Industrial application of microalgae in the circular bioeconomy

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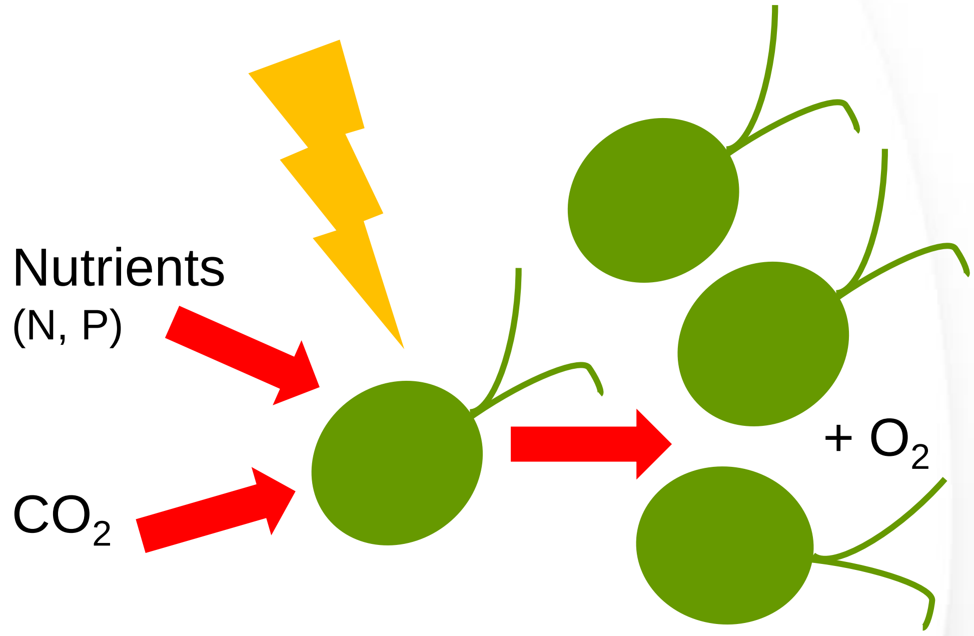
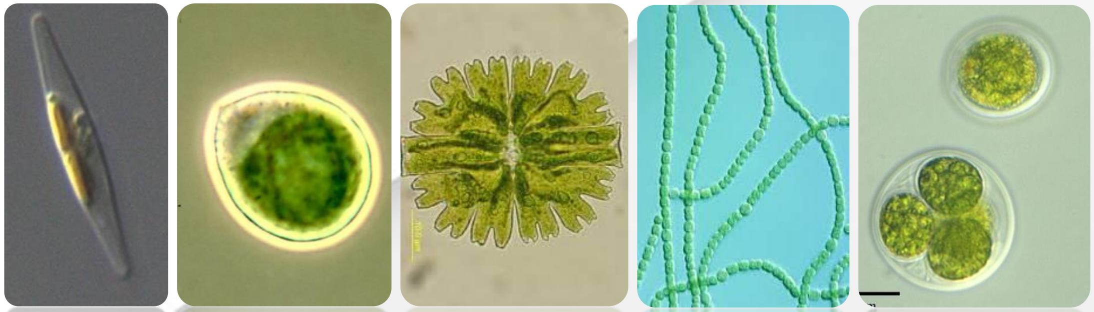
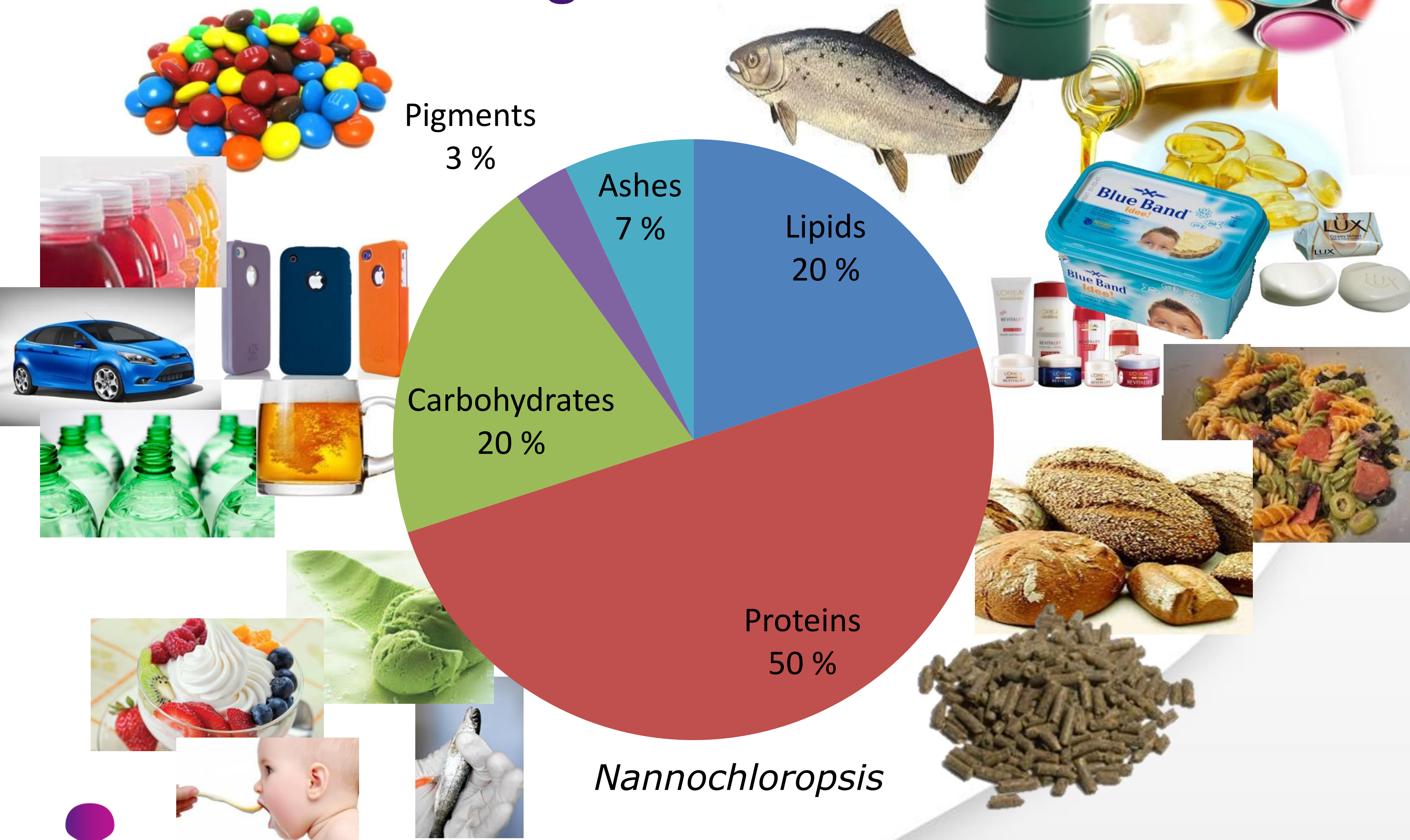
Why microalgae?



- High areal productivity
- CO_2 mitigation
- No arable land
- Low water use
- Seawater and wastewater
- Can use residual streams for nutrients
- High diversity, many products



Products with algae inside



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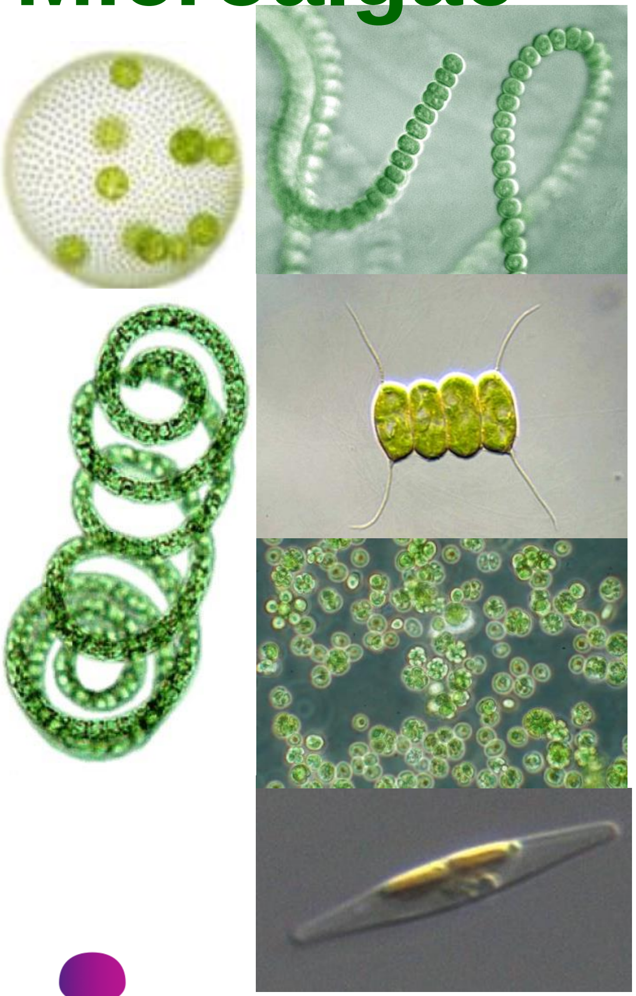
There is a large gap

