Design Scenarios for Large Scale Micro-Algae Production

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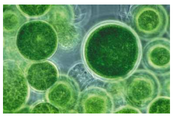
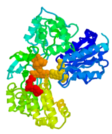
Microalgae

- Photosynthetic cell factories
- Promising for the production of
  - Omega fatty acids
  - Pigments
  - Pharmaceuticals
  - Feed/Food
  - Chemicals
  - Biofuels





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Systems analysis and design scenarios

- Reach economical and sustainable production process
  - Integrate production process and production chain
  - Make efficient use of environment of algae plant
- Design scenarios
  - Quantify effect of different system designs, location, algae species
  - Identify critical points in algae cultivation
  - Specify development directions

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LCA and TE are important assessment tools

- Analyse economic feasibility and sustainability
- Outcomes vary between different studies
  - Analysis border
  - System design

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How realistic are the outcomes?

- Often not performed for outdoor conditions
- Large uncertainties in assumptions
- Lack specific information on e.g. daily production cycles

- Additional steps needed to analyse system under local conditions
  - Location
  - System design
  - Algae species

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Predictive model for biomass production has been developed

1. Insight in dynamics of algae and their needs during the day/year
2. Effect of algae species
3. Quantify the effect of location and design variables
4. Determine settings for peak biomass production

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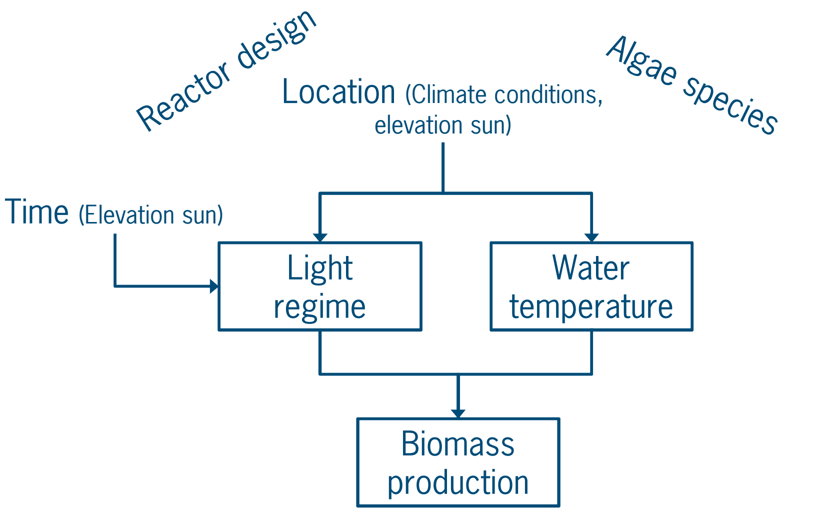
Model overview



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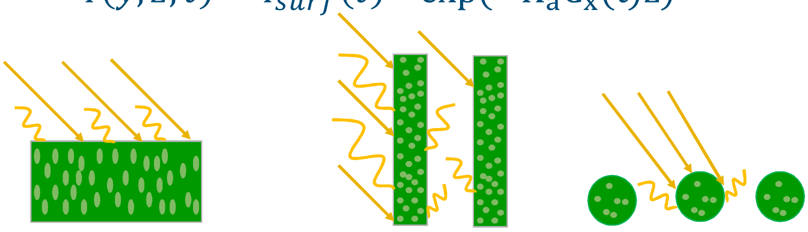
Light regime

1. Quantify the light falling on reactor wall

   Reactor geometry, reflection, alteration diffuse light

2. Quantify light regime in reactor volume

$$I(y,z,t) = I_{surf}(t) * \exp(-\mathrm{K_a C_x}(t)\mathrm{z})$$



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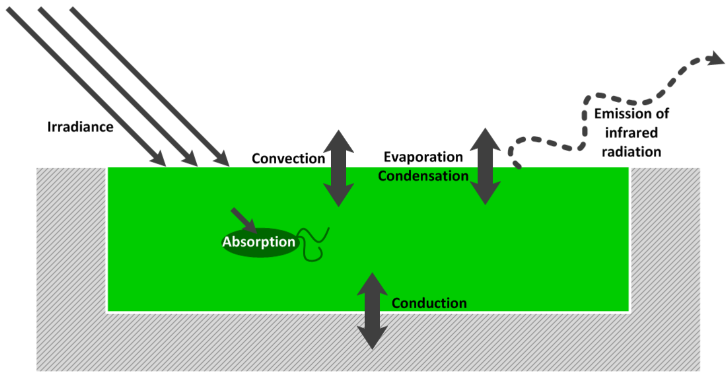
Water temperature

