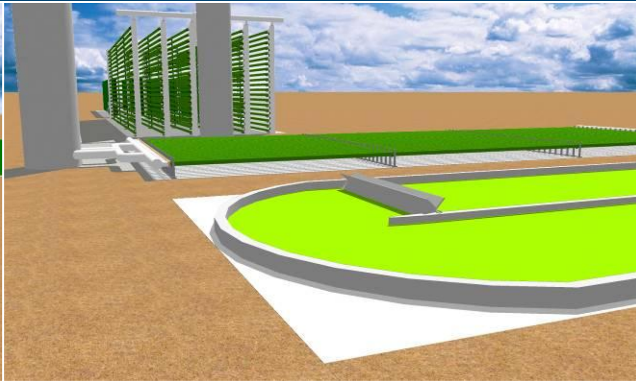
AlgaePARC

Towards optimal cultivation processes for sustainable microalgae production

Packo Lamers, Dorinde Kleinegris, Maria Barbosa, Rouke Bosma & René Wijffels



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From a craft to a sustainable 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)
- Economically viable, but not sustainable
- Parallels with microalgal biofuels

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

Efficiency in supply and use of nutrients and resources

Sunlight

Water

CO_2, Nitrogen and Phosphorus

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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%

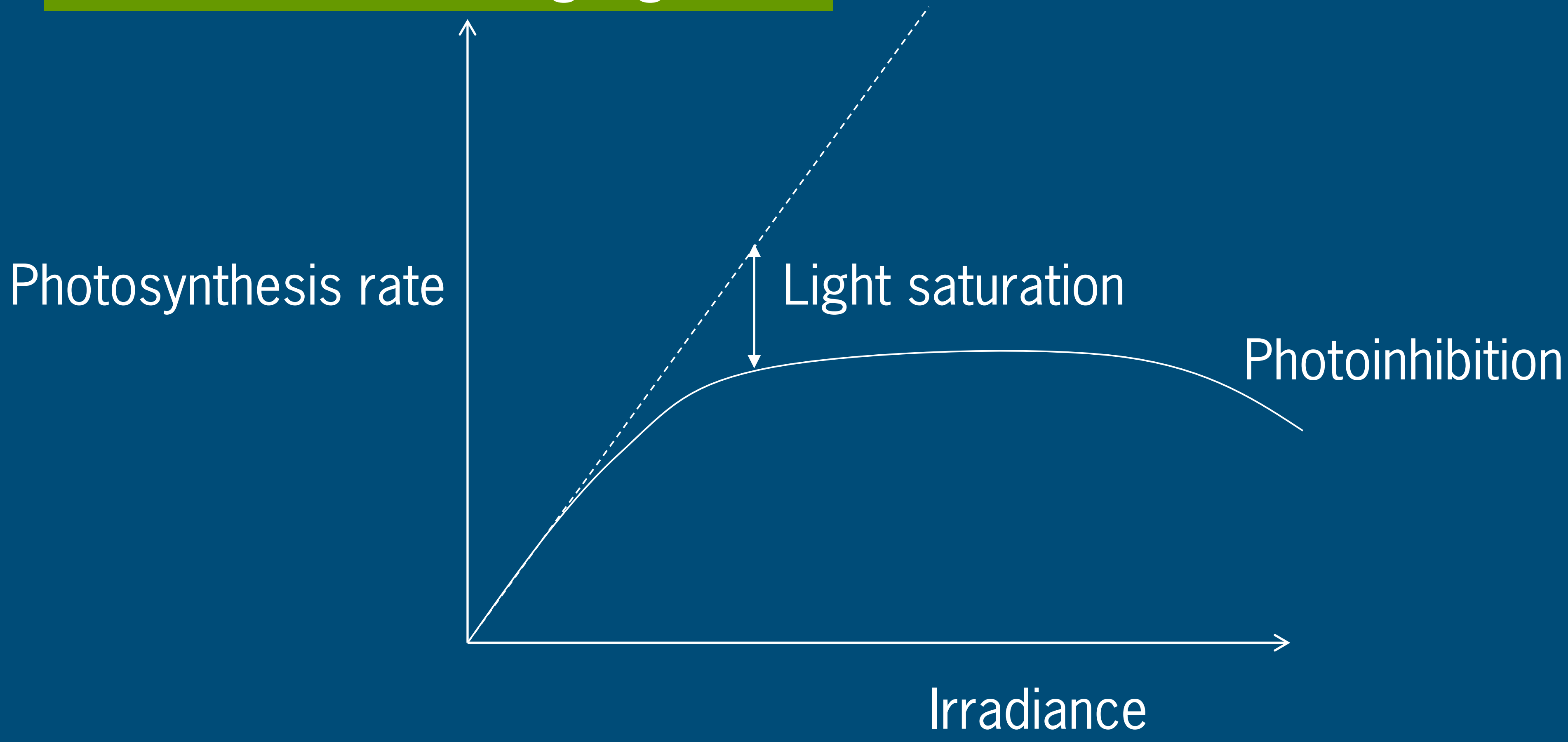
What's determining photosynthetic efficiency outdoors?

