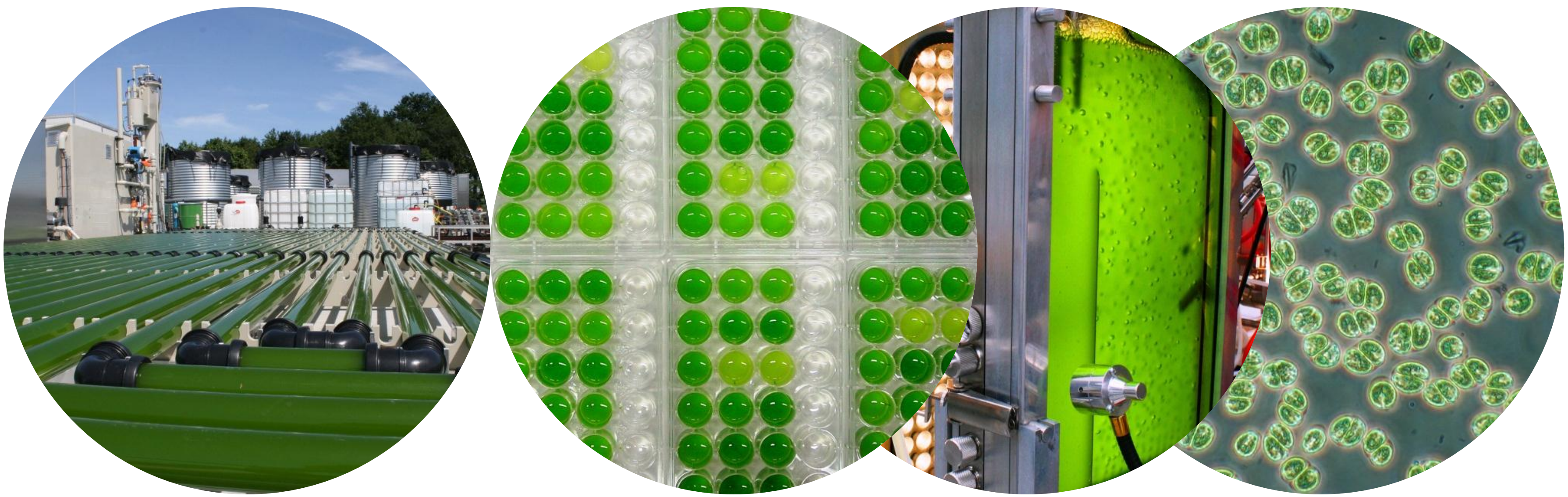
AlgaePARC

Algae Production and Research Centre

René Wijffels, Maria Barbosa



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Contents

- Research strategy and objectives
- Research programs
    - AlgaePARC pilot
    - AlgaePARC biorefinery
- Business cases
- Sustainability of production chains

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Can algae replace commodities of today?

- European market:

Fossil fuels:	400	Mtonnes/year
Polymers and chemicals:	100	Mtonnes/year
Palm oil:	7	Mtonnes/year
Soy:	8	Mtonnes/year

- Global microalgae market today:
  - < 10,000 tonnes/year

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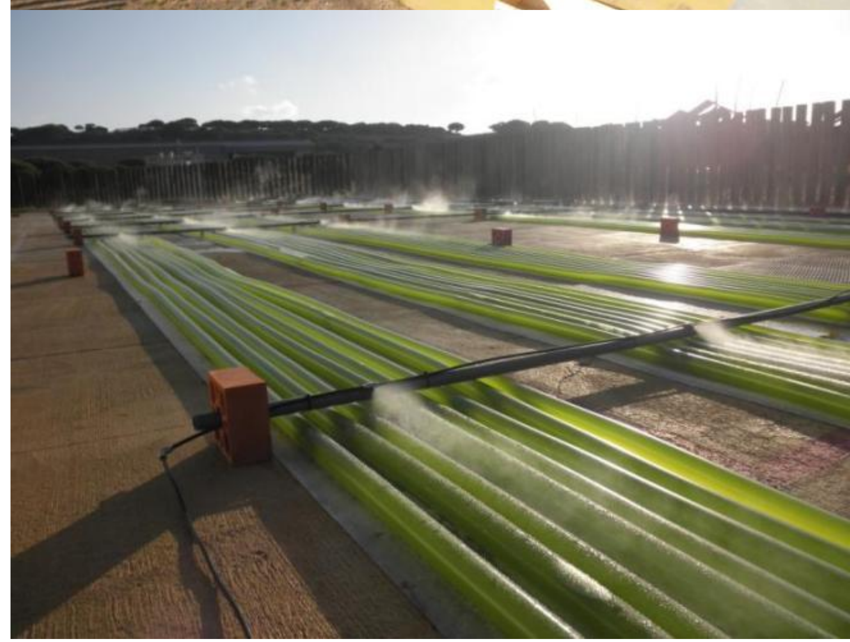
Research objectives

- Development of scalable technology
- Sustainable production of bulk products
  - Biofuels (biodiesel)
  - Food (protein, oil)
  - Feed (protein, oil)
  - Chemistry (amino acids, oil)
  - Materials (silica, polysaccharides)



