



## Microalgae: From biofuels to biopharmaceuticals

Theodor Fahrendorf  
ACP S&T Biofuels Workshop at SANUMARC  
Henties Bay: 3-5 June 2010

# Jacobs University



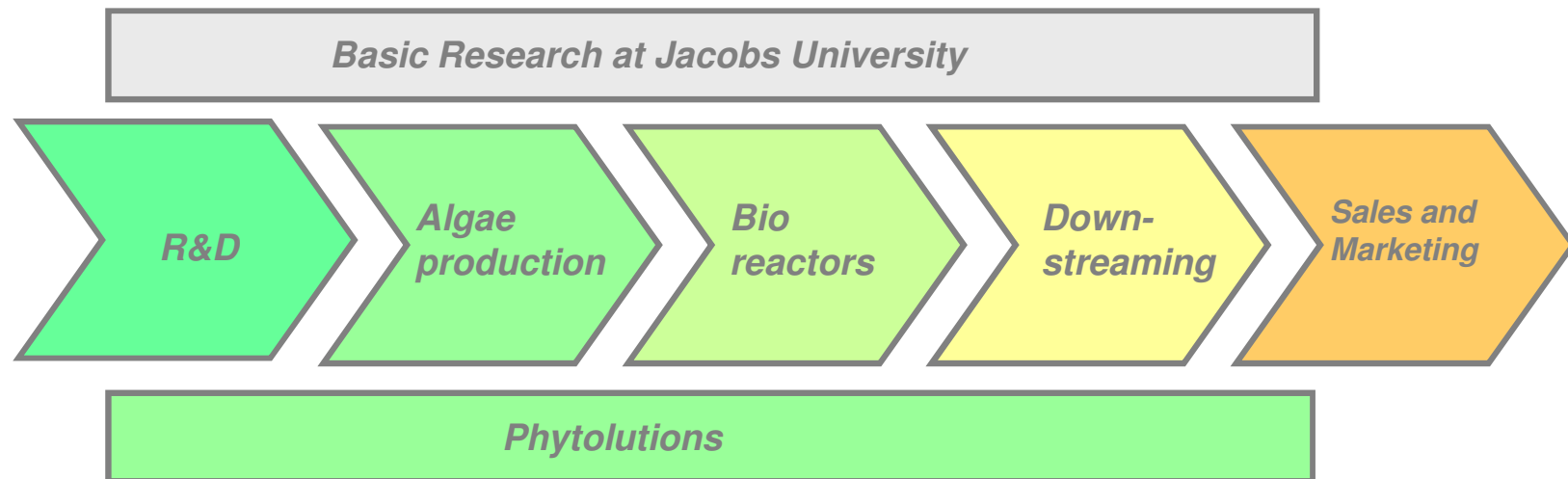
## History of Jacobs University

•1999 - Founded by City-State of Bremen, University of Bremen and Rice University, Texas as International University Bremen

2006 – Renamed to Jacobs University Bremen

- One research focus: BioGeoMarine Resources
- Currently 1200 students from 95 nations, 100 professors
- June 2008 - 1st spin-off company Phytolutions founded

# Company Profile



Phytolutions provides complete phytoplankton solutions and is a partner for research and development in the field of renewable energies and environmental engineering.

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## Phytolutions in a nutshell:

Provider of:

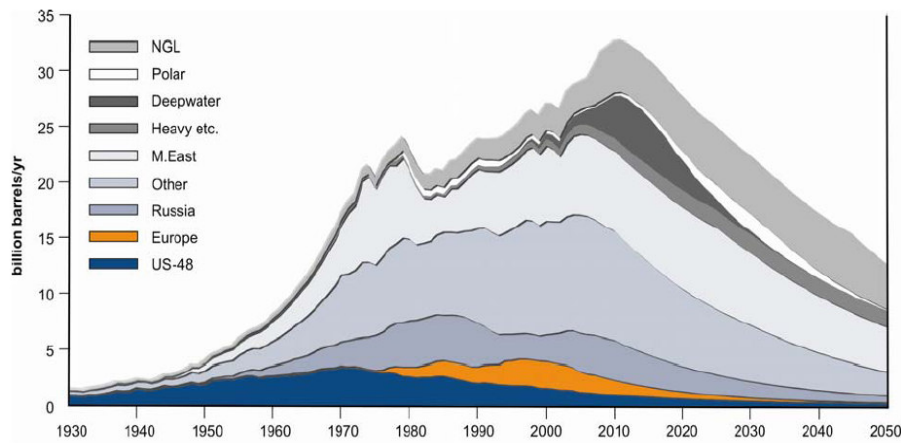
Algal production systems, incl. downstreaming components

