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Finnish actions in algae cultivation (in CCSP)

Kristian Spilling, Jonna Piiparinen, Kaisa Manninen

Finnish Environment Institute SYKE

Matti Sonck

Fortum

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Regional challenges for large-scale cultivation of microalgae

- **Climatic**
  - Sunlight
  - Temperature
- **Infrastructure**
  - Nutrients & CO_2
  - Land use
  - Water use
  - Downstream processing
  - Markets
- **Societal**
  - Education
  - Legislation

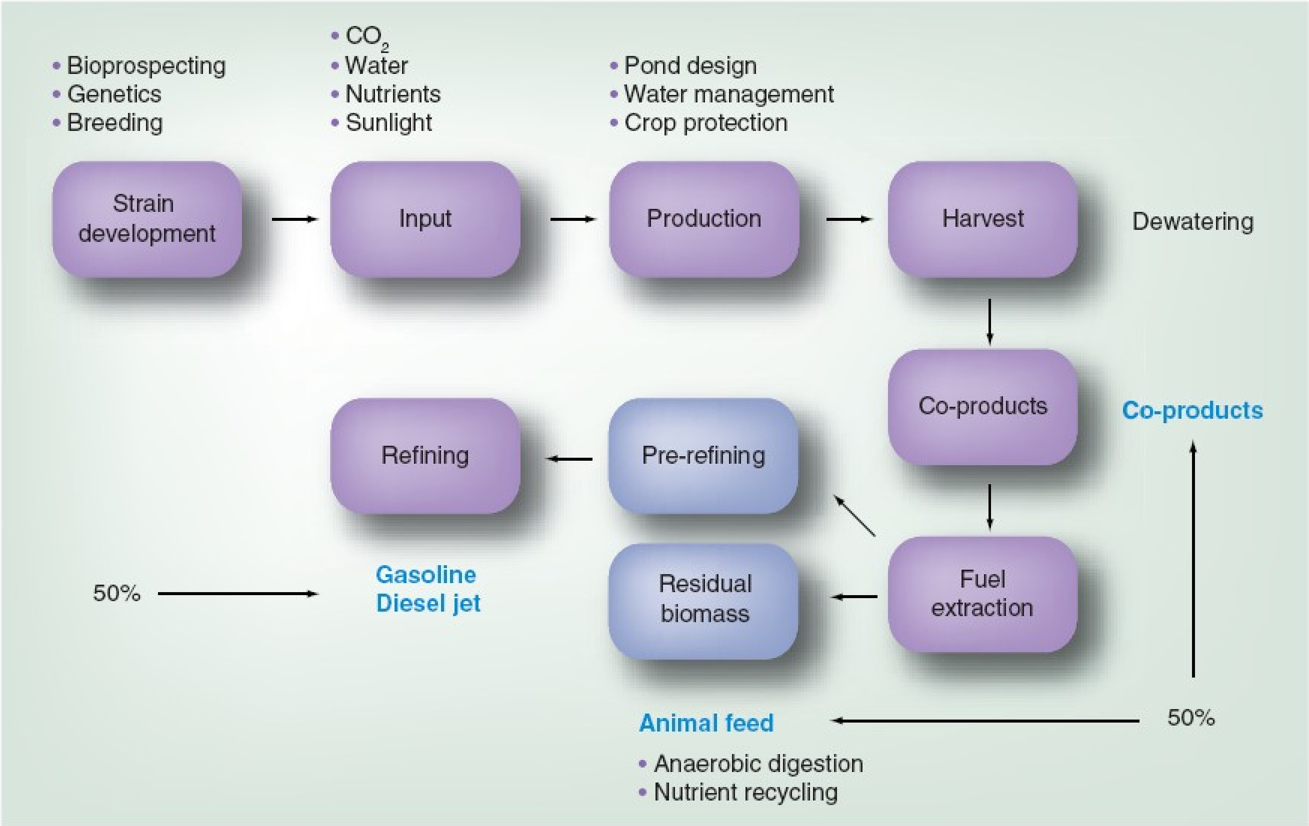

Figure 3. Algal biofuels production chain. Improved strains, as well as downstream efficiency, are integral aspects of the algae biofuel production strategy.

Source: Hannon etal. Biofuels (2010) 1(5), 763–784

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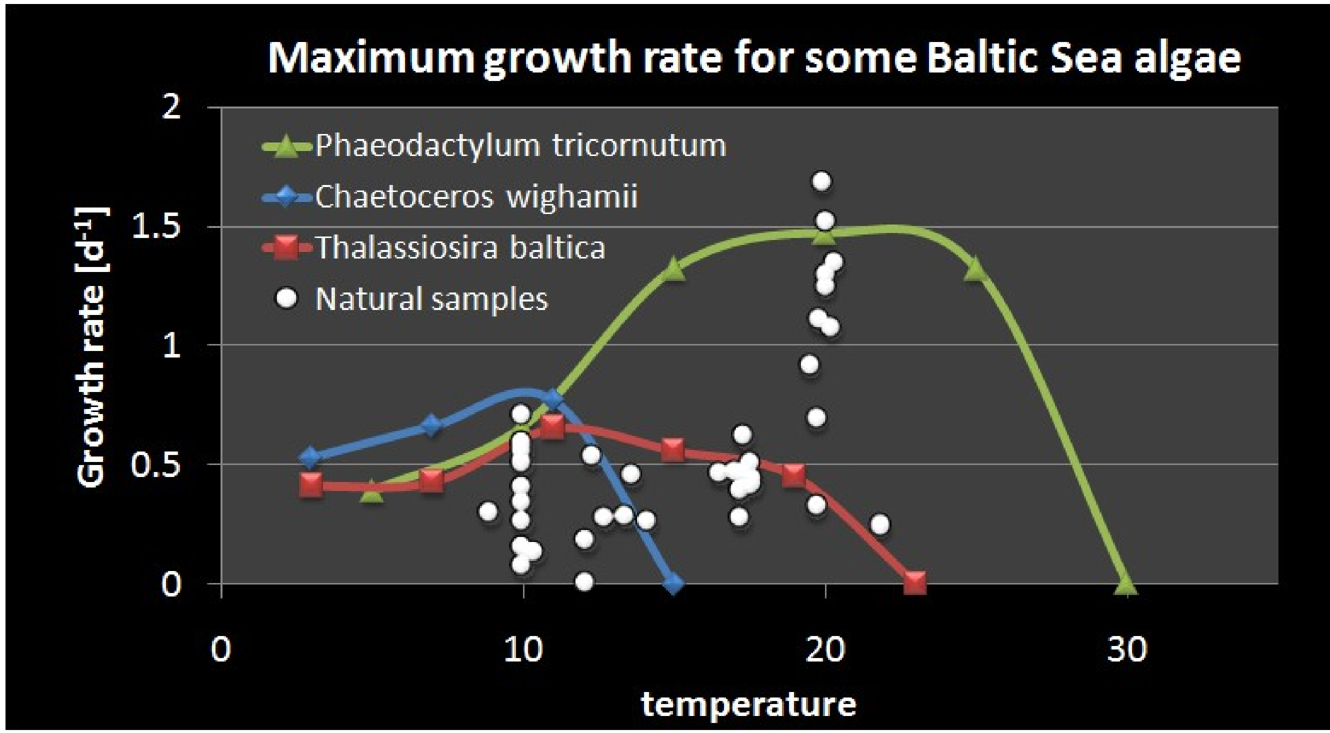
What about temperature?



