FAPESP-NERC

Scoping Workshop for Brazil-UK Sustainable Gas Futures

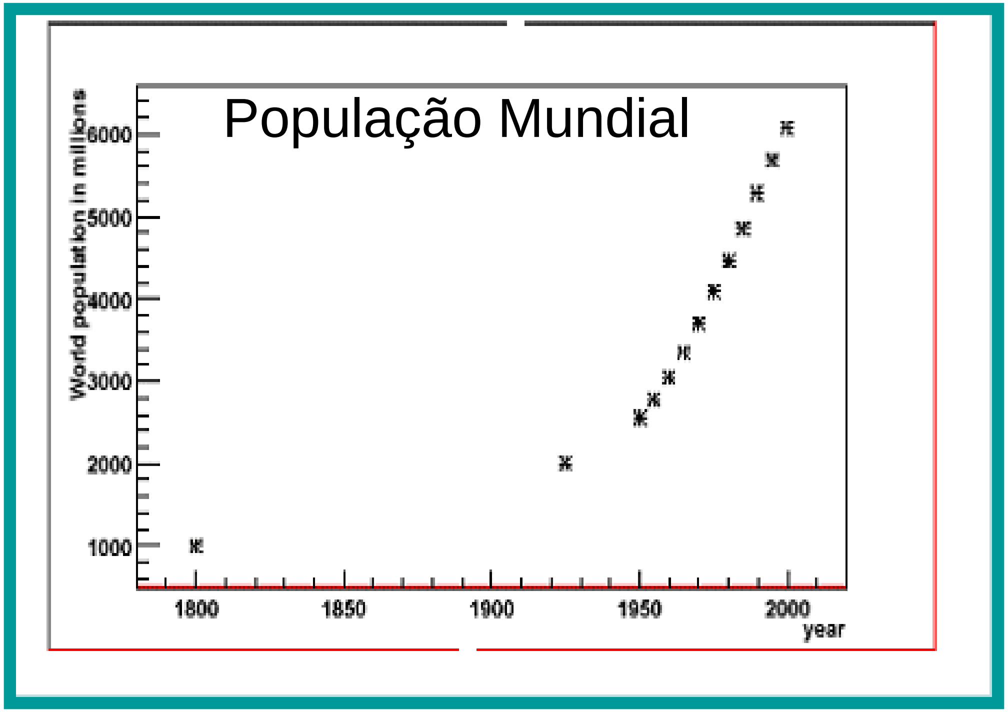
25 – 27 February 2014

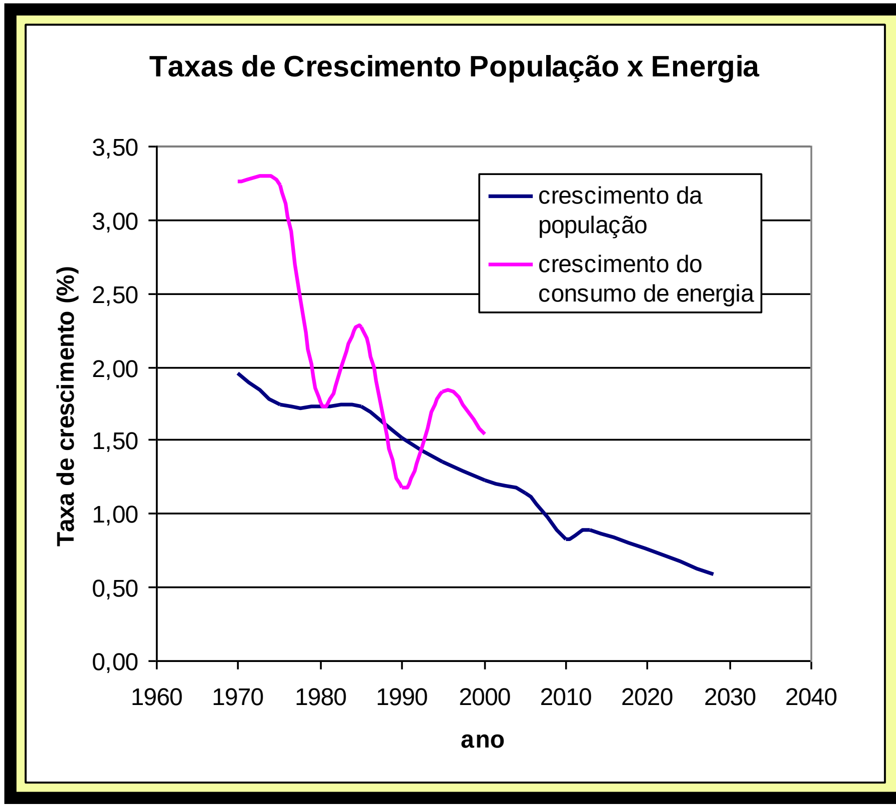
Universidade de São Paulo
B R A S I L

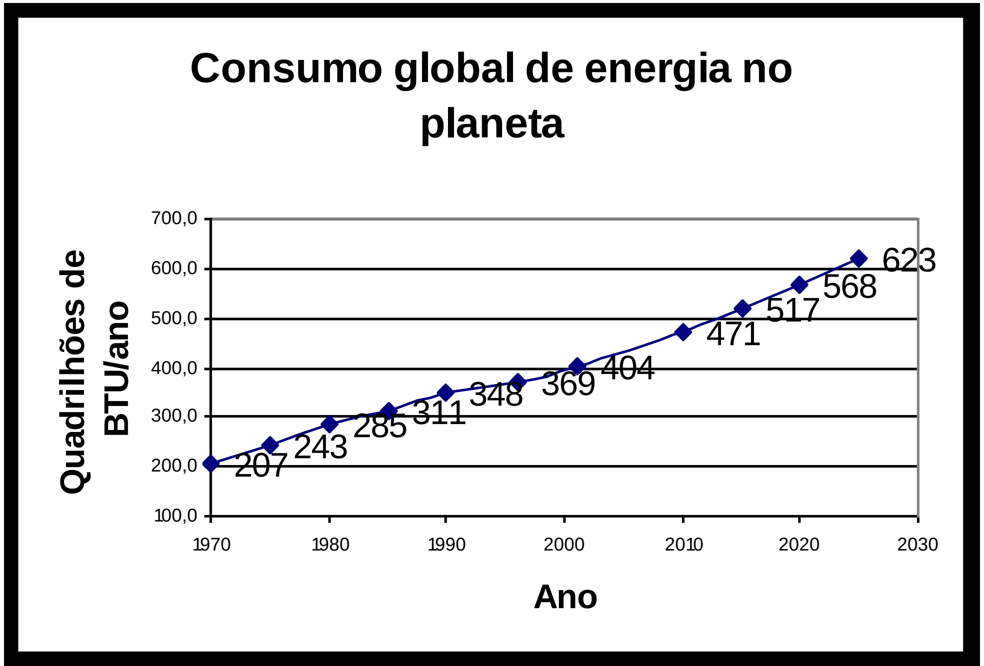
CO2 Sequestration with Algae: Challenges