<u>Measured / controlled parameters</u>

- Incident light intensity
- Temperature
- O_2 partial pressure
- CO_2 partial pressure
- Gas flow rate / Liquid velocity
- Dilution rate
- pH
- Nutrients

Photosaturation and photoinhibition

Diluted cultures – no light gradient

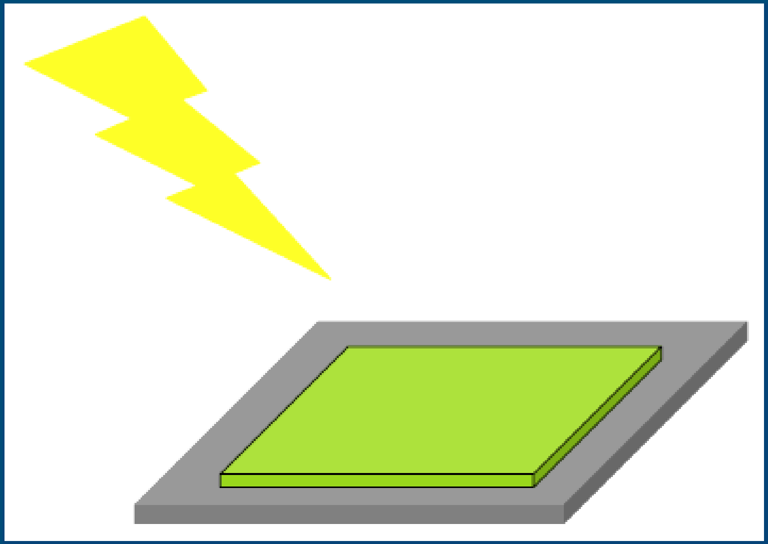


Increasing PE under oversaturating light

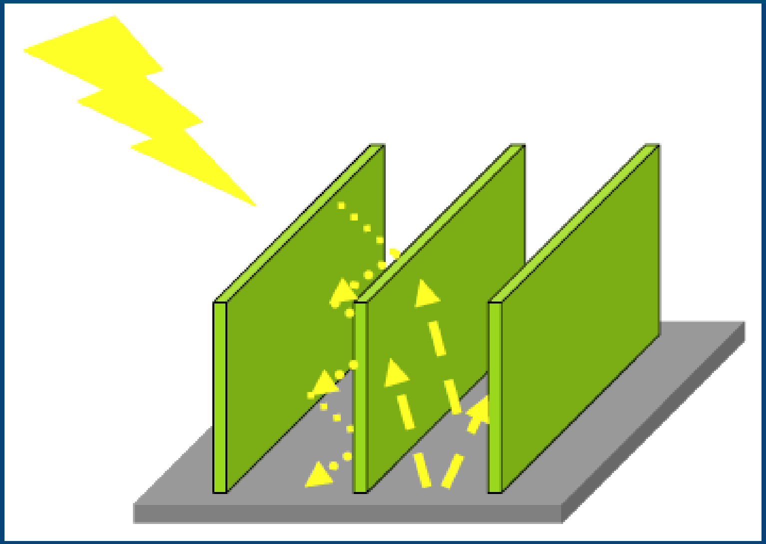
- Decrease antenna size
- Reactor design:
  - Decrease light path of photobioreactors while increasing turbulence

    High energy input?!
  - Light dilution

The principle of light dilution – go vertical!