Sources: Seppälä et al. In prep. Virkkala, In prep

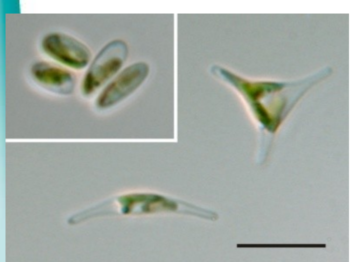
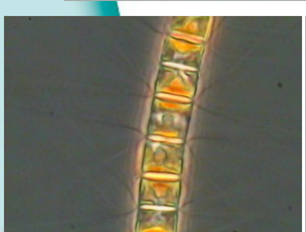
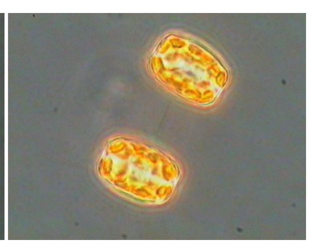


Photo: A. Gruber, Universität Konstanz





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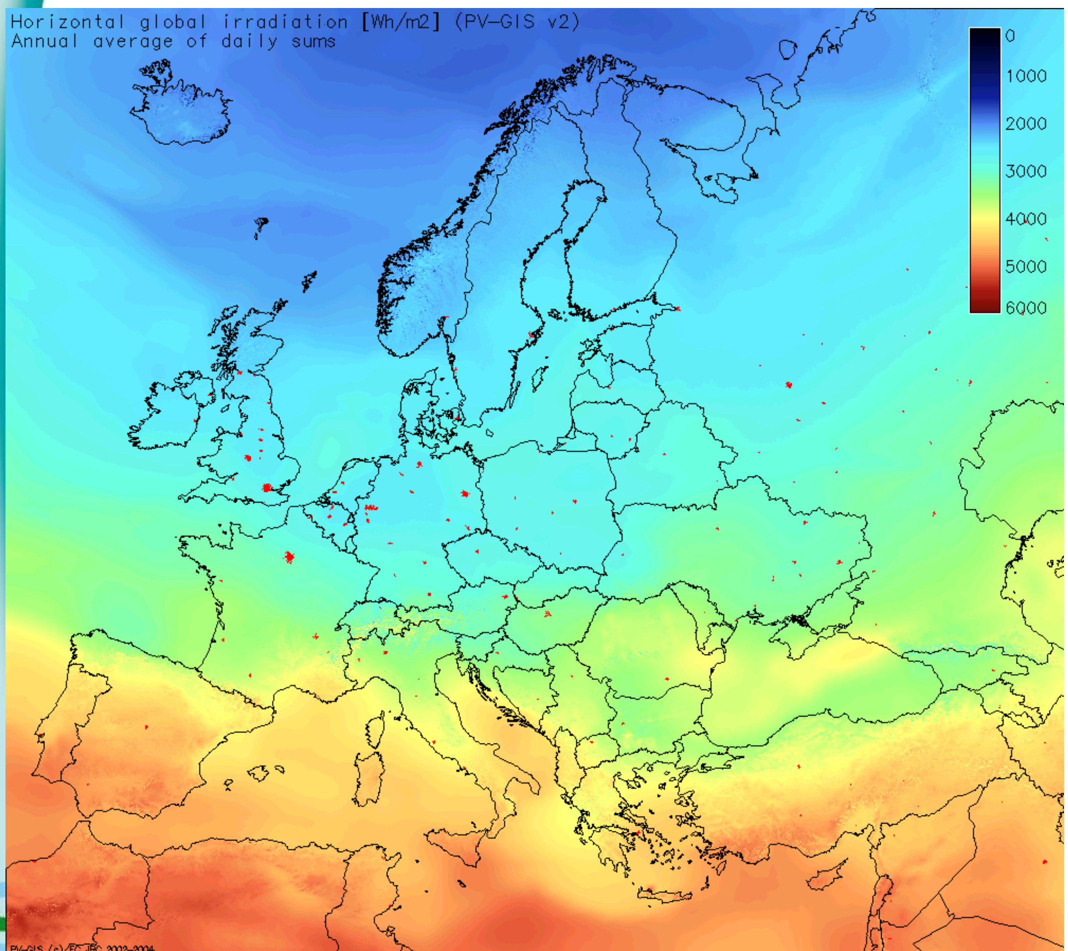
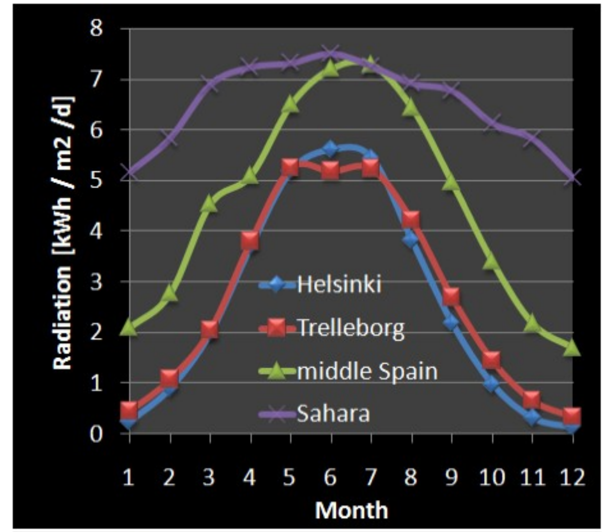
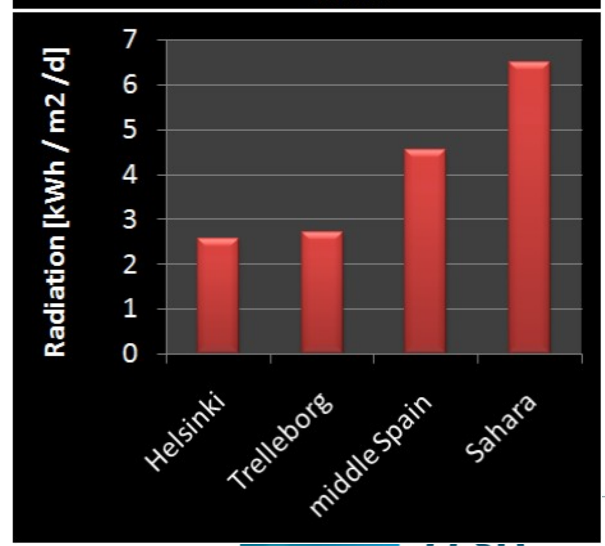
Is there enough light?

Energy from the Sun (Wh m^{-2} d^{-1})







Data from: re.jrc.ec.europa.eu/pvgis

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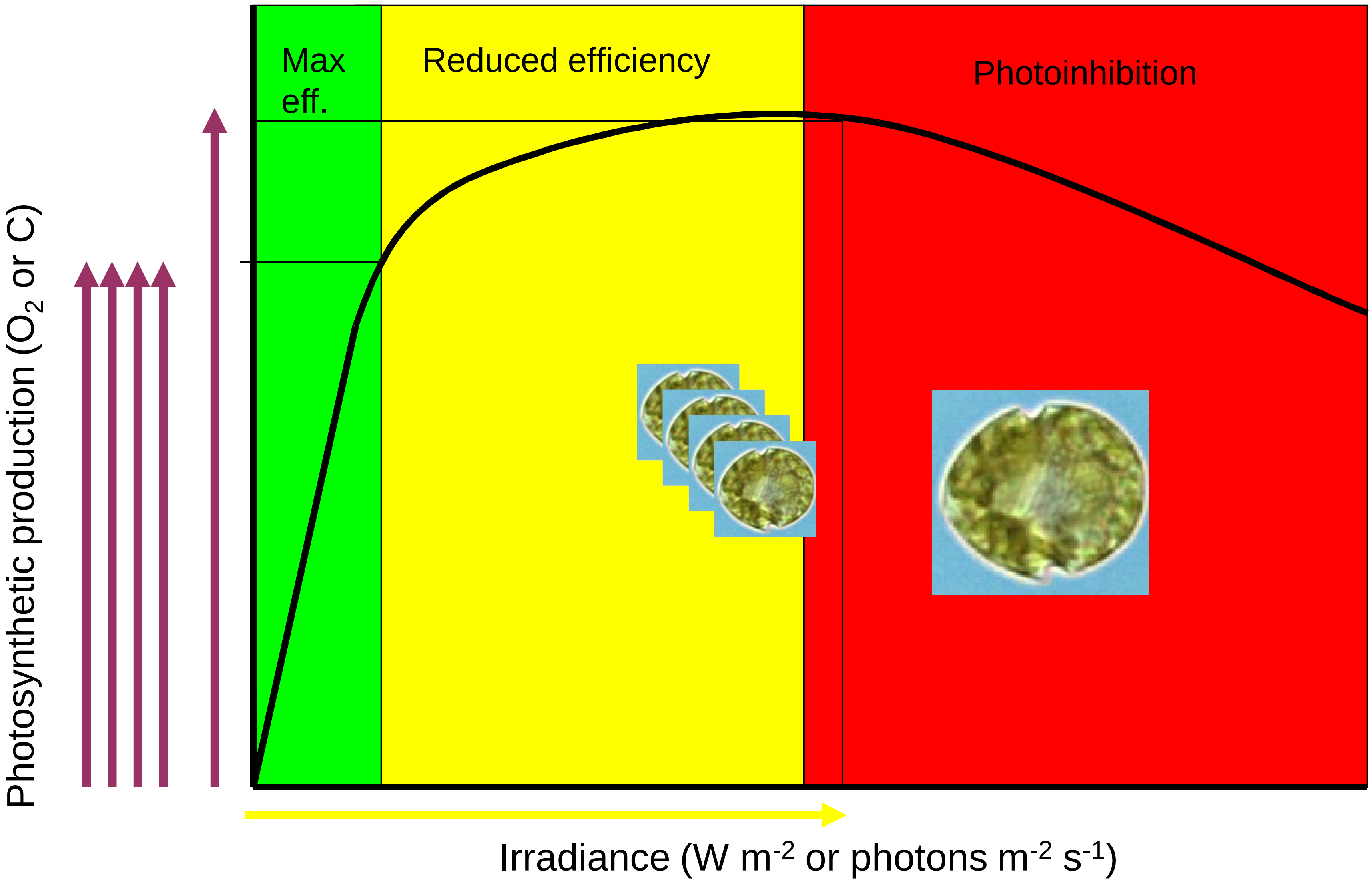

Max
eff.
Reduced efficiency
Photoinhibition
Photosynthetic production (O_2 or C)
Irradiance (W m^{-2} or photons m^{-2} s^{-1})

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Work on cultivating algal in flue gas

School of Chemical Technology

Degree Programme of Chemical Technology

Matti Sonck

CULTIVATION OF MICROALGAE FOR THE FIXATION OF CARBON DIOXIDE FROM POWER PLANT FLUE GAS

Master's thesis for the degree of Master of Science in Technology submitted for inspection, Espoo, 22 November, 2012.