Algal biomass and high value ingredients

Pilot and large scale installations and corresponding services

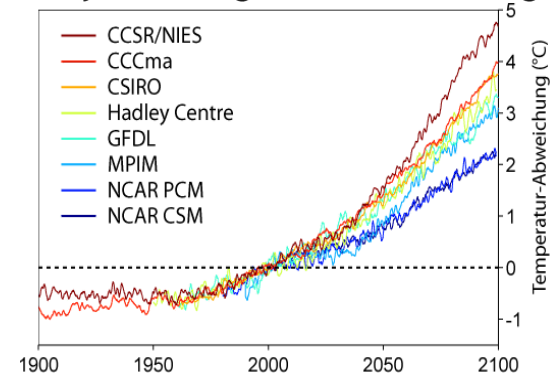
# Limited Fossil Energy Resources and Global Warming

## Fossil energy resources

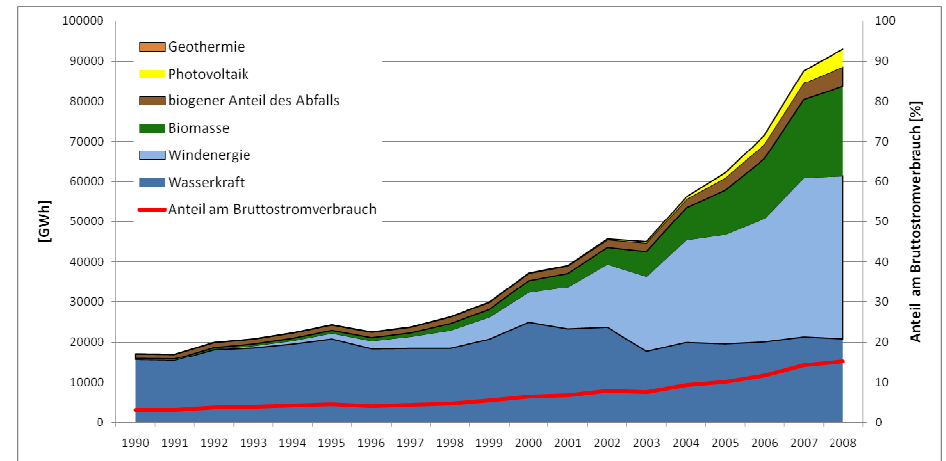


Source: Survey of Energy Resources, World Energy Council 2007

## Projektionen globaler Erwärmung

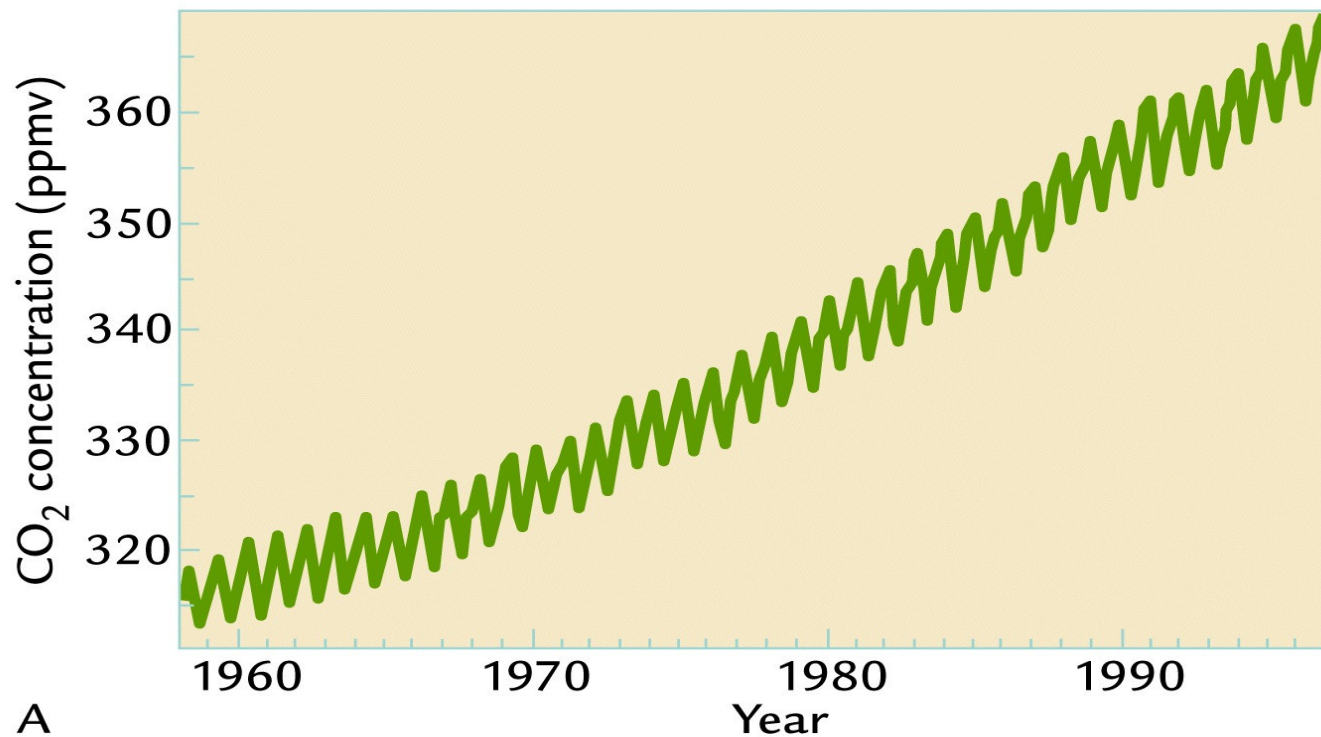


## Electricity from renewable energy resources in Germany



# Global Challenges

Increase in Global Energy Demand and CO<sub>2</sub> Concentration



A