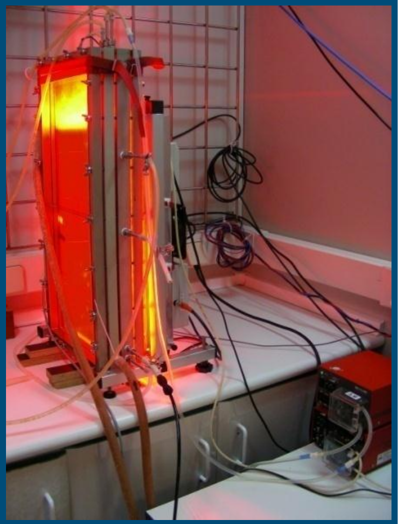


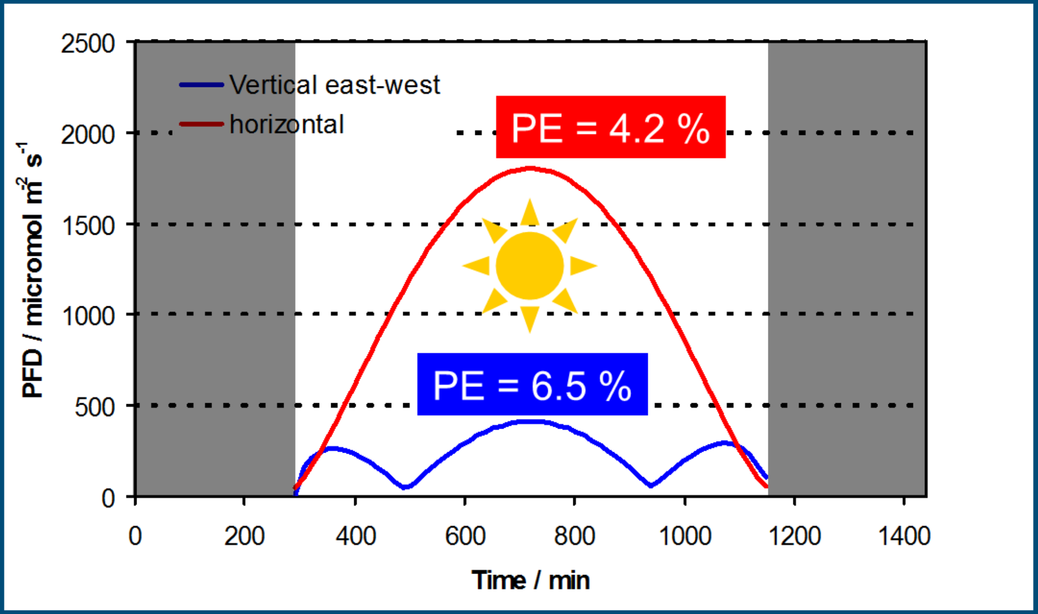
I_{max}: 1800 μmol photons m^{-2} s^{-1}
(direct sunlight)