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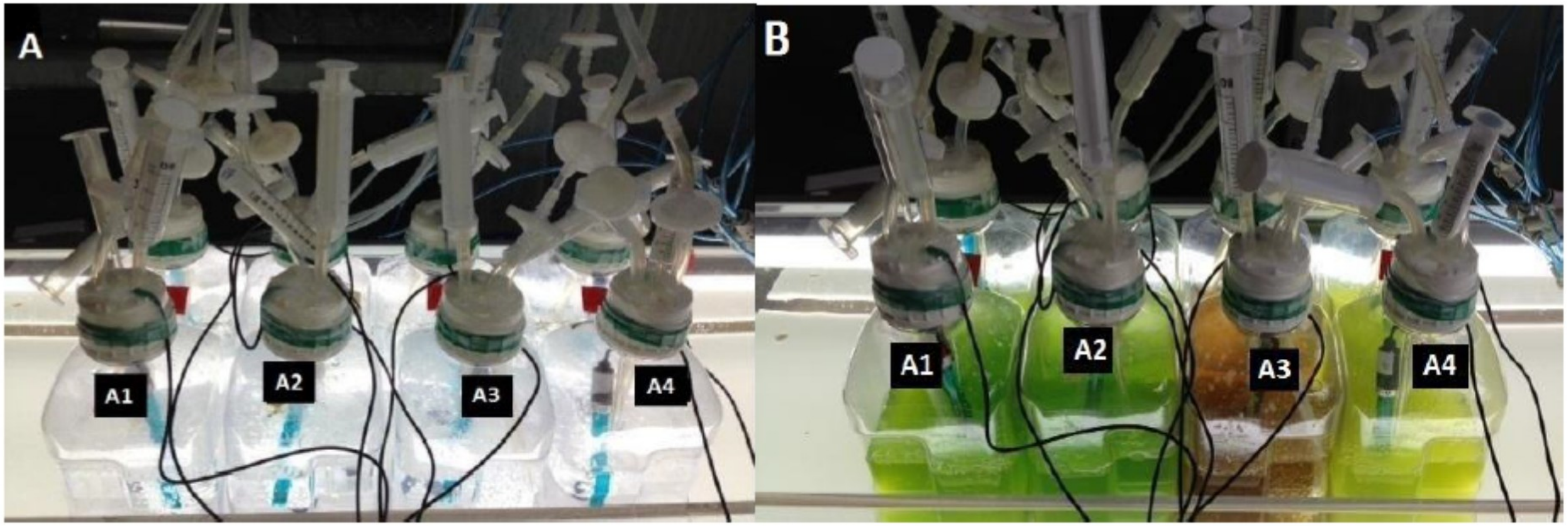

Figure 9. The arrangement of cultivation bottles during the beginning (A) and end (B) of Exp1, containing the cultivated species A1, A2, A3 and A4. A replicate containing same species is located behind each bottle.

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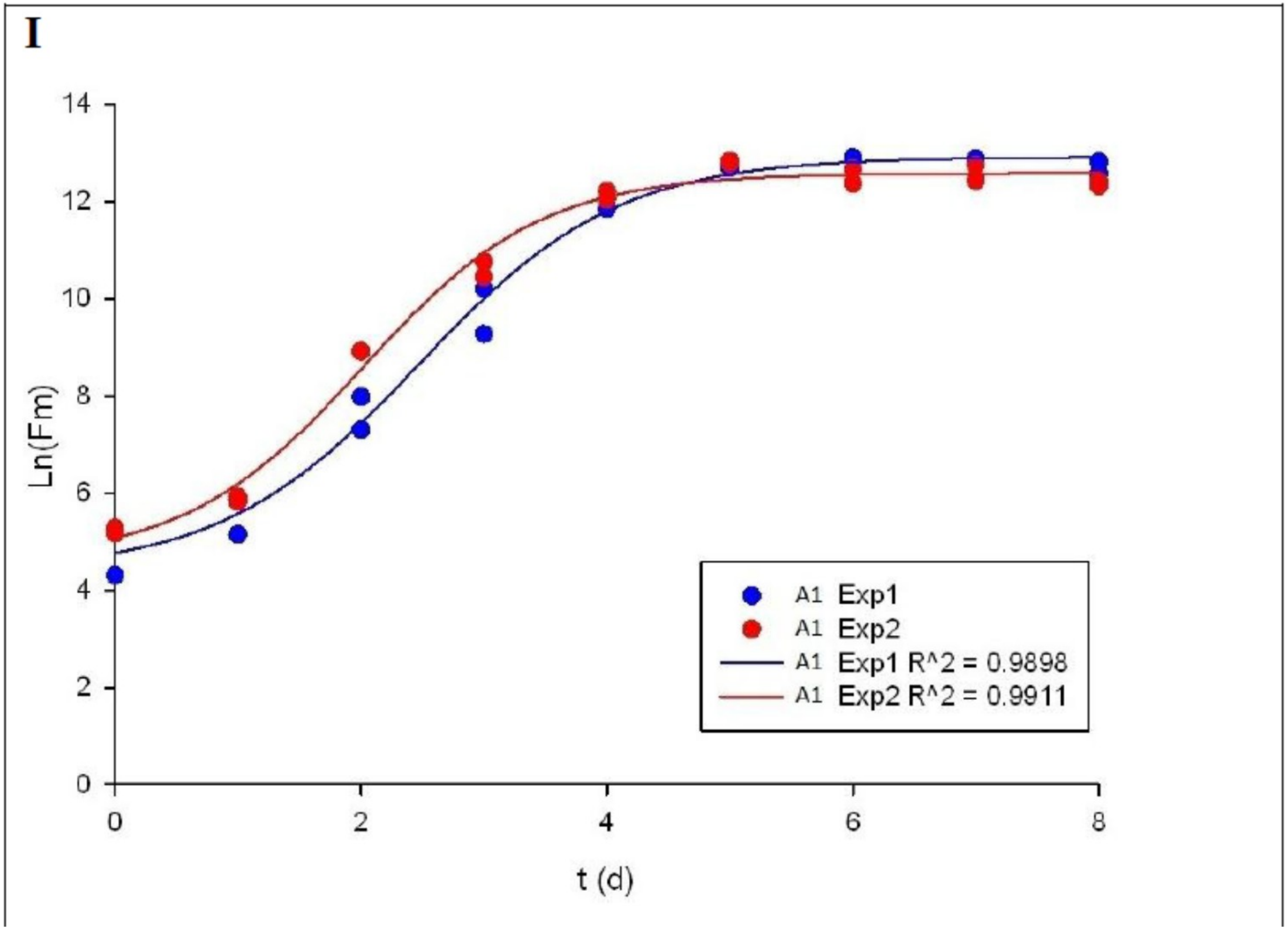
Pure CO2 (blue) compared with flue gas (red)



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Research Report nr D244
Helsinki 2013

Kaisa Manninen, Matti Sonck, Kristian Spilling

ENVIRONMENTAL IMPACT ASSESSMENT OF ALGAE CULTIVATION UNDER FINNISH CONDITIONS

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Two systems examined

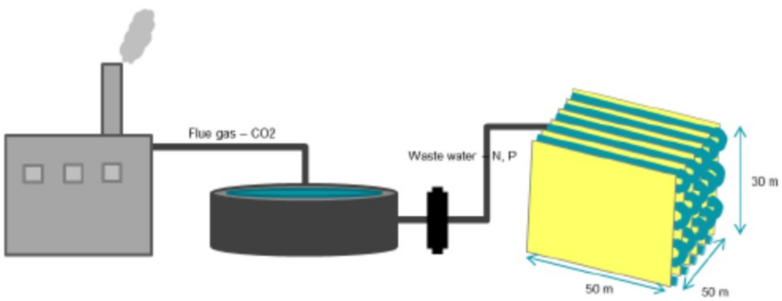
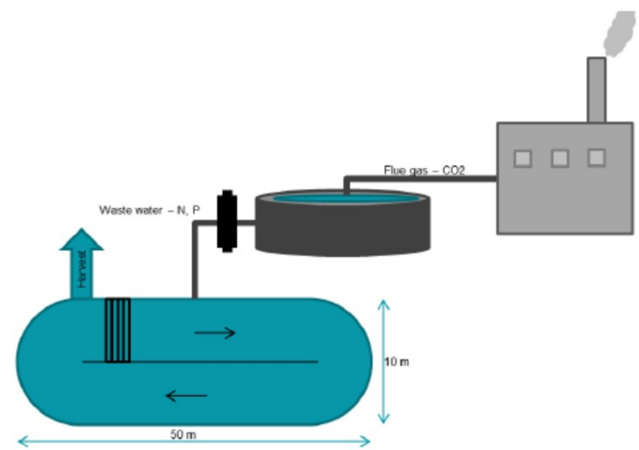


Figure 2. System 1.