Research facility in Matalascañas, Spain

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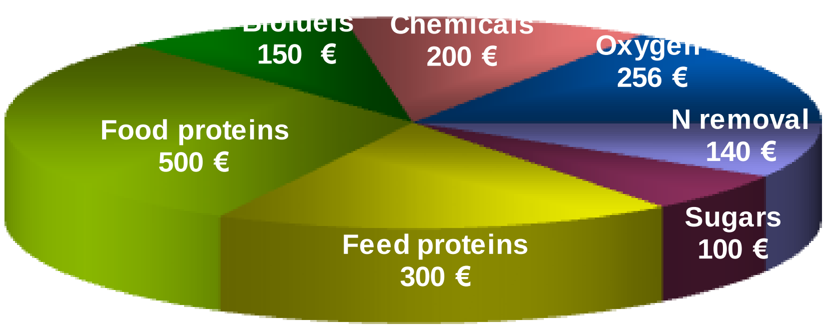
Microalgae markets

- Present market volume:

  € 1 billion
- Present market segment: biomass value > € 50/ kg
- Objective market segment: biomass value <0.40 €/kg
- Value algae biomass: 1.65 €/kg
- Biorefinery essential

Applications	Value/Kg Biomass	Market volume
Nutraceuticals (human consumption)	€100	€60 million
Nutraceuticals (animal- and fish feed)	€ 5-20	€ 3-4 billion
Bulk chemicals	€1-5	>€ 50 billion
Biofuels	< €0.40	> €1 trillion



Wijffels et al. (2010). Microalgae for the production of bulk chemicals and biofuels. *Biofuels, Bioproducts, & Biorefining*, **4**: 287-295.

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PERSPECTIVE

An Outlook o

René H. Wijffels[1] a

Microalgae are c
of these photosy
step or two aw
for arable lan
technology n
microalgae a
the methods
develop this

Develop this process is a sustainable and economical way within the next 10 - 15 years

The co was al (1), but oil crisis in the in Japan and the oping microalgal 1978 to 1996, the Office of Fuels Devel develop renewable trans (2). The main focus of the Aquatic Species Program (AS tion of biodiesel from high-lipi grown in ponds, using waste CO_2

power plants. In Japan, the government financed a large research project entitled "Biological CO_2 Fixation and Utilization" from 1990 to 1999 (3). These programs yielded some successes—such as ...ising lipid production strains, open produc...ystems (raceway ponds), and principles for ...ioreactor design (the use of fiber optics to ...ht inside the systems)—that are still the ...research today, but none has proven ...on a large scale.

...e been several critical issues that ... had a large influence on stim...gence of algal biofuels research. ...xperienced record crude oil prices, ...gy demand, and environmental ...ave pushed biofuels research in ...fore. In the narrower context of

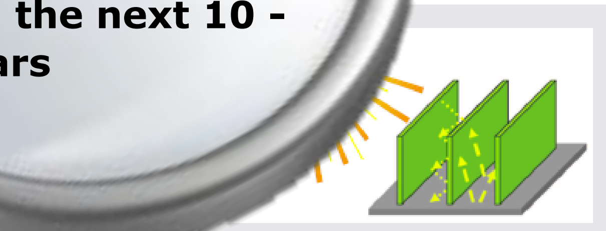

Fig. 1. The principle of light dilution. The light intensity (I) striking closely spaced vertical panels is much lower than the intensity striking a horizontal reactor on the same surface.

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reason for this is that raceway ponds are used much more at larger scale and there is less room for improvement in these systems. Although generally assumed that production in photobioreactors is much more expensive than in a raceway system, we found that after optimization, cost prices in closed systems were actually lower than in a raceway pond.

Biorefining of microalgae

The next question is whether it is economically feasible to produce biodiesel from microalgae if we are able to reduce

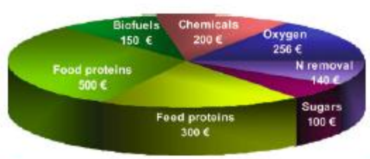

Figure 3. Value of algal biomass per 1000 kg after biorefining.

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Review

Biofpr Biofuels Bioproducts & Biorefining

Microalgae for the production of bulk chemicals and biofuels

Rene H Wijffels, Bioprocess Enginee... ...etherlands
Maria J Barbosa, Food and Bi... ...enter, the Netherlands
Michel H M Eppink, Bioproc...

Received January 19, ...
Published online in W...
Biofuels, Bioprod. ...

Abstract: The feas... ...duced at large scale for ... ...ins unlikely, however ... ...der to develop a mo... ...car-bohydrates) shou... ...and use of the functio... ...to lipids for biodiese... ...es for f... and ... ...on of ... ...against ...costs ... ...ible. ...ain that ... ...ich sys-...gy, metabolic ... ...efining, integrated production chain... ...10 Society of Chemical Industry and John...

To develop a more sustainable and economically feasible process, all biomass components should be used