Microalgae



Commodities

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Commercial production: challenges

Product costs

Scale

Production chain analysis

Market development

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Biomass Production costs: Model

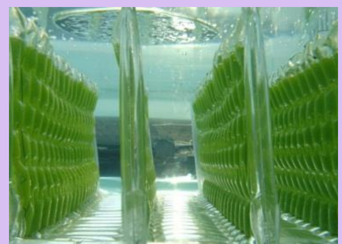
Input

Location

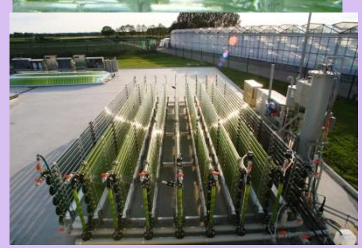
Netherlands
Saudi Arabia
Canary Islands
Turkish Riviera
South Spain
Curacao

Light Intensity
Electricity costs
Taxes
Labor

Cultivation System

Empirical data

Specific parameters

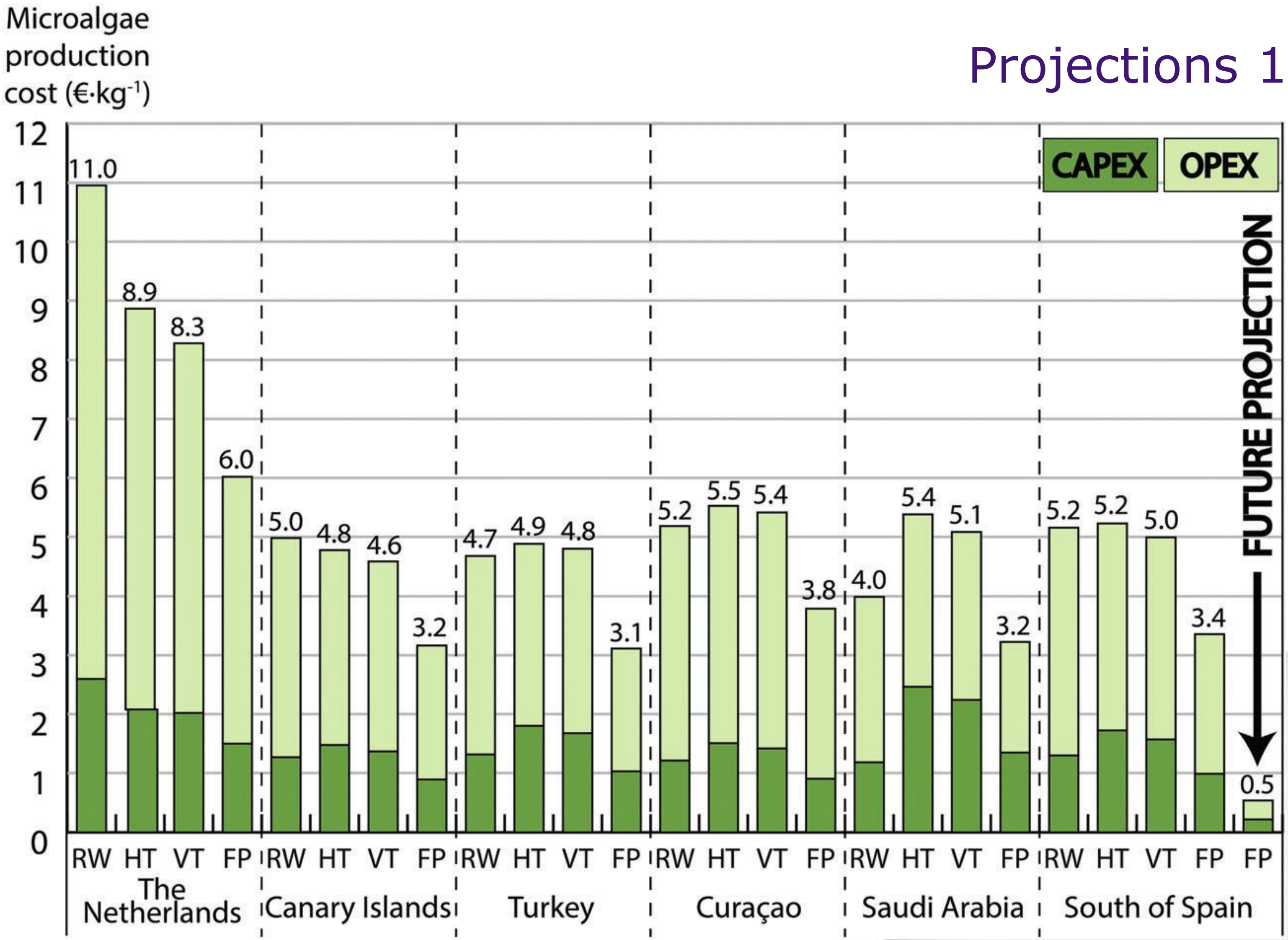
Culture temperature
Daily Dilution
Mixing day/night)
Operation days per year
...

Output

- € / Kg biomass
- CAPEX & OPEX
- NER
- Sensitivity Analysis
- Areas to focus

Product costs - biomass production

Projections 100ha



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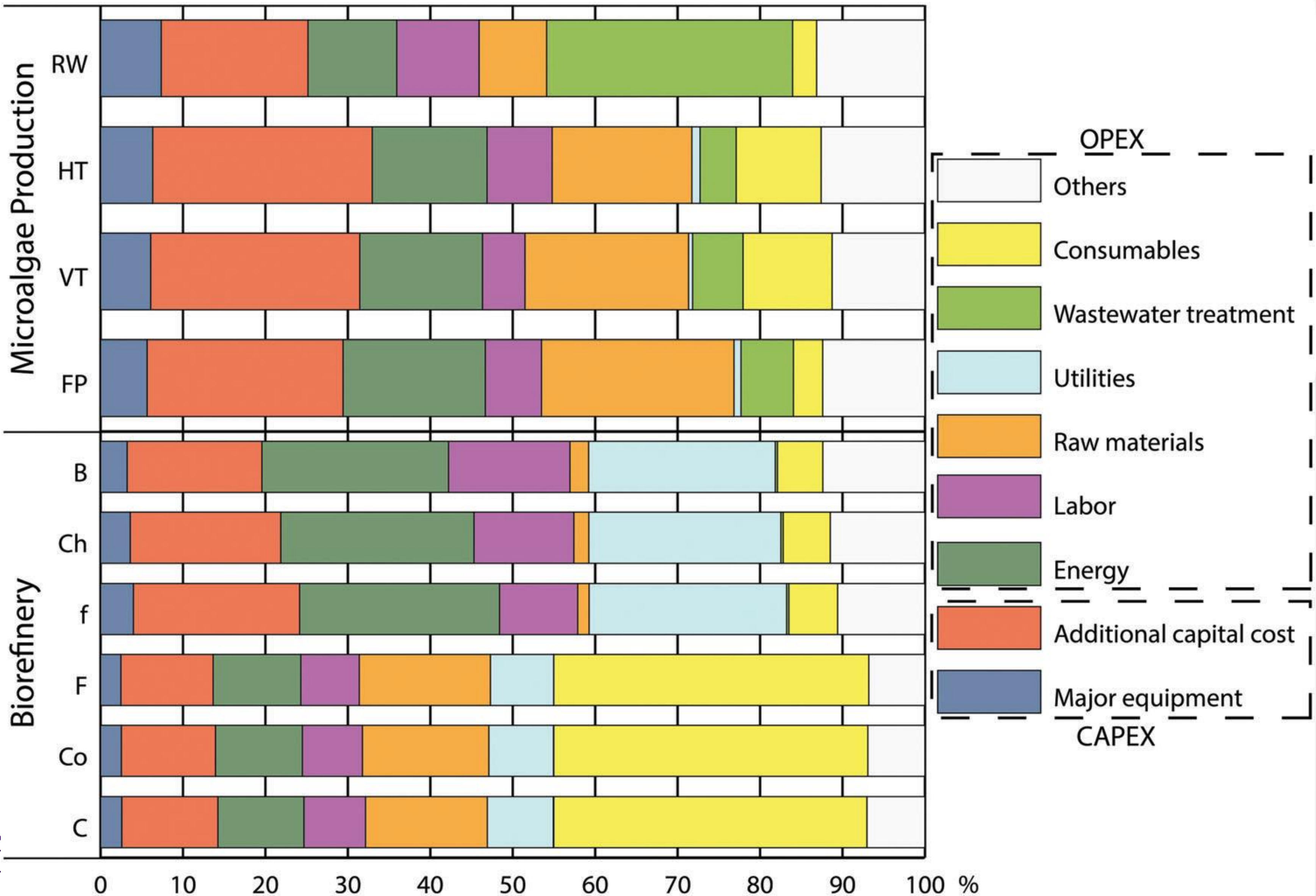
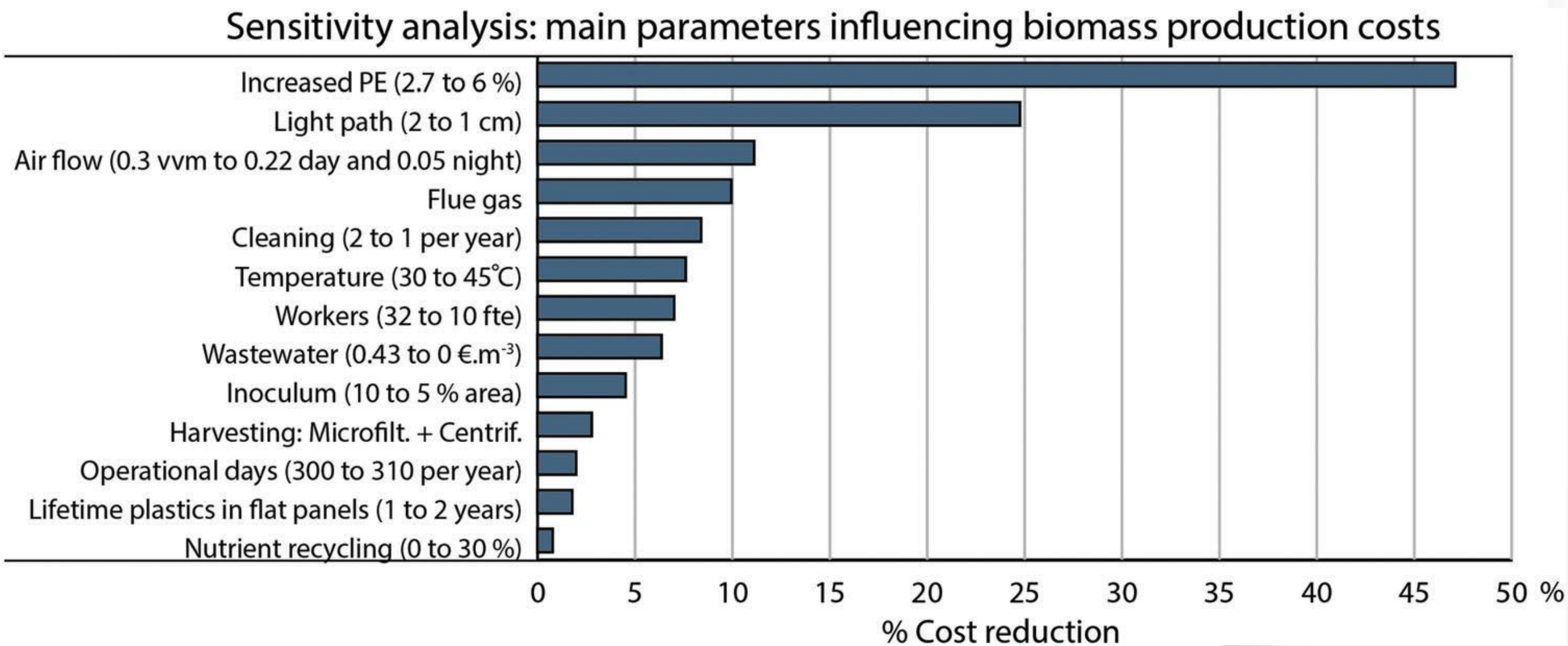
Cost breakdown: cultivation costs



