Microalgae - a sustainable renewable resource for fine chemicals, food components and energy

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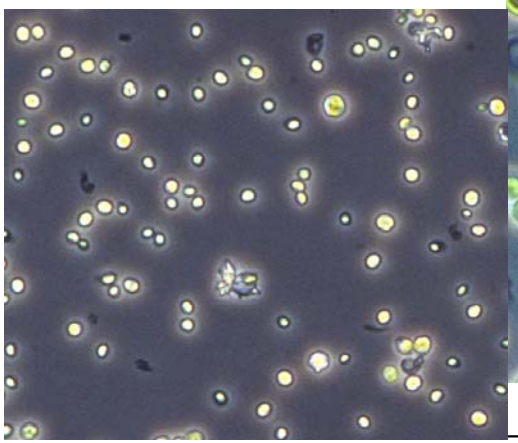
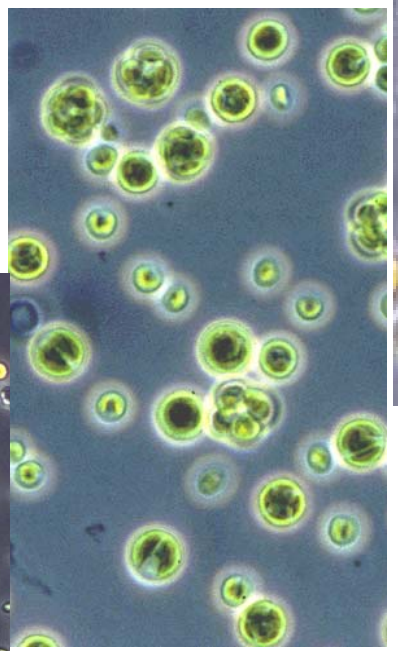
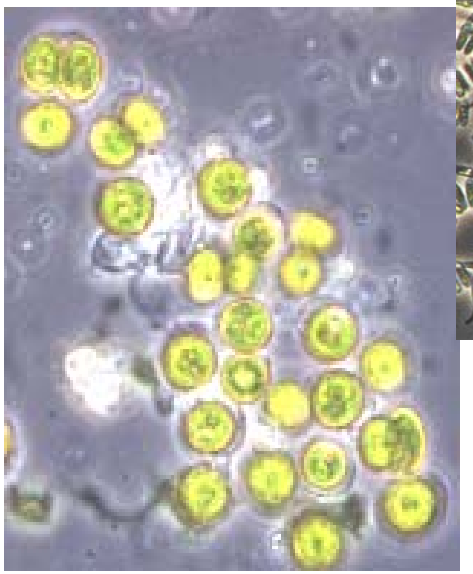
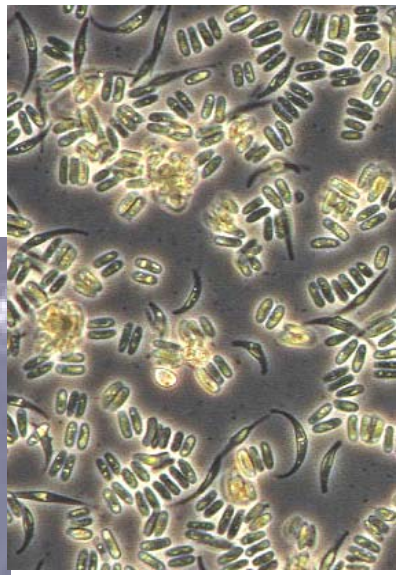
Microalgae - microscopic small „plants“

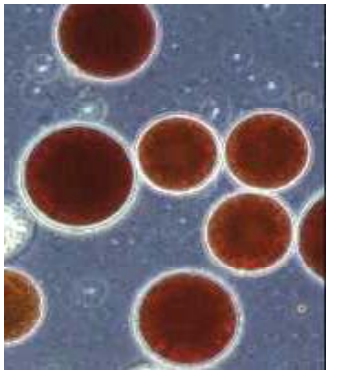
Ubiquitous - seawater
freshwater
soil
air











- About 40.000 different algae in marine water sytems
- Algae are consumed by mankind for thousand of years
- 40-50 Gigatons of carbon are fixed by marine algae every year

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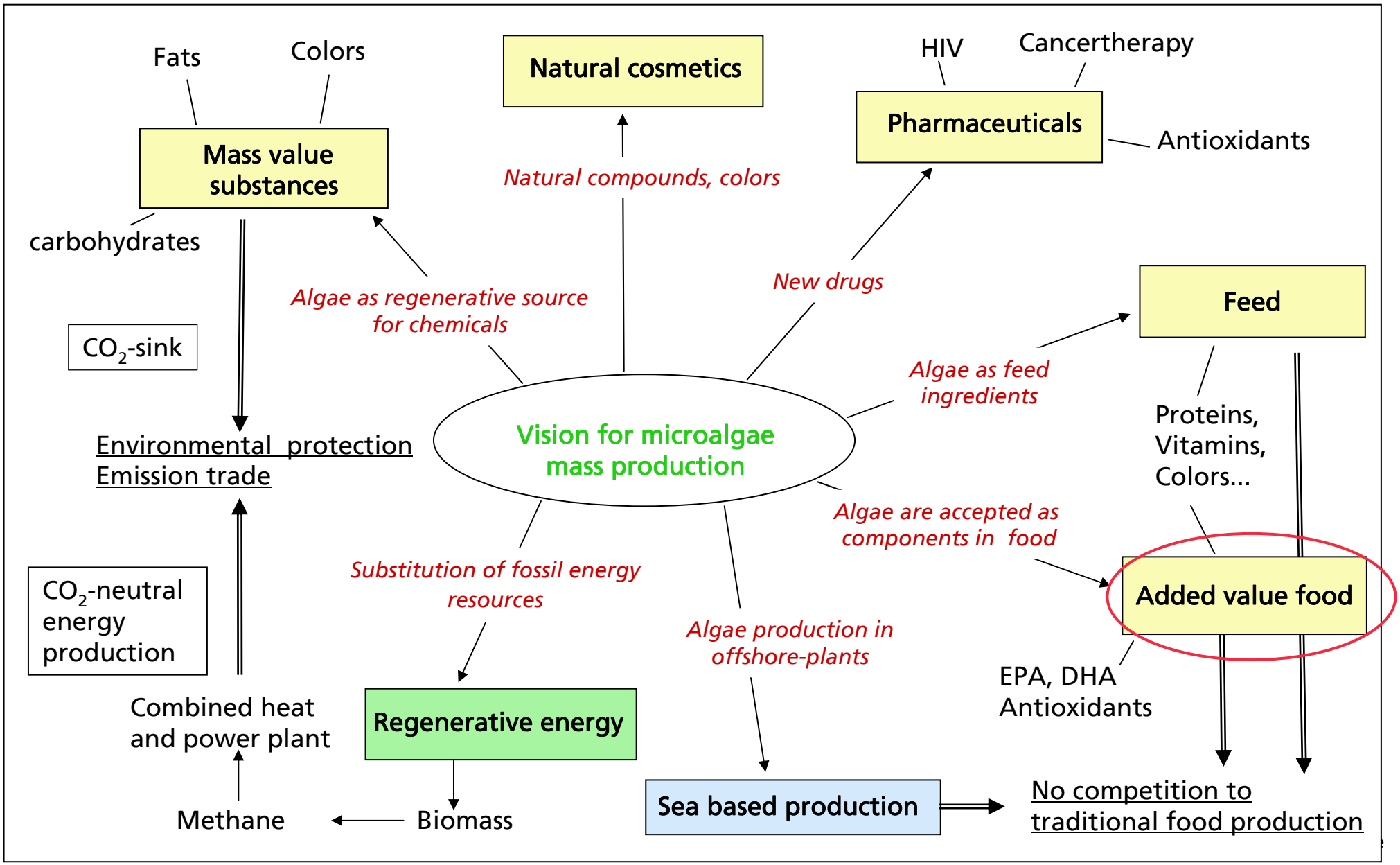
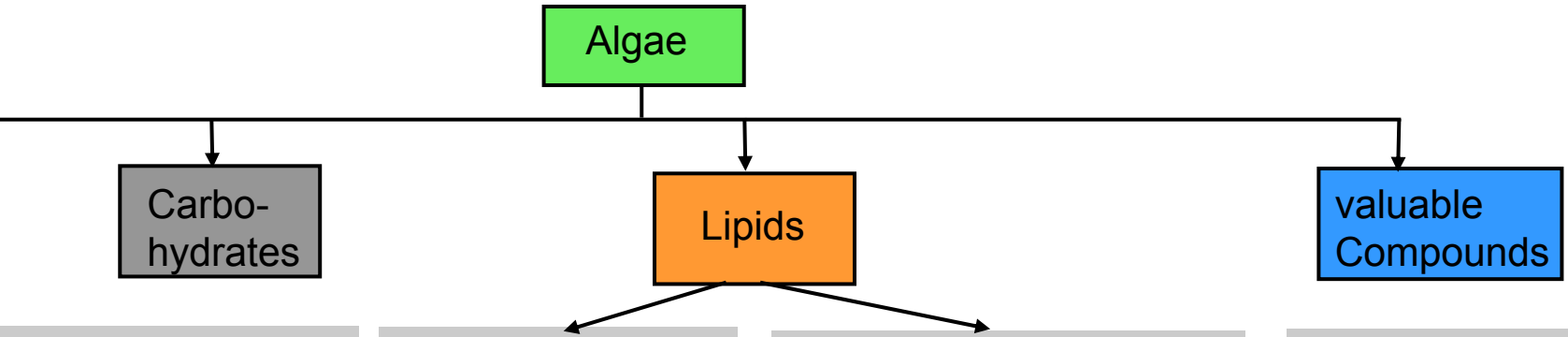
Utilization paths: overview