Claudio A Oller Nascimento

February 25, 2015



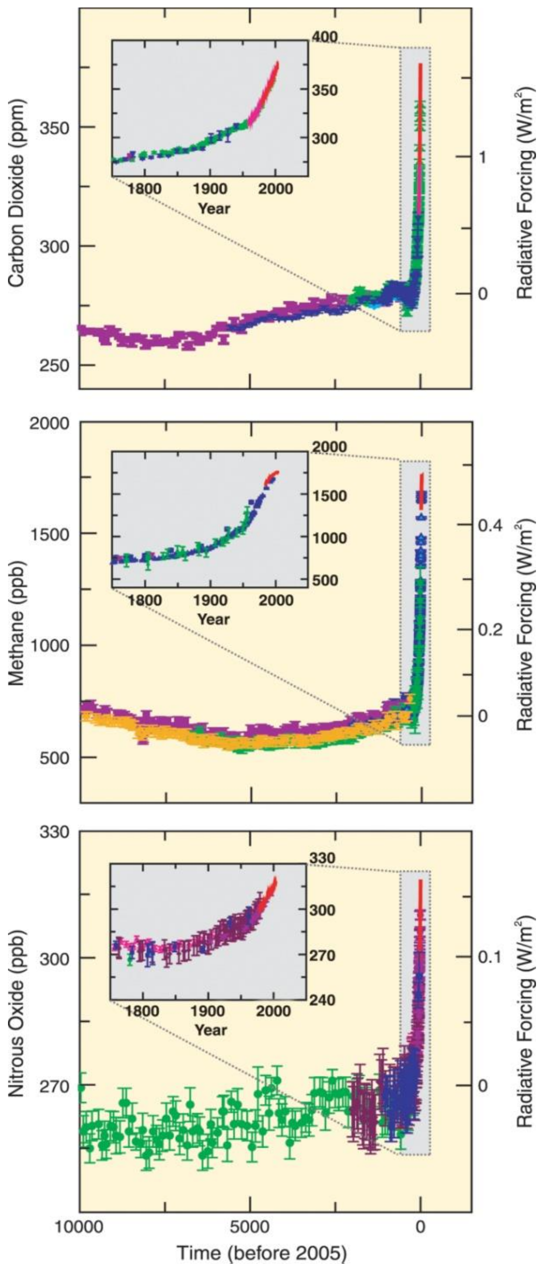


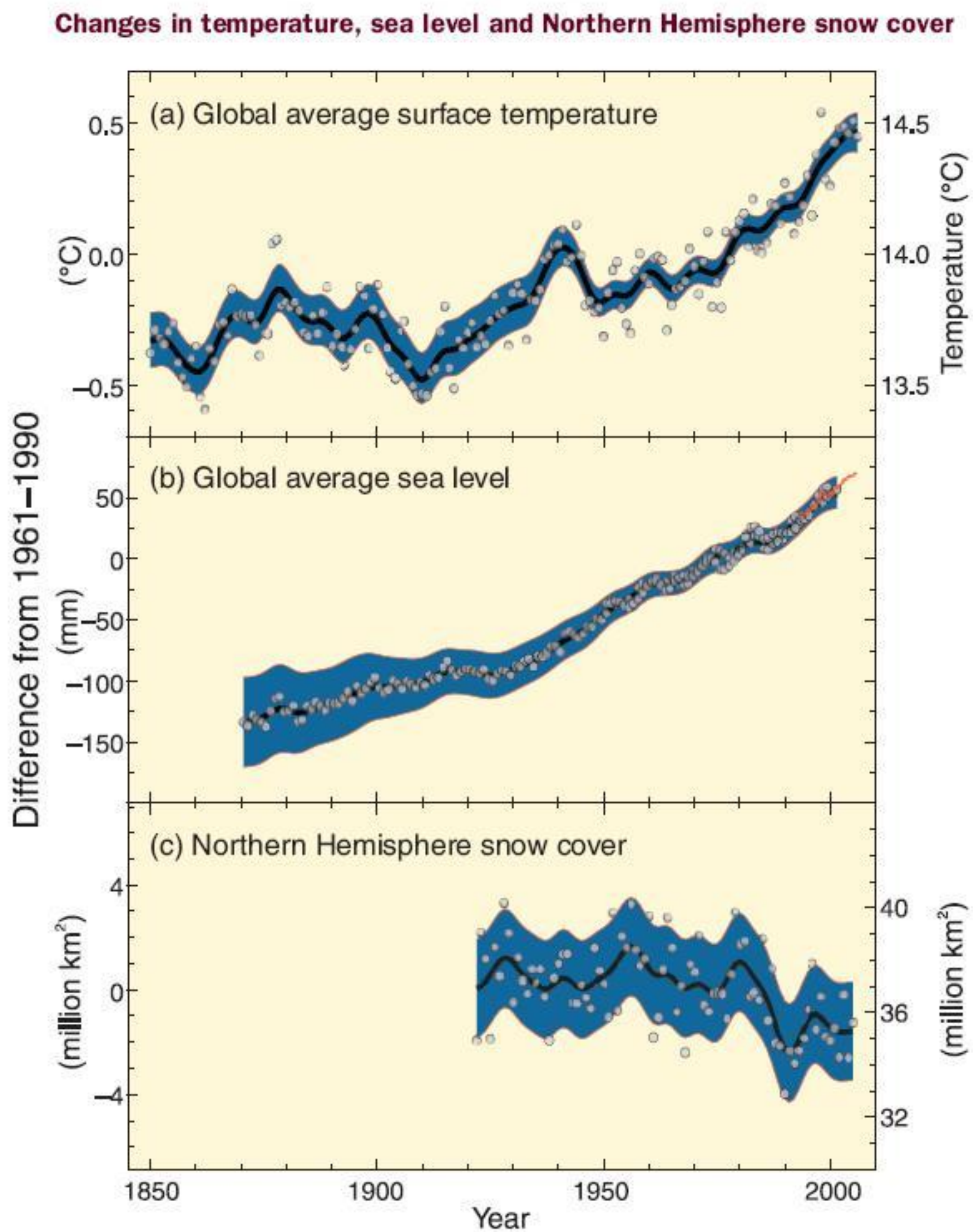


Prediction of the world population in 2050 : 9 billions

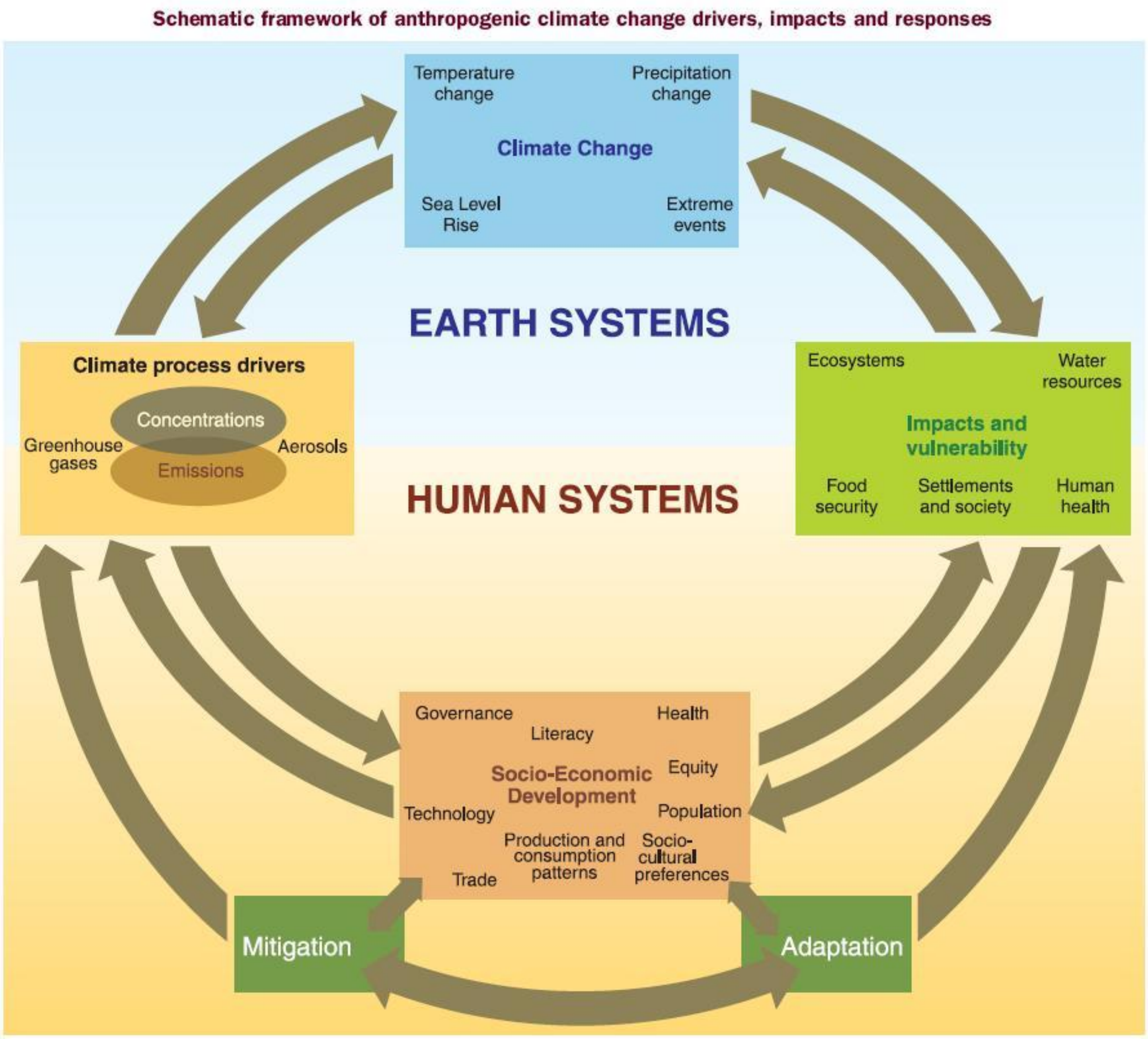
Fontes: International Energy Outlook 2004, Energy Information Administration, http://eia.doe.gov
: One Planet Many People, http://na.unep.net/oneplanetmanypeople

