The potential of using algae as feedstock for biofuel, a Nordic perspective

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At first glance, areas in the high latitudes, like the Nordic Region, seem suboptimal for large-scale outdoors phytoplankton cultivation. It is obvious that dark winter season is not suitable for growing any photosynthetic organism. However, beyond winter months, the supply of solar energy is sufficient for phytoplankton growth. In this presentation, theoretical and realised phytoplankton productivities at various latitudes are compared. Temperature is considered another limiting factor for phytoplankton growth at high latitudes. Some phytoplankton species are, however, adapted to temperatures close to the freezing point. We show that they may have high growth rates and accumulate large amount of lipids, thus being potential candidates for biofuel production.

Fertilizers and CO_2 is a major cost when growing phytoplankton at large scale. Using waste streams as nutrient source for cultivation may thus reduce both the production cost, and also provide additional societal services by reducing nutrient fluxes to the sea. We present estimates for how much phytoplankton biomass may be produced using municipal waste waters. As a conclusion of this analysis, nutrient recycling becomes crucial for large-scale, cost-efficient production of phytoplankton biomass.

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Large-scale cultivation of microalgae in Northern Europe

Commercial algae cultivation for biofuels and other low-cost products is not yet profitable.

Why to introduce a Nordic perspective?

Photos: Jukka Seppälä

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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