Trösch & Degen 2002



Main components of microalgae



- high content up to 50% of dry weight in growing cultures
- all 20 amino acids

- storage products
  ά-(1-4)-glucans
  ß-(1-3)-glucans,
  fructans
  sugars
- only very low cellulose content

storage lipids

- mainly TAGs
- with solvents extractable from wet biomass
- recovery by pressing the dry ruptured biomass out

membrane lipids

- different lipid classes
- up to 40% of total lipids are PUFA
- solubilized by solvent extraction of wet biomass, then transesterification
- recovery not by pressing the crushed cells out

- pigments
- antioxidants
- fatty acids
- vitamins
- anti
  -fungal,
  -microbial
  -viral
  toxins
  sterols
  MAAs

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Demands to Sustainable Microalgal Processes

- **Energy efficient** algae biomass **production** process
  high rate of photosynthesis, photobioreactor, CO_2-utilization, net energy balance
- **Product recovery**
  solvents (which and quantity)
  extraction from wet biomass, avoiding energy intensive drying steps
- **Residual biomass utilization**
  free of lignocellulose, in anaerobic digestion converting it to biogas,
- **Recycling of nutrients**
  CO_2, nitrogen, phosphate
- **Water use**

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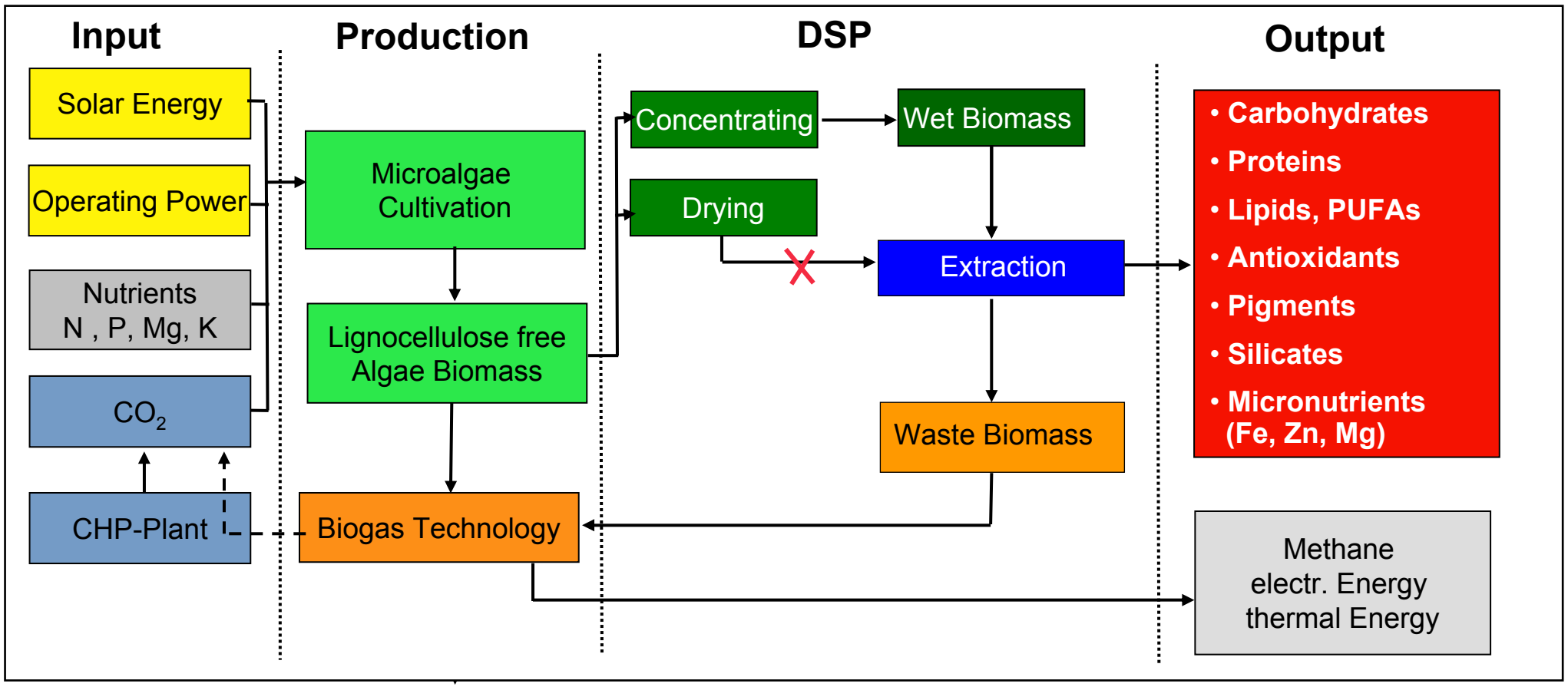
Sustainable Algae-based Processes