Impacts





IPCC Climate Change 2007: Synthesis Report



IPCC Climate Change 2007: Synthesis Report

Universidade de São Paulo
B R A S I L

- Route for reduction of CO_2 emission

- Energy Efficiency
- Renewable Energy
- Carbon Sequestration

DEFINITIONS (US Department of Energy)

Carbon sequestration is the placement of CO_2 into a repository in such a way that it will remain permanently sequestered. Efforts are focused on two categories of repositories: geologic formations and terrestrial ecosystems.

- **Geologic sequestration involves injecting CO_2 into underground reservoirs that have the ability to securely contain it.**

- **Terrestrial carbon sequestration is the net removal of CO_2 from the atmosphere by plants and microorganisms in the soil and the prevention of CO_2 net emissions from terrestrial ecosystems into the atmosphere.**

Universidade de São Paulo
BRASIL

Storage or Transformation?

Why Are Microalgae Interesting?

- Fast growth [1]
- High productivity: 40.000 to 140,000 L/hec/year[2]

Culture	Oil Yield (L.ha^{-1})
Corn	172
Soybean	446
Colza	1190
Jatropha	1892
Coconut	2689
Palm (dendê)	5950
Microalgae (a)	136900
Microalgae (b)	58700

Source: 1 - My Belo Jardim. Available in: < http://mybelojardim.com>. Access in: September 29 2011.
2 - Gladue, R. M. 1991.

Why Are Microalgae Interesting?

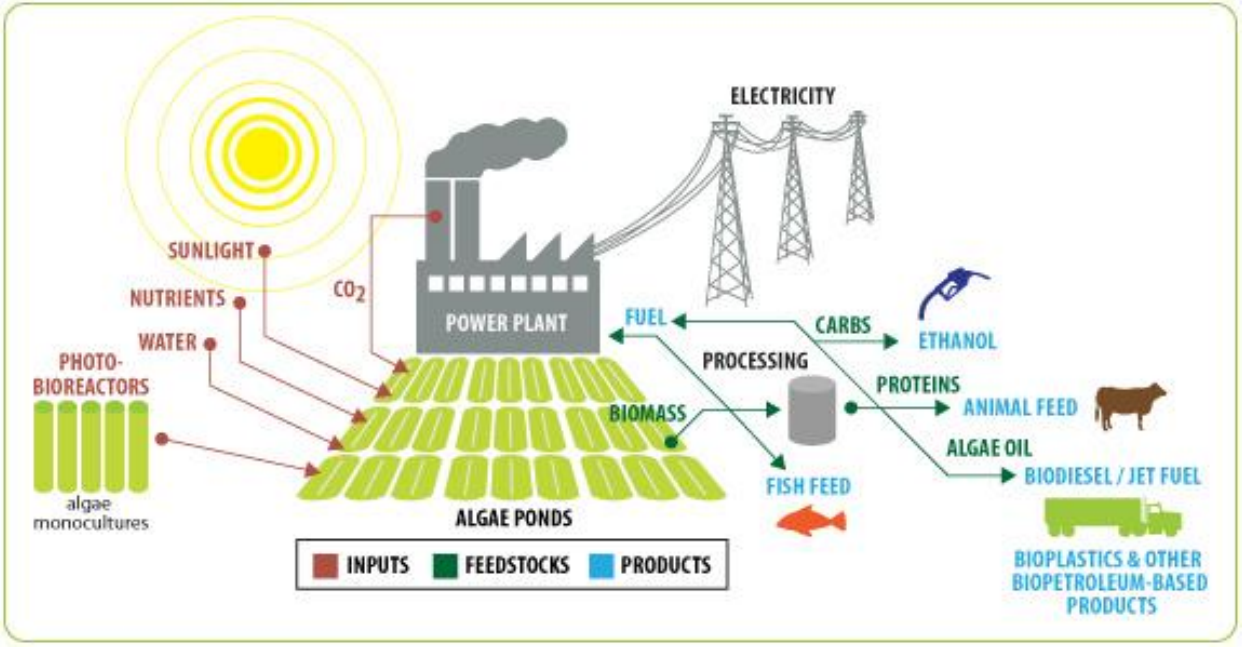
- It does not compete with food production [1]
- High lipid contents [2]
- High protein levels [3]
- It can be grown using wastewater [4]

- Carbon sequestration

  2 tons of microalgae - 1 ton of CO_2 is absorbed [5]

Source: 1 - Cornell, C. B., 2011.
2 - Mata, M. T., Martions, A. A., Caetano, N. S., 2007
3 - Becker, E.W., 2007.
4 - Chisti, Y. 2007.
5 - BIODIESEL BR. Available in: <http://gas2.org>. Acess in: September 29 2011.

What is needed?



1. Energy Source (Solar Energy)
2. Nutrients Source (Carbon and some salts)
3. Control of Temperature
4. optimal pH
5. Agitation
6. Cell Concentration

Source: Kovacevic, V.; Wesseler, J. 2010.

Universidade de São Paulo
B R A S I L

Why algae system is not use in large scale?

It only needs solar energy and water!!!!!

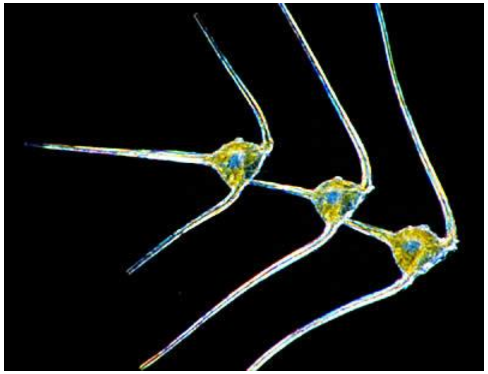
Universidade de São Paulo
B R A S I L

The sequestration of CO_2 in laboratory scale is not difficult.

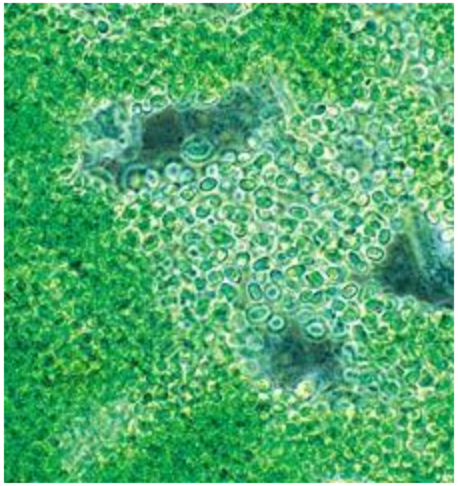
We find some suitable micro algae (~10^5 especies !!!!!!!)