## Why Algae

Target of European Community for 2020: 20% renewable energy.

Algae grow 10 to 20 times faster than land based biomass.

Independent from agricultural land and infrastructure.

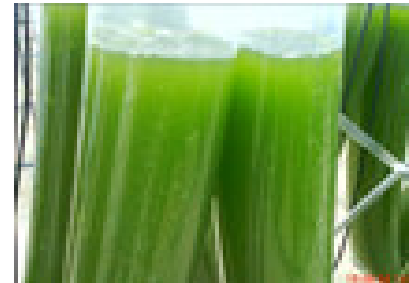
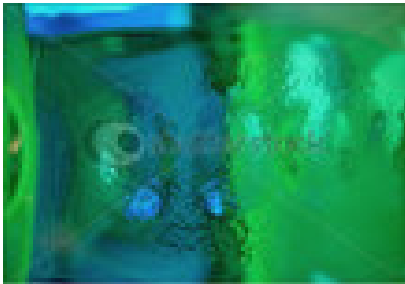
Unique ability of algae to grow in saline water.

Efficient CO<sub>2</sub> sink. The ocean will become the ultimate sink for anthropogenic CO<sub>2</sub>.

Cleaning of flue gas.

Products:

Bio fuels, platform chemicals (green chemistry), animal food, pharmaceuticals, building materials, bio plastics, etc.



