Microalgae for sustainable production of fuels and chemicals

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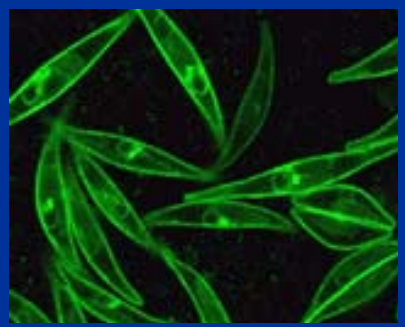

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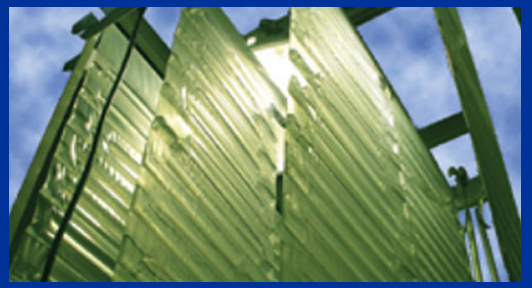
Outline



1. Why microalgae?
    - Potential products
    - Advantages of using algae

2. Microalgae biomass production options
    - Raceways and photobioreactors

3. Photobioreactor engineering aspects

4. Production of algal biodiesel – an example product

5. Summary and conclusions

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Why microalgae?

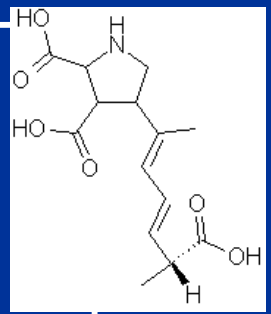
Microalgae and cyanobacteria

Aquaculture

Agriculture

- Biofertilizers
- Soil inoculants

Speciality chemicals & materials



Nutraceuticals/pharmaceuticals

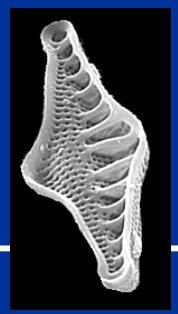
- PUFAs
- β-carotene

Pigments and colorants

- Astaxanthin

Others

- Insecticides
- Nanomaterials



Environment

- Wastewater treatment

Animal feed

Energy options from algae

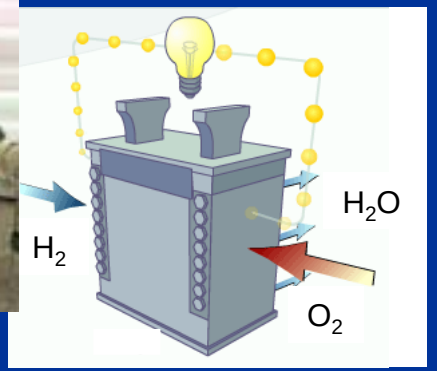
Microalgae

Biogas – methane
- Anaerobic digestion

Bioethanol
- Fermentation

Biodiesel – microalgal oils
- Liquid hydrocarbon fuels
- Jet fuel

Biohydrogen
- H_2 fuel cells



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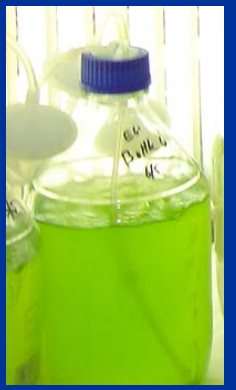
Advantages of microalgae

1. **Direct conversion** of **sunlight** to a **bioproduct**
2. **Renewable** and **sustainable** production
3. **Rapid growth** compared to most plants
4. Little or **no competition** for **agricultural land**
5. **No competition** with **food/feed supplies**
6. **Low requirement** for **freshwater**



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Microalgal biomass production

Option 1: Raceway ponds

Typical biomass productivity

0.025 kg m^{-2} day^{-1} (~82 tons ha^{-1} $year^{-1}$)