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

Production costs: Photosynthetic Efficiency





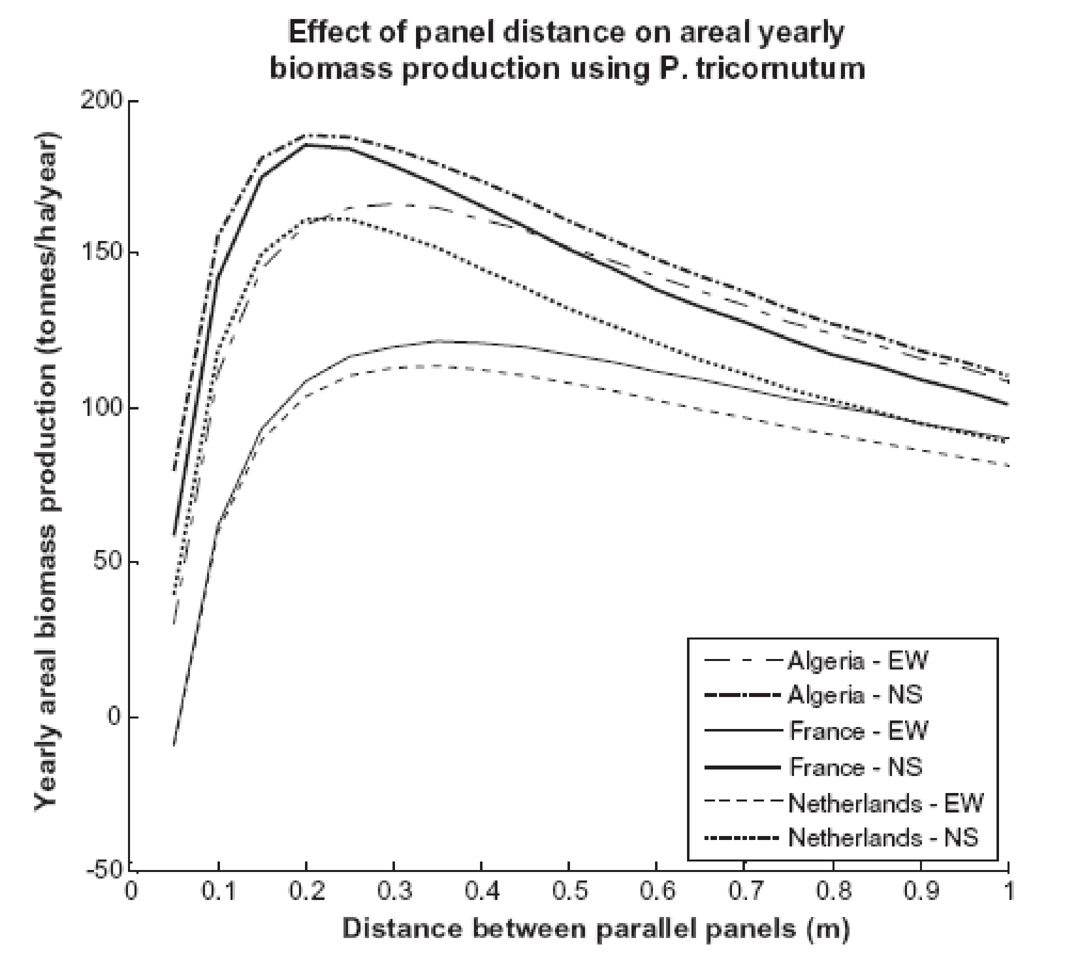
At lab scale a photosynthetic efficiency of 6% is within reach