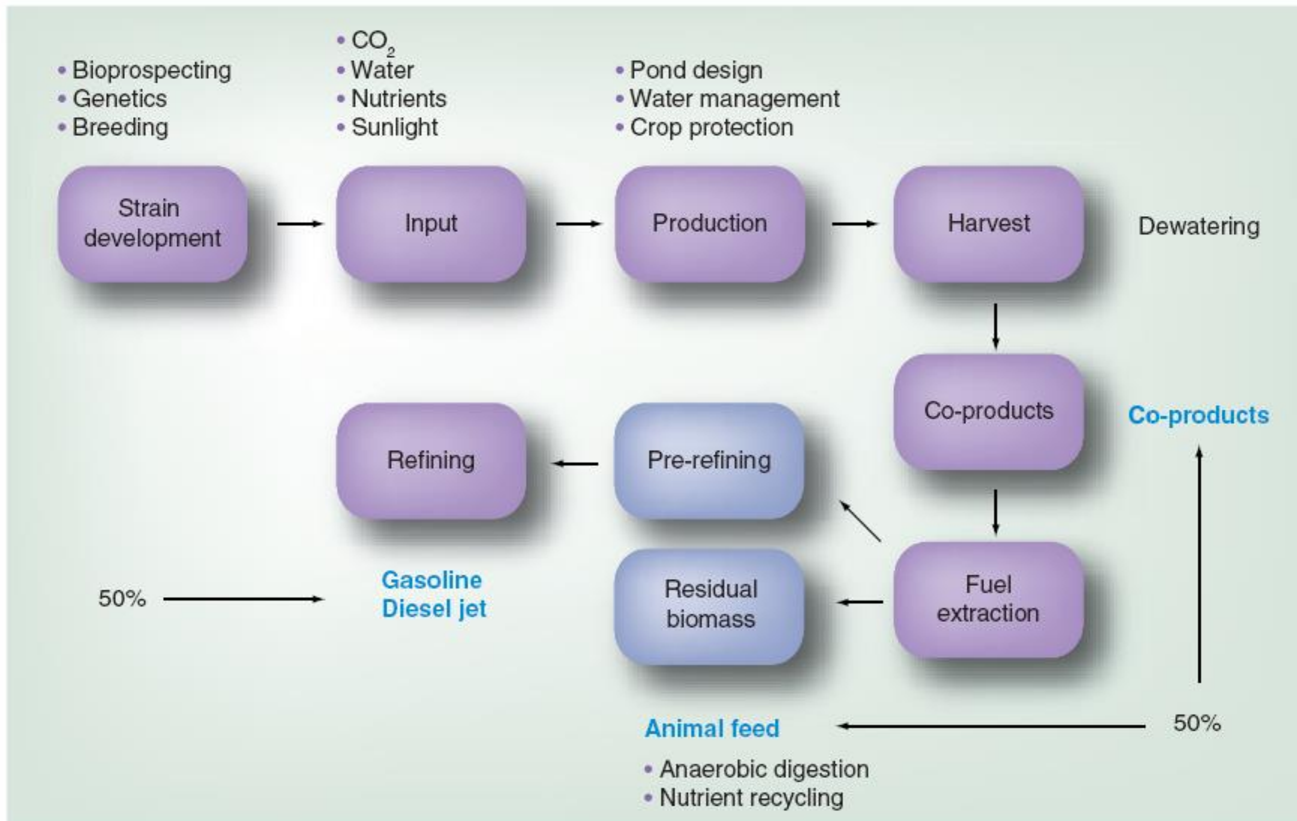
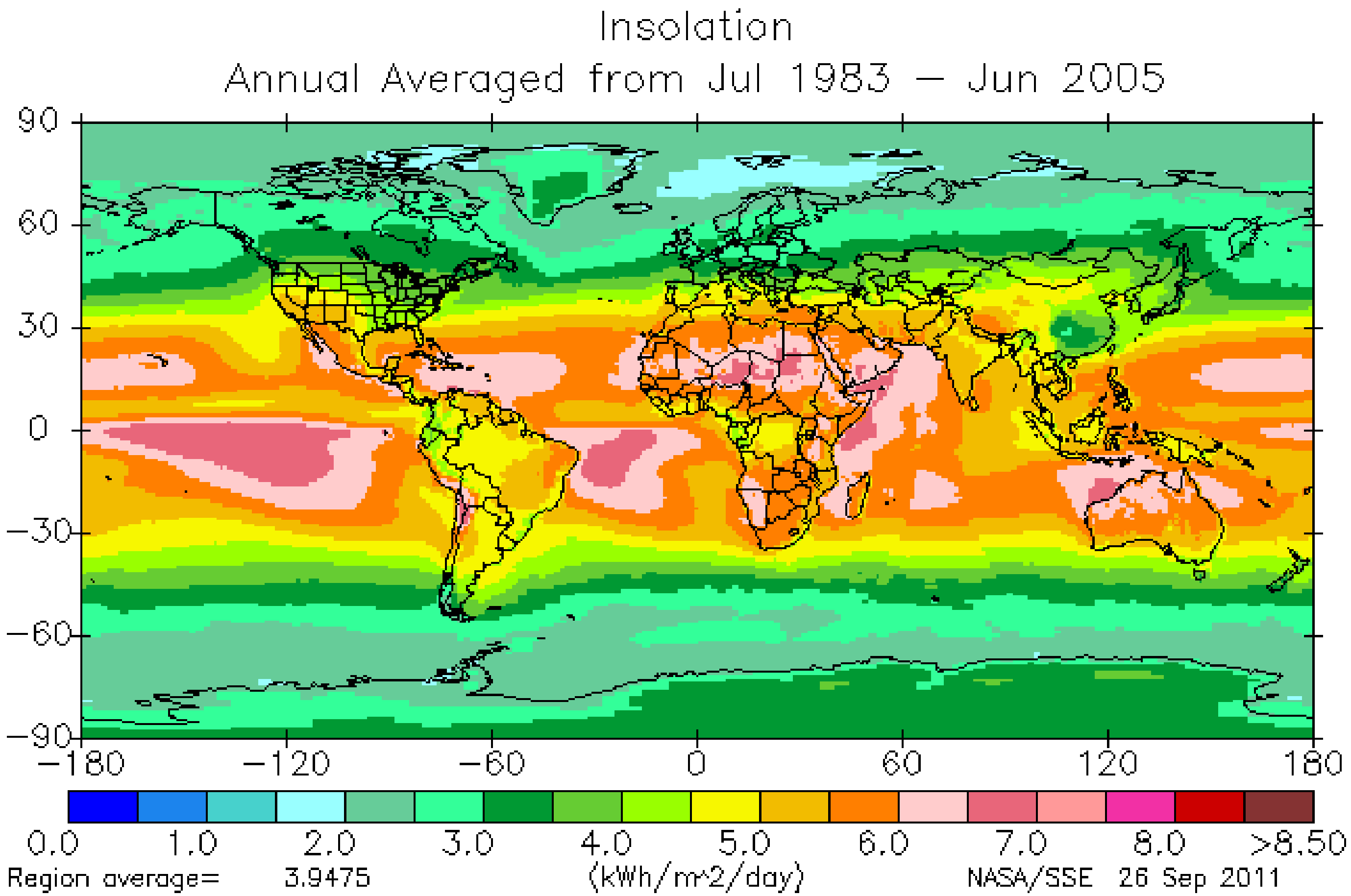


Figure 3. Algal biofuels production chain. Improved strains, as well as downstream efficiency, are integral aspects of the algae biofuel production strategy.

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

Is there enough light?