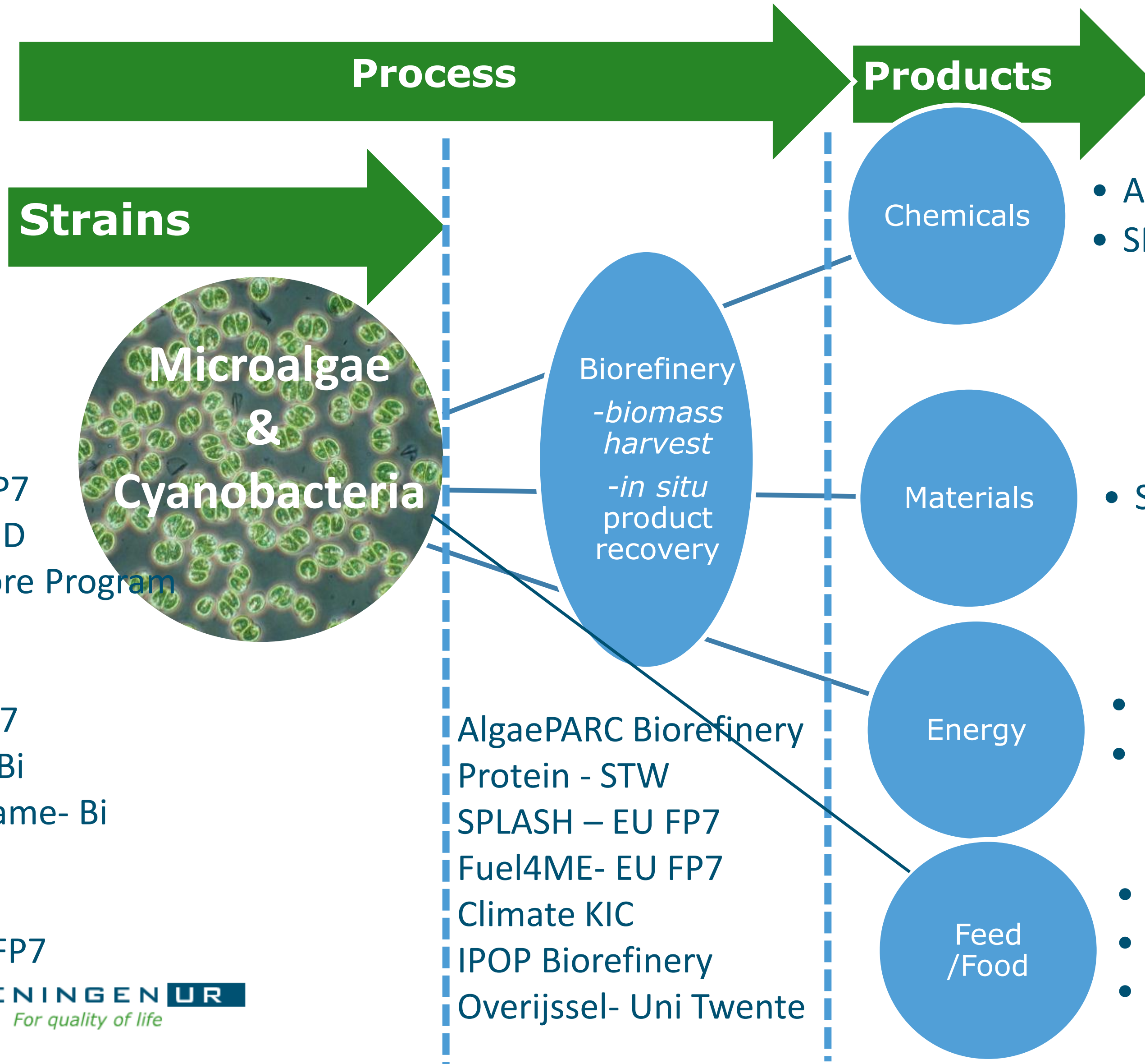
Keywords: microalgae; bulk chemicals...

Strategy to collaborate with industry

- Demonstrate that biobased products have the quality to replace existing products
- Convince we can produce economically in the future
- Imagine we can reach the right market volumes
- Create awareness: it is not

  going to be easy
- Join forces
- Create a long term commitment

Projects portfolio



FUEL4ME – EUFP7
Emerald Oils- FND
BioSolar Cells Core Program
AlgaePARC -PPP
SPLASH- EU FP7
InteSusAl- EU FP7
Petrochemical - Bi
StaatsOlie Suriname- Bi
Neste Oil - Bi
LG-SWITCH
AlgaeDISK – EU FP7

AlgaePARC Biorefinery
Protein - STW
SPLASH – EU FP7
Fuel4ME- EU FP7
Climate KIC
IPOP Biorefinery
Overijssel- Uni Twente

Chemicals:
- AlgiCoat- EOS
- SPLASH- EU FP7

Materials:
- SPLASH- EU FP7

Energy:
- Fuel4ME – EU FP7
- Bi -NesteOil

Feed /Food:
- Emerald Oils
- Coulorants
- ECOFERM

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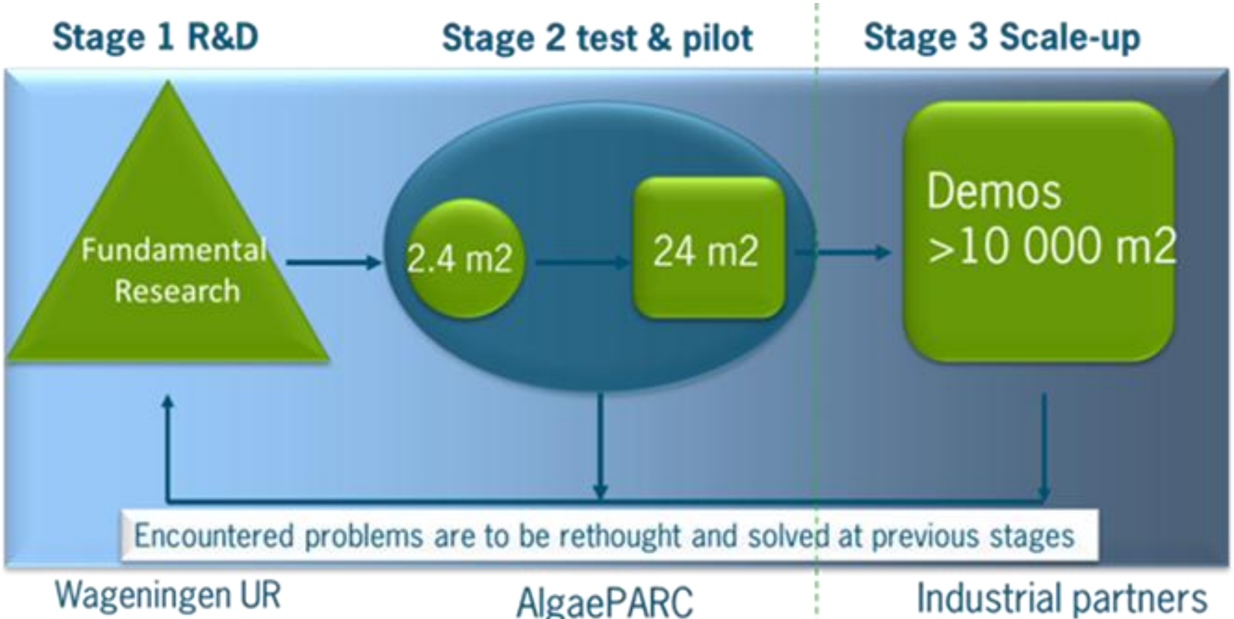
AlgaePARC