- Dynamic water temperature for open ponds

$$V_w \rho_w Cp_w \frac{dT}{dt} = Q_{irradiance} - Q_{absorption} - Q_{evaporation} - Q_{convection} - Q_{conduction} - Q_{radiation}$$



Biomass production

- Growth as function of light and temperature

$$\mu(y,z,t) = \mu(I(y,z,t) * f(T)$$

- Based on pI-curves (Geider, 1997)

$$\mu(y,z,t) = P_m^c \left(1 - \exp\left(\frac{-\alpha I_{PFD}(y,z,t)\Theta(z,t)}{P_m^c}\right)\right) - r_m$$

- Based on equation by Blanchard, 1996.

$$f(T) = \left(\frac{T_{let} - T_w}{T_{let} - T_{opt}}\right)^{\beta} \exp(-\beta \left(\frac{T_{let} - T_w}{T_{let} - T_{opt}} - 1\right)$$

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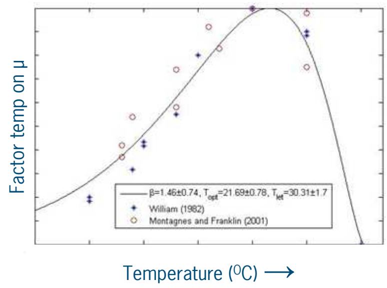
Biomass production



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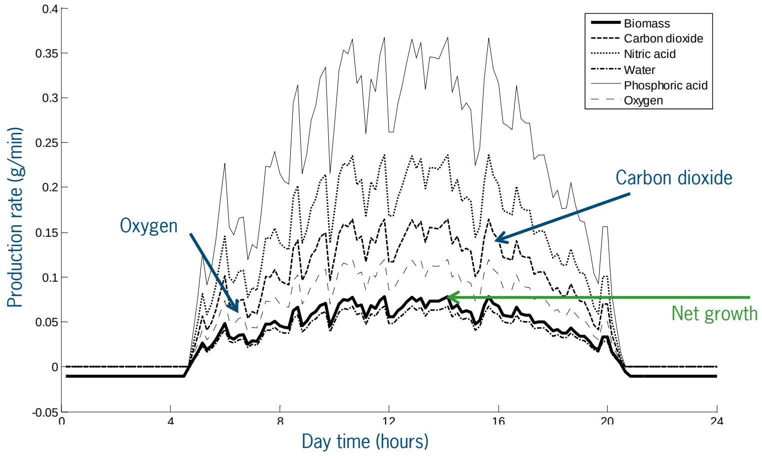
- Results
- Based on measured meteorological data

Daily fluctuations in production

Summer day in the Netherlands



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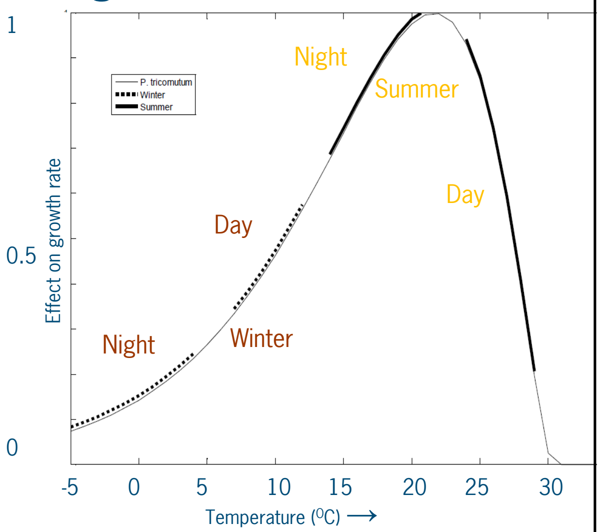
Effect temperature on growth (Netherlands)

- During day light and temperature limit growth
- During night temperature has a beneficial effect -> reduced maintenance