Chlorophyta

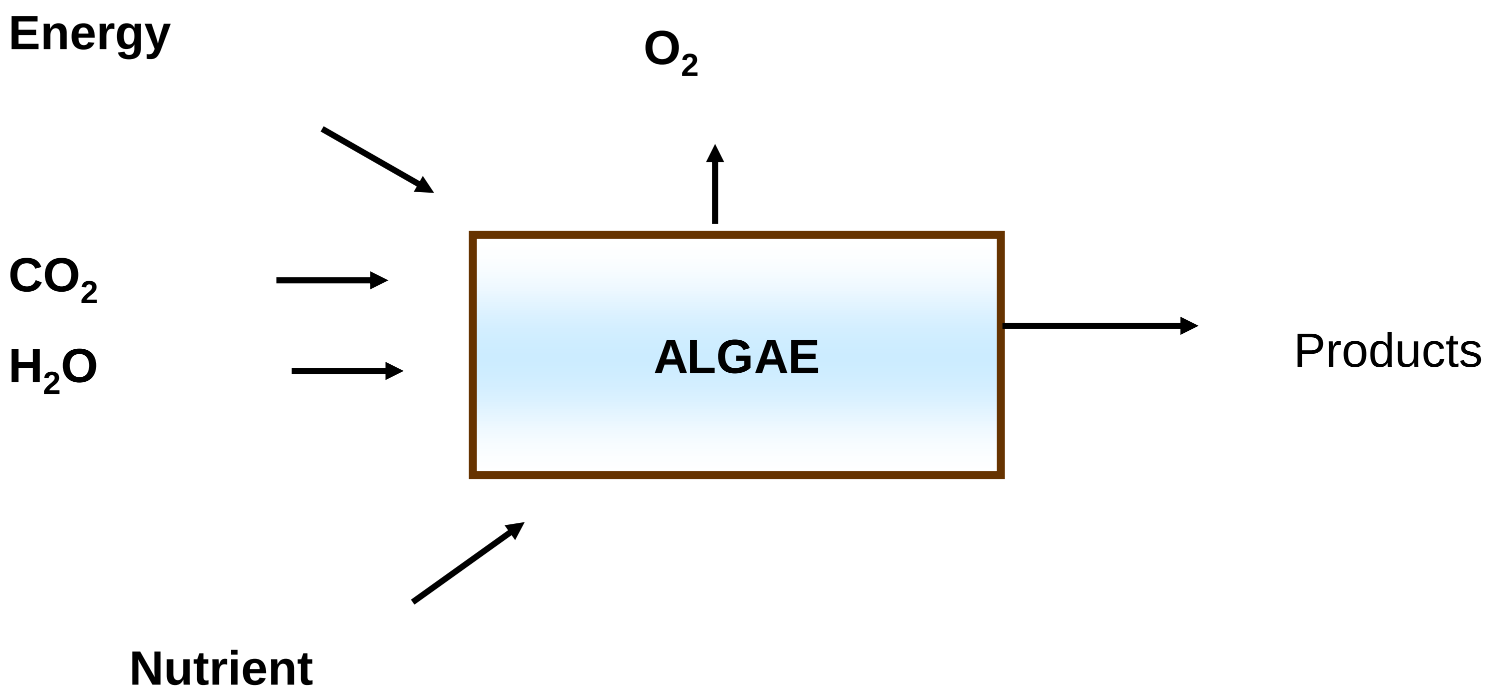
Glaucophyta



Dinoflagelados



Cianobactérias**


Energy
O_2
CO_2
H_2O
ALGAE
Products
Nutrient

USP Universidade de São Paulo

B R A S I L

The amount of **CO_2** produced is enormous.

The scale must be large for sequestration.

The system can be:

a) open

b) close

Some pilot facilities around the world
Close systems

A 1000 L helical tubular photobioreactor at Murdoch University, Australia. Courtesy of Professor Michael Borowitzka, Murdoch University

AlgaeLink® Algae Growing Systems

(NL)

Solix Biofuels Inc., a startup company based in Boulder in cooperation with Colorado State University

(US)

GREENFUEL TECHNOLOGIES CORPORATION

Some production facilities in operation Open Systems

Nature Beta Technologies, Eilat (Israel)

Earthrise, Imperial Valley (CLA – US)

Biodiesel from algae in the world

- Many efforts are being undertaken in this area, but very few have reached pilot scale
- Industrial scale facilities are used only for algae-derived specialties, such as carothenes. As far as we know, no large-scale facility for biodiesel production is in operation at present

The system will employ salted water (from the sea) or not.

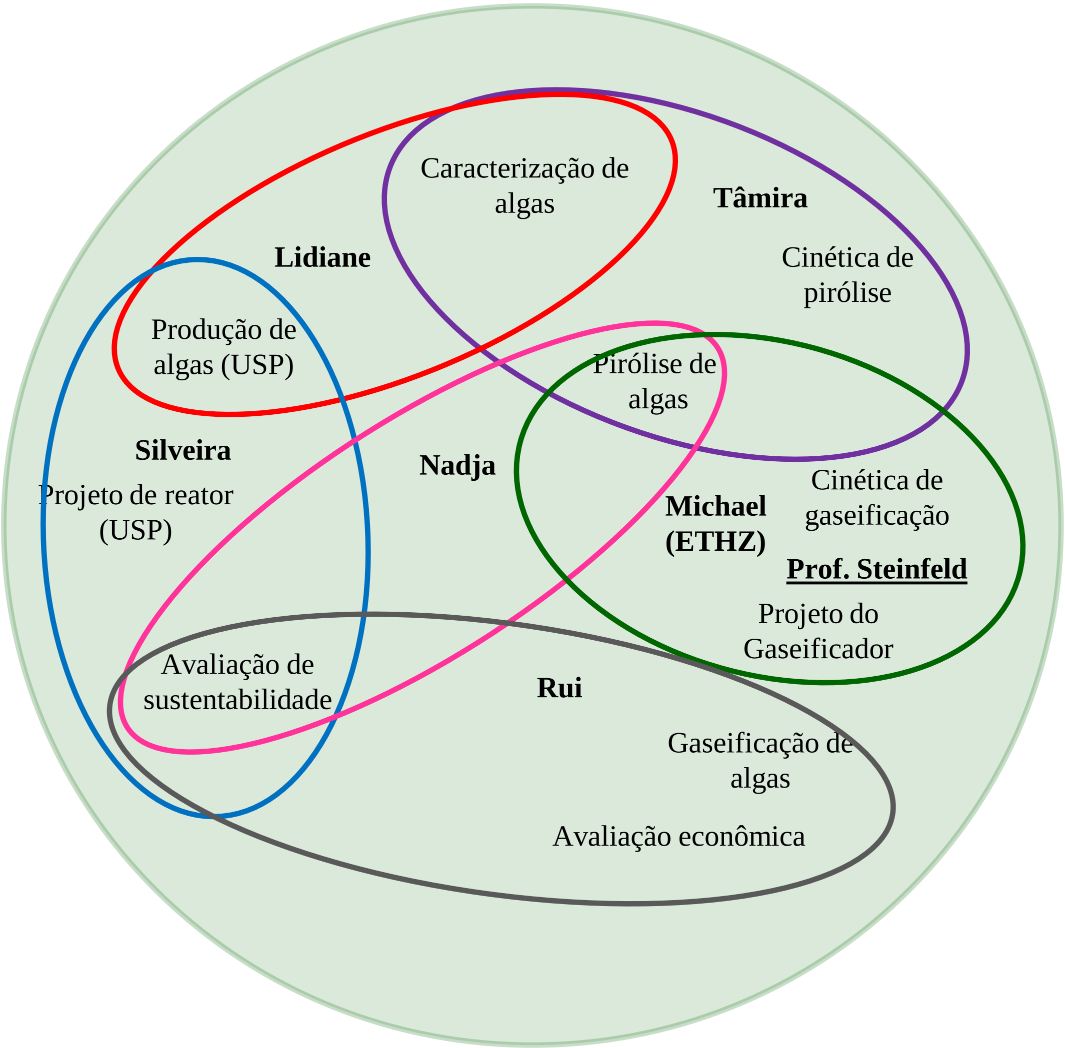
salted water – diminished the competition of the local biodiversity
- separation and oil extration?
- biomass gasification?

Closed system – diminished the competition of the local biodiversity

Closed system – temperature control?
- maintenence?
- surface area?

Open system - biological competition?