- 8. 8 M€
- Facility: 3.3 M€ subsidy
- Research program: 2.2 M€ subsidy, 2.8 M€ companies
- 19 companies

Objectives

- Basic research is not sufficient
- Gap between basic research and commercial applications
- Continuous interaction between basic research and pilots
- Follow up in demonstrations
- Products
- Scale
- Production chain



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AlgaePARC

- International centre of applied research
- Intermediate between basic research and applications
- Development of competitive technology (economics, sustainability)
- Acquire information for full scale plants
- Algal biomass for food, feed, chemicals and fuels

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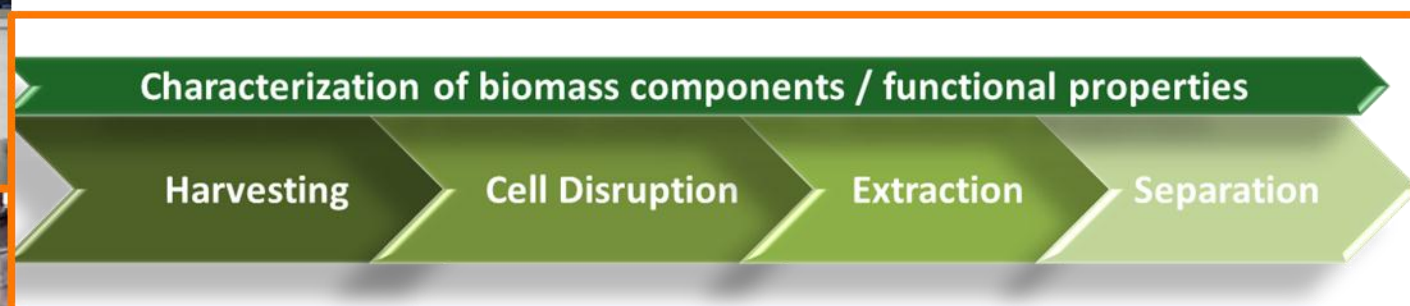
AlgaePARC biorefinery

- 5.2 M€
- 3 M€ subsidy
- 12 companies



AlgaePARC Biorefinery

Business cases

- Future production costs: 400 €/Ton
- Value?
  - Nannochloropsis
  - Scenedesmus

	Nannochloropsis	Scenedesmus
Lipids	20-50%	15-40%
Saturated FA	4-9%	1-2%
Monounsaturated	5-11%	6-17%
Polyunsaturated	6-14%	5-15%
Omega-3 (EPA)	4-10%	
Unsaponifiables	3-7%	1-3%
Waxes (algaenan)	2-4%	<1%
Terpenes (lutein)		0,2-0,5%
Carbohydrates	15-30%	10-20%
Proteins	30-50%	30-50%
Phenolics	2%	<2%
Other organics	4-5%	5%
Vitamins	0,2-0,5%	
Chlorophyll	0,1-0,7%	
Nucleic acids	2-4%	2-4%
Minerals	7-10%	10-12%