Closed photobioreactor



Open pond system

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LCA of microalgae cultivation – System boundaries

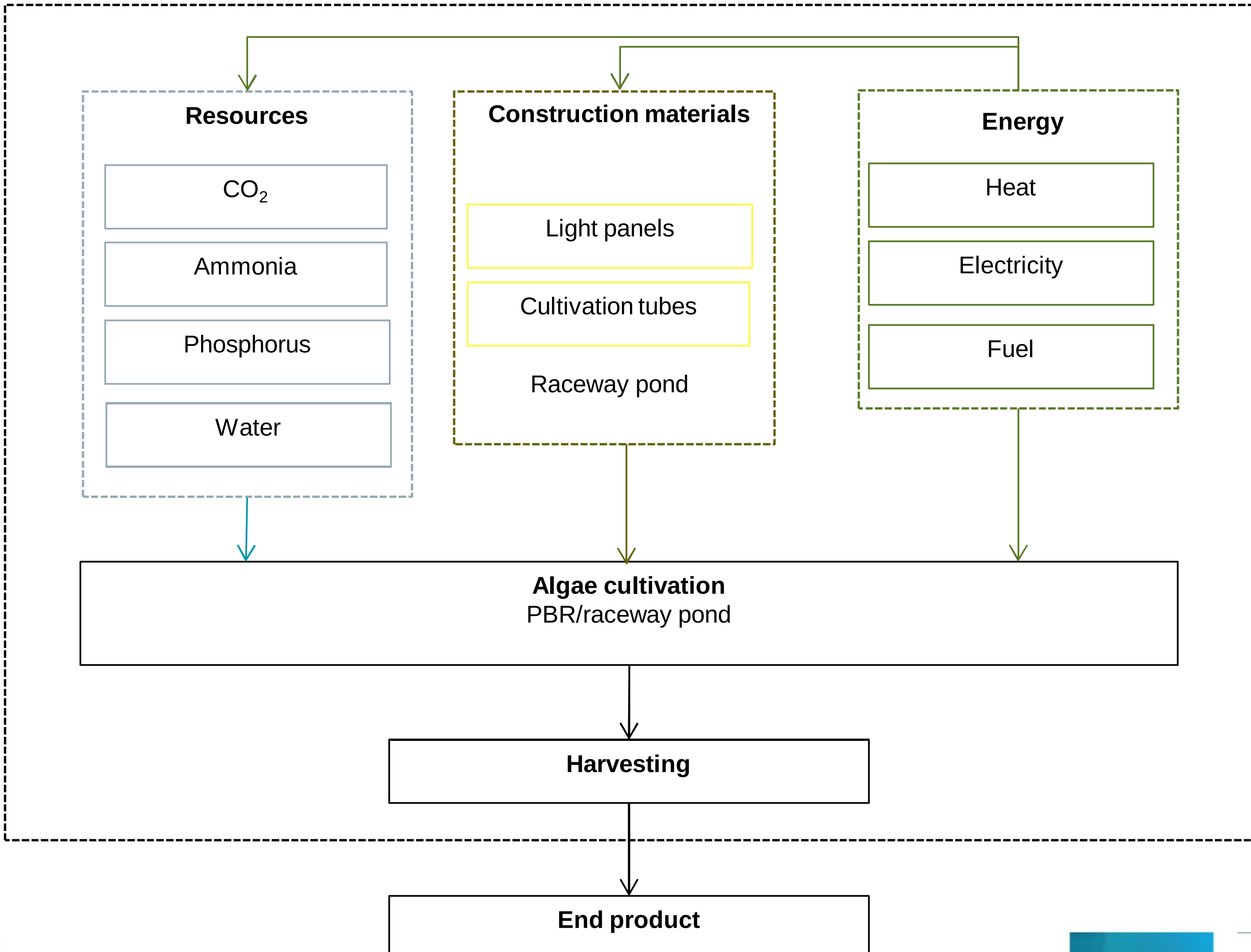
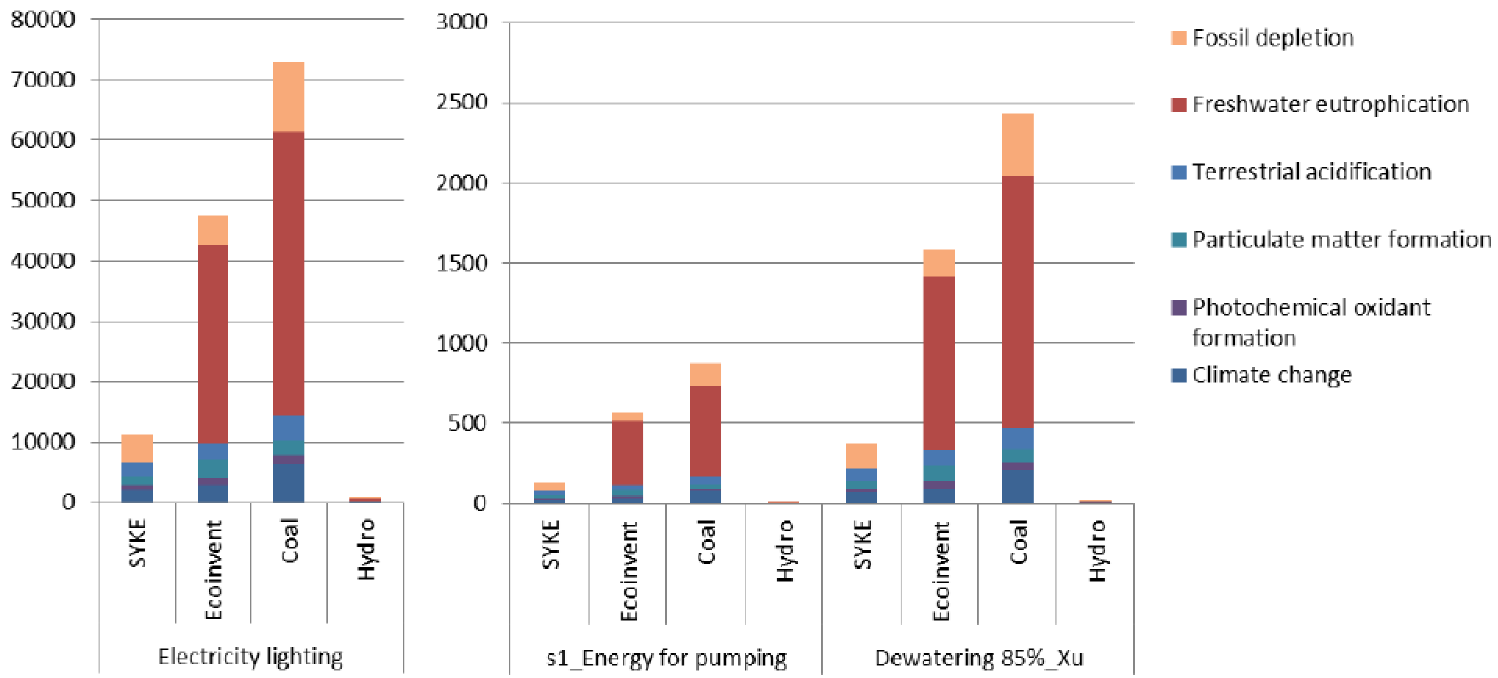


Table 5. LCI data used in the calculations.