General Goals



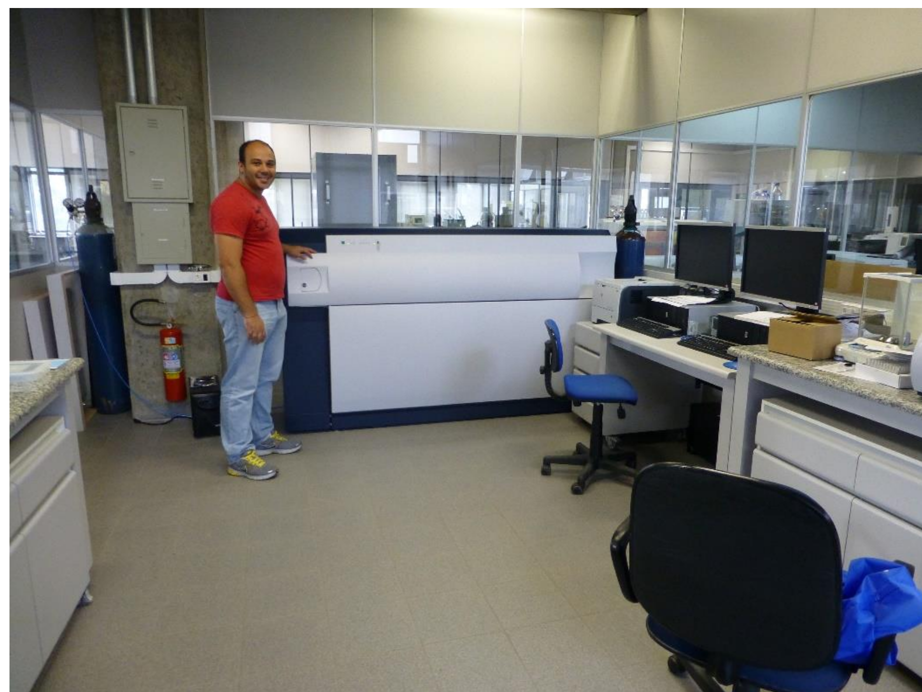
Technical information: Haueter P., Seitz T., Steinfeld A., "A New High-Flux Solar Furnace for High-Temperature Thermochemical Research", *ASME Journal of Solar Energy Engineering*, Vol. 121, pp. 77-80, 1999.

Algae Characterization

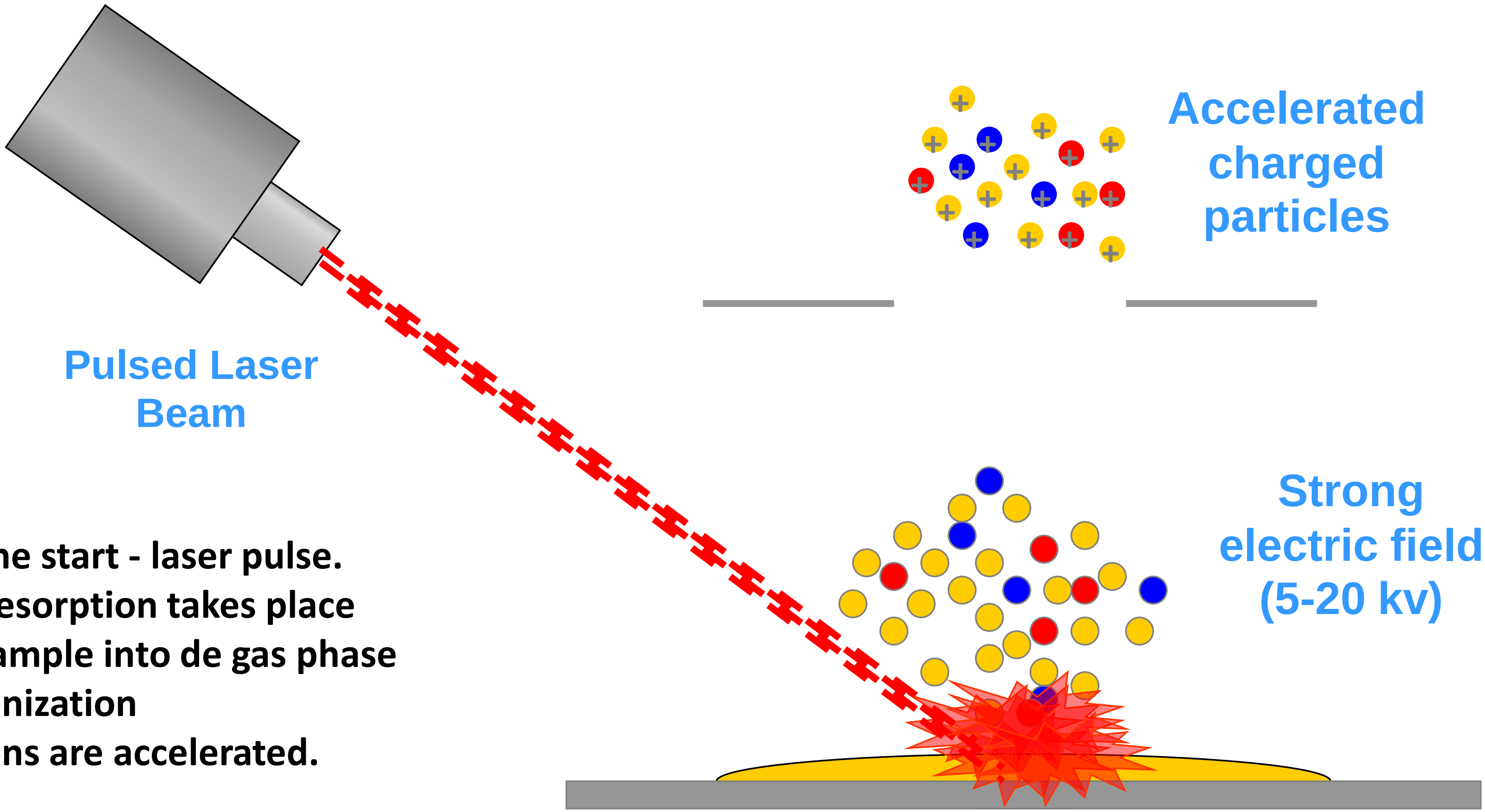
- Cultivation of microalgae species: *Chlorella vulgaris* (Cv), *Chlorella sp*. (Csp), *Desmodesmus sp*. (Dsp), *Monoraphidium sp*. (Msp)

- Protein profile of microalgae species by MALDI-TOF-MS using different matrices.