Sensitivity analysis



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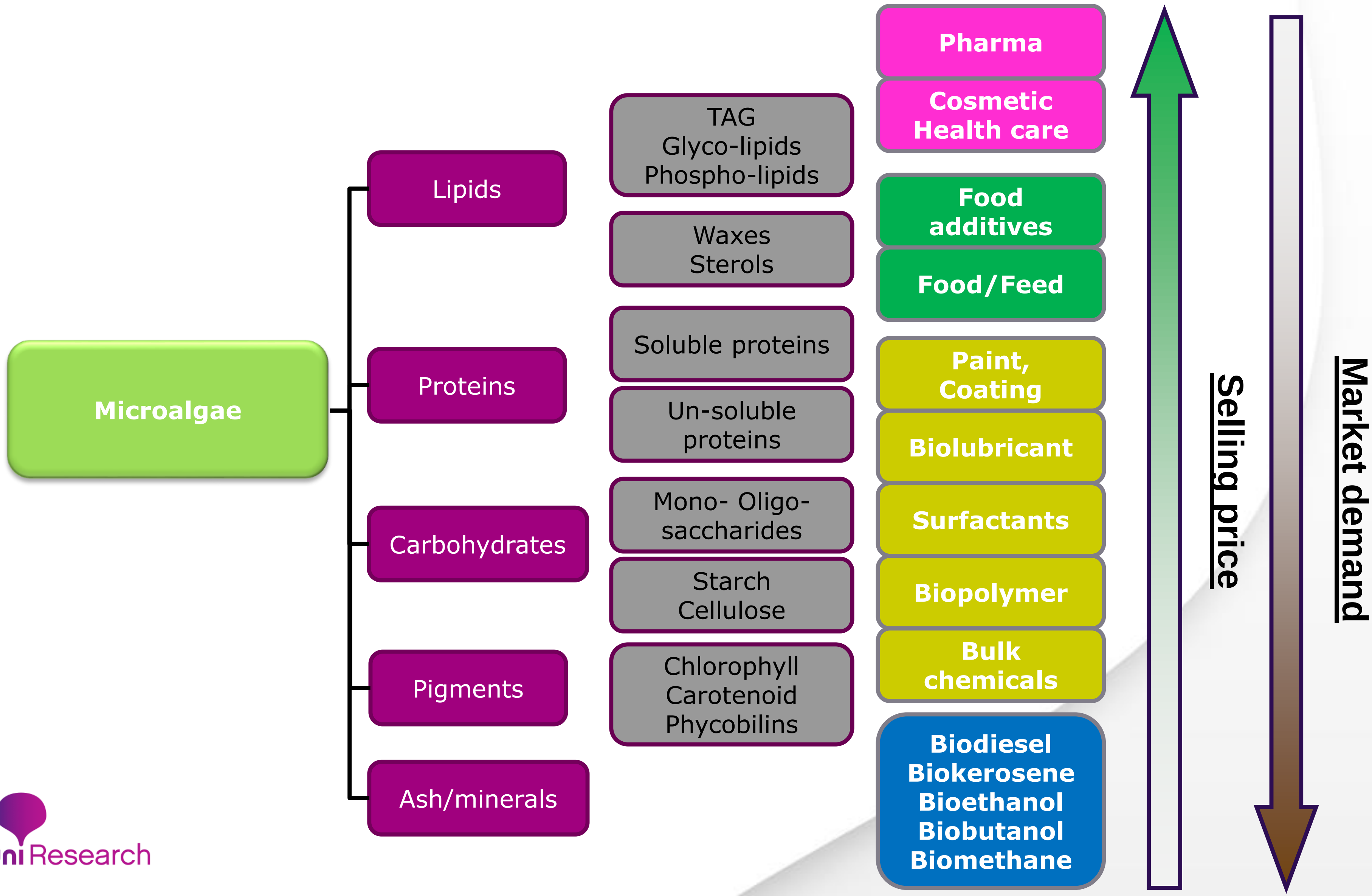
Biomass composition: benchmark on *Nannochloropsis*

	N-replete				N-limited			
Lipids	20%				50%			
		SFA*	MUFA*	PUFA*		SFA*	MUFA*	PUFA*
Glyco-, Phospho-lipids	12%	35%	30%	35%	10%	45%	40%	15%
Triacylglycerides	2%				37.5%			
Waxes	3%				1.25%			
Sterols	3%				1.25%			
Proteins	50%				30%			
Water soluble	20%				12%			
Non-water soluble	30%				18%			
Carbohydrates	20%				15%			
Monosaccharides	5%				3%			
Polysaccharides	15%				12%			
Pigments	3%				1%			
Ashes	7%				4%			

Microalgal biorefinery



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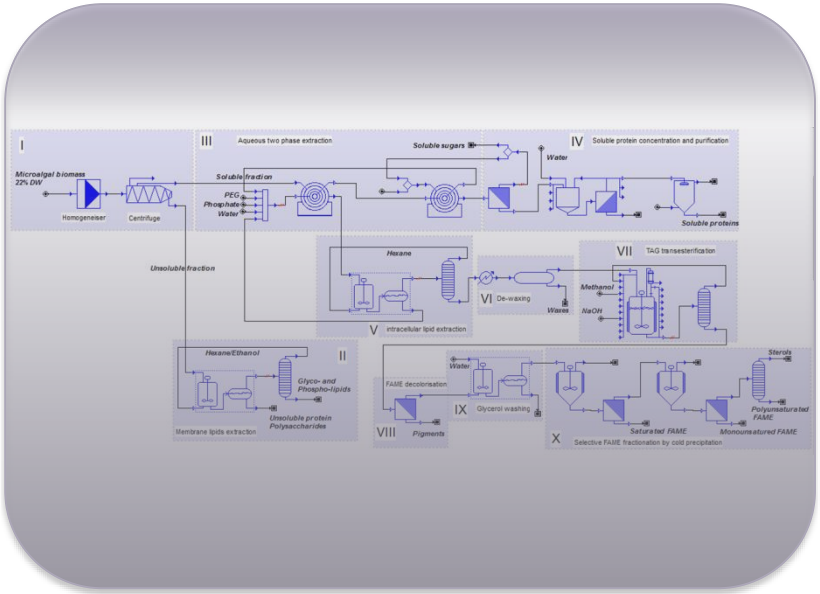
Microalgal biorefinery
design and techno-economical analysis