Input parameters	System 1	System 2	Unit
Area needed	2 500	544 929	m^2
Total volume of the cultivation reactor	16 513	163 479	m^3
Areal productivity	29	20	g/m^2,d
Volumetric productivity	0,66	0,07	kg/m3,d
Used materials	Tubes: polymethyl-methacrylate, Lights: LED technology	Channels: concrete	
Energy consumption, pumping	876	-	MWh/a
Energy consumption, pad-dlewheel	-	2 053	MWh/a
Energy lighting	72 927	-	MWh/a
Cultivation time	24	24	h
Biomass production	3 978	3 978	t/a
CO2_absorbtion	85	85	%
CO2 consumption	1,83	1,83	kg/kg
P consumption	7,5	7,5	g/kg
N consumption	60,0	60,0	g/kg

Environmental impacts varies with electricity source



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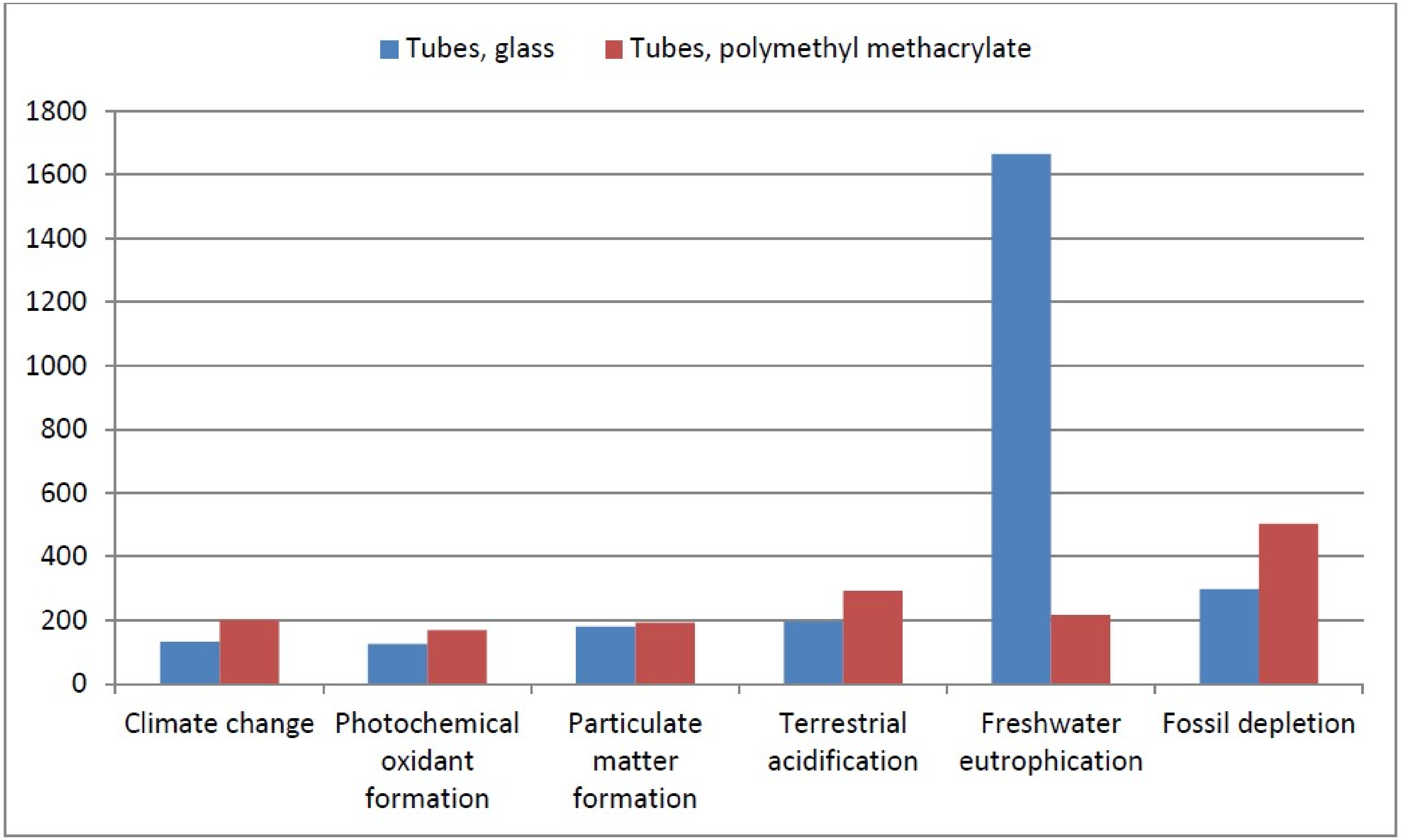
Environmental impacts varies with material use



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Comparing closed vs open system

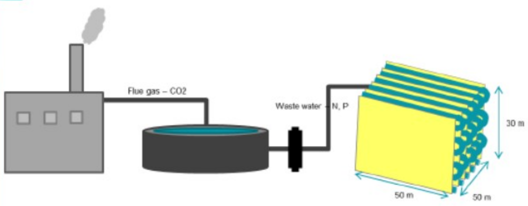
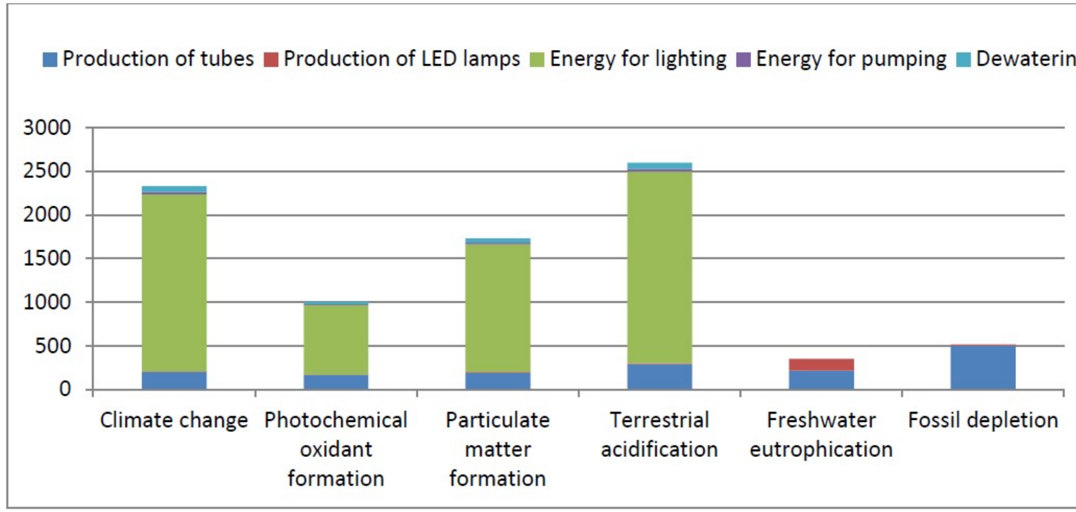
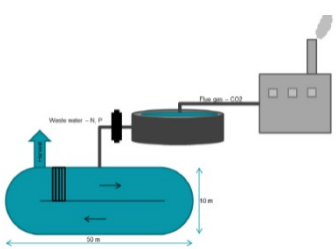
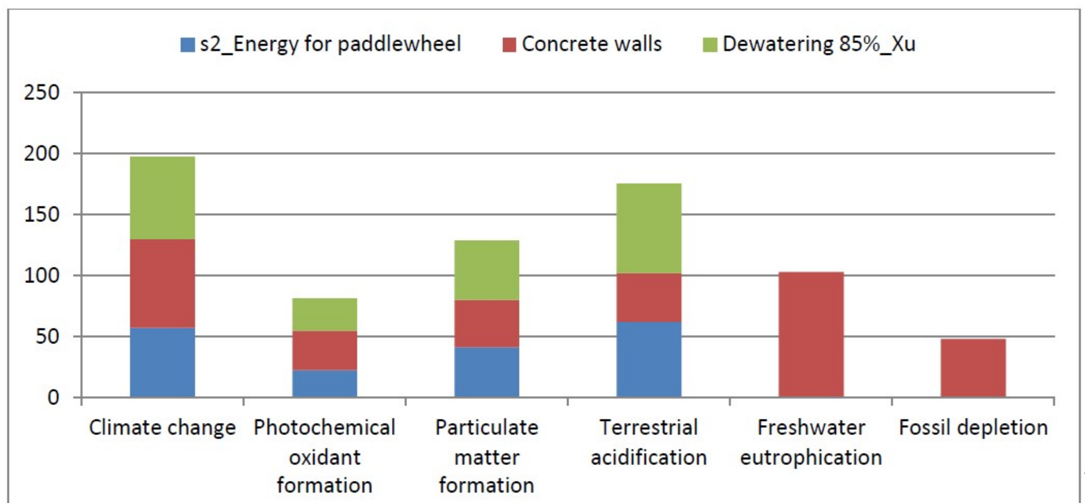


Figure 2. System 1.







