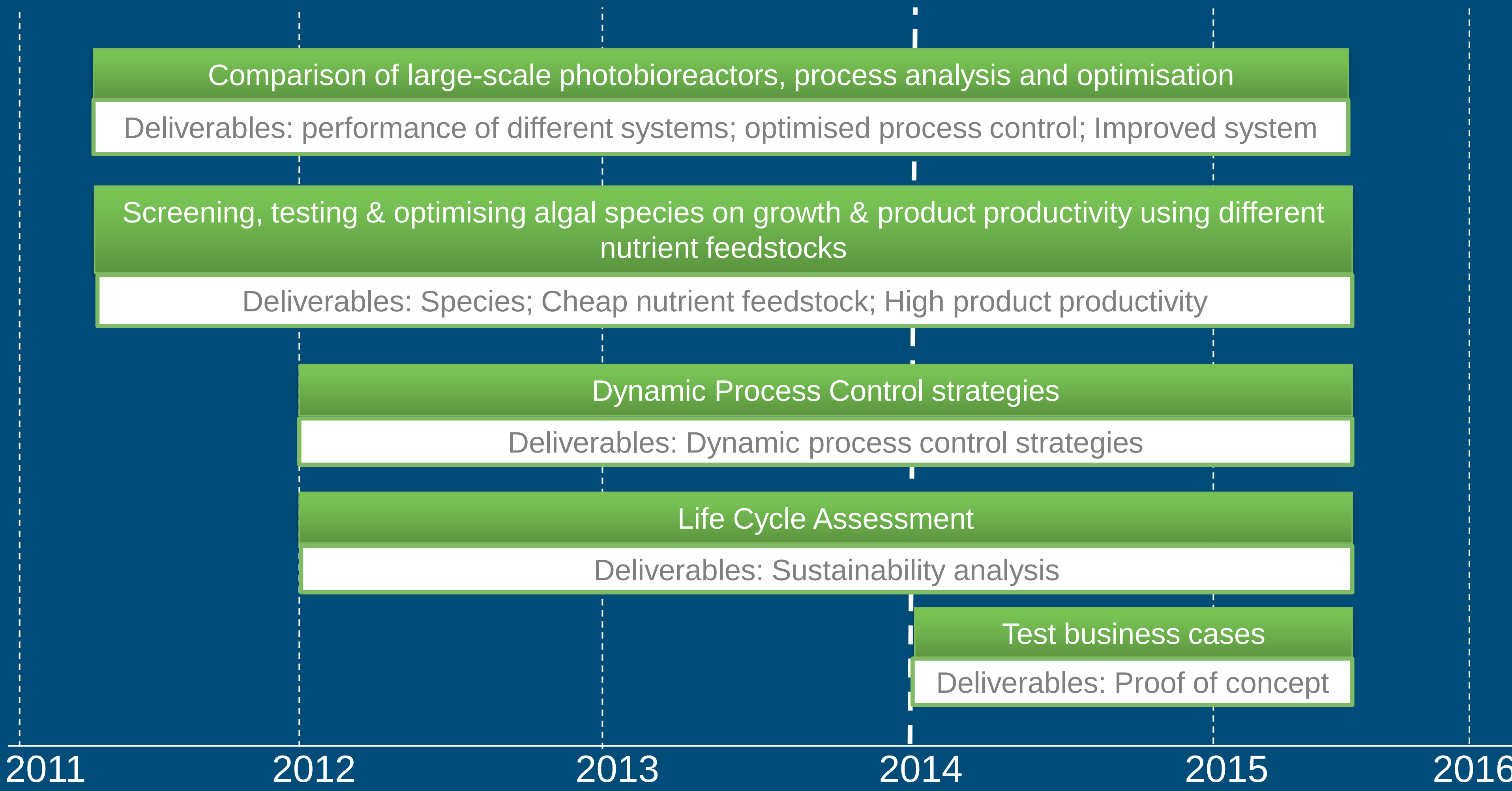
# R&D activities AlgaePARC

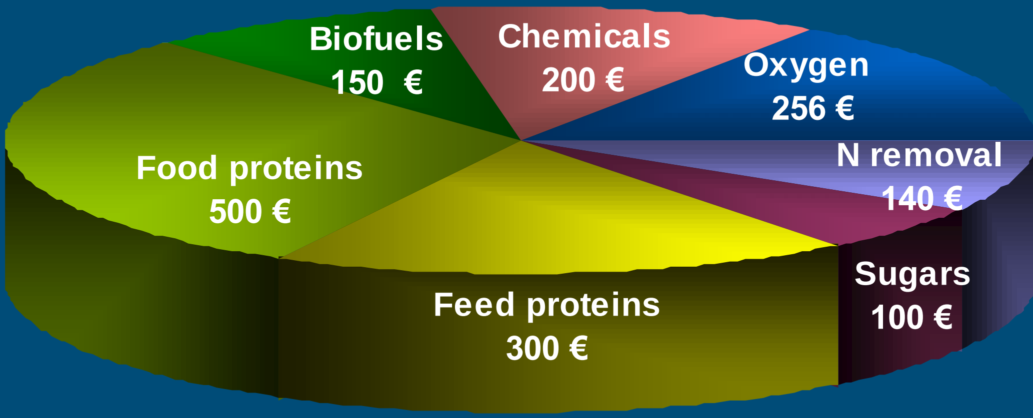


# Funding AlgaePARC

- Facility financed by
  - Ministry EL&I
  - Province Gelderland
  - Wageningen UR
- Research program financed by

# Next steps

- Development of demo projects
- Biorefinery
  - Mild cell disruption techniques
  - Fractionation biomass with maintainance of functionality of proteins
- From cell physiology to process strategies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# The Algaeneers


- June 2012

  PhD student conference

- 2012/2013

  PhD course on photobioreactor design

www.algae.wur.nl

www.AlgaePARC.com

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