LCMS-IT-TOF



Principles os MALDI-TOF-MS

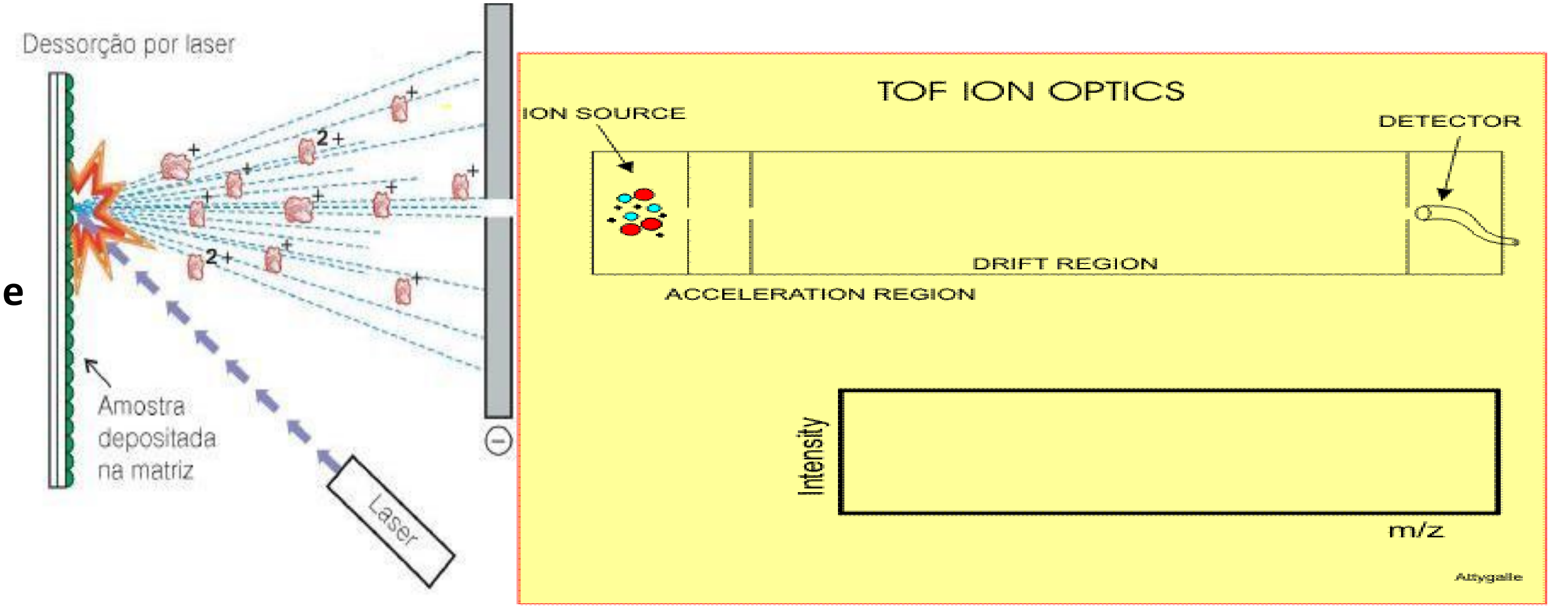


The start - laser pulse.
Desorption takes place
Sample into de gas phase
Ionization
Ions are accelerated.

MALDI is typically coupled to TOF MS due the pulsed nature of both techniques

Principles os MALDI-TOF-MS

Sample

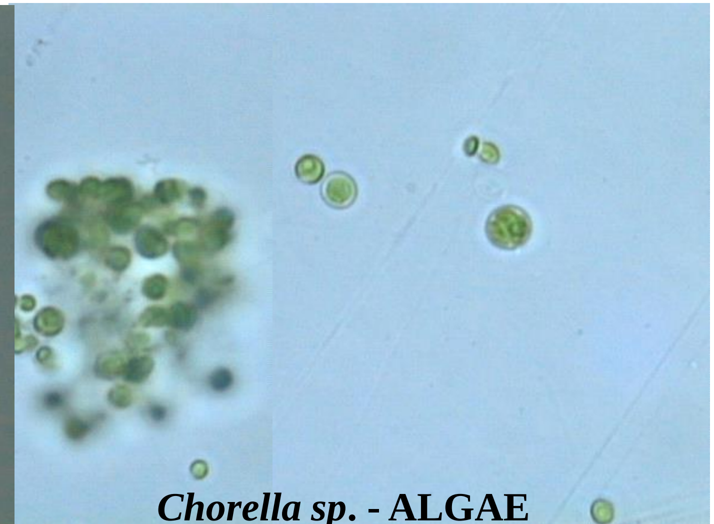


The ions are formed with the same kinetic energy… Heavier ions are slower than lighter ions

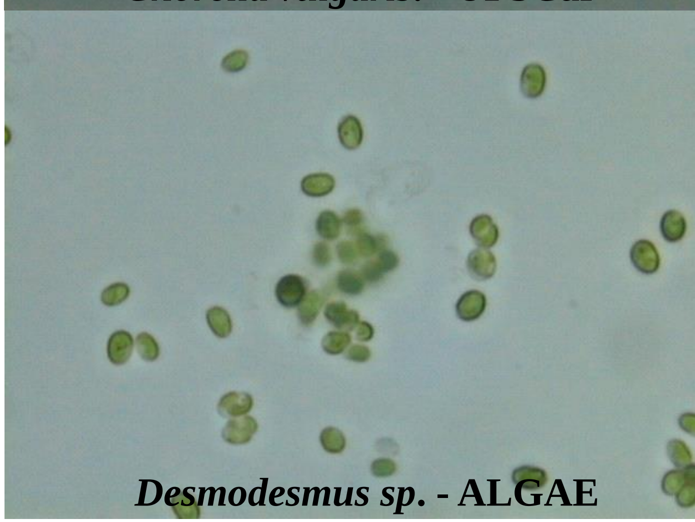
Karas & Hillkamp (1998)