Biomass productivity

Biomass composition

Utilities cost

(energy, labour)



Mass and energy balances

CAPEX

OPEX

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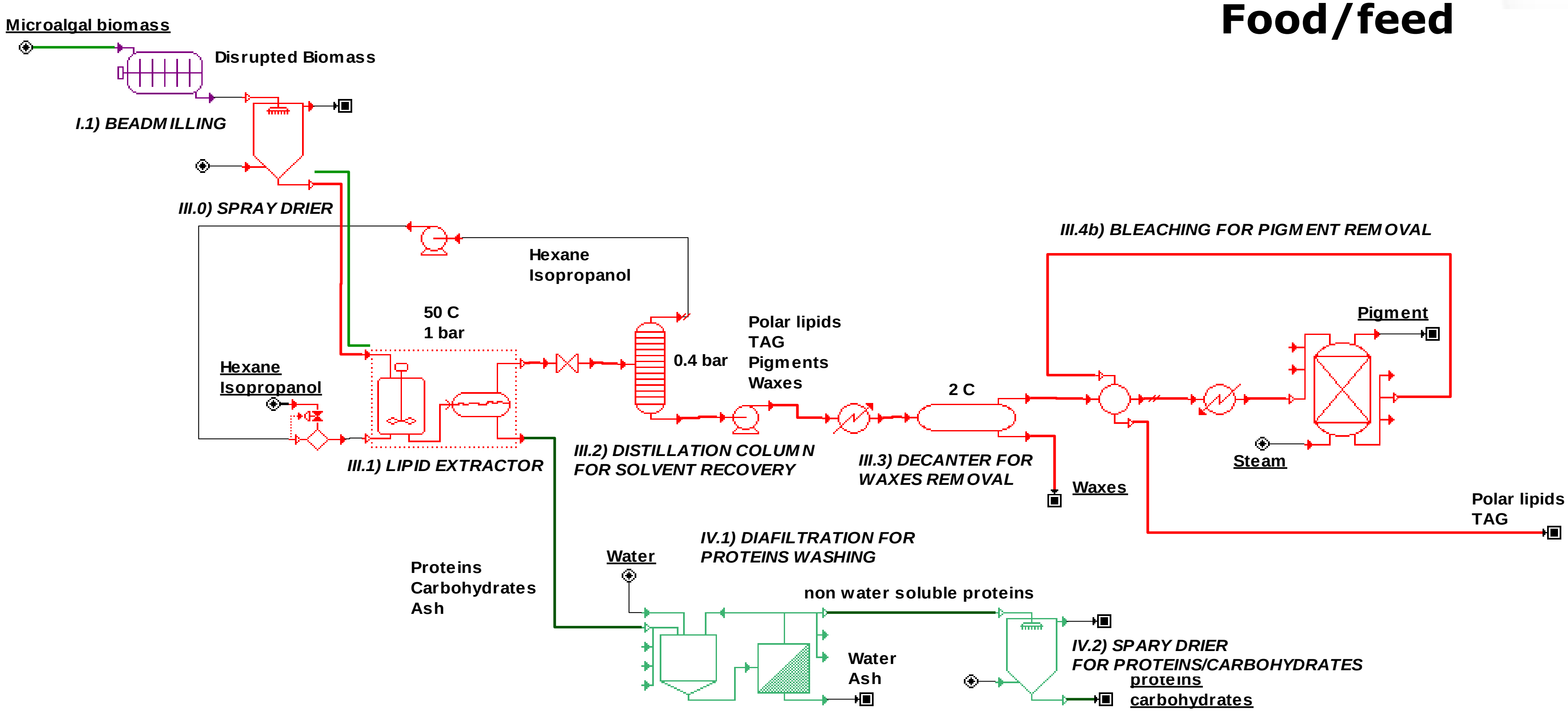
Microalgal biorefinery design and techno-economical analysis



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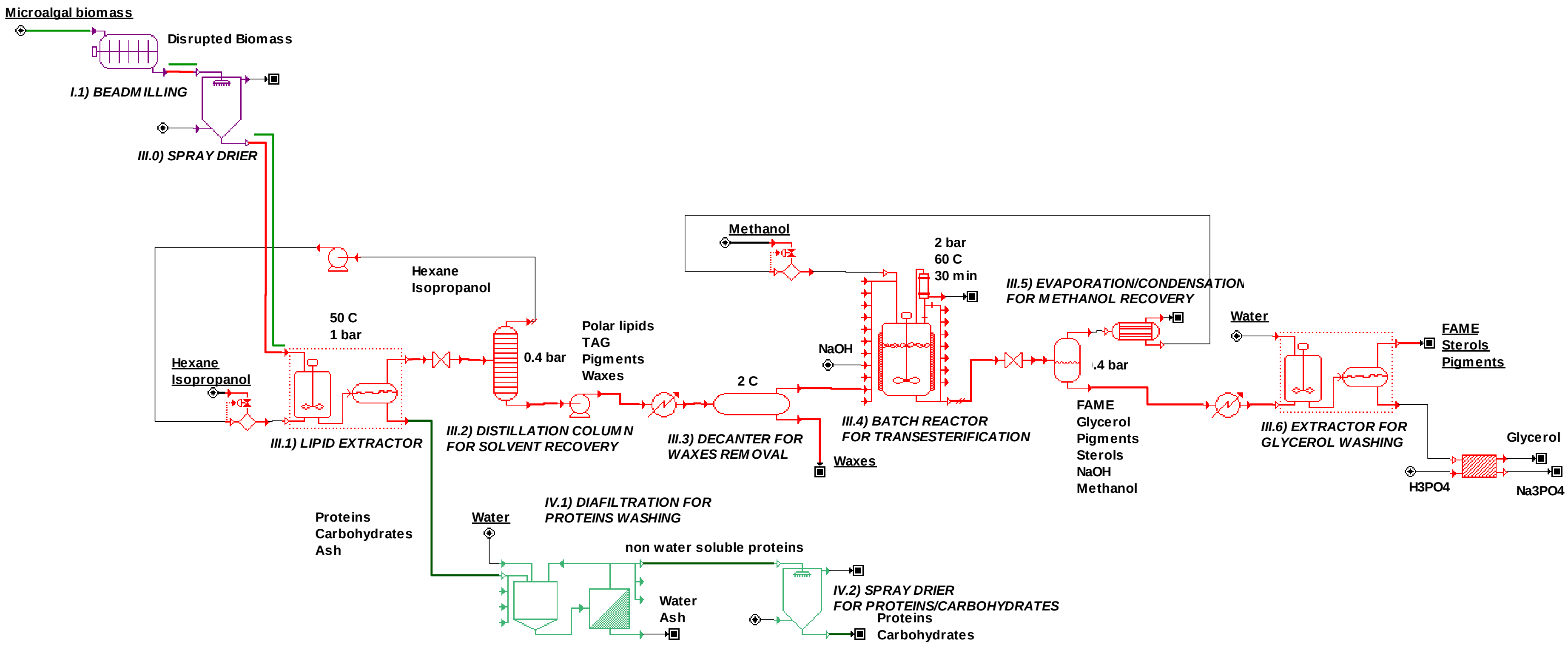
Microalgal biorefinery design and techno-economical analysis