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



Source: *eosweb.larc.nasa.gov*

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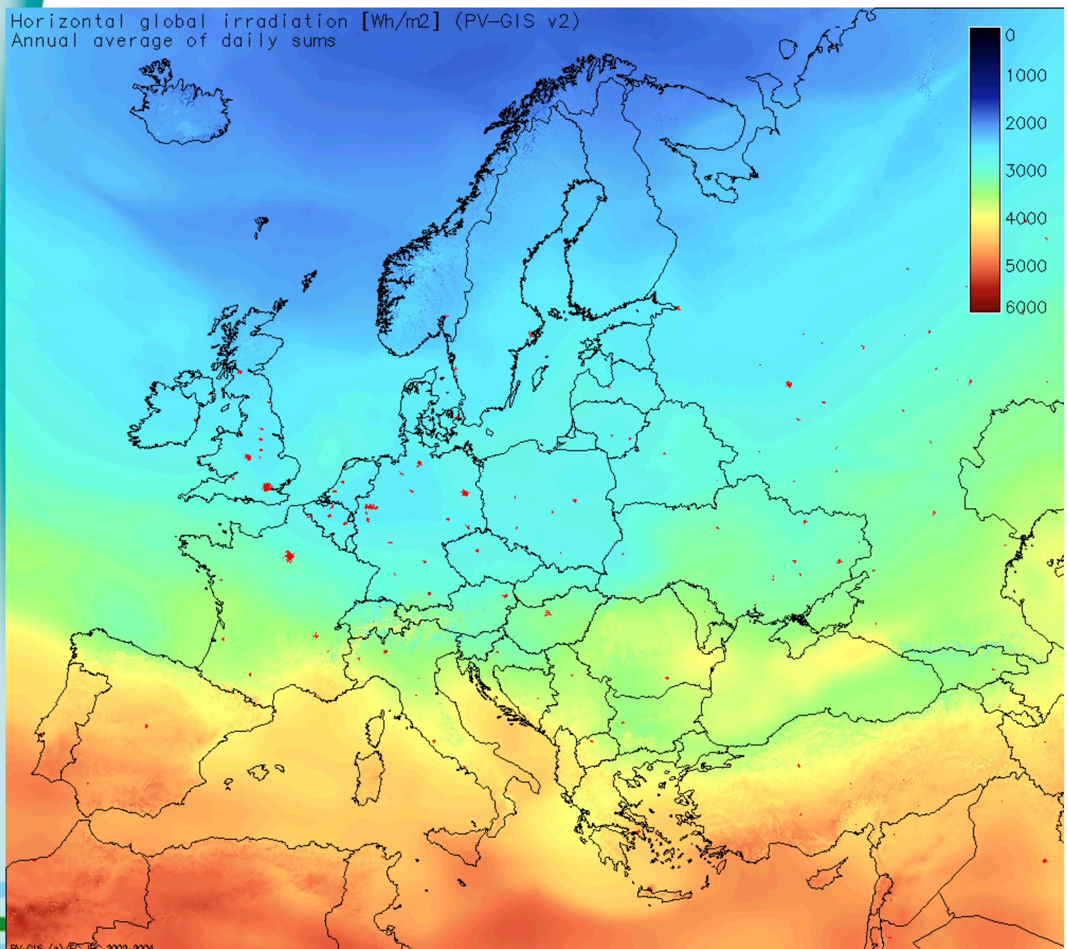