What about

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

Scale-up: design studies

e.g Effect panel distance and orientation

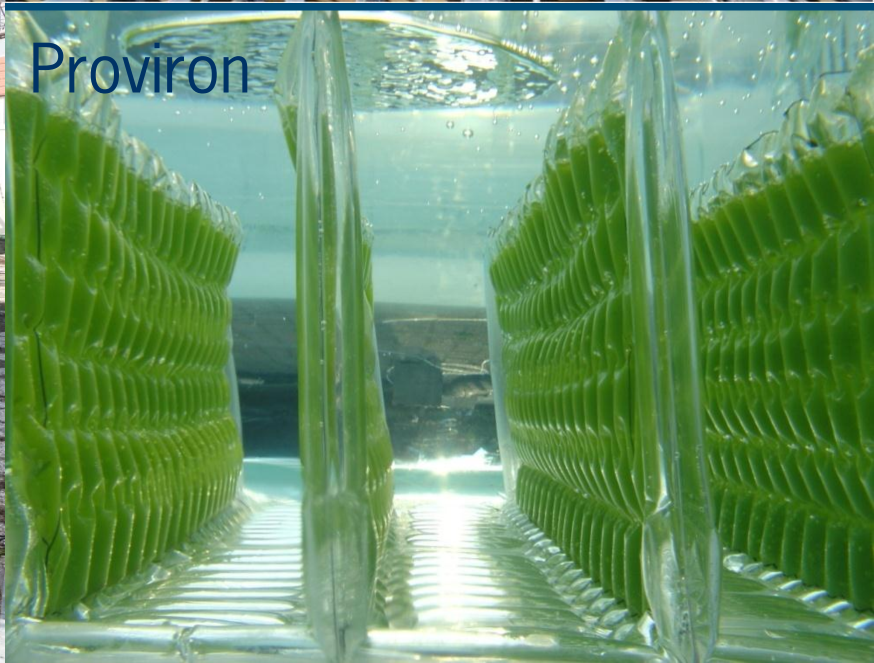


Slegers et al. (2011) Applied Energy

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

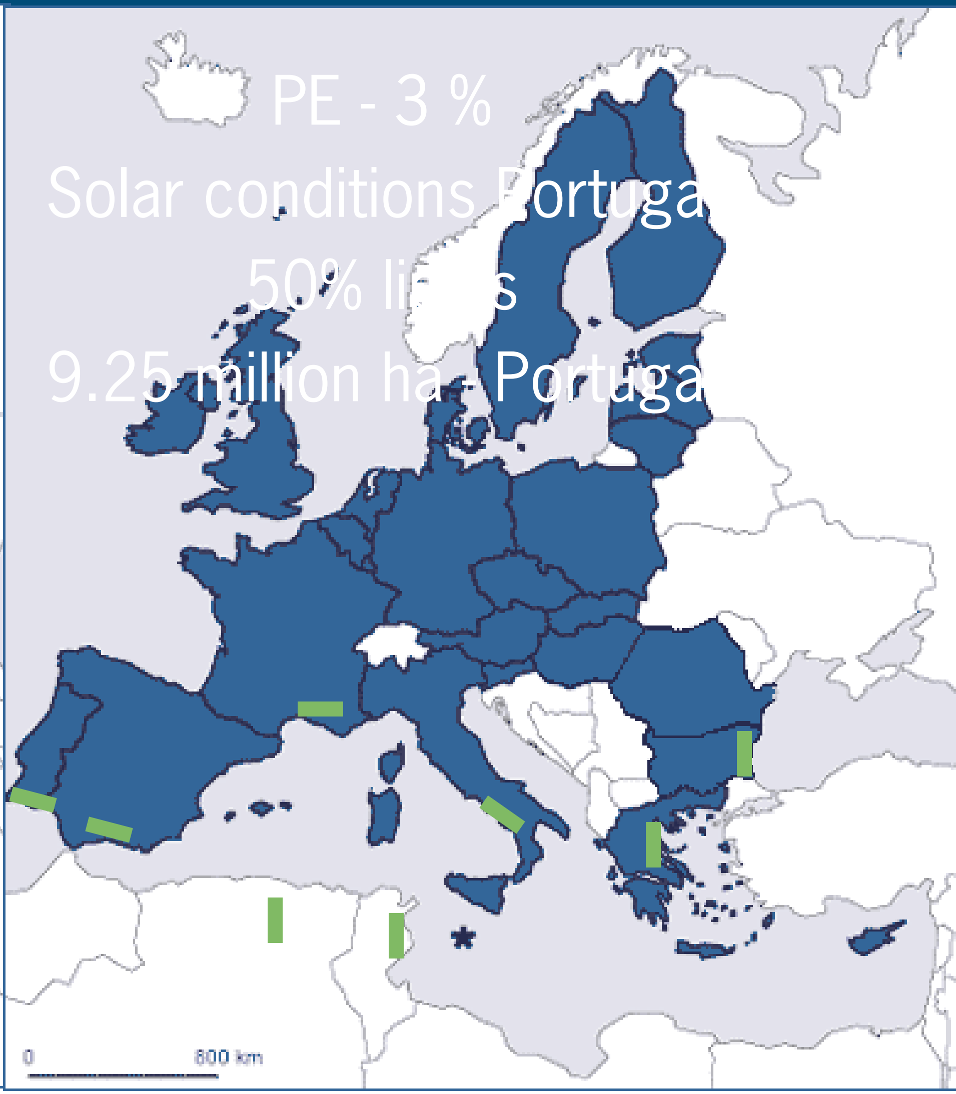