Maximum biomass concentration

1 kg m^{-3} (0.5 kg m^{-3} typical)

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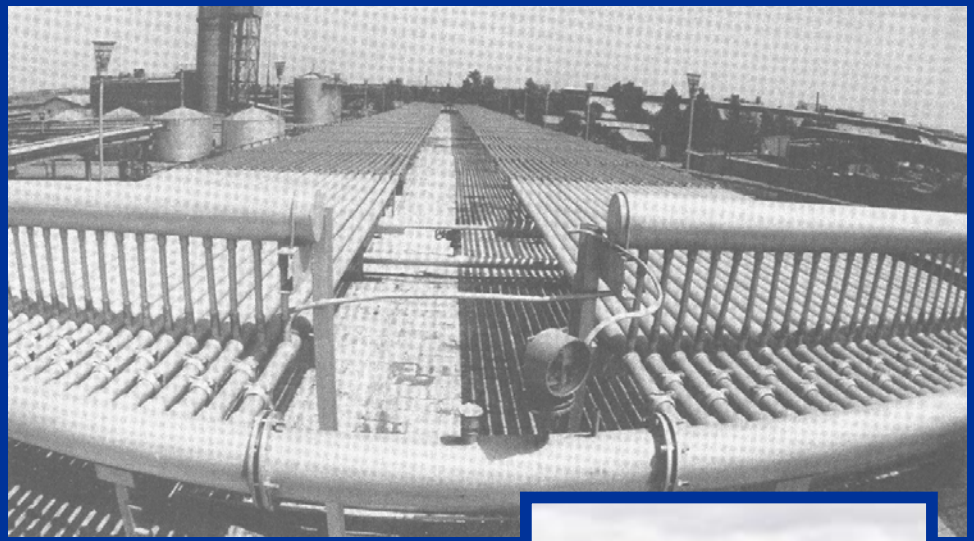
Microalgal biomass production…

Option 2: Tubular photobioreactors



Proved biomass productivity

1.535 kg m^{-3} day^{-1} (~158 tons ha^{-1} $year^{-1}$)