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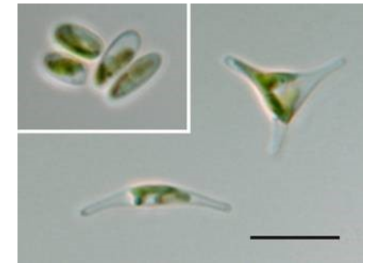
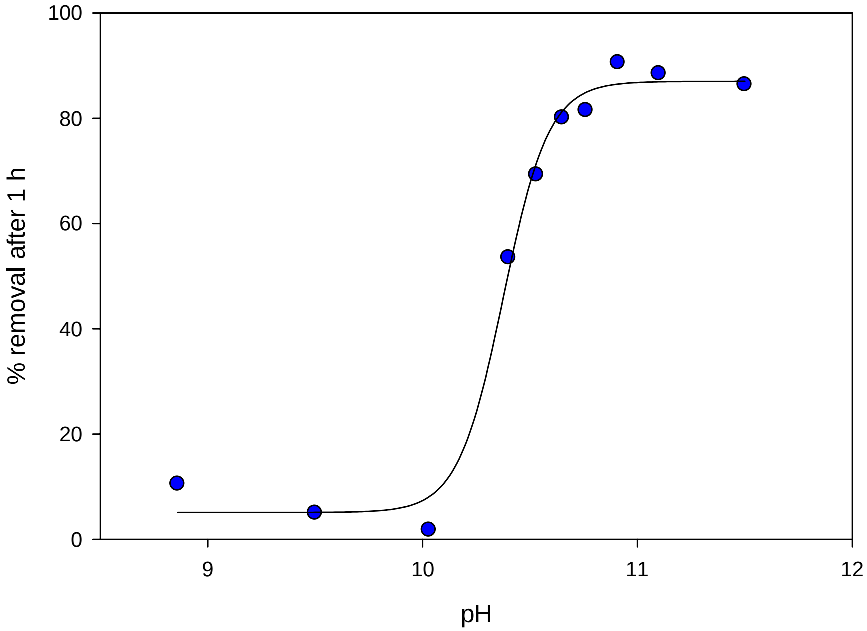
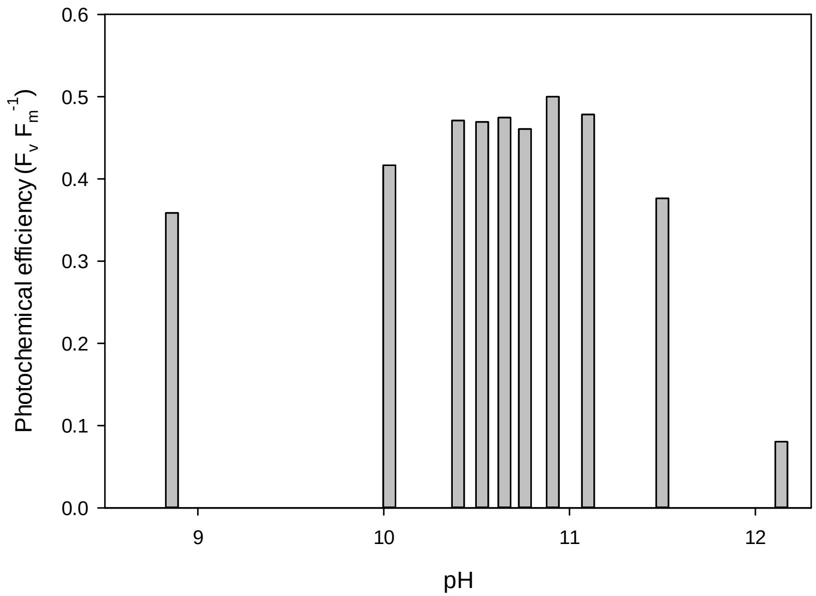
Harvesting