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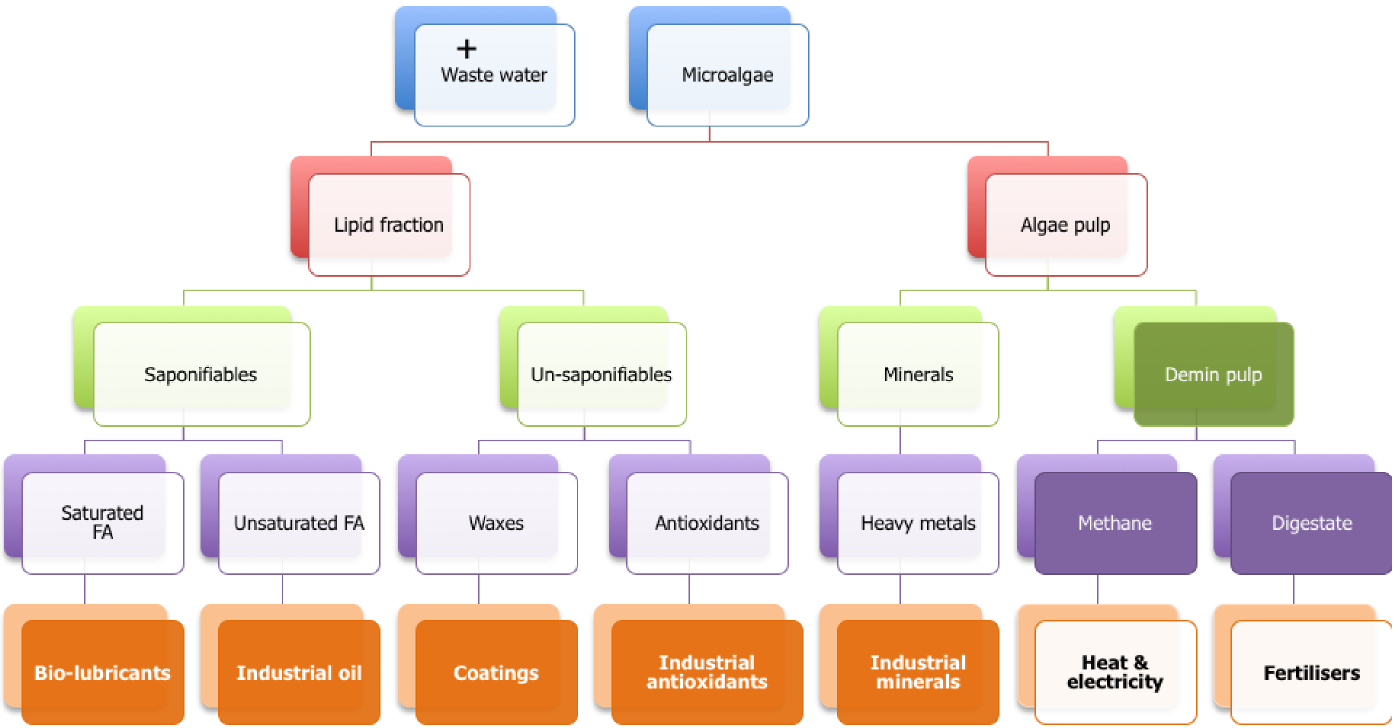
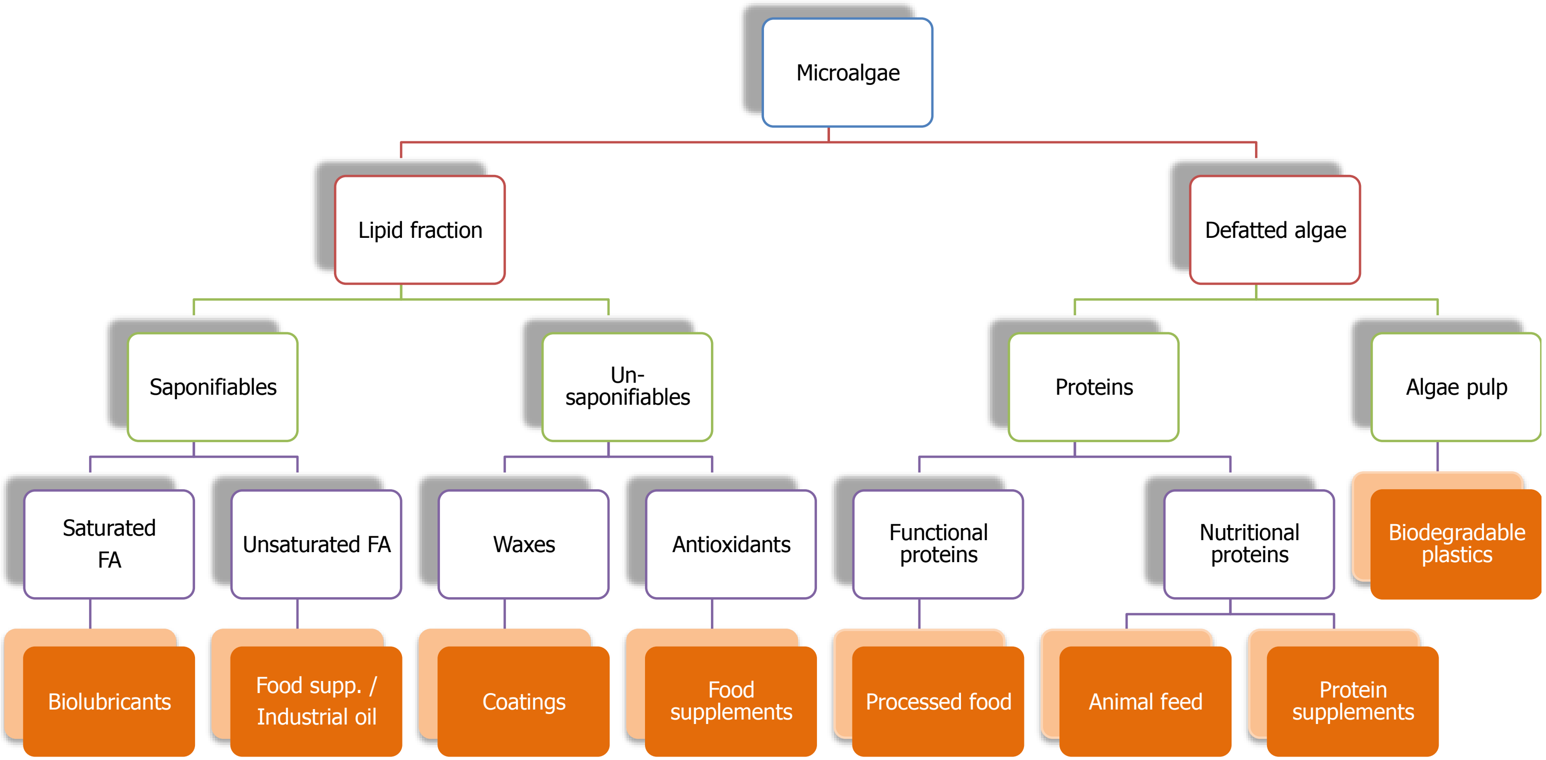
Scenario: Lipids + Biogas energy