Biofuel



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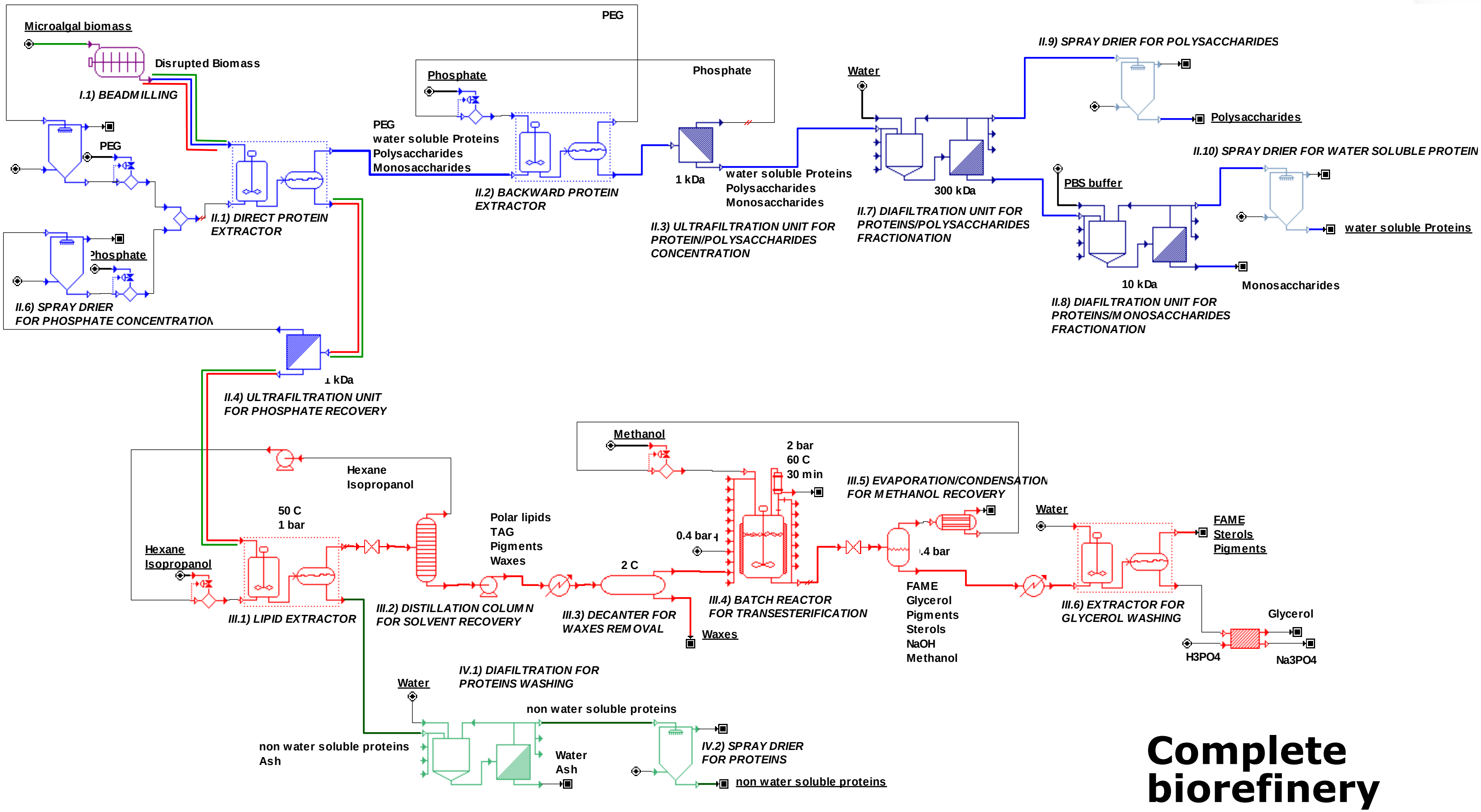
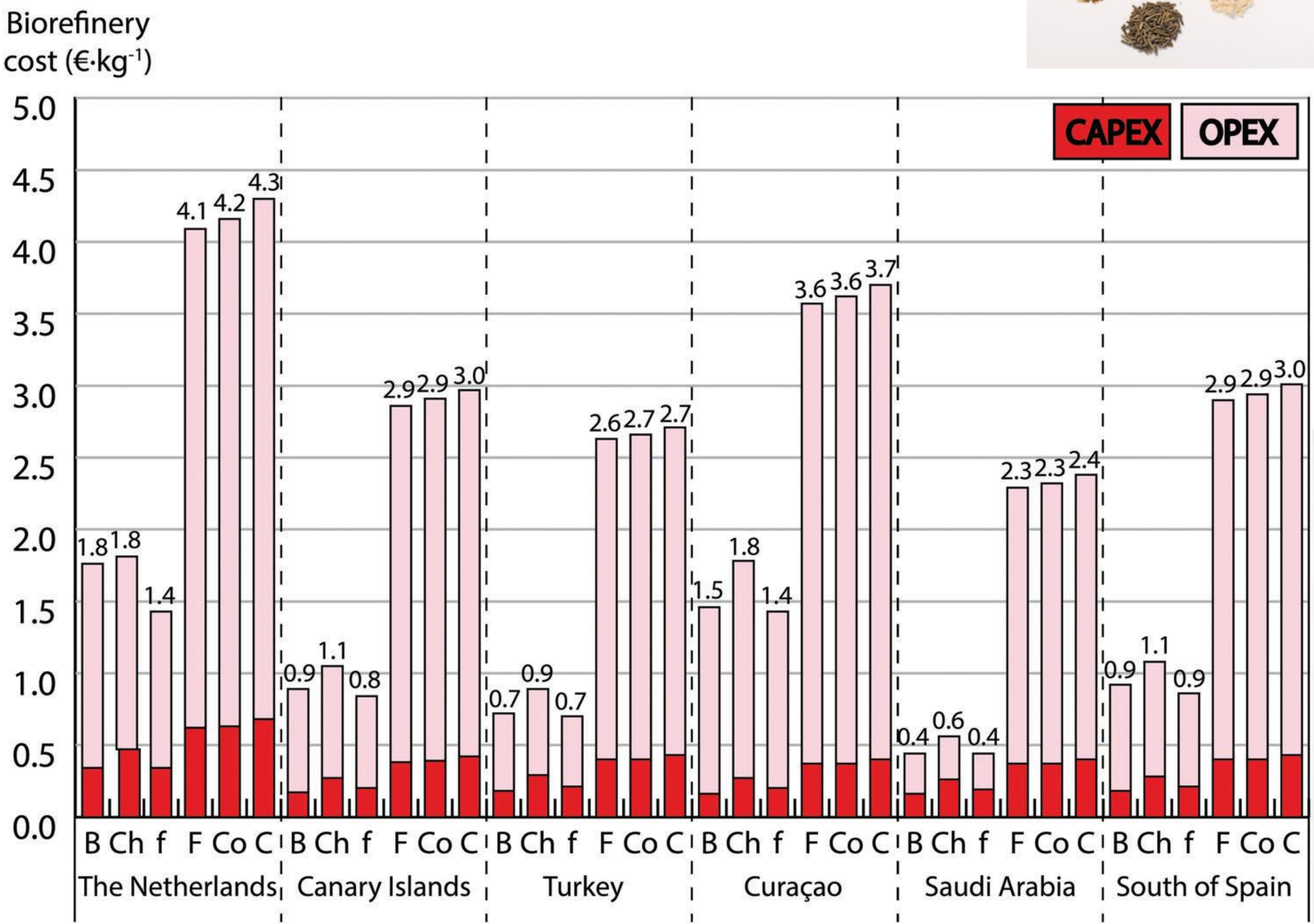
Microalgal biorefinery design and techno-economical analysis