CO_2, Nitrogen and Phosphorus

Main inputs in the process

To produce 1 ton of algal biomass:

- 1.8 tons of CO_2 is needed
- 0.07 ton N
- 0.01 ton P

Transport Fuels in Europe - 0.4 billion m3



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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?

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Main inputs in the process N & P

Biomass: 7% N

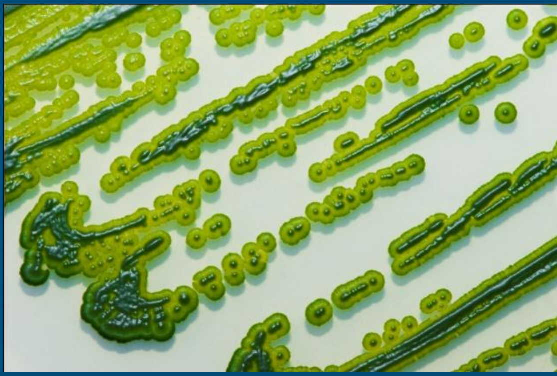
1 % P

- ~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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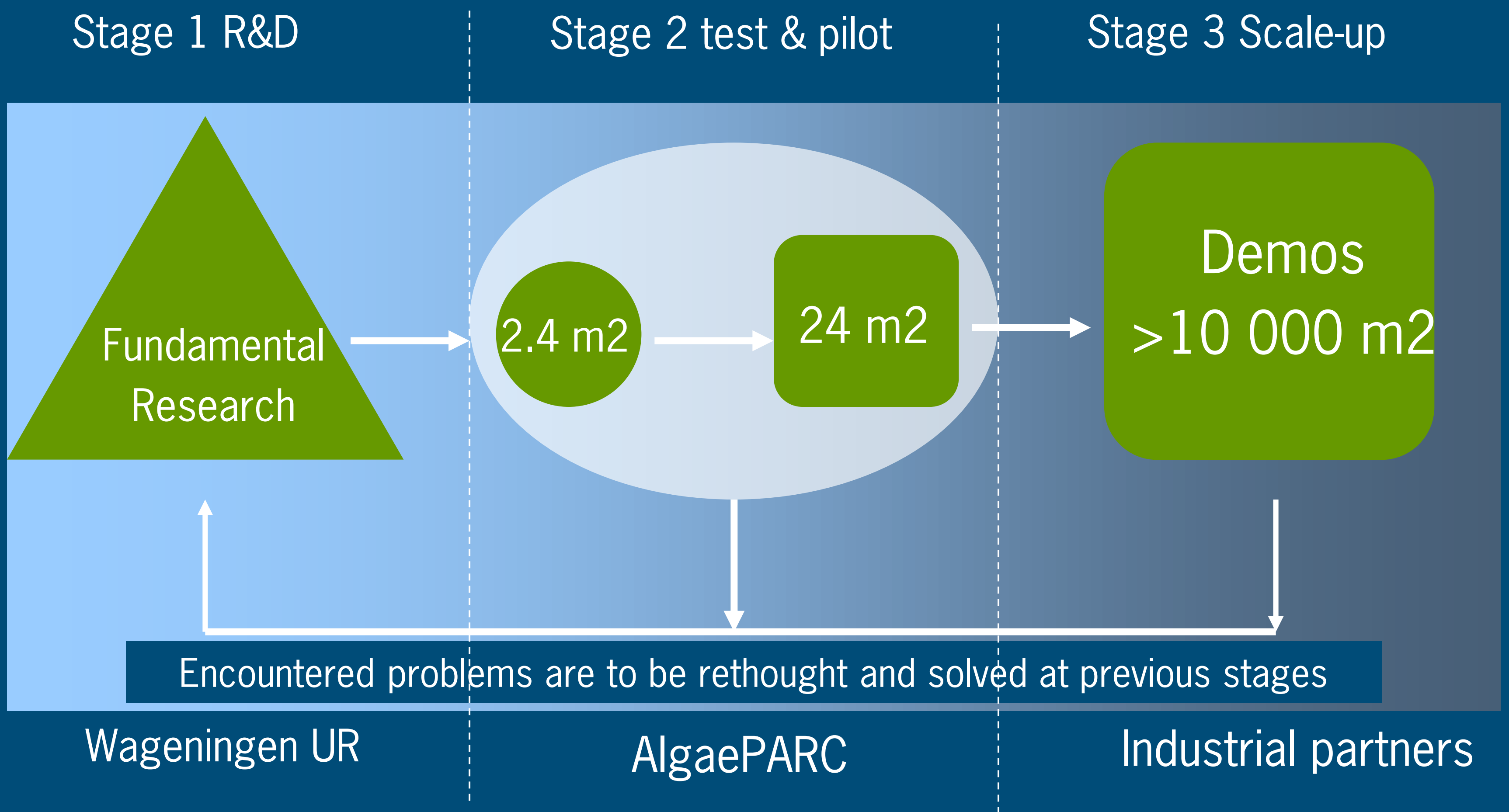
AlgaePARC