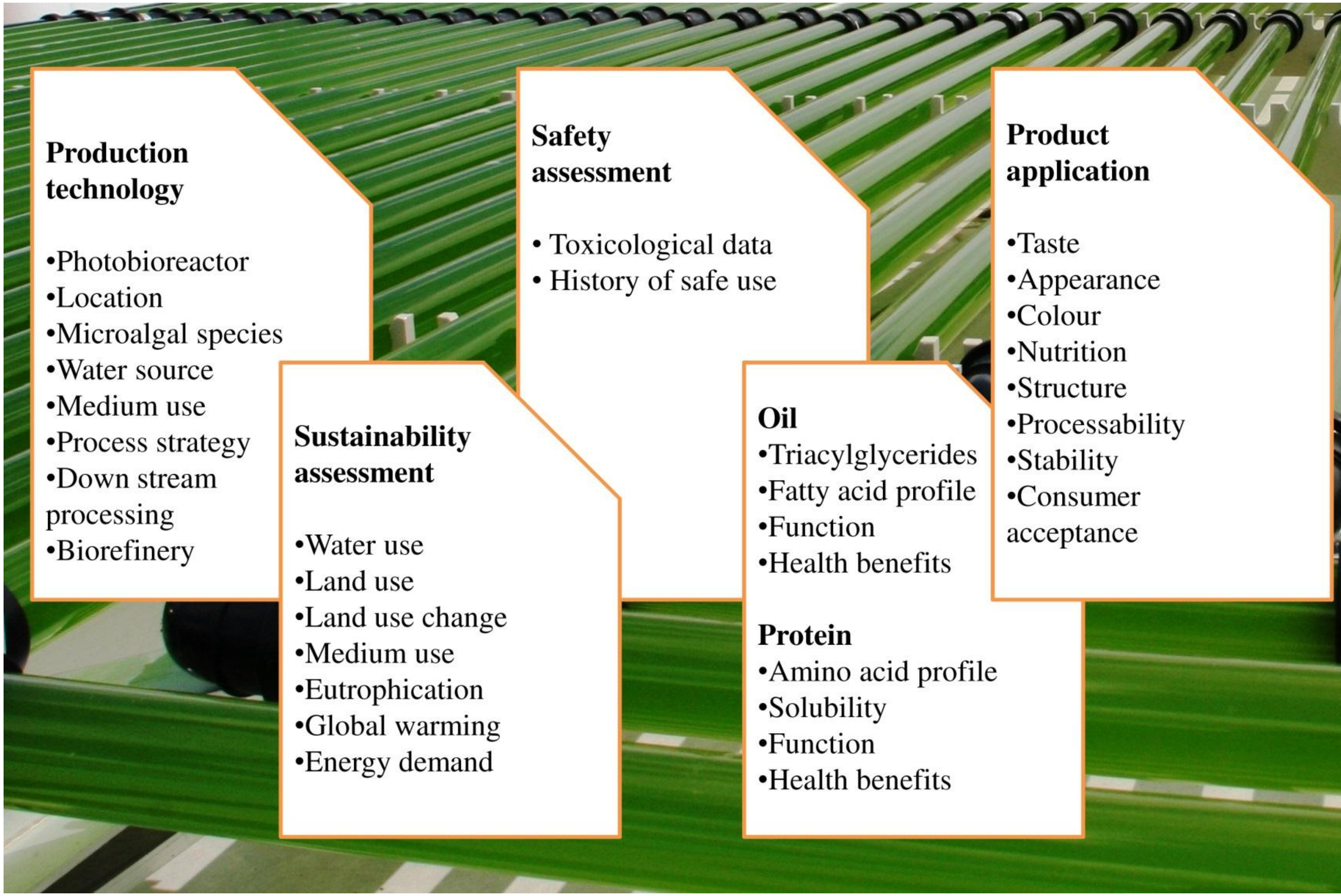
Scenedesmus: €600/T
Cost of production: €400/T

Scenario: Lipid & protein biorefinery



Nannochloropsis: €8,000/T
Cost of production: €400/T

Sustainability of production chains



Draaisma B.B., Wijffels R.H., Slegers P.M., Brentner L.B., Roy A., Barbosa M.J. (2013) Food commodities from microalgae. Current Opinion in Biotechnology 24: 169-177