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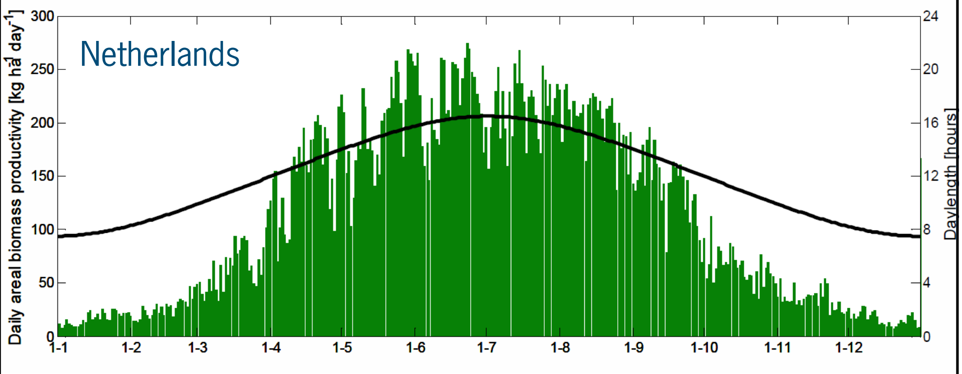
Production in 30 cm deep pond (*P. tricornutum)*



Production with dynamic temperature

P. tricornutum	Source	Average prod. (ton ha^{-1} $year^{-1}$)
Netherlands 52 °N	Model	41.5
Algeria 22.8 °N	Model	63.7

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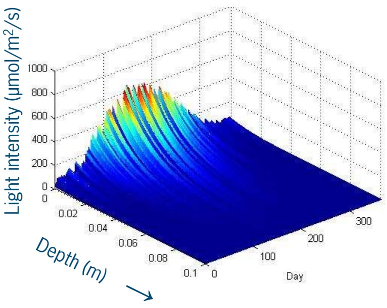
Production with dynamic temperature

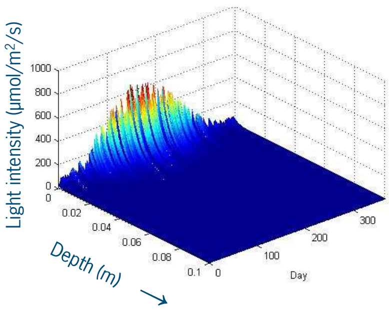
P. tricornutum	Source	Average prod. (ton ha^{-1} year^{-1})
Netherlands 52 °N	Slegers et al, 2011 Model	41.5
Algeria 22.8 °N	Slegers et al, 2011 Model	63.7
England 50-54°N	Ansell, 1963 Experiment (40cm deep)	29.0
California 32.5°N	Thomas, 1984 Experiment (temp. controlled)	80.0

Algae species affect potential productivity

P. tricornutum



T. pseudonana



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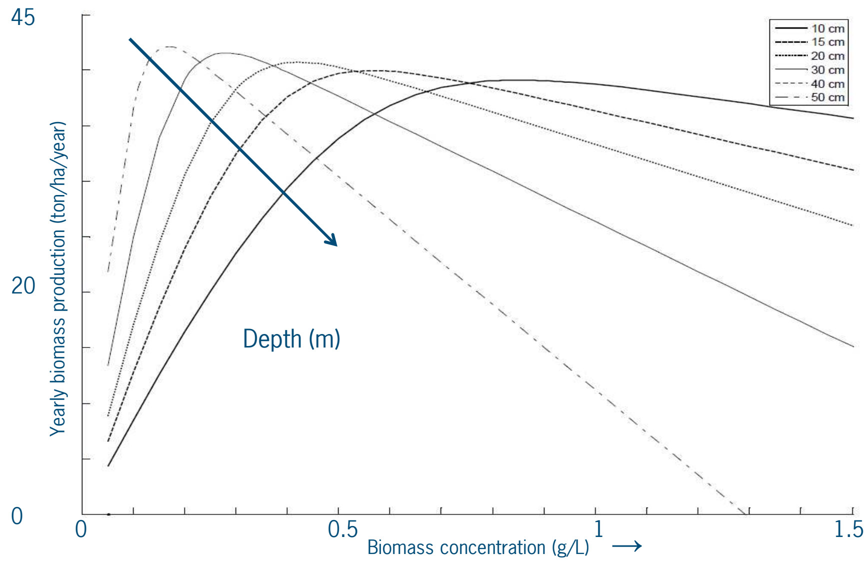
Achieving yearly peak production

using a constant biomass concentration during the year



Conclusions

- We are able to predict year round biomass production
  - Dynamic sun light input
  - Dynamic water temperature
  - Design parameters and location
- Effect of design and decisions are visible
- Model is a good basis for further LCA and TE analysis

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