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.

Translate research towards applications



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AlgaePARC objectives

- International center of applied research
- Intermediate between basic research and applications
- Development of competitive technology (economics, sustainability)
- Acquire information for full scale plants
- Algal biomass for food, feed, chemicals and fuels

24 m^2 systems

- Long time performance (1 yr)
- High level of measurement and control
- Representative productivities for full scale
- Information for design of full scale plants

2.4 m^2 systems

- Phase between lab and pilot
- Testing – short term experiments
- Different strains
- Different feed stocks
- Adaptations in design and process
- If successful
  - To 25 m^2 scale
- If not successful
  - More experiments
  - Reject

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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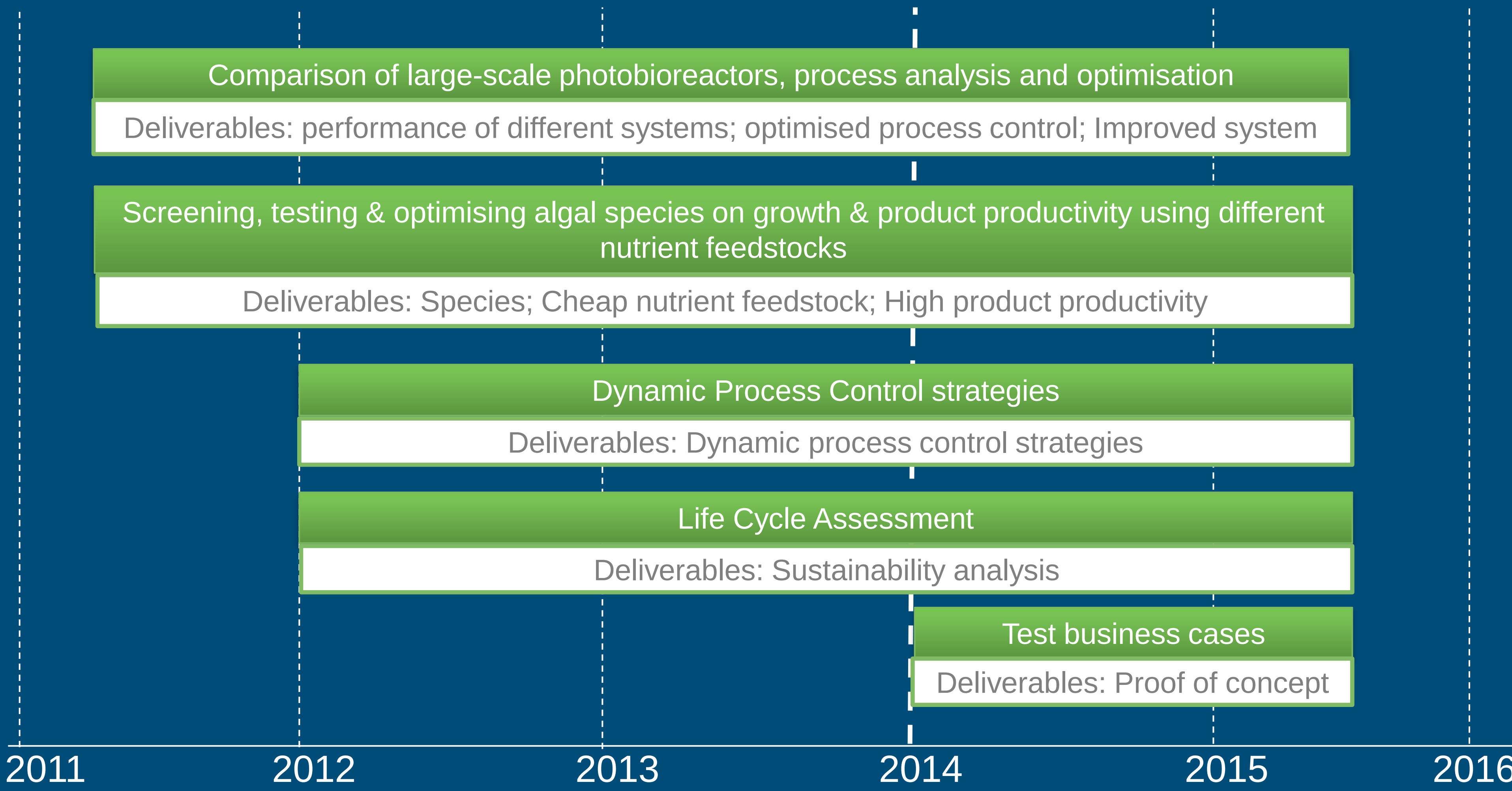
R&D activities AlgaePARC

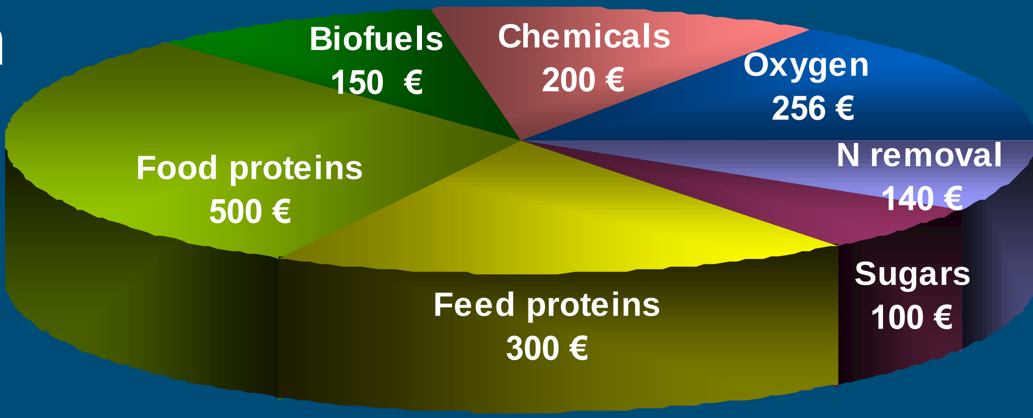


Funding AlgaePARC

- 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



www.algae.wur.nl

www.AlgaePARC.com

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