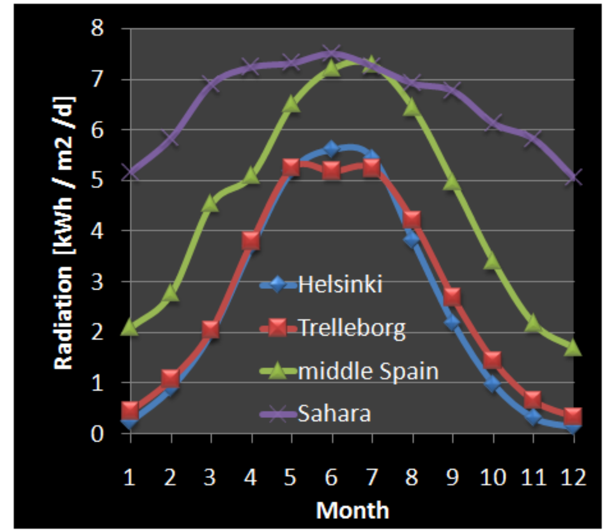

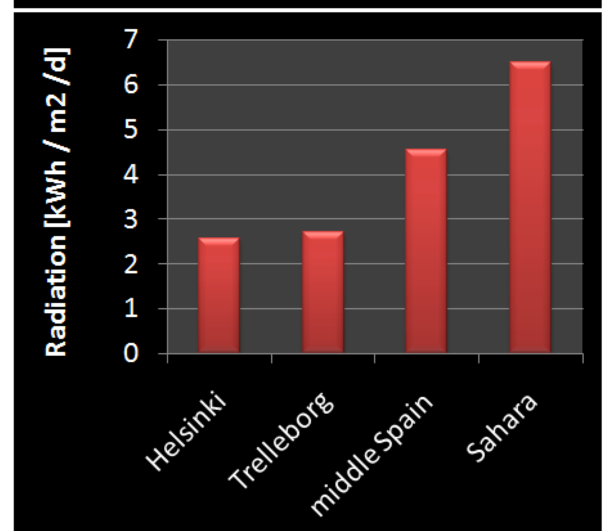

Data from: re.jrc.ec.europa.eu/pvgis

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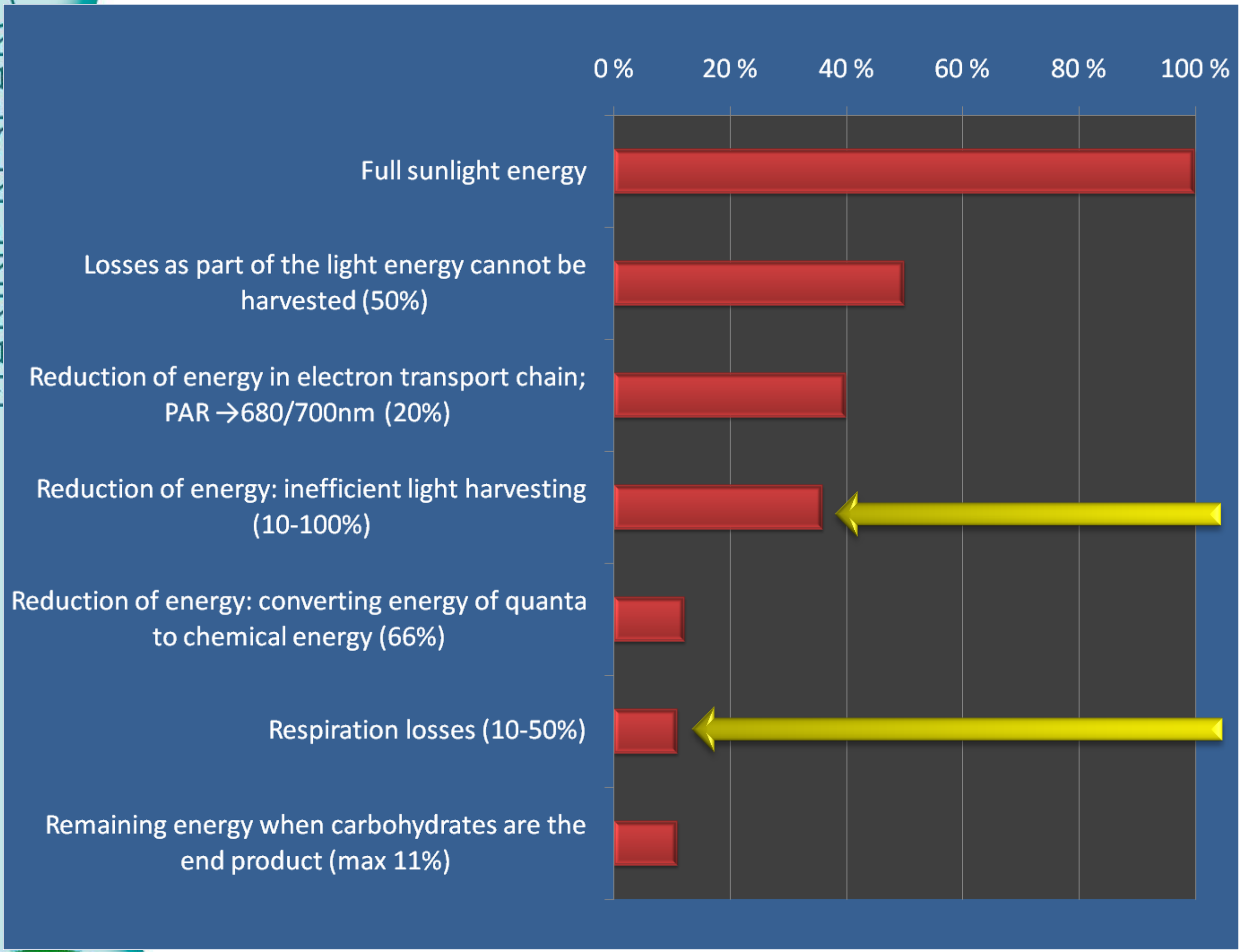
What happens to the light energy during photosynthesis?