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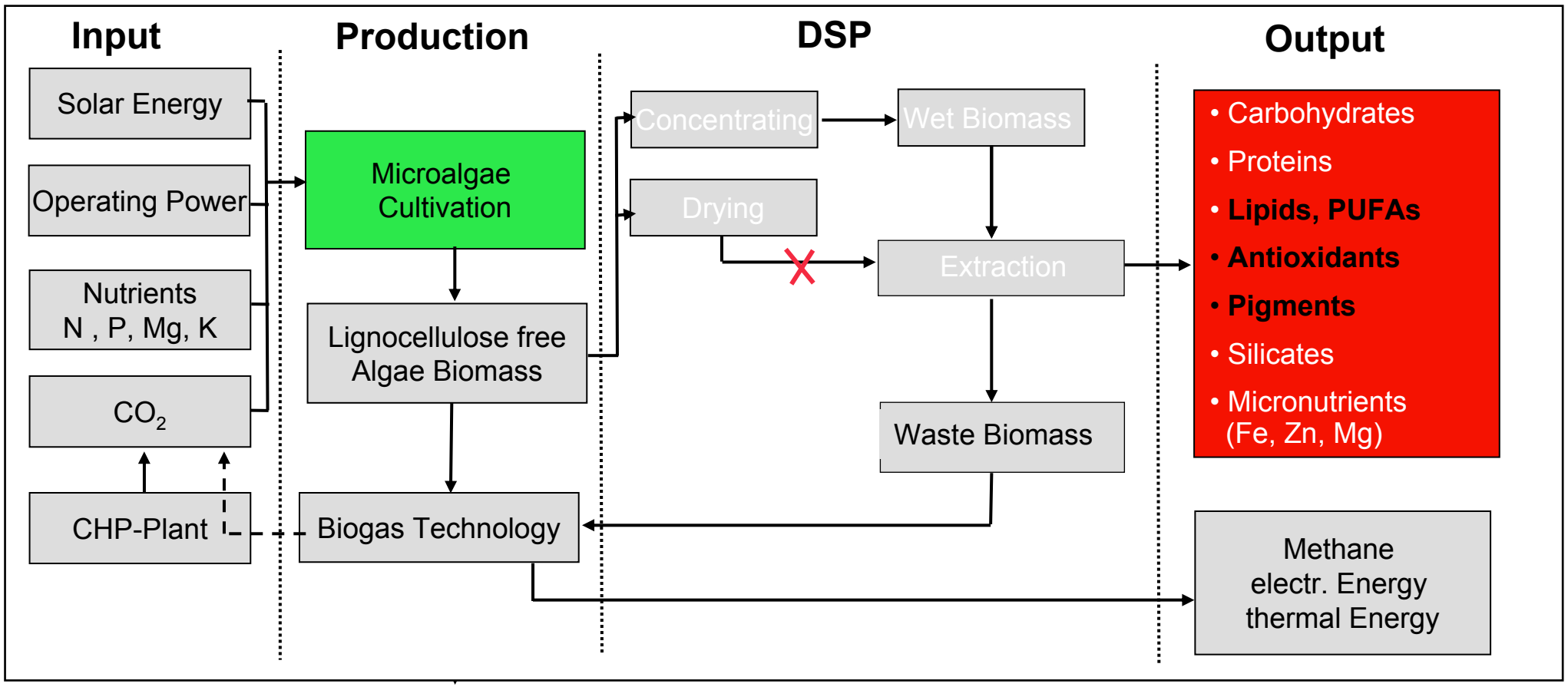

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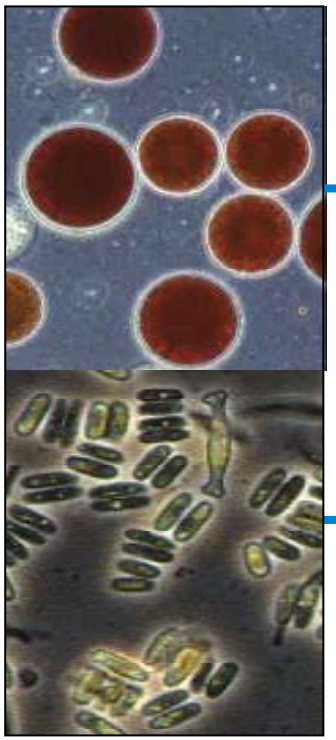
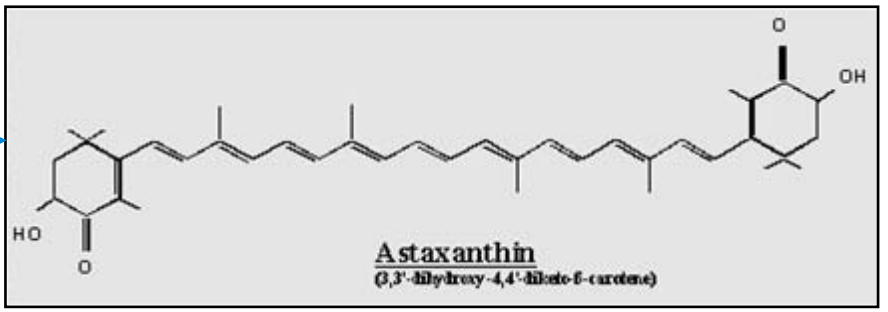
Photoautotrophic Production

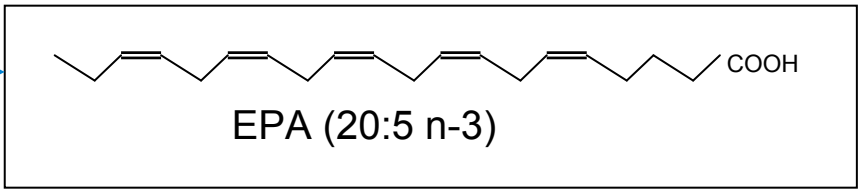
Haematococcus pluvialis — astaxanthin

Phaeodactylum tricornutum — EPA (eicosapentaenoic acid; $C_{20:5}$)

Light, CO_2, N, P, H_2O







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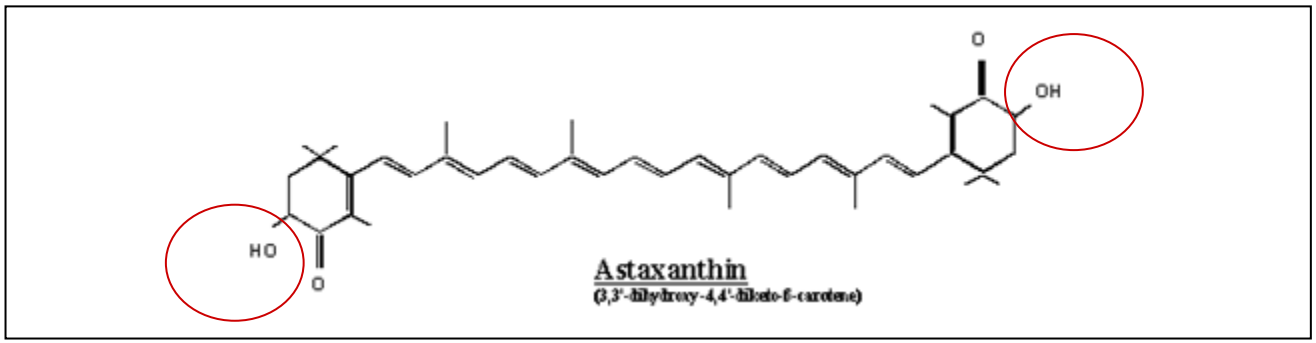
Valuable products: astaxanthin from Haematococcus – properties and potential indications



Properties:

- 10 times higher antioxidative effect than ß-carotene or lutein
- 50-80 times higher antioxidative effect compared to alpha-tocopheroles
- Antioxidants are effective against free radicals and save cells of lipid peroxidation and oxidative harms to cell components

Potential Indications:

- ageing
- sun protection
- joint diseases
- Alzheimer´s disease
- atherosclerosis
- cancer
- macula degeneration
- epilepsy
- Parkinson´s disease