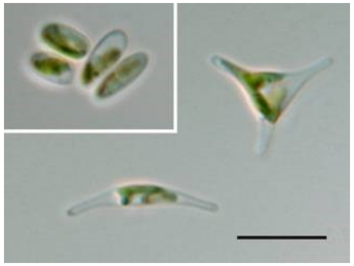


Phaeodactylum tricornutum, from www.awi.de

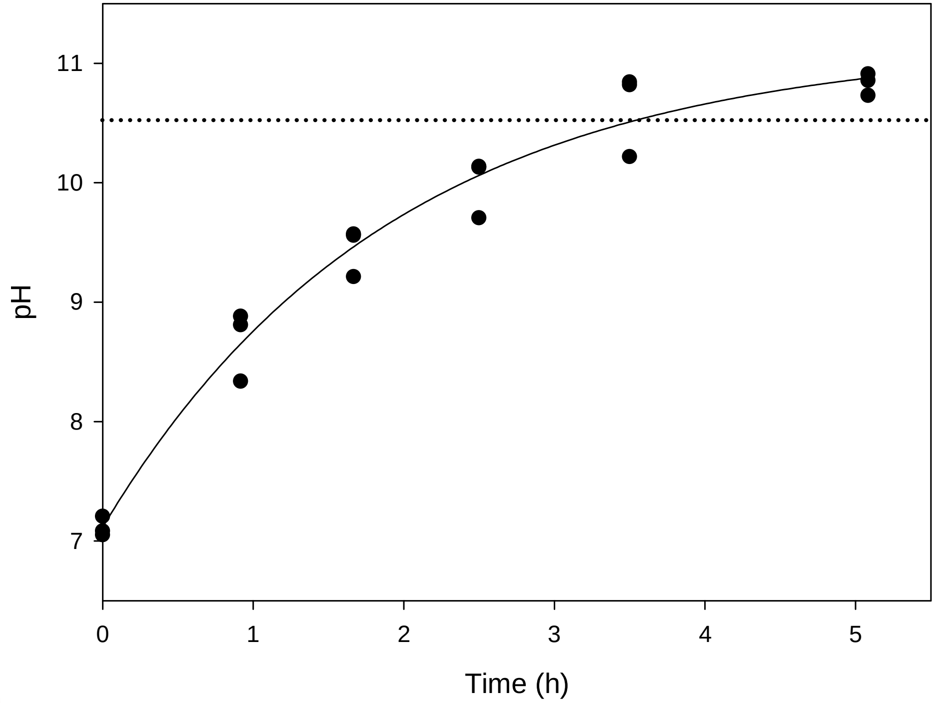


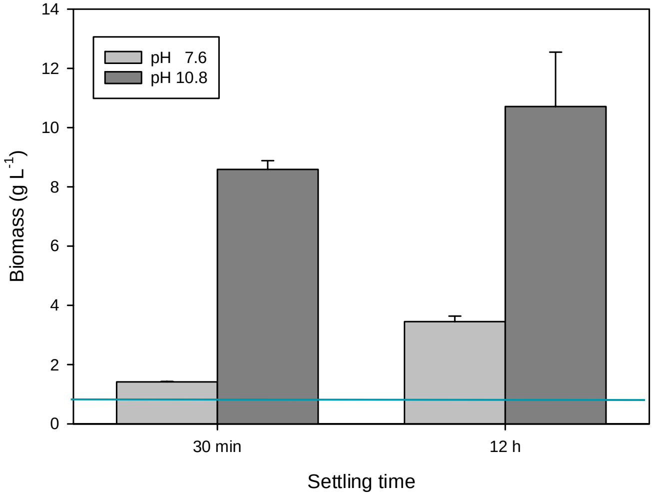


Harvesting



Phaeodactylum tricornutum, from www.awi.de





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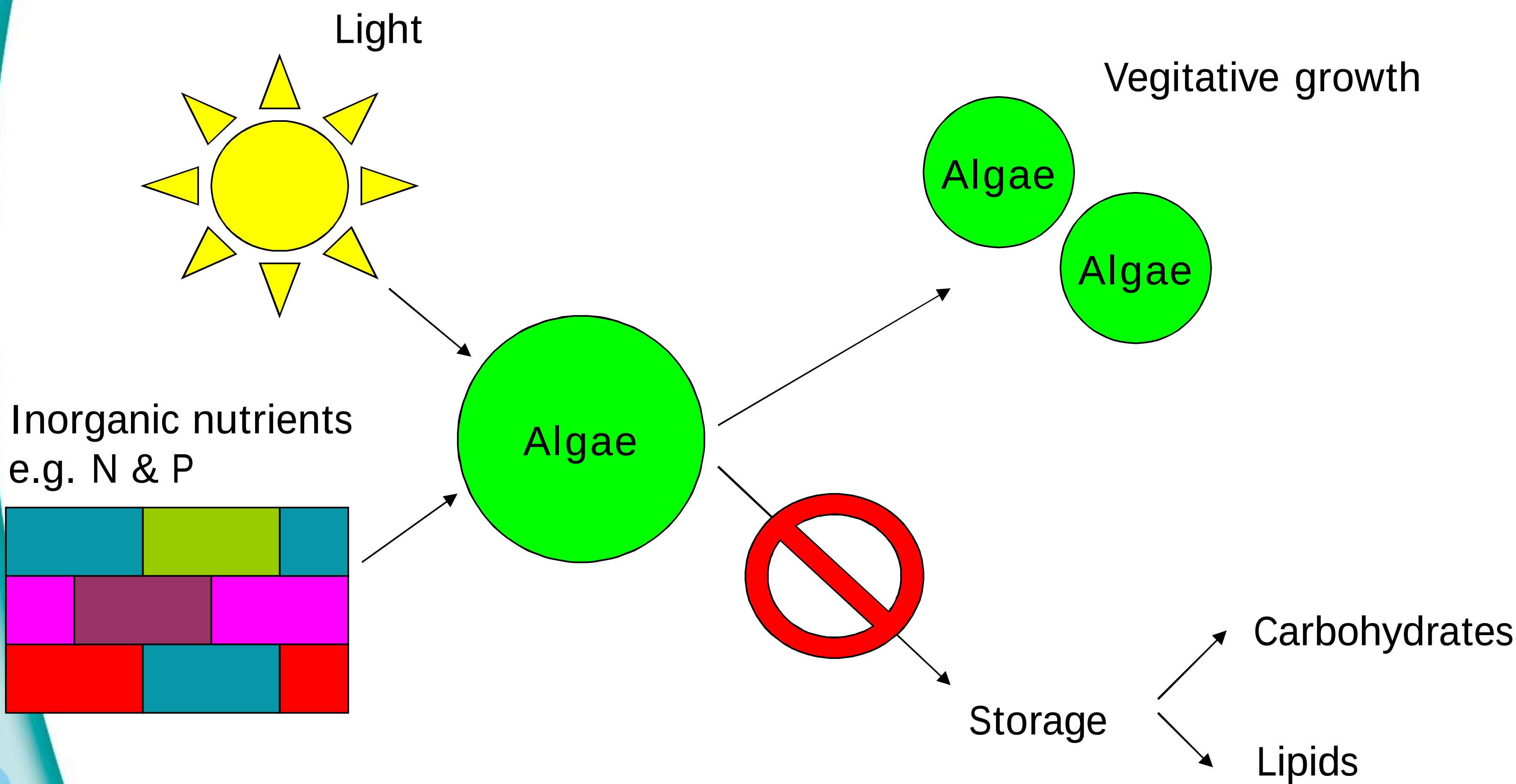
Nutrients



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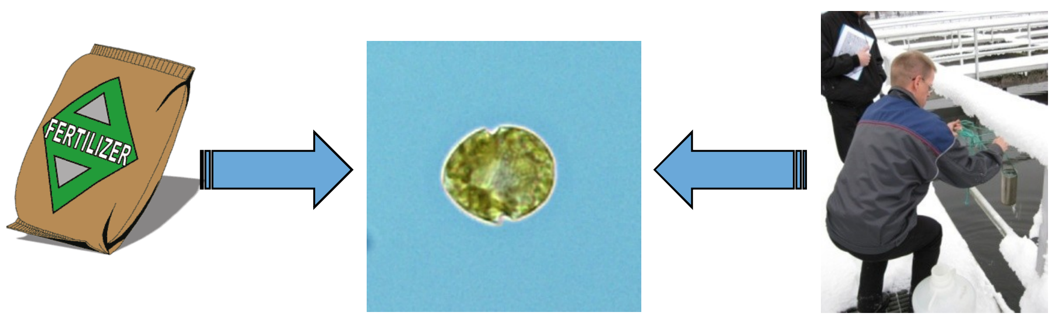
Nutrient requirements

	Exponential growth	N-limited growth
N content	8%	4%
P content	1%	0.5%
C content	45%	52%
Lipid content	13%	28%

(data compiled from Schwenk et al 2013)



Suomenoja wastewater treatment plant

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How much algae oil can be produced with waste waters

Suomenoja, a municipal waste water treatment plant in Espoo, Finland, serves 310000 inhabitants, 100 000 $m^3\ d^{-1}$

Amount of nitrogen	**4850 kg /d**
Amount of phosphorus	**700 kg / d**
Production of lipids	**~ 30000 L / d**
CO2 consumption / area	**75 m^2 / t**
Area required (at production rate 20 g dw $m^{-2}d^{-1}$)	**~600 ha**
Area / person	**~20 m^2**
Production / person	**~0.1L oil d^{-1}**

In Finland, **2%** of all liquid transport fuel need may be produced if ALL nutrients in municipal waste waters are used in algae cultivation. However, nutrients may be recycled, as they are not in the oil fraction.

The biggest revenue may come through reduction of nutrient loads to environment.

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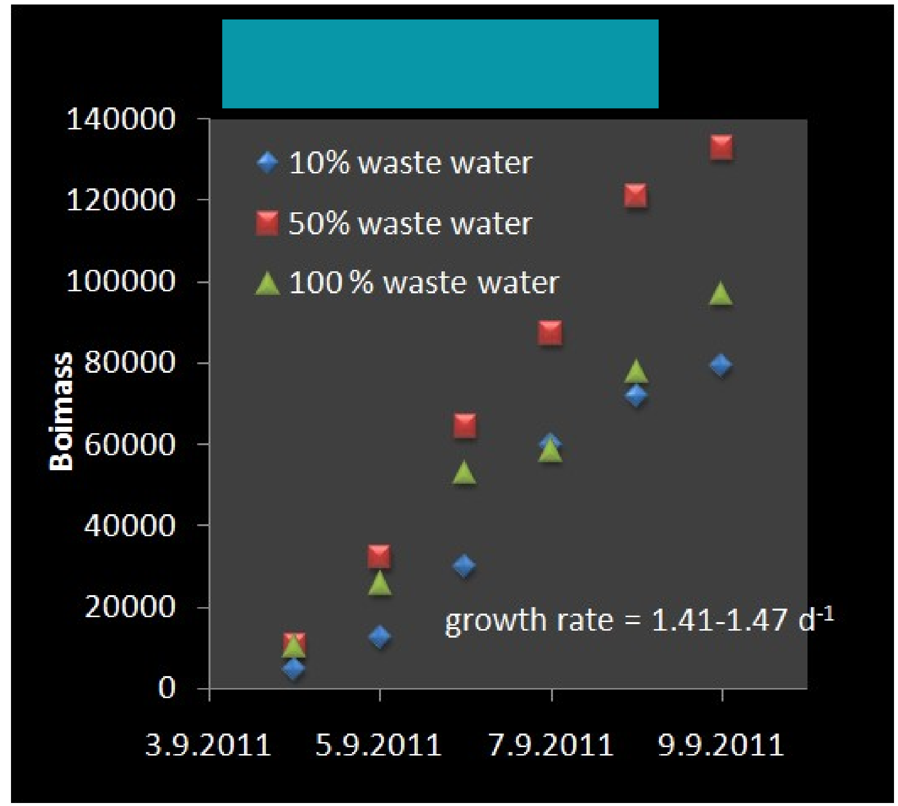
Where does the nutrients come from

- Nutrient rich waste waters
  - Municipal
  - Industry
  - Agriculture
- Getting nutrients for free
- Providing an environmental service
- An absolute need in order to obtain an environmental sustainable solution