Sustainability of production chains

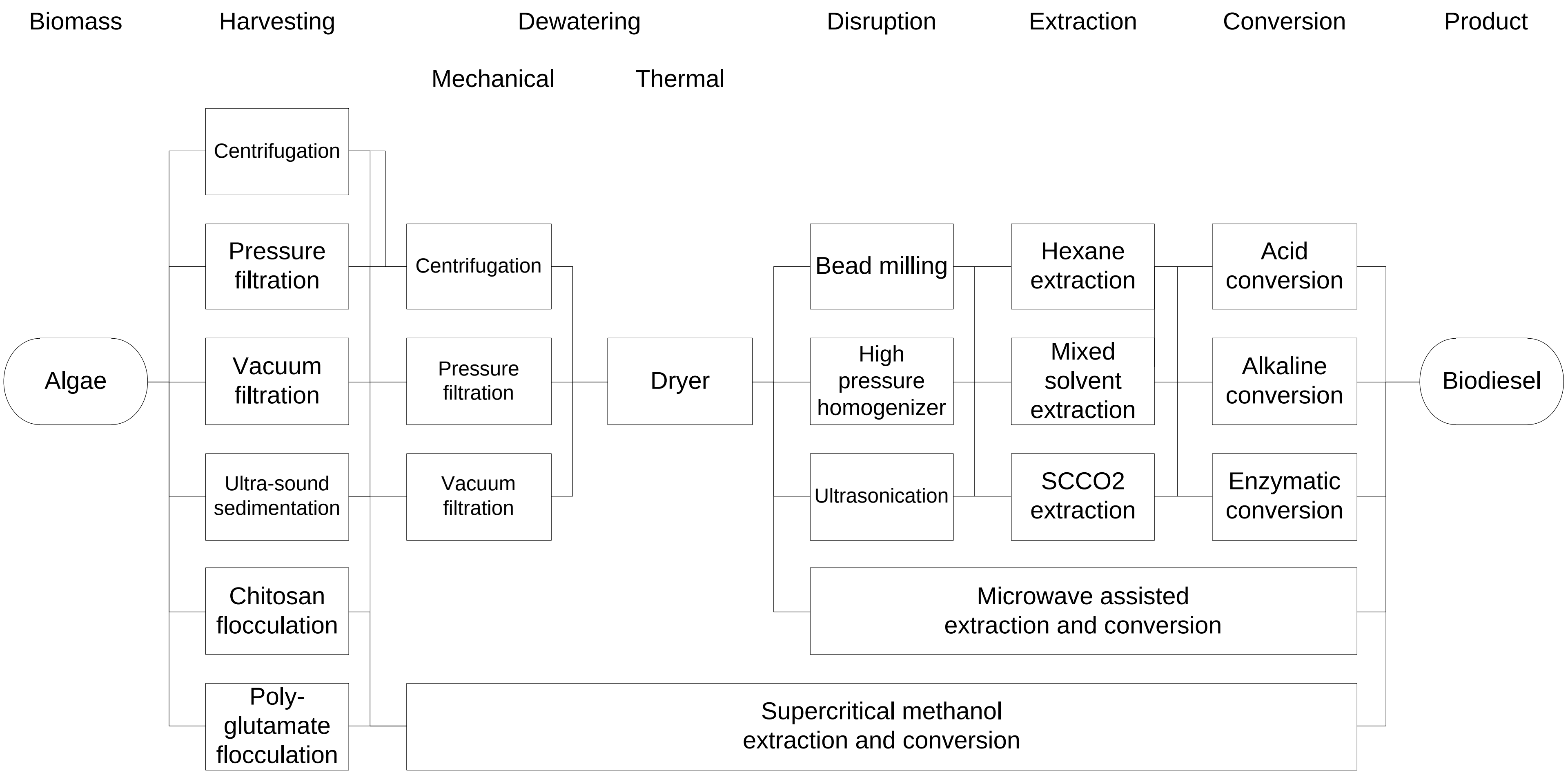
- Scenario analysis
- Life cycle assessment driven biorefinery design
    - Processing conditions
    - Product routing and resource recovery

- Integration of algae biorefinery with supply chain

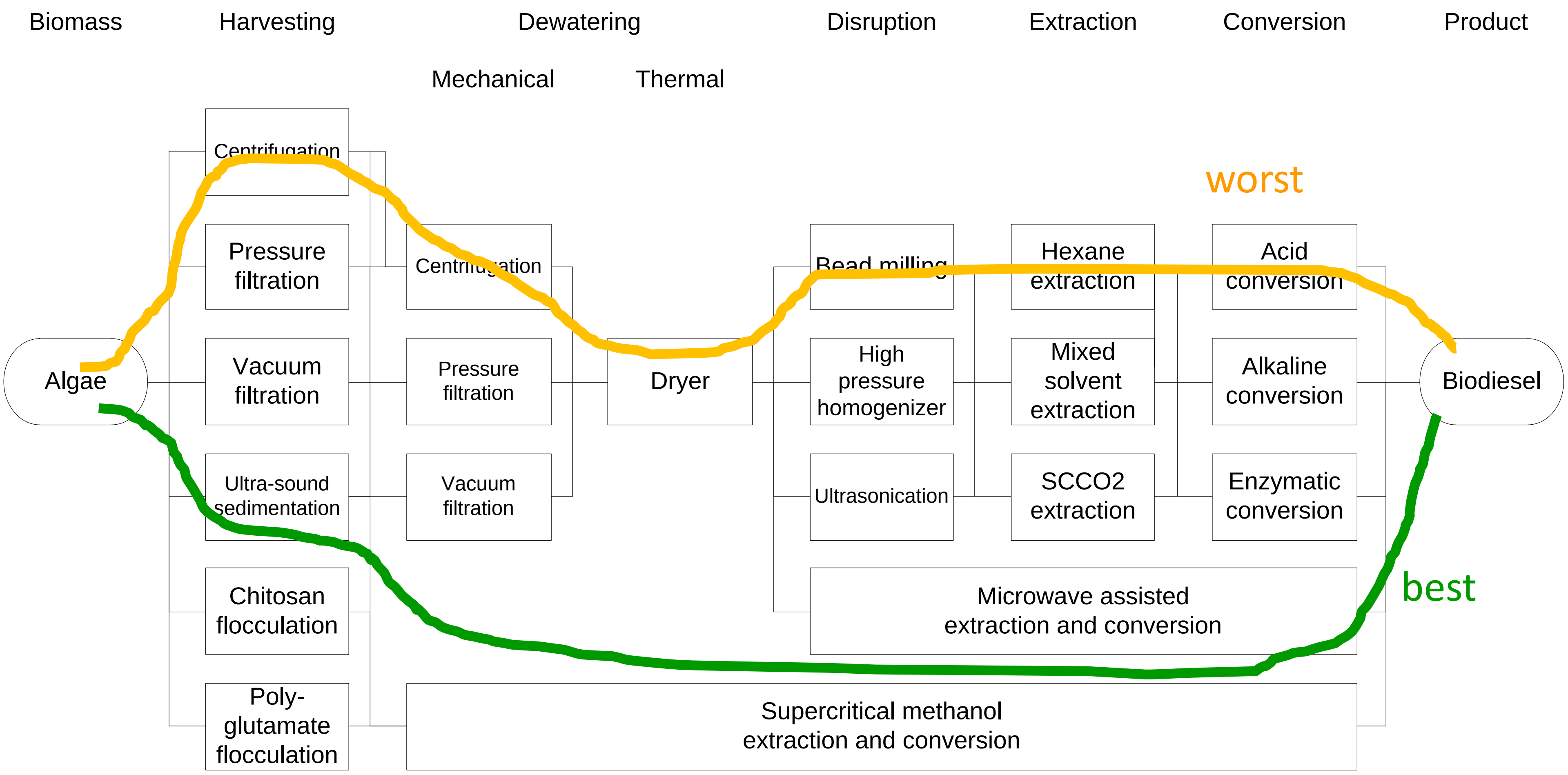
Draaisma B.B., Wijffels R.H., Slegers P.M., Brentner L.B., Roy A., Barbosa M.J. (2013) Food commodities from microalgae. Current Opinion in Biotechnology 24: 169-177