Theoretical maximum photosynthetic yield 11-12%, but in reality 1-5% obtained.

Not all light absorbed can drive photosynthesis

Need to maintain metabolism during darkness & repair of components

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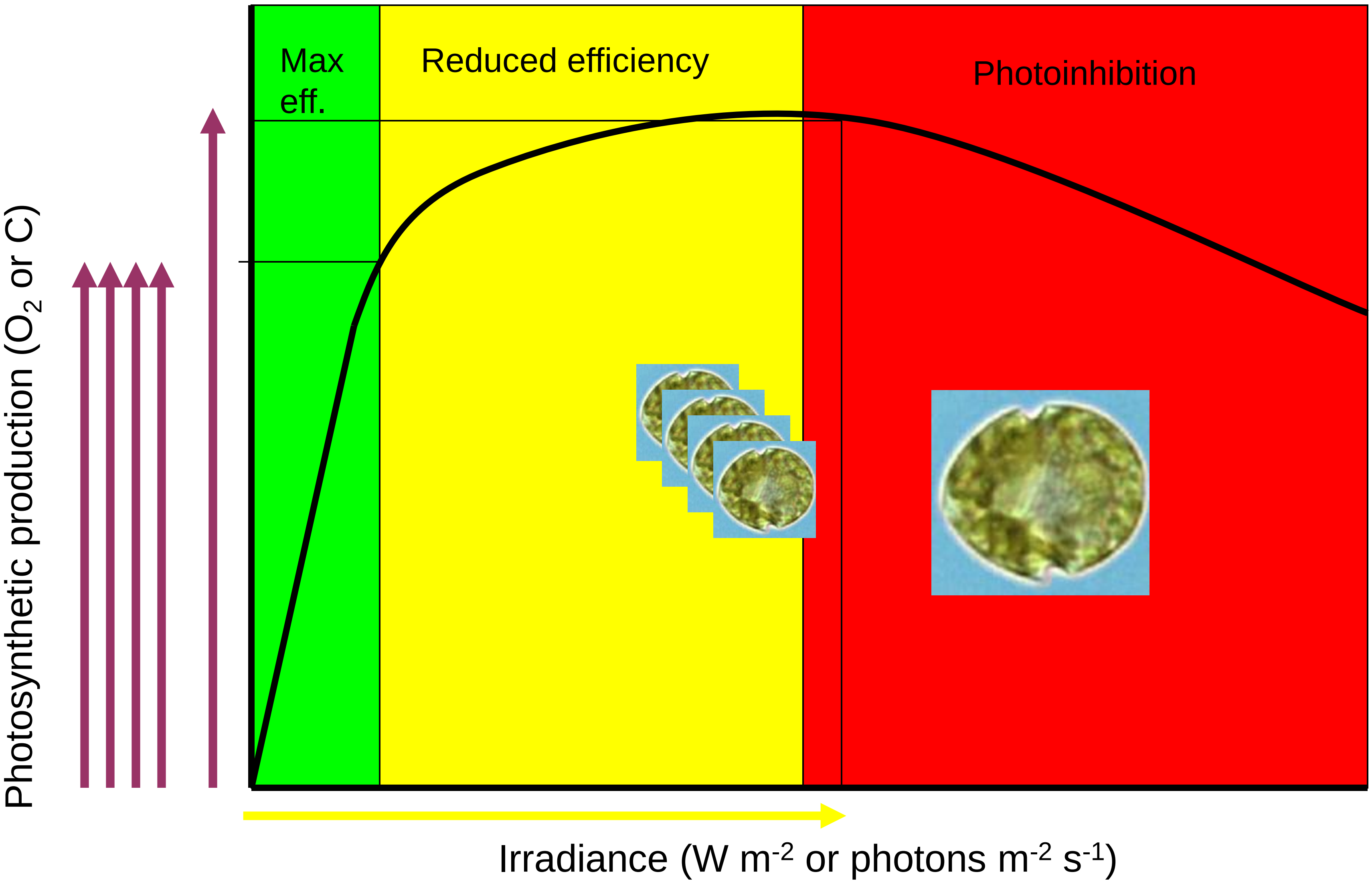
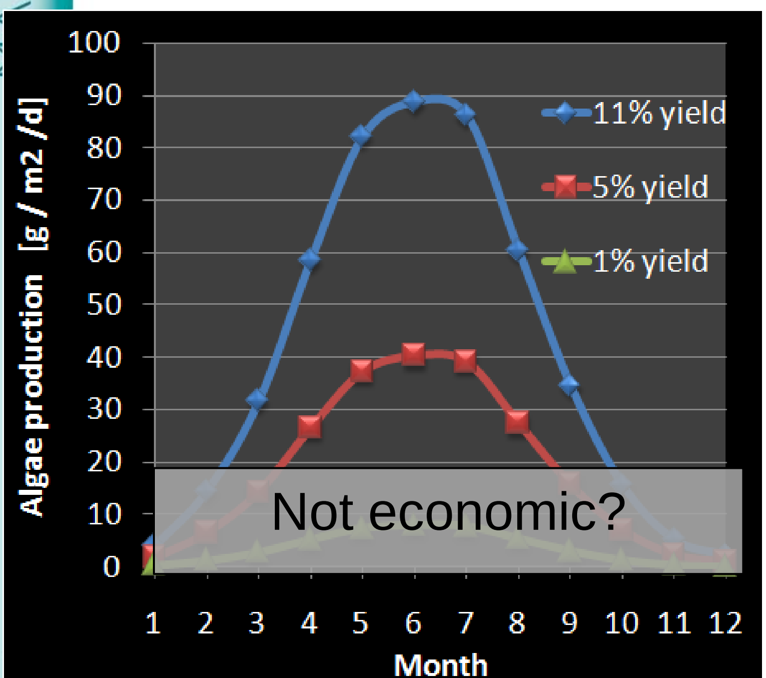
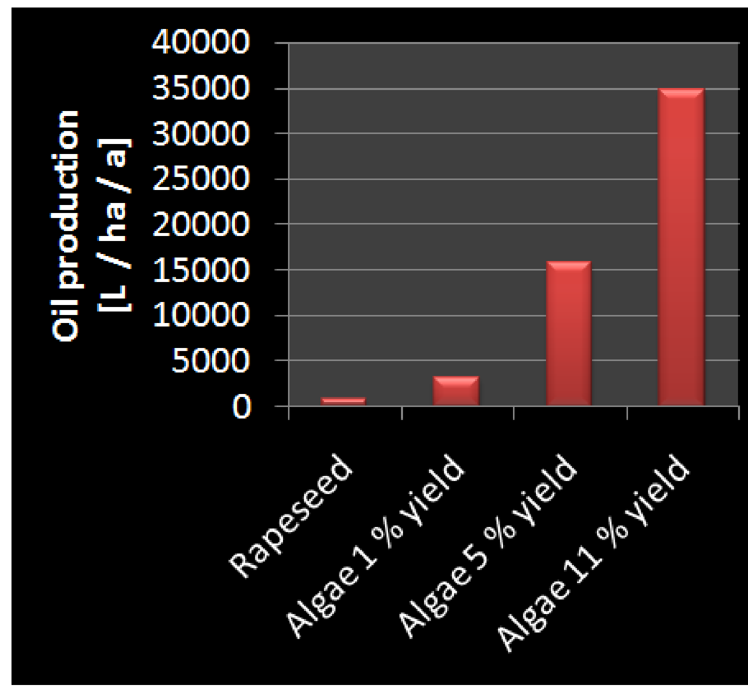