Scenedesmus obliquus



Source: Haupt, Stockenreiter, et al. unpublished

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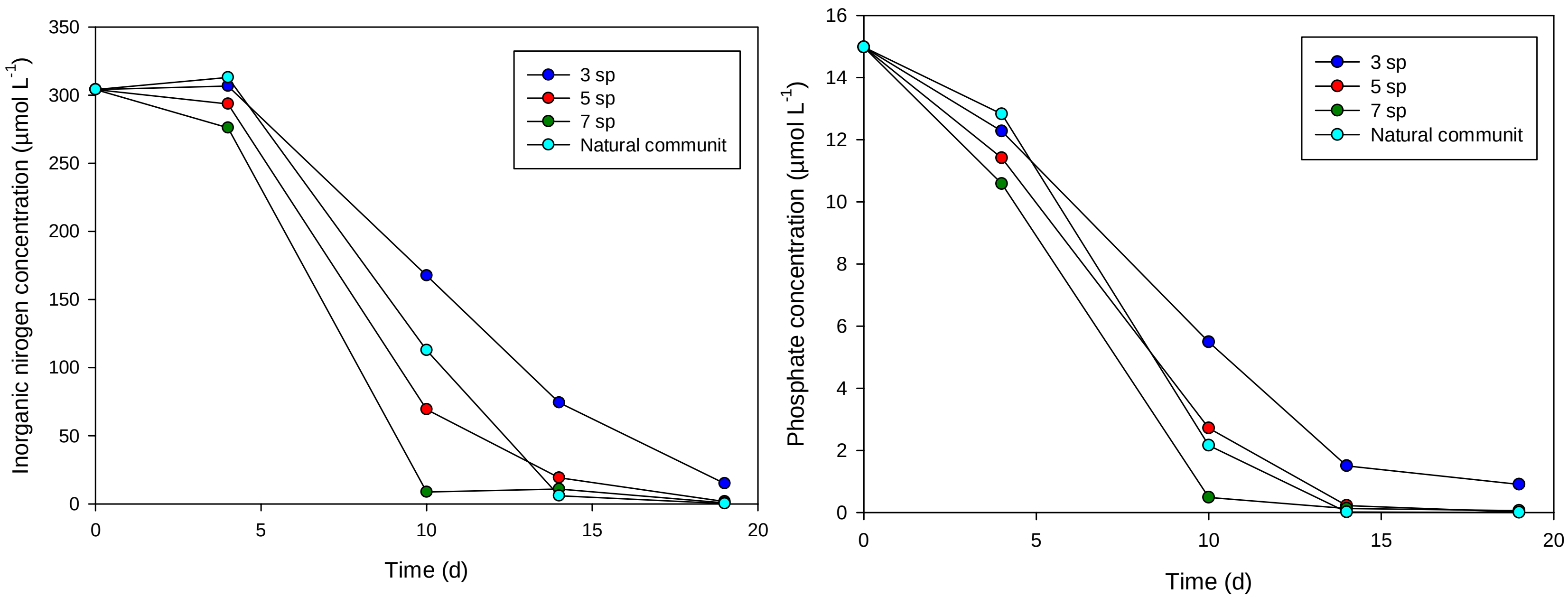
Nutrient removal from wastewater – biodiversity effect



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Research Report nr D602
Helsinki 2014

Jonna Piiparinen, Kristian Spilling

WASTEWATER TREATMENT BY ALGAE IN DEVELOPING ASIAN COUNTRIES: AN INTEGRATED APPROACH TO CARBON CAPTURE

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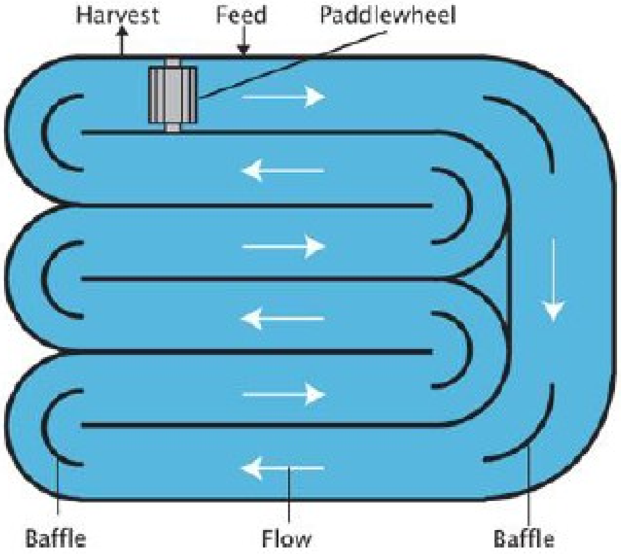
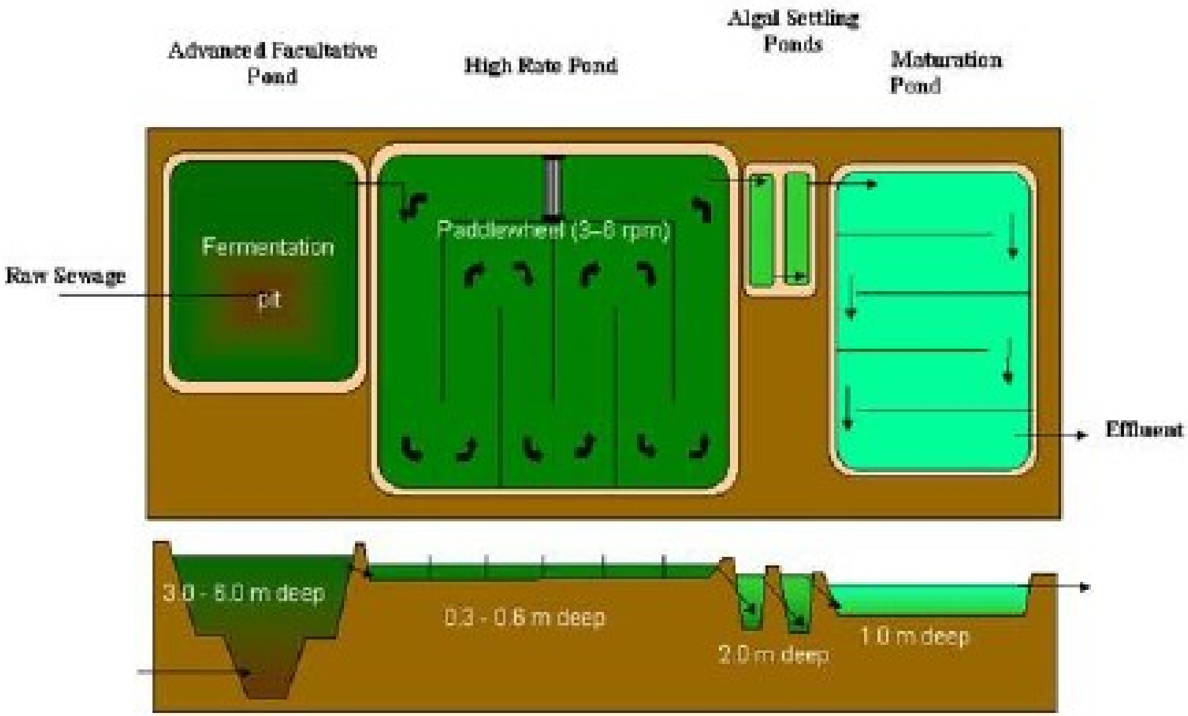
High rate algal pond (HRP)


Open ponds



Wen and Johnson 2009

Advanced integrated wastewater ponds



Ramadan and Ponce

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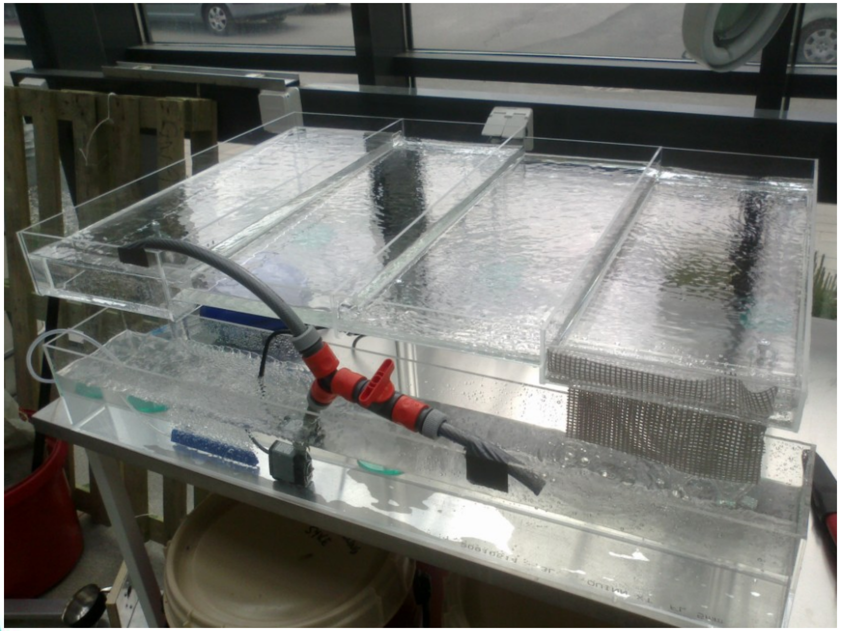
Immobilized systems



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Main recommendations

- Algal treatment of wastewater and uptake of CO_2 has a lot of potential but will have a relatively large areal footprint and is most suitable for decentralized operation
- Wastewater with high BOD should be pretreated in a facultative pond; high BOD produces CO_2 during oxidation reducing the overall CO_2 uptake
- Recycling of process water is needed to some extent depending on inflowing wastewater and loss processes e.g. evaporation
- R&D need is lowest for using the algal biomass in biogas production

Key issues for the road ahead

Sustainability criteria

Is Algae Worse than Corn for Biofuels?
A new analysis suggests so because of the need for copious fertilizer
Scientific American 22.1.2010

Infrastructure

What is needed to produce biofuel from algae
Water, nutrients, harvesting technology, downstream processing, refining

Production yield

Theoretical estimates can never be reached, but algae has the potential to reach higher productivity then traditional terrestrial crops

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Thank you for your attention

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