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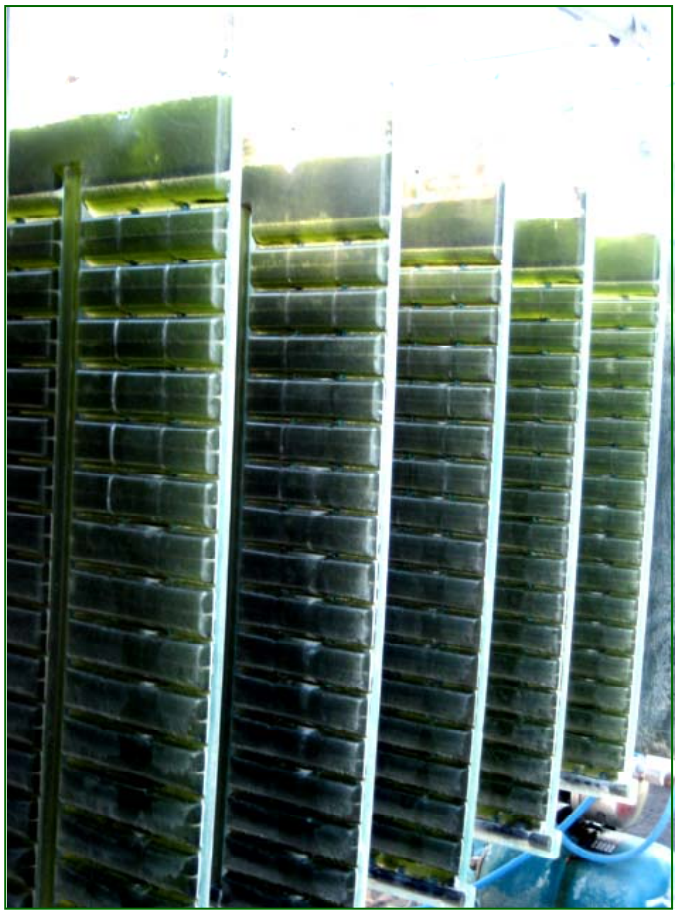
Production of astaxanthin in FPA-reactors

Phase 1

Growth
and proliferation



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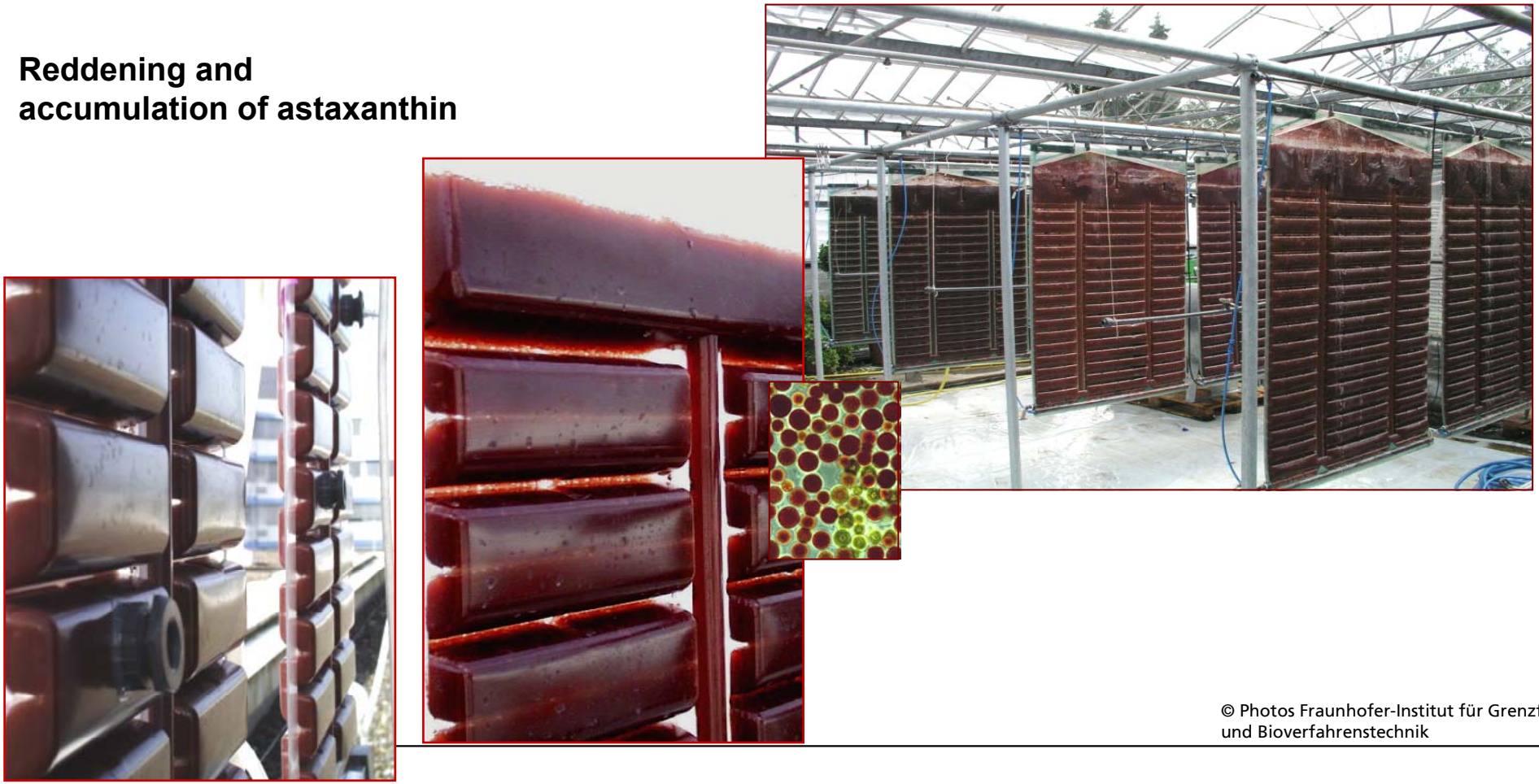
Process development: up to 4% astaxanthin in the biomass

Phase 2

Reddening and accumulation of astaxanthin



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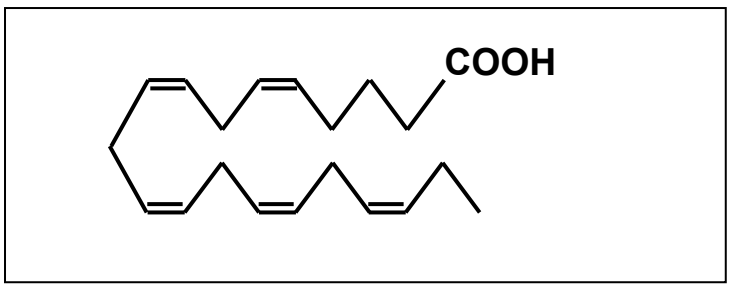
Valuable products: EPA (eicosapentaenoic acid) production from *Phaeodactylum tricornutum – properties and potential indications*

Facts about EPA:

Broad levels of the population in the developed countries show a deficiency of EPA supply



EPA from algae reveals considerable advantages

- Neutral taste and odour
- No seasonal variations in supply
- No contamination by environmental pollutants

Potential Indications of EPA:

- cardiovascular disesases (atherosclerosis)
- rheumatoid arthritis (anti-inflammatory).
- Autoimmune disorders: multiple sclerosis
- diabetes mellitus
- several cancers
- Morbus Crohn
- light hypertension

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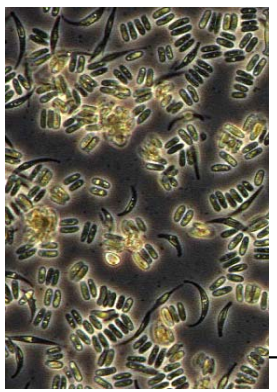
Process development for EPA production with *Phaeodactylum tricornutum*