Studied specie

***Chorella vulgaris*. - UFSCar**



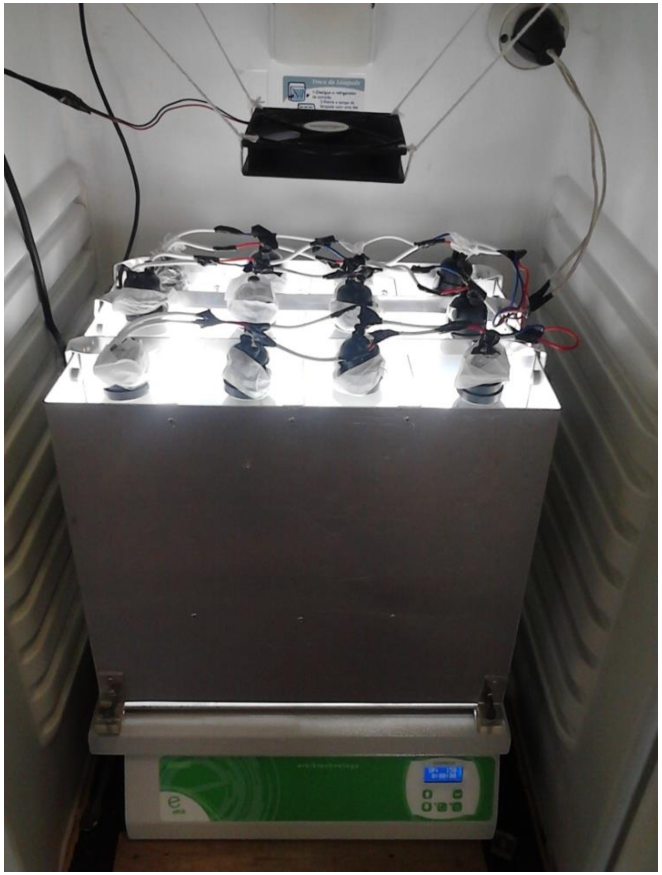
***Chorella sp*. - ALGAE**



***Desmodesmus sp*. - ALGAE**

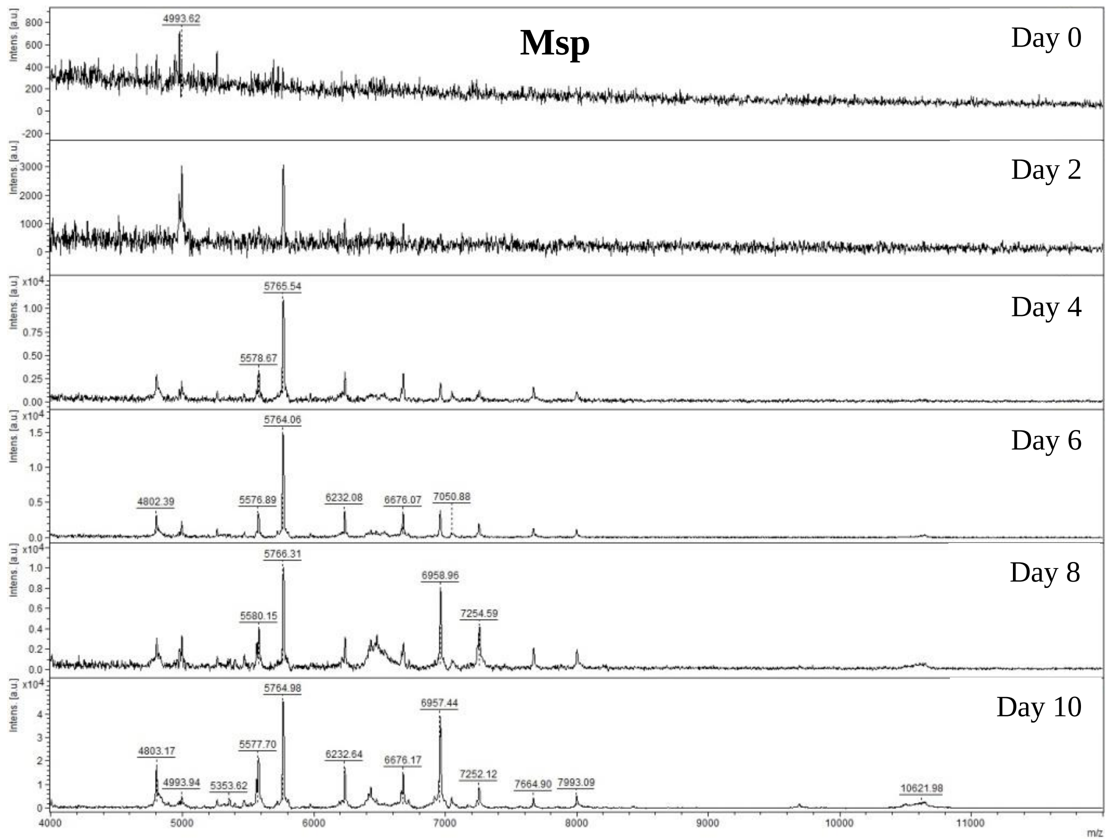
***Monoraphidium sp*. - ALGAE**

Cultivation system



12 erlenmeyers:
- same light intensity
- same temperature
- same agitation

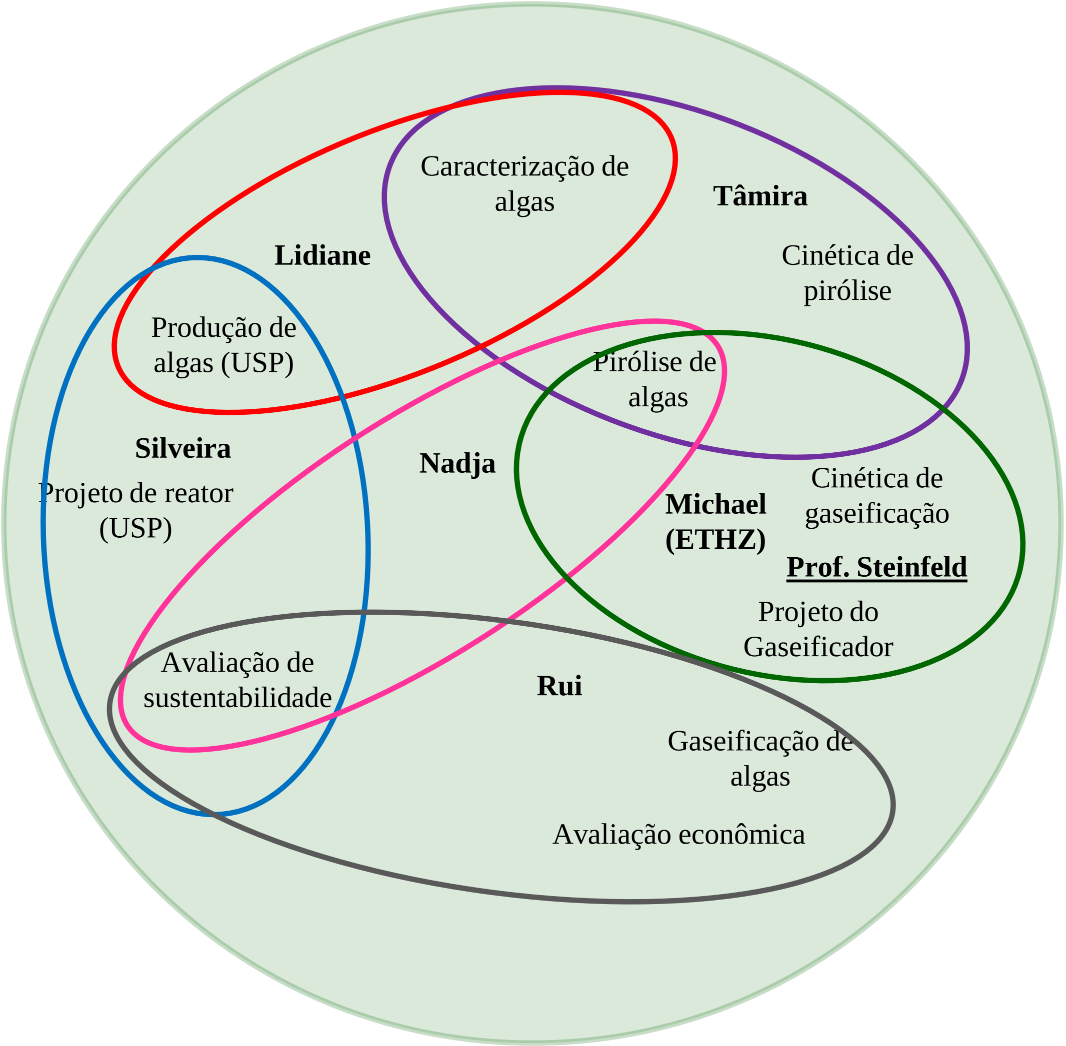
MALDI – Protein Profile by cultivation day



Microalgae specie: *Monoraphidium sp.* - Msp
HCCA as matrix

Similar profile during growth curve
Spectra Acquisition – difficulties as observed using Msp specie
An optimization is necessary!!

General Goals



Technical information: Haueter P., Seitz T., Steinfeld A., "A New High-Flux Solar Furnace for High-Temperature Thermochemical Research", *ASME Journal of Solar Energy Engineering*, Vol. 121, pp. 77-80, 1999.

MICROALGAE “OPEN POND” PHOTOBIOREACTOR

MICROALGAE “OPEN POND” PHOTOBIOREACTOR
What do we already know?

1. Microalgae:

1.1: How to grow them:

Medium: Modified medium WC (Guillard & Lorenzen, 1972) containing 2,5 g/L urea as N source

NOVO MEIO

(baseado no WC, sem NaNO3)

Component	*Stock Solution ($g \cdot L^{-1}$ dH_2O)*	*Quantity Used*	*Concentration in Fina Medium (M)*
$CaCl_2 \cdot 2H_2O$	36.76	1 mL	2.50×10^{-4}
$MgSO_4 \cdot 7H_2O$	36.97	1 mL	1.50×10^{-4}
$NaHCO_3$	43.30	2 mL	1.15 E-3
$Na_2SiO_3 \cdot 9H_2O$	28.42	1 mL	1.00×10^{-4}
K_2HPO_4	8.71	1 mL	5.00×10^{-5}
Trace metals solution	(See following recipe)	1 mL	—
Vitamins solution	(See following recipe)	1 mL	—

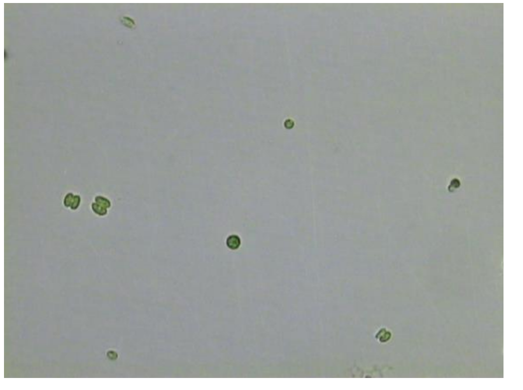
MODELING AND SIMULATION OF MICROALGAE "OPEN POND" PHOTOBIOREACTOR
What do we already know?