Algae biorefinery: possible process units

- Example: biodiesel



Energy consumption: worst/best≈10/1



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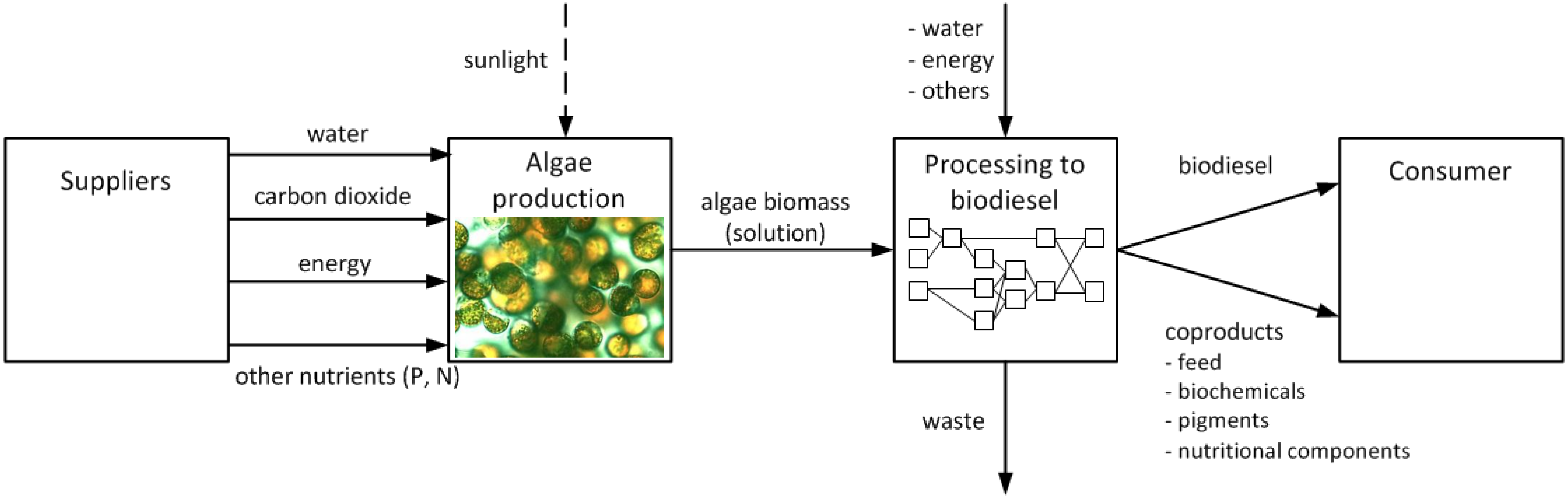
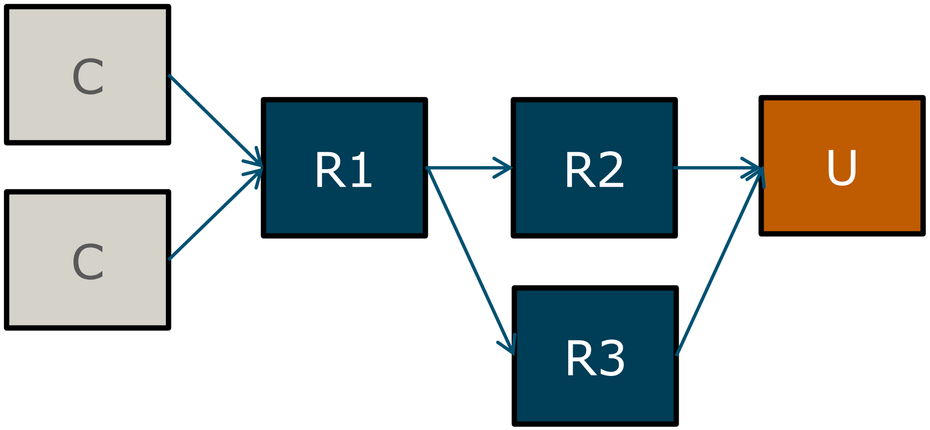
Algae cultivation and supply chain



Algae biorefinery and supply chain

- How to organize the cultivation-refinery-user chain?
- Transport of large volumes has impact on sustainability and economy
- Specialization in processing
- Economy of scale?
- Seasonal variation in cultivation request for operational flexibility or storage
- What is the effect of storage on quality/yield?
- What is the effect on the processing methods?



Algae for commodities

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www.AlgaePARC.com

[Vacancy: tenure track assistant professor algal biorefinery]

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