Phaeodactylum tricornutum
outdoor cultivation
in 33 litre reactor modules

- ✓ Optimal **aeration rate** defined
- ✓ Growth on different **nitrogen** sources examined
- ✓ Requirements of **nutritients** characterized
- ✓ Influence of **light intensity** determined
- ✓ Optimal **growth temperature** defined
- ✓ **Continuous culture** process implemented
- ✓ Effects of **exchange rate** analyzed
- ✓ Influencing variables of **EPA content** characterized

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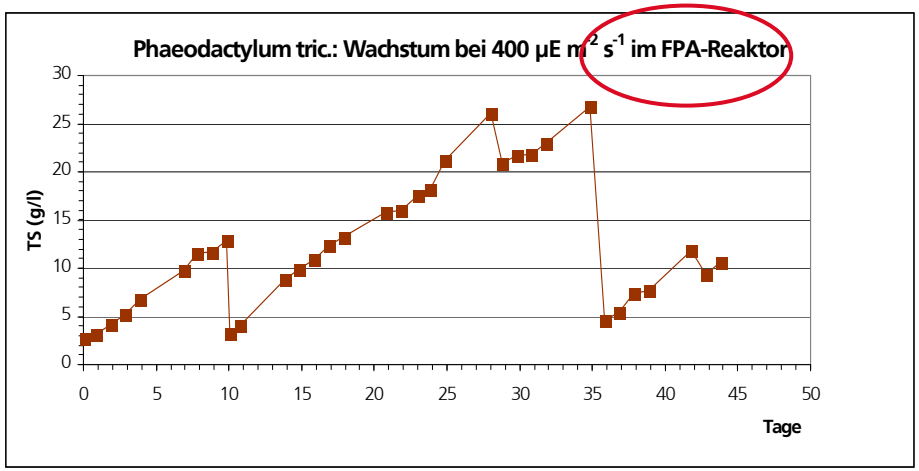
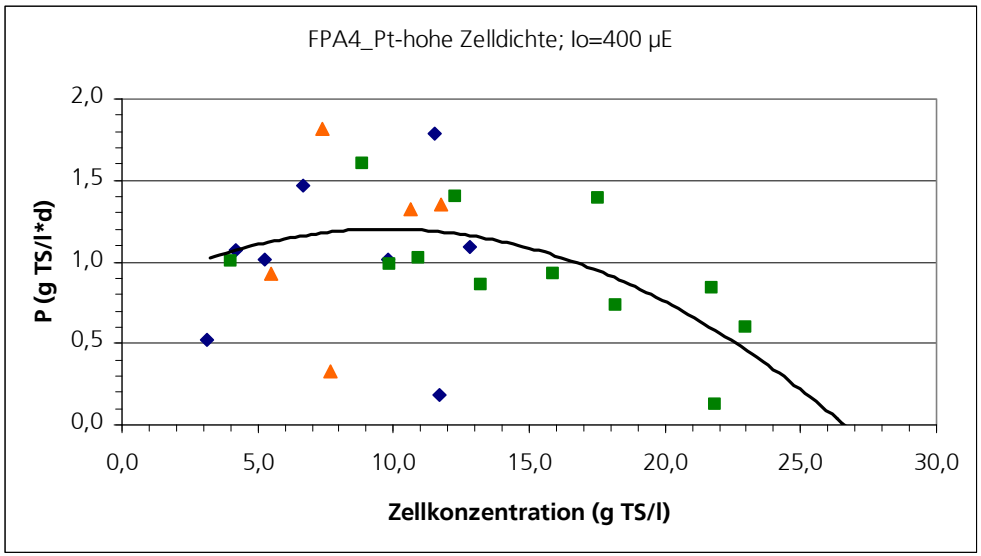
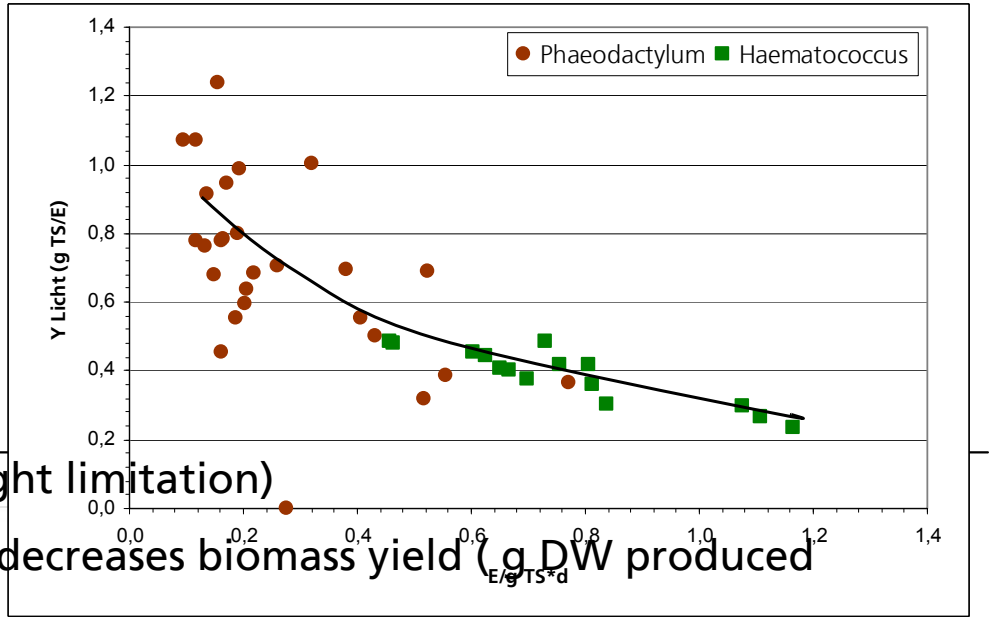
Wachstum und Biomasseproduktivität im FPA-Reaktor am Beispiel *Phaeodactylum tricornutum*





5-Liter FPA-Reaktor
Lichtintensität: 400 µE m^{-2} s^{-1}

Begasungsrate: 200-300 l/h
CO_2-Konz.: 2-3% (v/v)



- Productivity increases with light intensity (light limitation)
- increasing light availability per g dry weight decreases biomass yield (g DW produced per mole of photones (E).