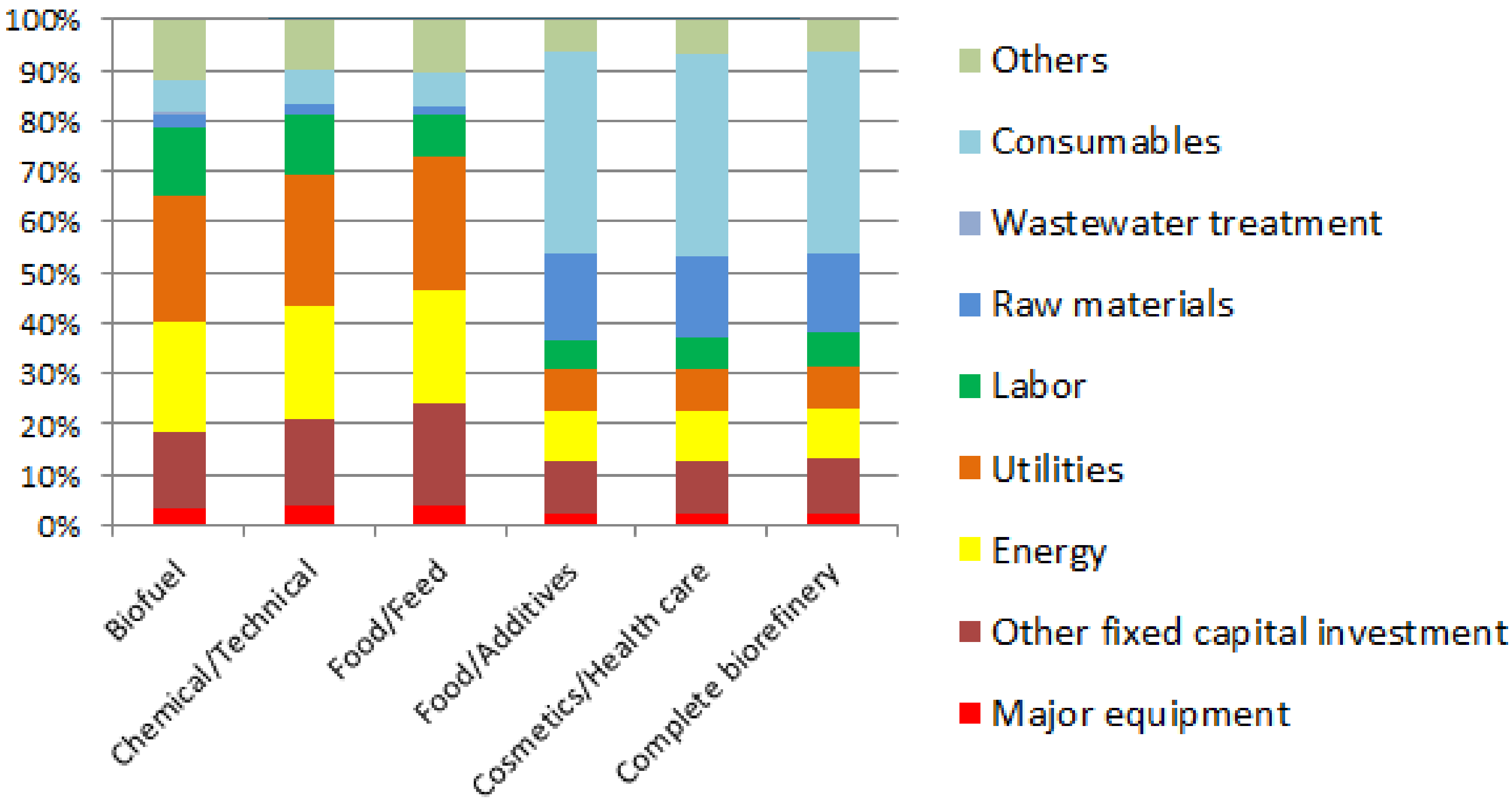
Complete biorefinery

Biorefinery costs

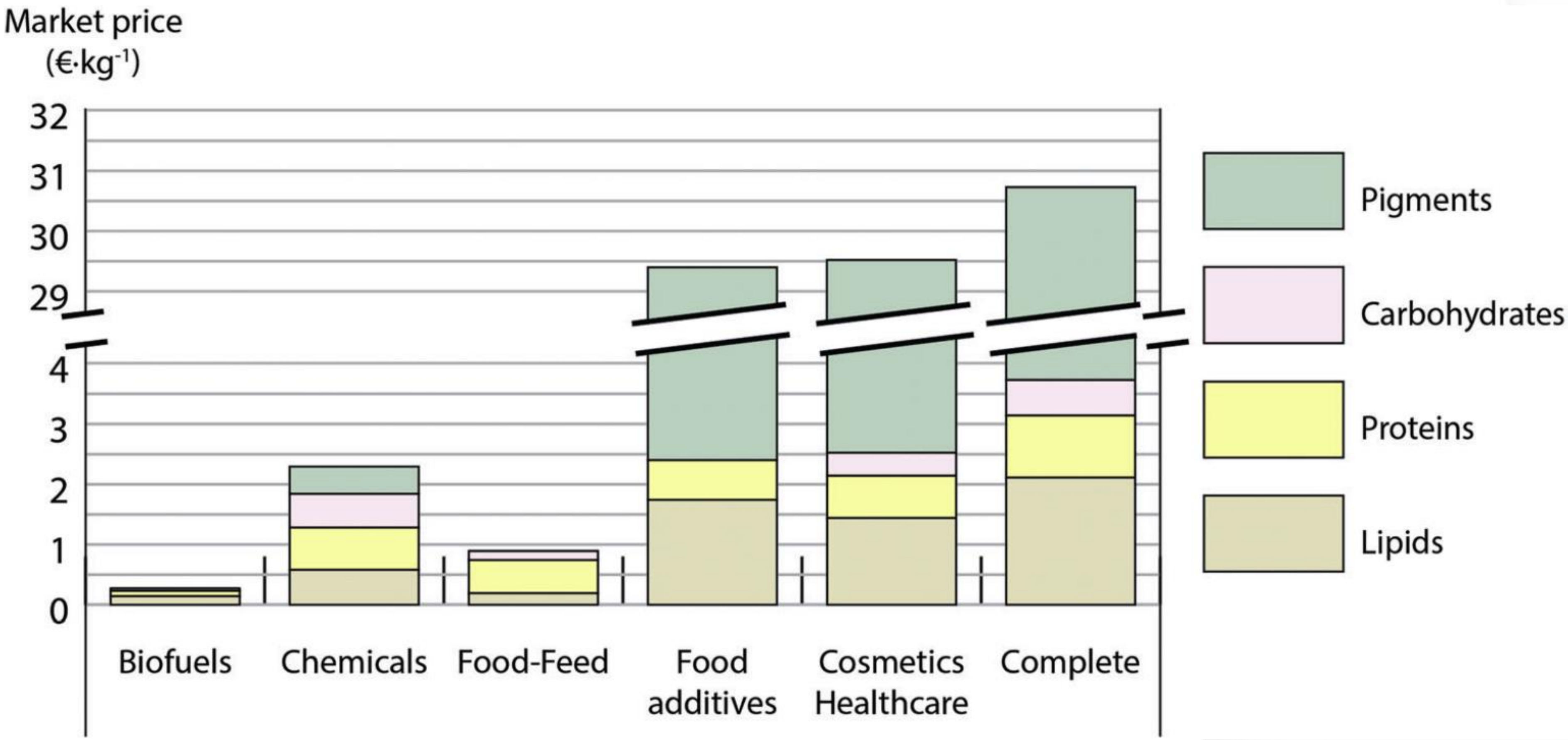


Biorefinery costs

Cost breakdown



Market value of biomass



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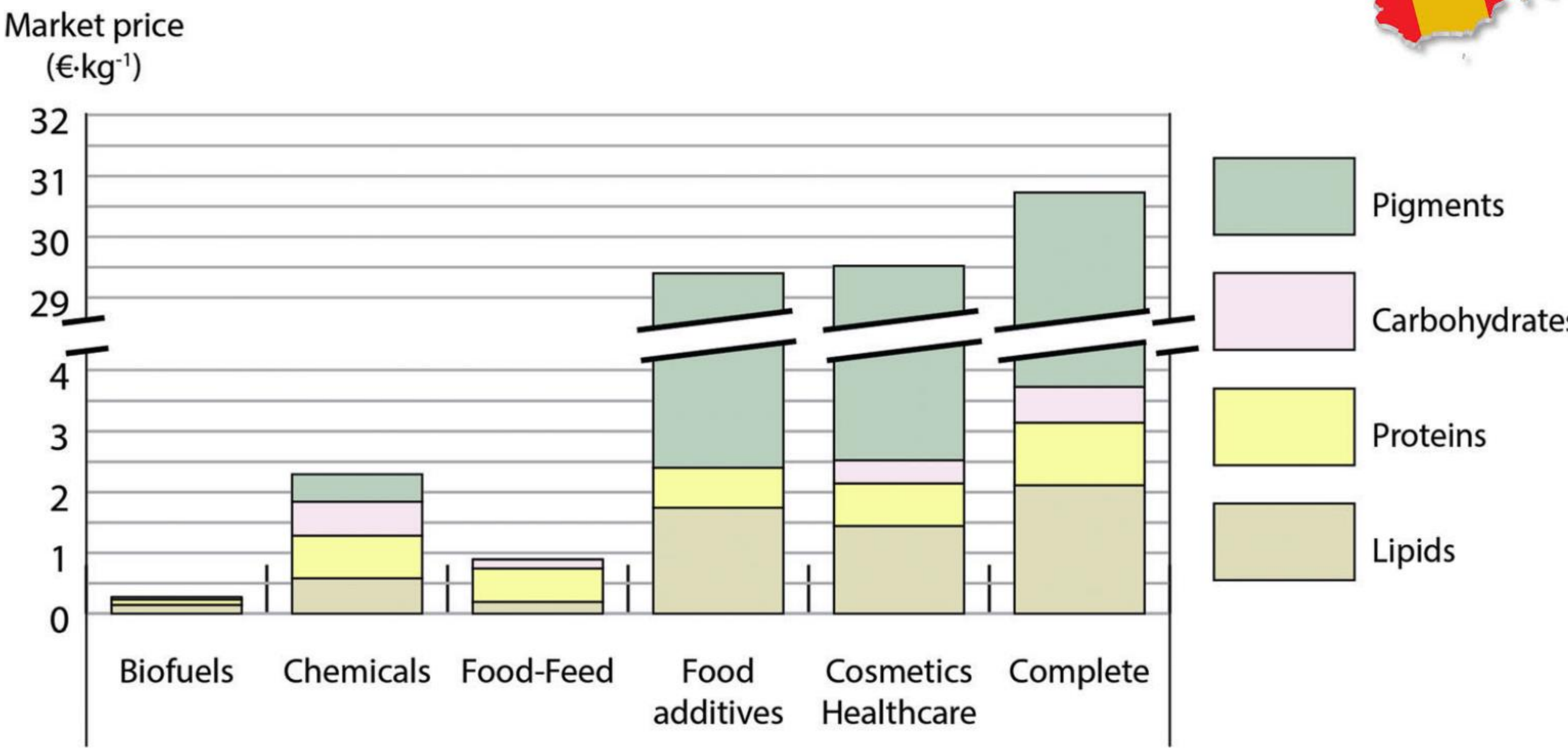
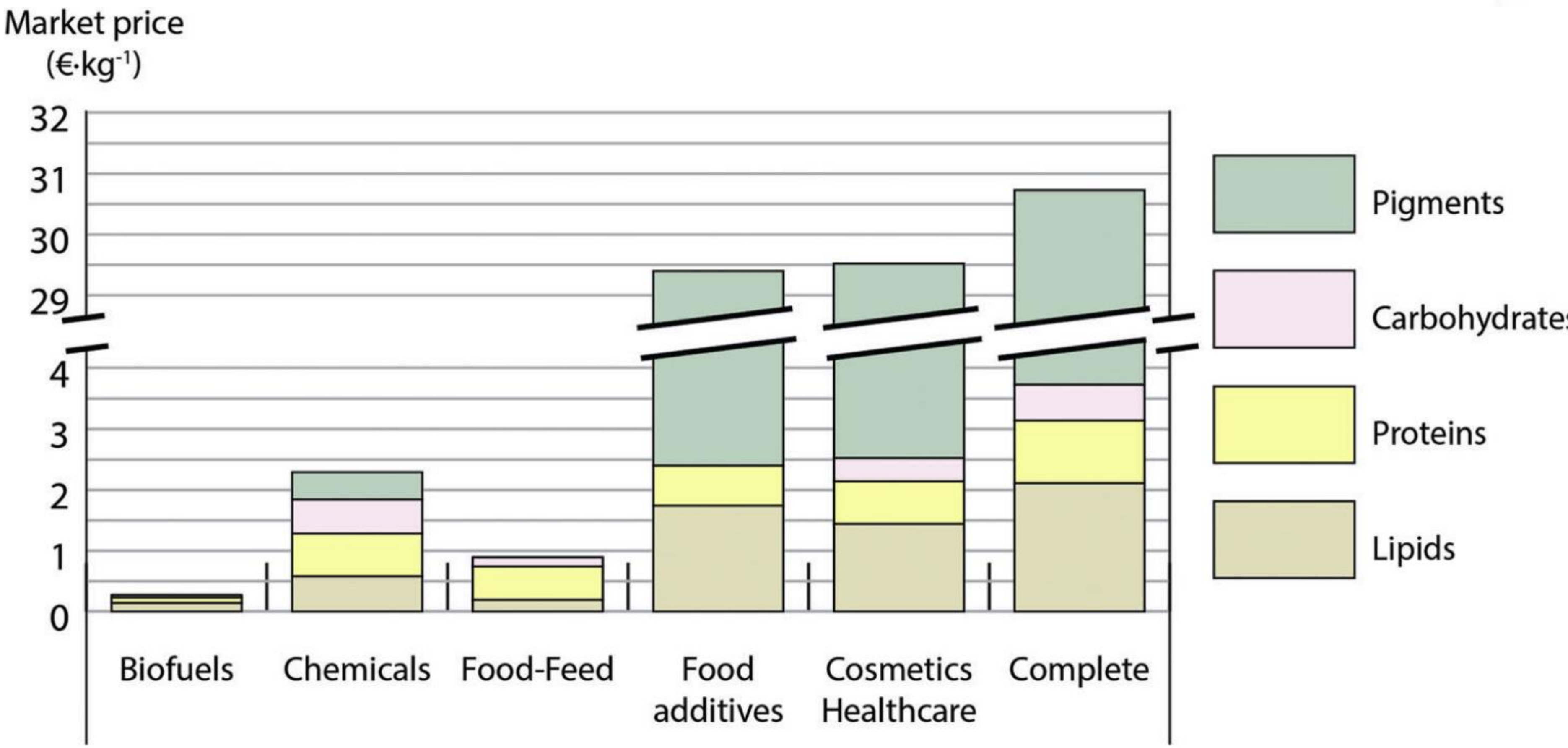
Market value of biomass