1. Microalgae:

1.2: How to grow them:

Microalga species adopted: *Chlorella vulgaris*, possibly containing other contaminant species that appear during the cultivation process





1.3: Optimal conditions:

Temperature: 20 to 30 C (Hirata et al., 1996)
pH: in the range 5,5 to 7,0 (Powell et al., 2009

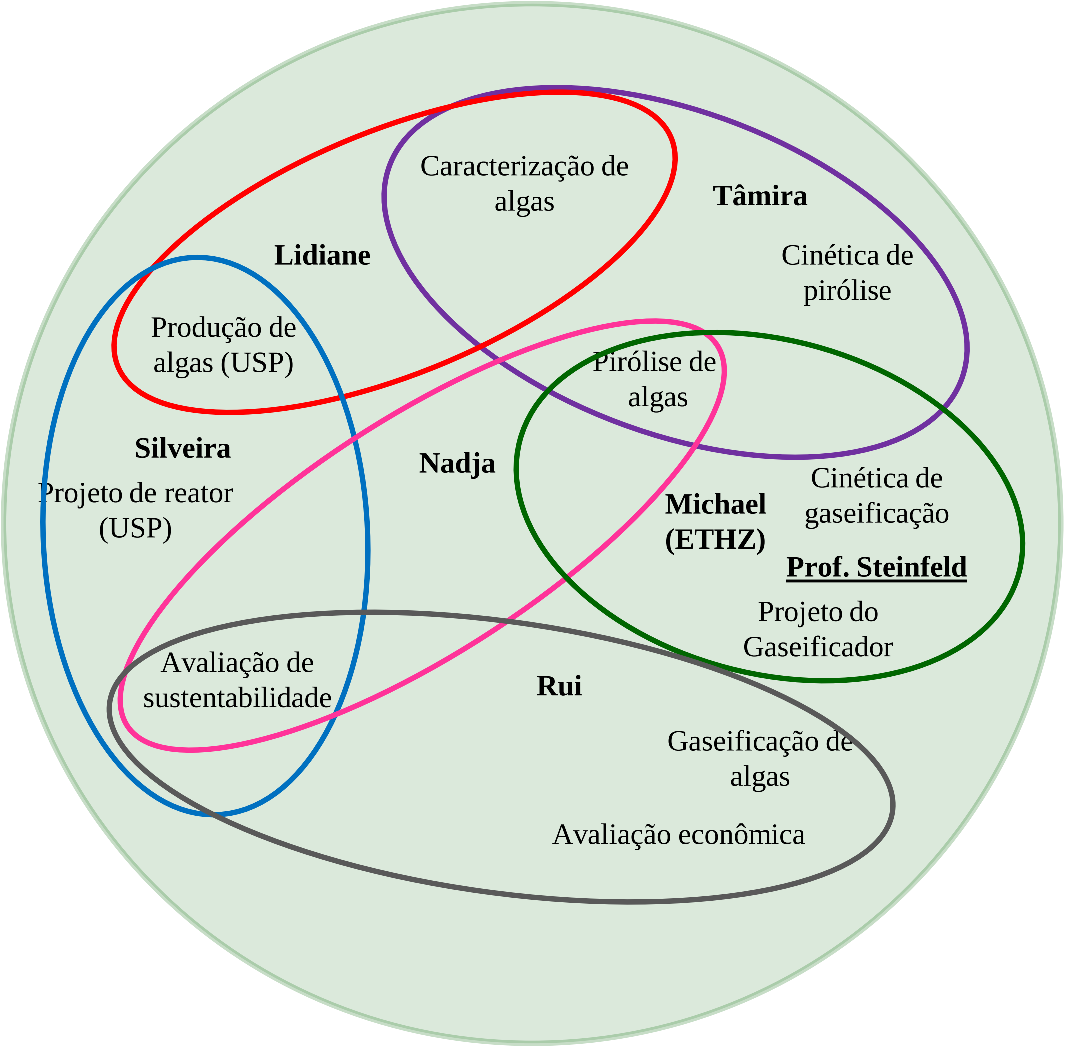
MICROALGAE “OPEN POND” PHOTOBIOREACTOR
What do we already know?

2. Reactors:

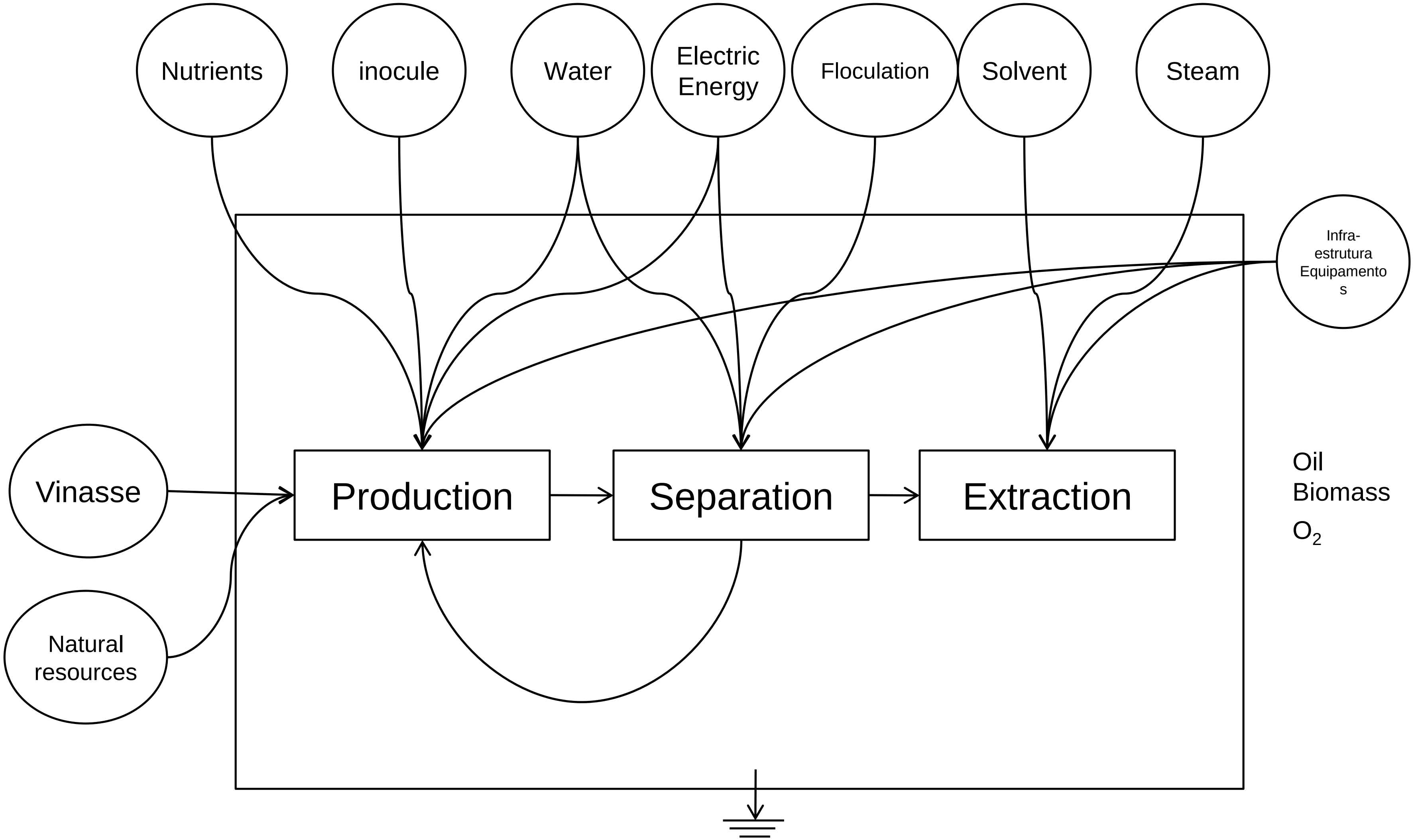
1.4: Reactors:

Lab scale – 5L   Pilot scale: 1000L

General Goals



Technical information: Haueter P., Seitz T., Steinfeld A., "A New High-Flux Solar Furnace for High-Temperature Thermochemical Research", *ASME Journal of Solar Energy Engineering*, Vol. 121, pp. 77-80, 1999.



CRUZ, RUI VOGT ALVES DA ; **Nascimento, Claudio Augusto Oller do** . Emergy analysis of oil production from microalgae . Biomass & Bioenergy, v. 47, p. 418-425, 2012

USP

CEPEMA
POLI • USP
UNIVERSIDADE DE SÃO PAULO

FAPESP

CNPq

BNDES

INCT de Estudos
do Meio Ambiente

inct
institutos nacionais
de ciência e tecnologia

VALE

Internacional Support to CEPEMA-USP

Fulbright Chair (4 months per year)

DAAD Consultant–CEPEM
(4 months per year during 2 years)

Sustainability Cabinet at CEPEMA-USP
(2005-2009)

(One of the 5 Projects financed by Alcoa Foundation in the world. Universities partners London School of Economics, Michigan University, Tsunhg University, Curtin University)