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DSP EPA

4 Folien Andrea

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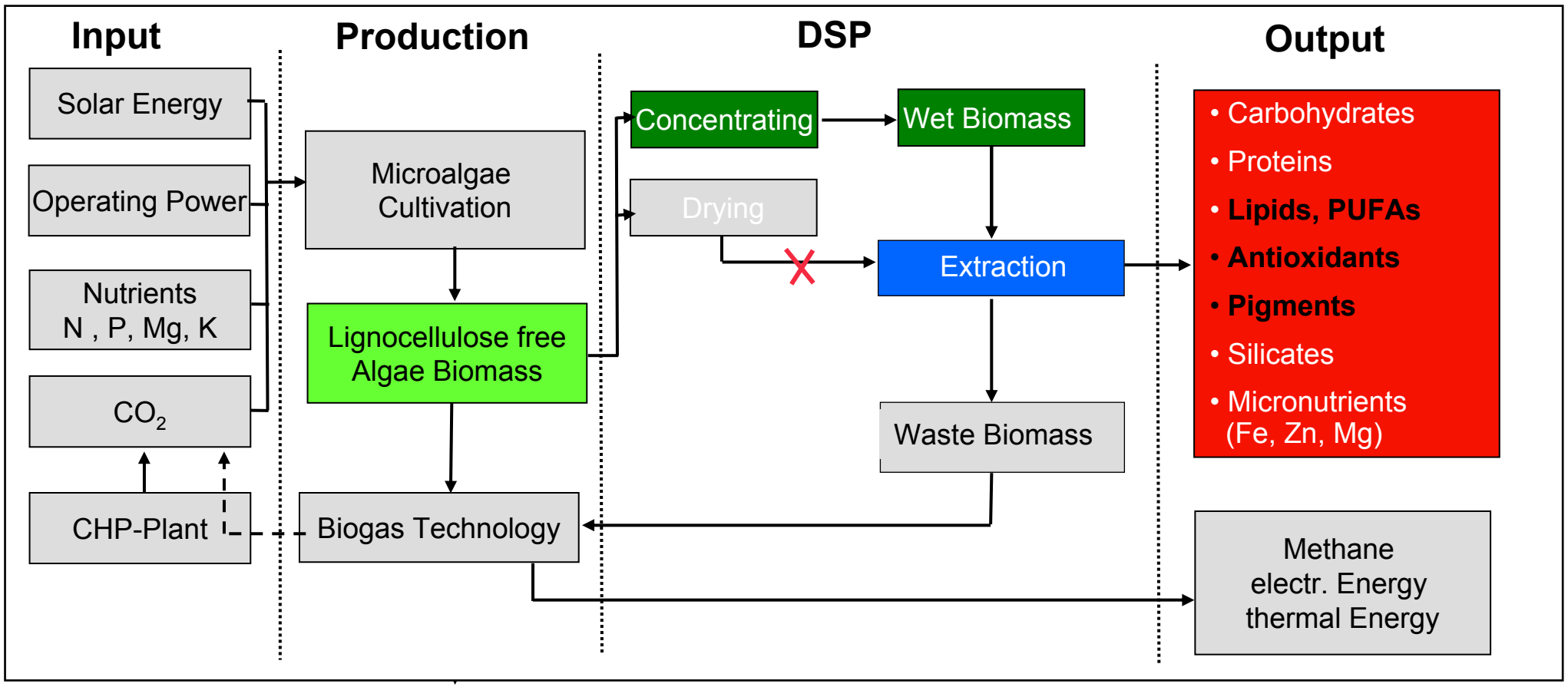

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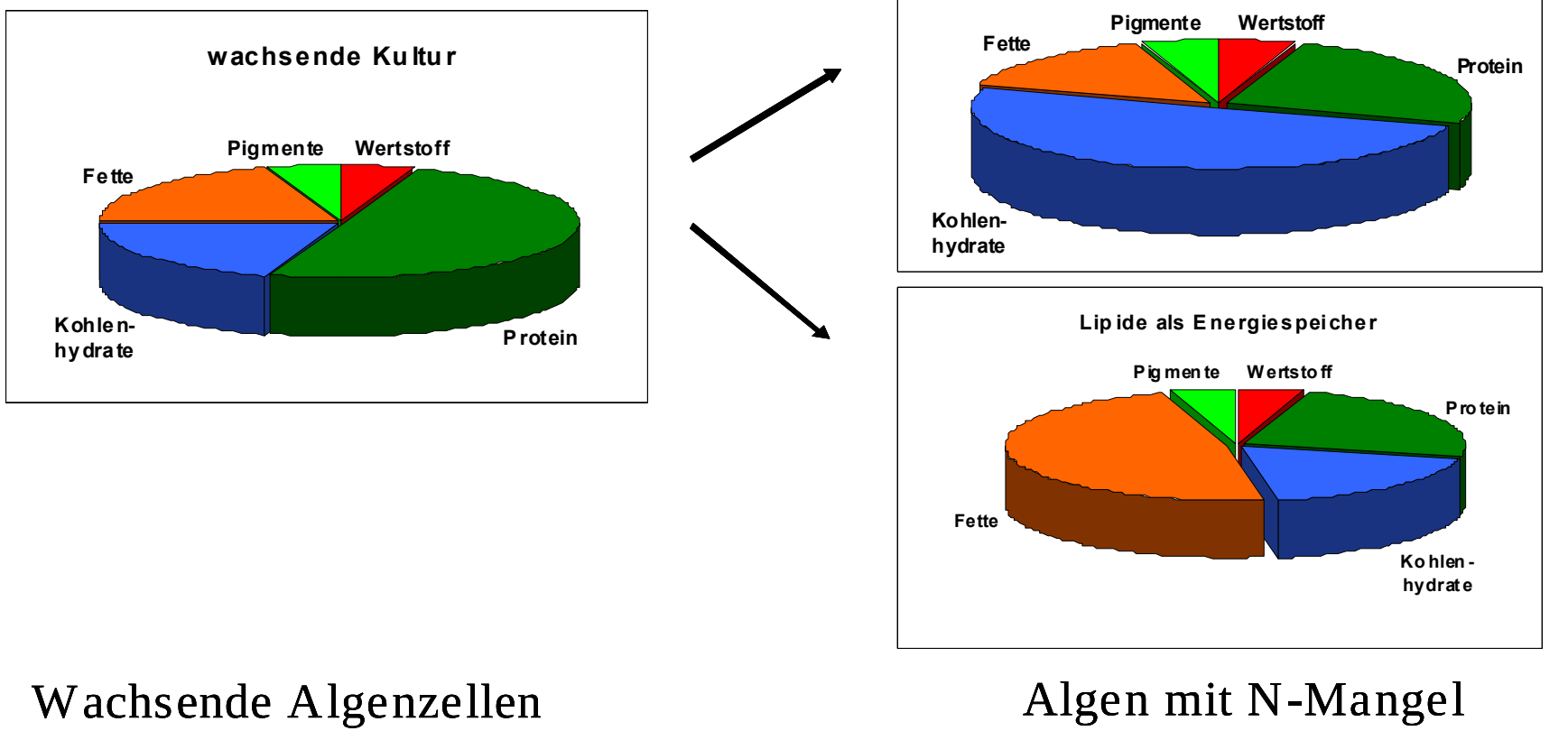
Energetic use of microalgae