€ 3.4	€ 3.4	€ 3.4	€ 3.4	€ 3.4	€ 3.4	Cultivation costs
+	+	+	+	+	+	South of Spain
€ 0.9	€ 1.1	€ 0.9	€ 2.9	€ 2.9	€ 3.0	Biorefinery costs
€ 4.3	€ 5.5	€ 4.3	€6.3	€ 6.3	€ 6.4	Total costs

Market value of biomass



€ 3.4	€ 0.5	€ 0.5	€ 3.4	€ 3.4	€ 3.4	Cultivation costs
+	+	+	+	+	+	South of Spain
€ 0.9	€ 1.1	€ 0.9	€ 2.9	€ 2.9	€ 3.0	Biorefinery costs
€ 4.3	€ 1.6	€ 1.4	€6.3	€ 6.3	€ 6.4	Total costs

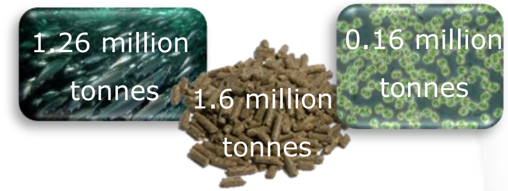
Scale - Salmon as example

- Objective: replace 10% of fish meal with algae

- There is a proof of concept

Without algae *With algae*

Scale - Salmon as example



- Objective: replace 10% of fish meal with algae

- Productivity: 14-28 (57*) ton ha^{-1} y^{-1}
  - solar conditions Norway / greenhouse + illum.
  - 150-300 days cultivation per year
- Hectare needed: 5621-11915 ha

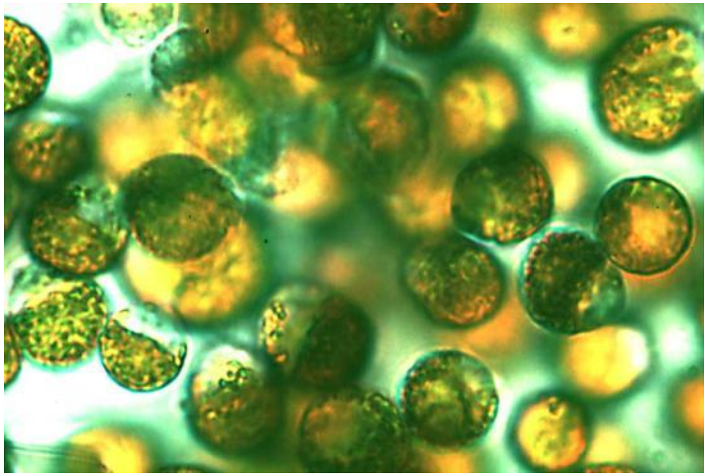
  → 59-119 km^2
- Current scale worldwide: ~40.000 ha

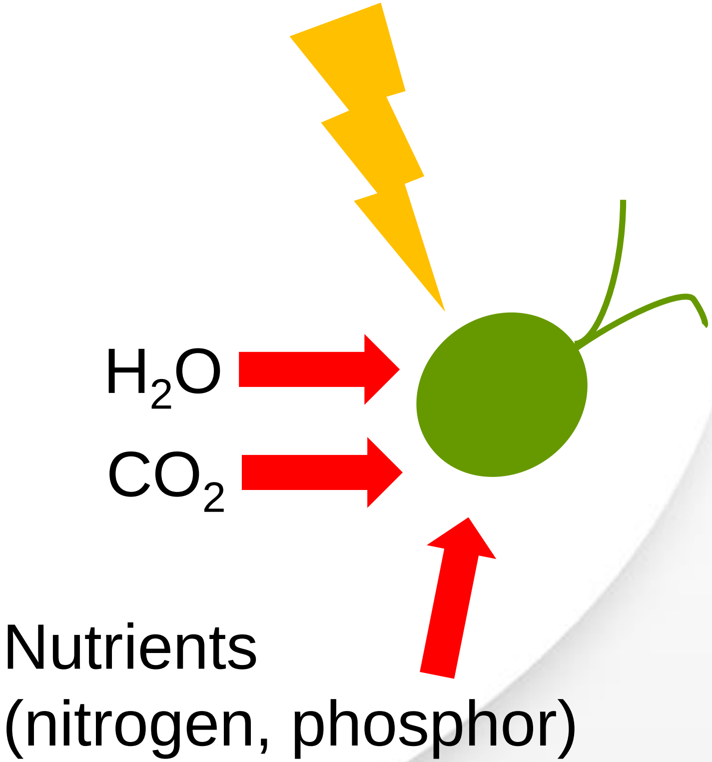
Land - County - Area	**[km^2]**
Norway - only land	307 860
Østfold	4 181
Akershus	4 918
Oslo	454
Hedmark	27 398
Oppland	25 192
Buskerud	14 911
Vestfold	2 225
Telemark	15 296
Aust-Agder	9 158
Vest-Agder	7 277
Rogaland	9 376
Hordaland	15 438
Sogn og Fjordane	18 623
Møre og Romsdal	15 101
Sør-Trøndelag	18 839
Nord-Trøndelag	22 415
Nordland	38 482
Troms	25 863
Finnmark	48 631
Bergen	446
Sotra	179
Algae – Needed for feed	59-119

Main inputs in the process

To produce 1 ton of algal biomass:

- 1.8 tons of CO_2 is needed
- 0.09 ton N
- 0.01 ton P
- micronutrients





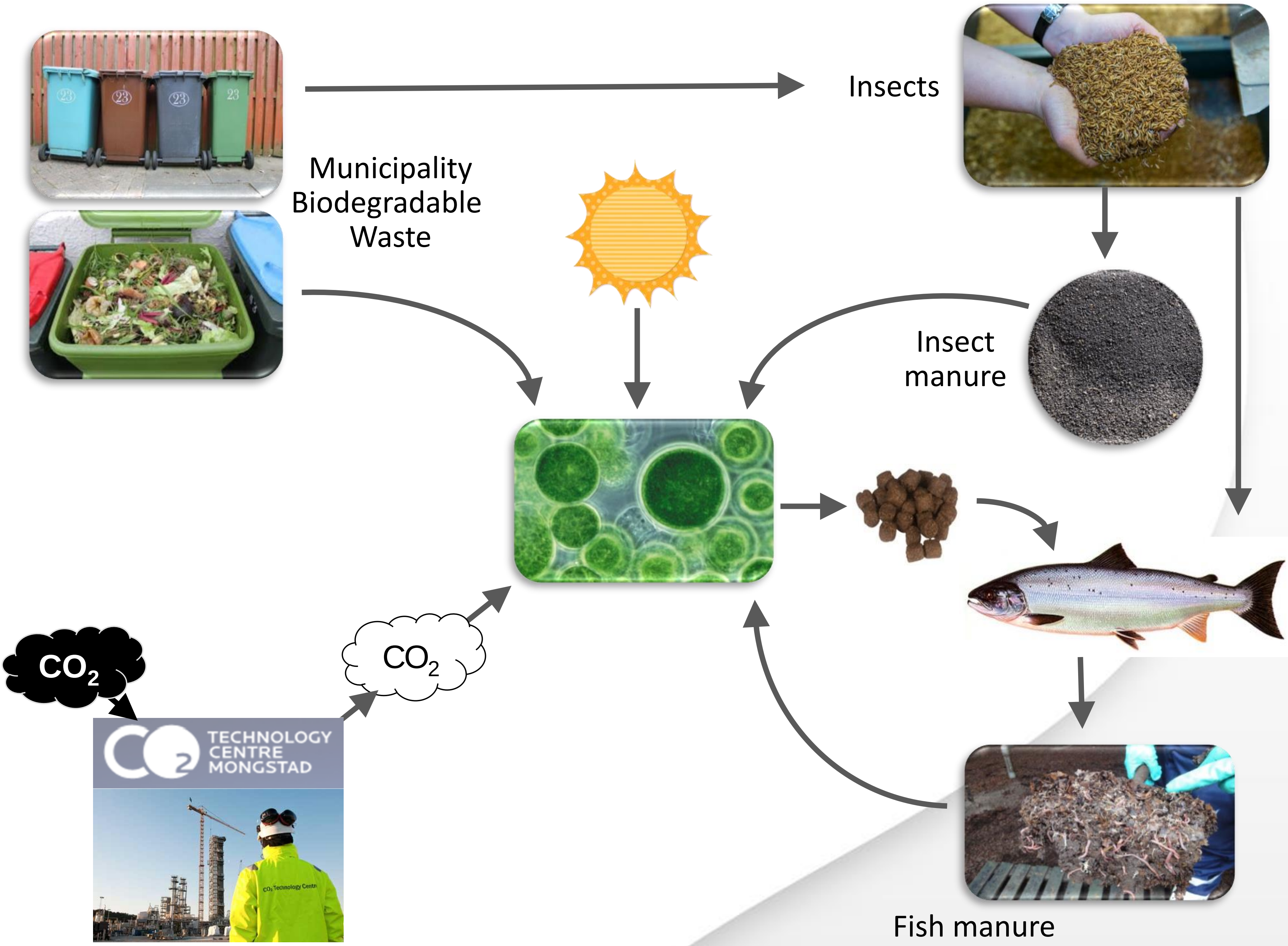
Scale - Salmon as example

- Objective: replace 10% of fish meal with algae

- Nutrients needed:
  - 293 400 tons CO_2
  - 14 670 ton N
  - 1 630 ton P

- TCM captures 100 000 ton CO_2 per year
- Yara produces in Norway alone 2,7 million ton NPK yearly

  BUT
- There are other sources as well....



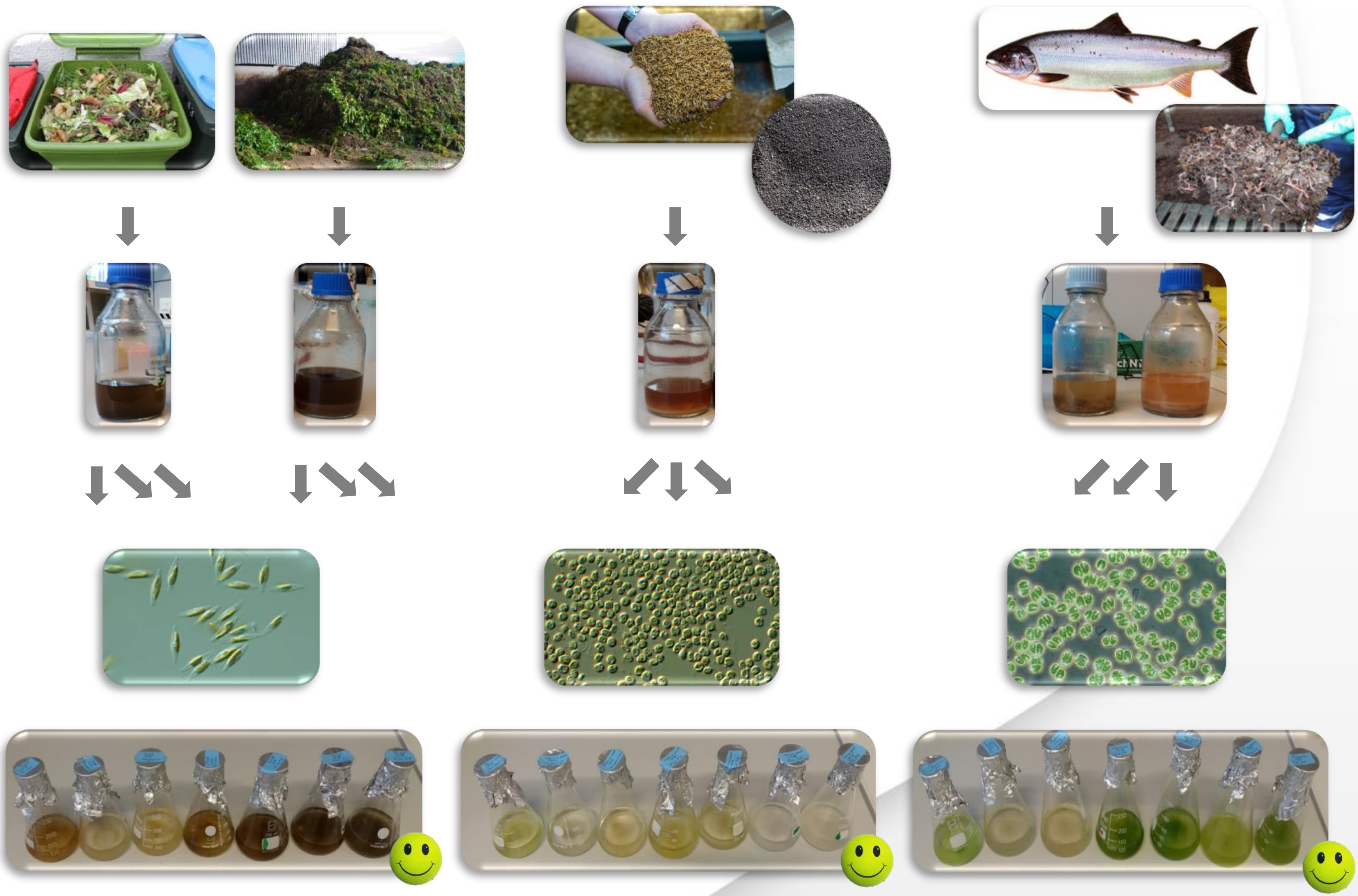
Insects
Municipality
Biodegradable
Waste
Insect
manure
CO_2
CO_2
TECHNOLOGY
CENTRE
MONGSTAD
Fish manure

First experiments

Municipality Biodegradable Waste

Insect manure

Fish manure



We need:

Product costs ↓

Scale ↑

Production chain analysis

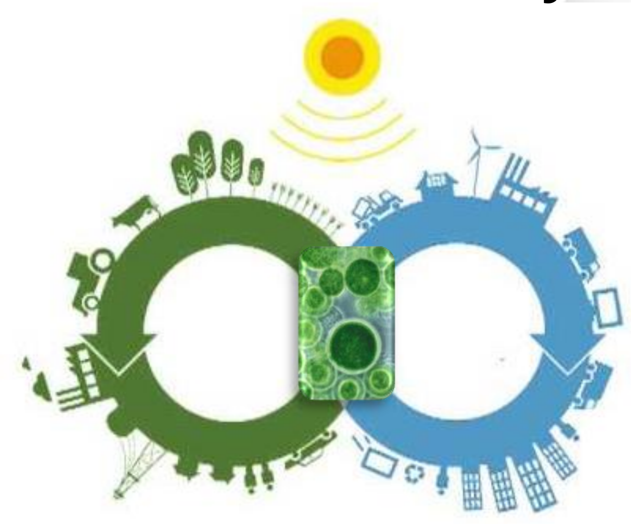
Market development

- More robust strains
  - a.o. higher productivity, temperature range
- Smart production chain
  - Integration with waste streams
- Market development → products

Conclusions

- Microalgae can be used for food/feed/chemicals and fuels as a by-product
- Decrease of costs and increase of scale necessary
  - E.g.: grow on various residual streams

They form a perfect link between the bioeconomy and the circular economy



Tusen takk!

Spørsmål?