Max
eff.
Reduced efficiency
Photoinhibition
Photosynthetic production (O_2 or C)
Irradiance (W m^{-2} or photons m^{-2} s^{-1})

Effect of irradiance on cultivation of microalgae

Projected algae production in Helsinki
(assuming caloric value for algae 25 kJ g^{-1})



Projected algae oil production (assuming 30% oil content and 80% conversion from oil to biodiesel)



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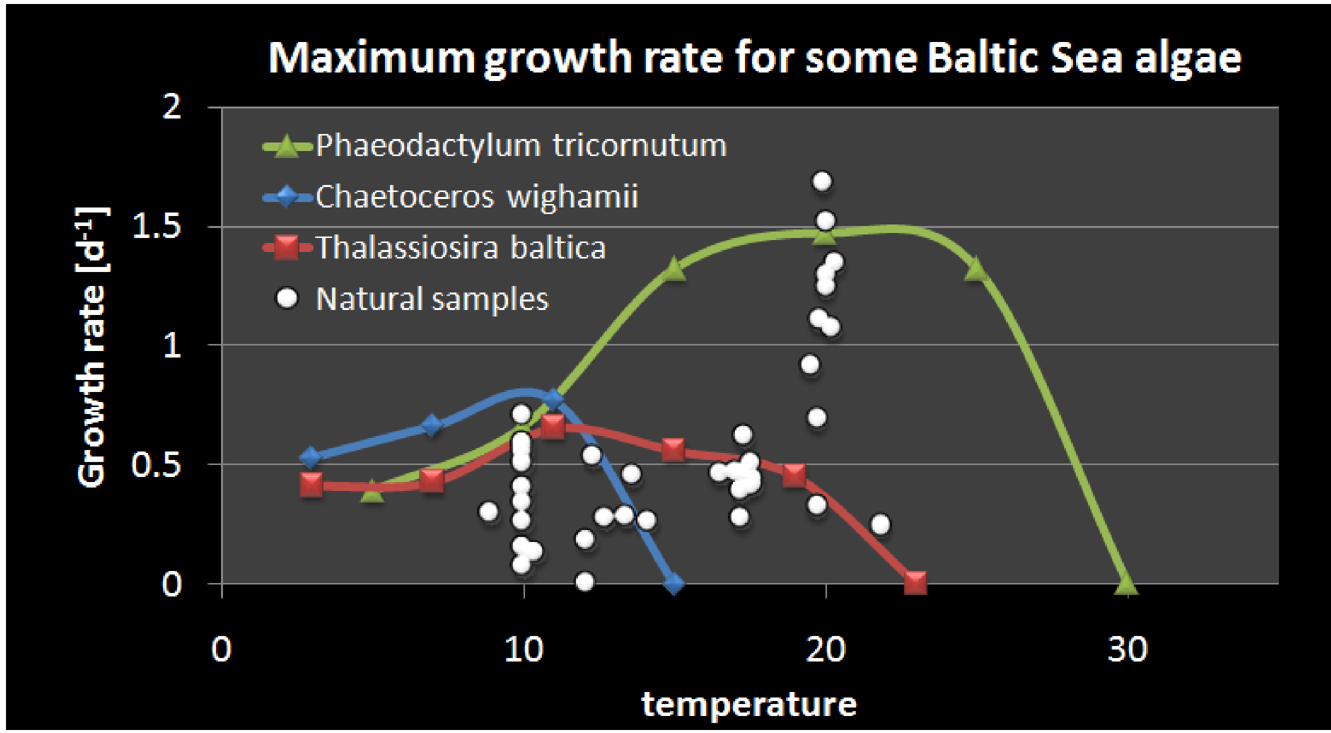
What about temperature?



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

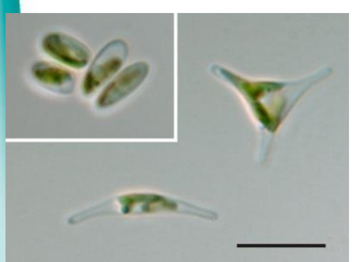
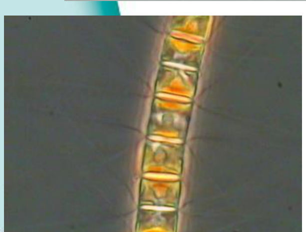
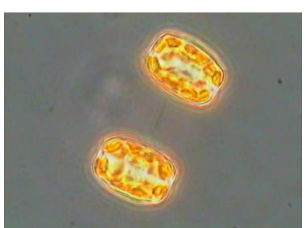


Photo: A. Gruber, Universität Konstanz

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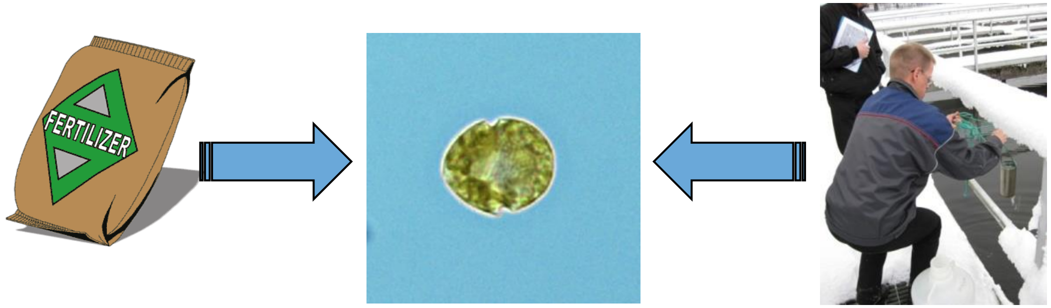
Nutrient requirements