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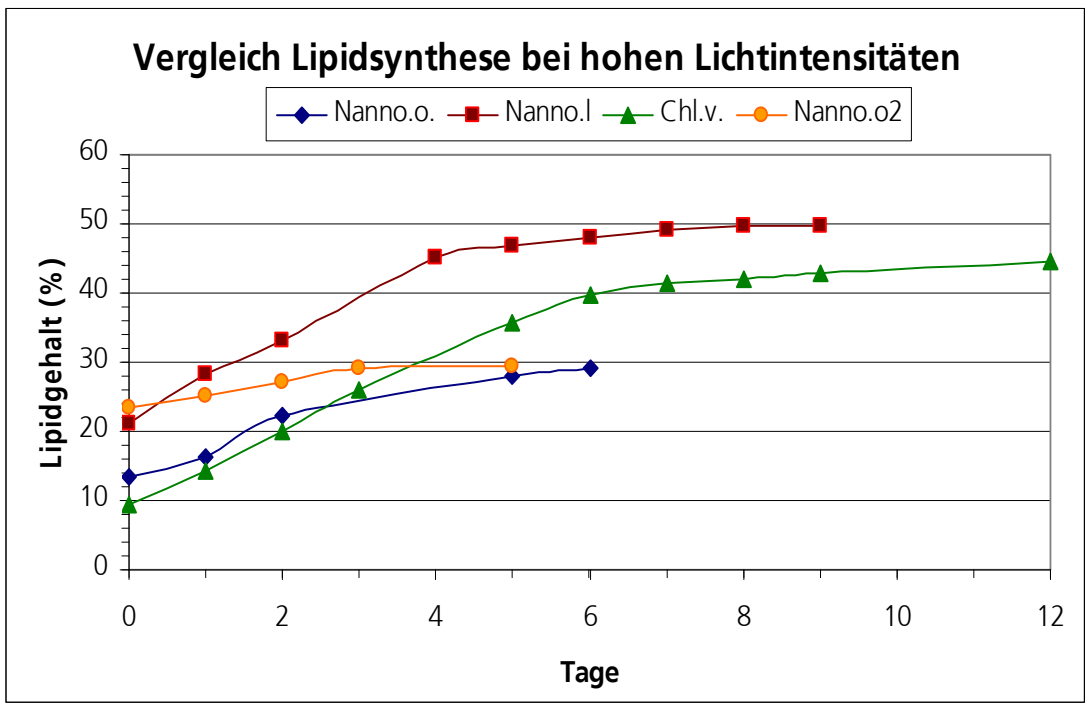
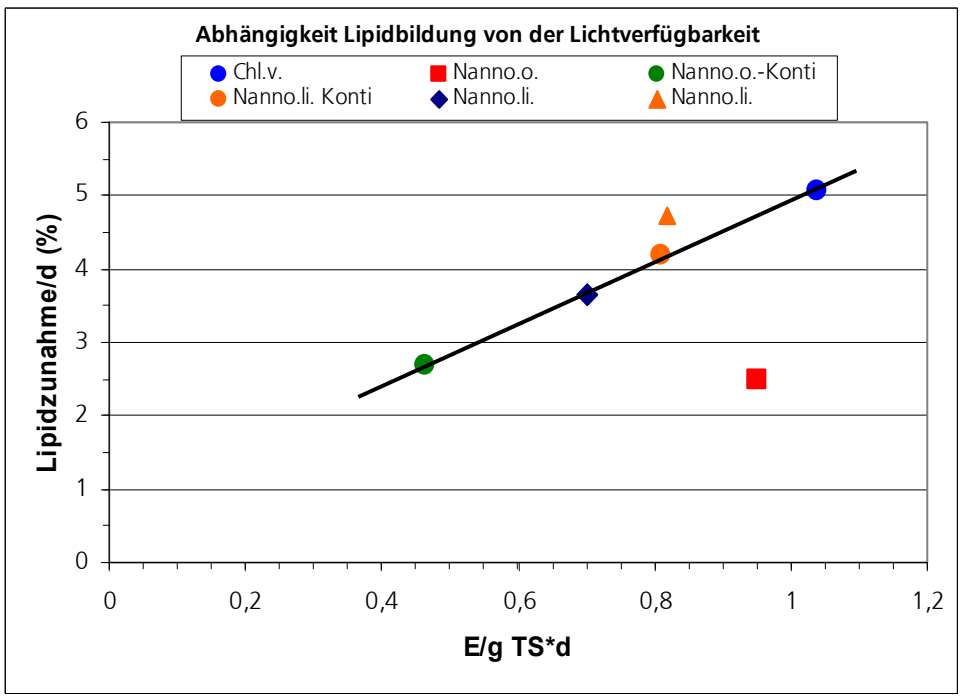
Lipidproduktion durch Mikroalgen – Abhängigkeit von der verfügbaren Lichtintensität pro Biomasse





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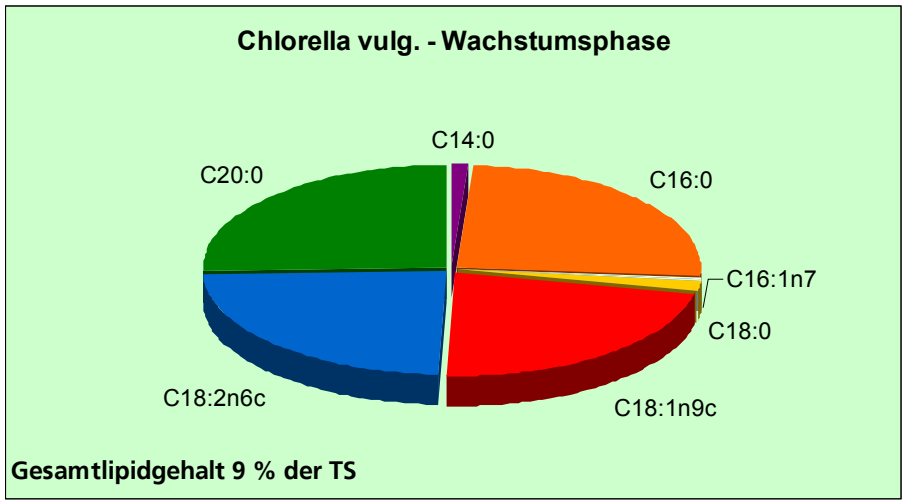
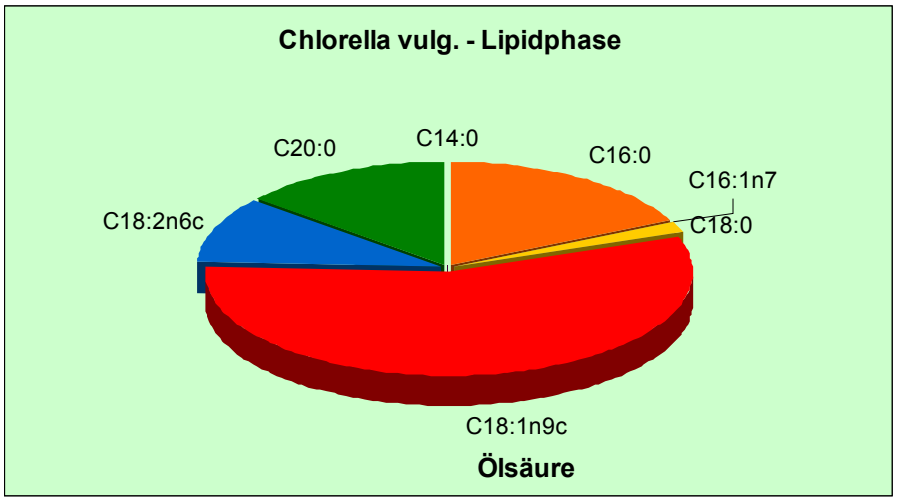
Fettsäuremuster





Gesamtlipidgehalt 9 % der TS

Gesamtlipidgehalt 45% der TS

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✓ **Product recovery**

solvents (which and quantity)