Biomass concentration

4 kg m^{-3}

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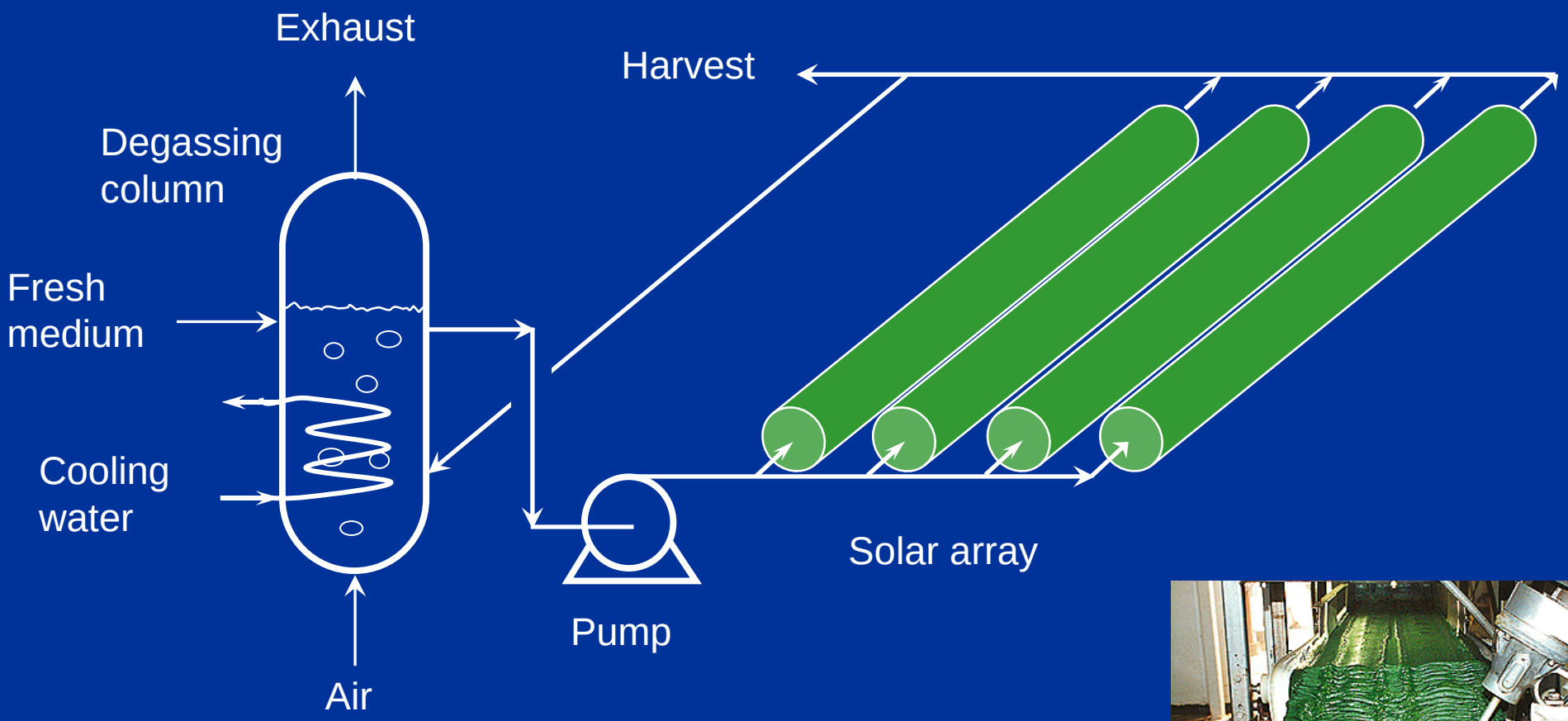
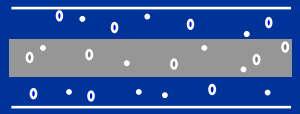
A tubular photobioreactor



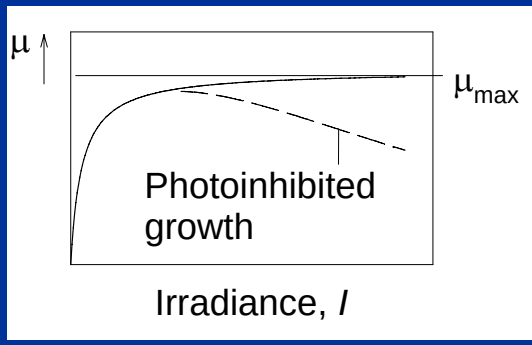
Photobioreactor engineering issues to be addressed

Irradiance

Flashing light effect



Photoinhibition



Growth kinetics

$$\mu = \frac{\mu_{max} \cdot I_{av}^{n}}{K^{n} + I_{av}^{n}}$$

Culture medium

Fluid mechanics

- Shear sensitivity of cells
- Mass transfer
- Temperature control

Mass transfer

- CO_2 supply
- O_2 removal

Thermal engineering

- Temperature control

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Biodiesel – a potential product from algae

United States biodiesel needs = 0.53 billion m^3
(to replace all transport fuel)

Not feasible

Crop	Oil yield (L/ha)	Land area needed (M ha)	Percent of existing US cropping area
Corn	172	3,080	1,692
Soybean	446	1,188	652
Canola	1,190	446	244
Jatropha	1,892	280	154
Coconut	2,689	198	108
Oil palm	5,950	90	48
Microalgae	35,202	15.2	8
Microalgae	70,405	7.6	4