	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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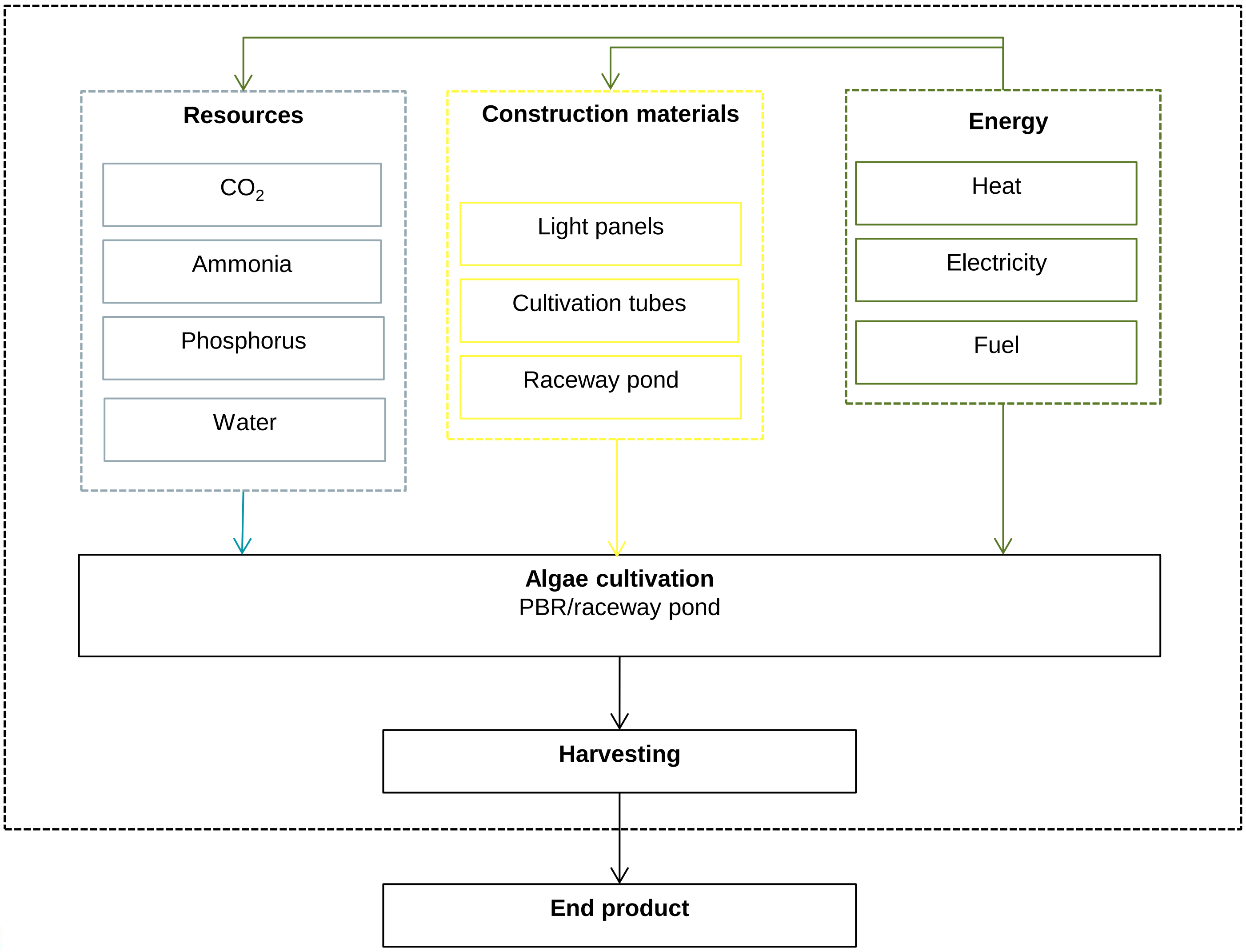
LCA of microalgae cultivation – System boundaries



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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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Conclusion

- We have:
  1) Nutrients in waste water and a lot of CO_2
  2) Water
  3) R&D facilities and knowhow
  4) Downstream processes and refining
  5) Land
- Limitation:
  1) Light during winter
- **In the end, getting lower production cost than the product value is the key for commercialization, not getting the highest absolute yield**

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