extraction from wet biomass, avoiding energy intensive drying steps

Residual biomass utilization

free of lignocellulose, anaerobic digestion to biogas,

Recycling of nutrients

CO_2, nitrogen, phosphate

Water use

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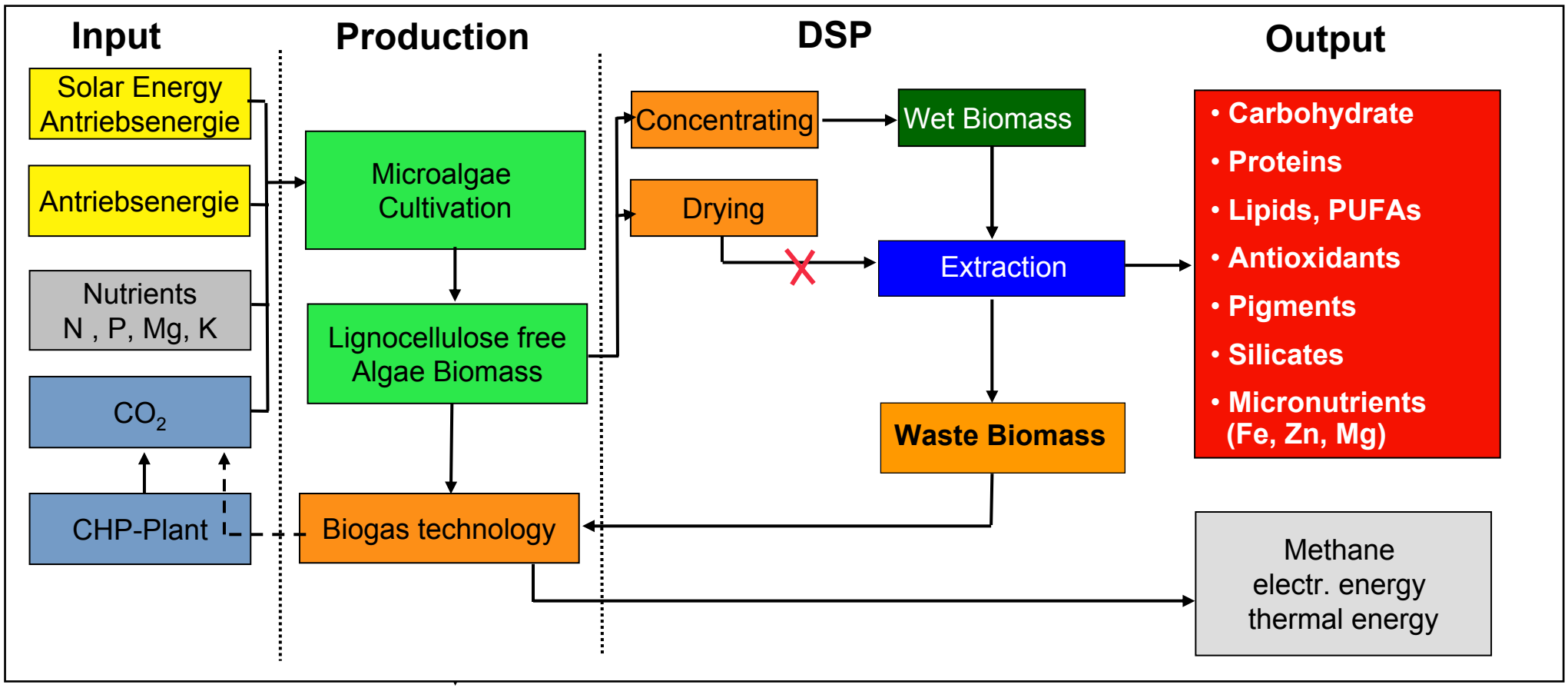

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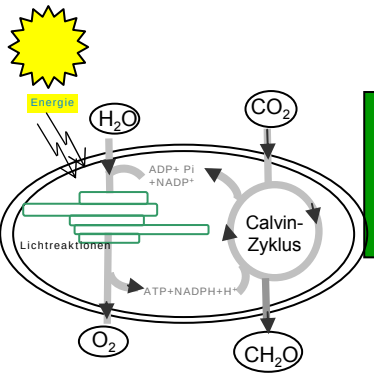
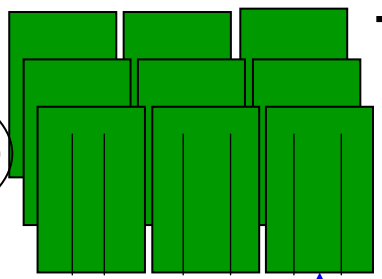
Outlook: Integrated process for mass and energy based utilization of microalgae





Algal biomass

Products: pigments
ω-3-fatty acids
vitamins

residual biomass

NH_4, PO_4 recycling

per kg algal biomass produced 1,85 kg CO_2 are fixed

CO_2

digestion / codigestion

Biogas

CHPS

8 MJ electricity

12 MJ heat per m³ biogas

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Subitec SUSTAINABLE BIOTECHNOLOGY

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Products of integrated algal processes

- Natural omega-3 fatty acids derived from algae, such as eicosapentaenoic acid (EPA)
- Natural astaxanthin from *Haematococcus*
- Algae with high lipid content for energetic use
- After extraction of valuable products like carotenoids, PUFAs or proteins the residual algal biomass can be digested to biogas
- Use of flue gas of combined heat and power units as free of charge CO2 source

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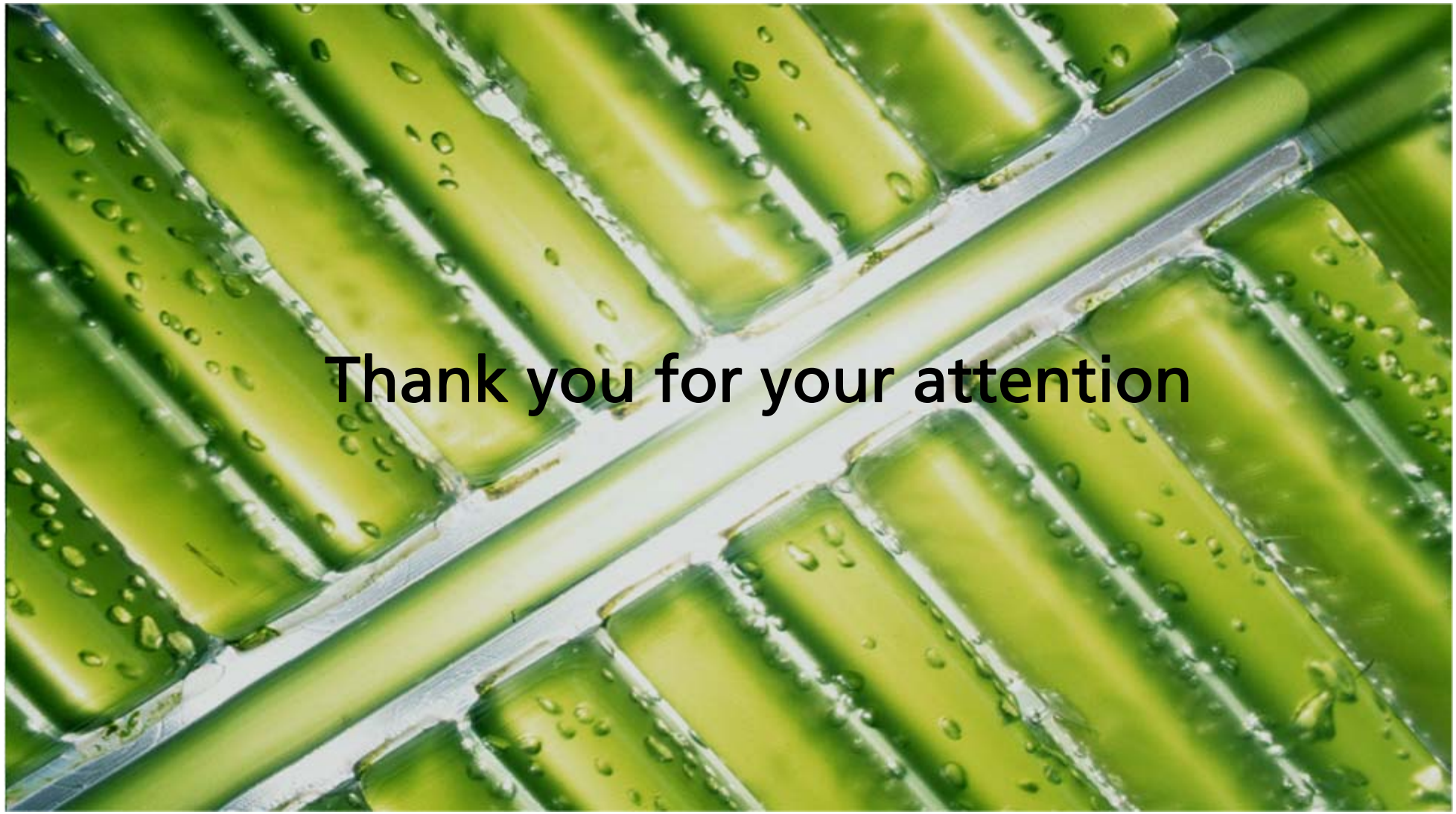

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