20% w/w oil in biomass

40% w/w oil in biomass

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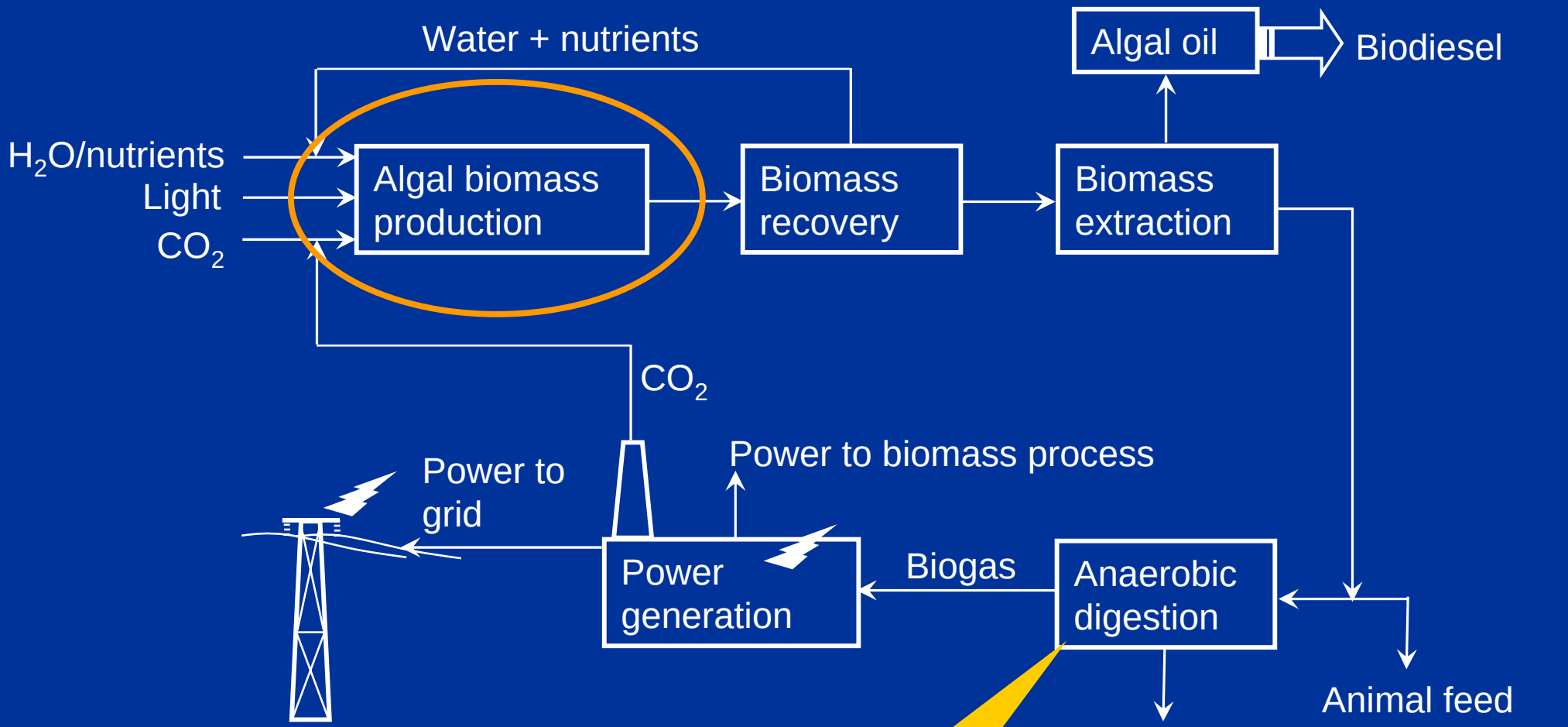
Microalgal biodiesel process concept



A necessary step

Biogas quality: 16.2–30.6 MJ m^{-3}

Yield: 0.15–0.65 m^3 kg^{-1} dry biomass

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Summary and conclusions

1. Products and energy options from microalgae
   - Advantages of using microalgae
2. Microalgal biomass production
   - Raceways and photobioreactors
3. Photobioreactor engineering issues
4. No terrestrial plant can provide sufficient biodiesel to fully displace fossil transport fuels, but algae can
5. A self sustaining process for producing algal oils

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