## Algae Challenges

Migration from industrial pilot applications to large scale exploitation

Further develop practical engineering systems

Increase productivity

Cost reduction

Demand for efficient photo bioreactors

Achieve efficient growth rates also in winter - mixotropic growth

Harvesting / Extraction

Efficient downstreaming



## Potential and Limitations

Algae can play a major role to supply energy and food

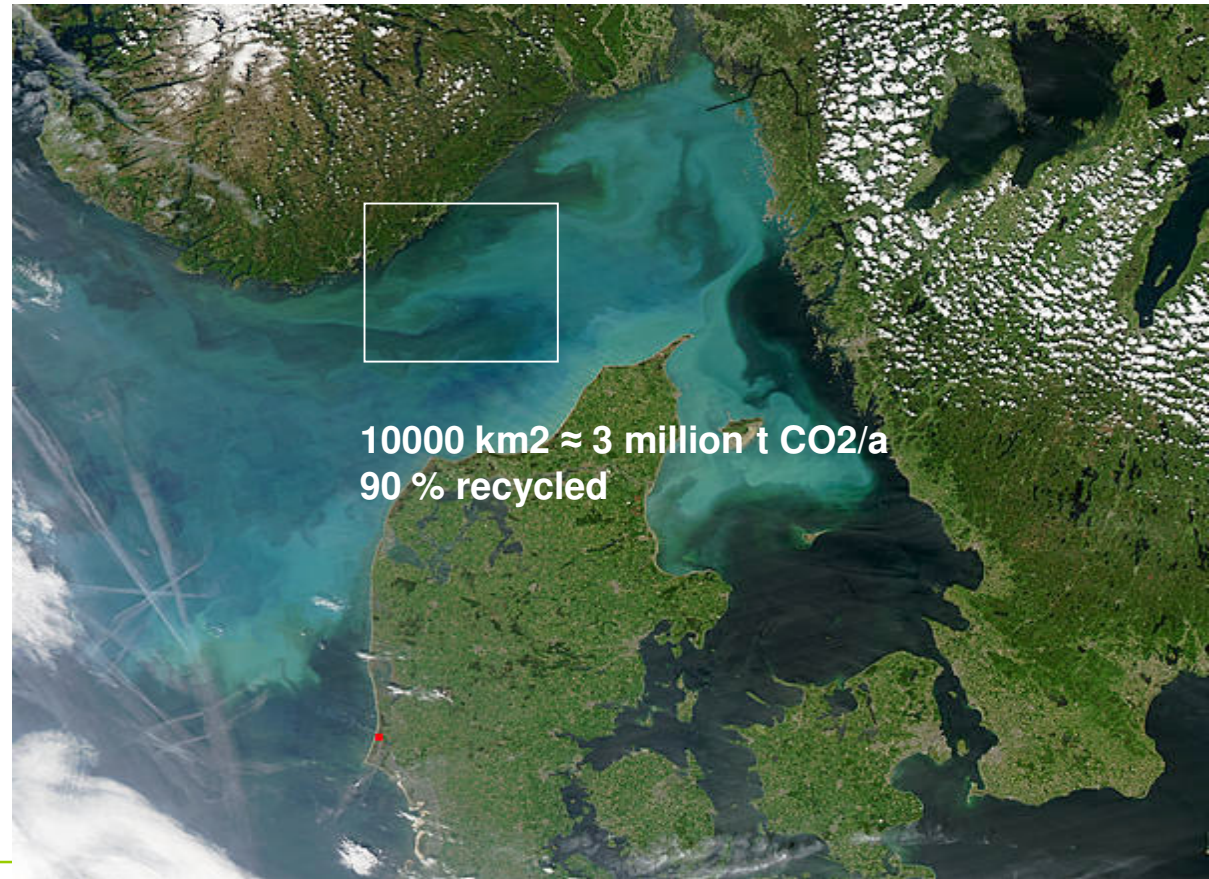
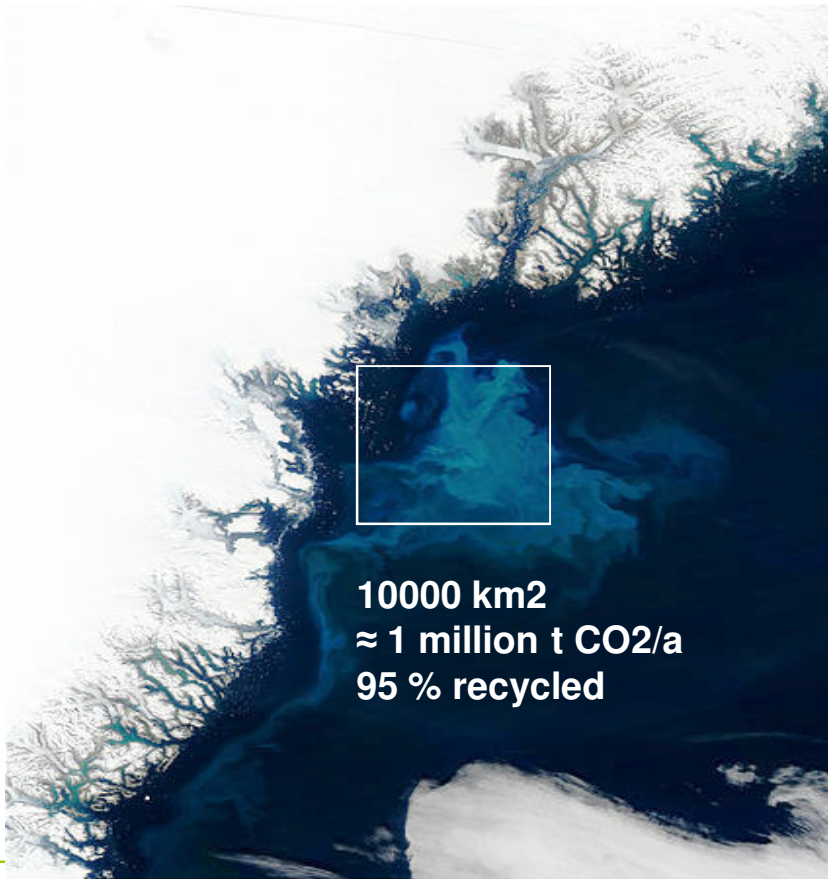
Production sites should address the following issues:

- - access to cheap land (no tourism, no agriculture)
- - access to CO<sub>2</sub> (proximity to emitting industries)
- - usable solar radiation and temperature
- - access to water, preferable salt water (coastal areas)
- - close to market

Algal products have been marketed for the food, feed and pharma segment. Production of energy from and through algae has still a long way to go.



# Where Algae Grow



## Phytolutions Systems for Algae Production

**Phytolutions has developed extremely economical and efficient systems for algae biomass production**

**Cost saving: Factor 5-10 with respect to competitors**

Photo bioreactor from special film

No greenhouse required

Energy efficient venting

Usage of waste heat

Automated process and remote control



# Downstream Biomass Utilization

Production of marine algae

short term

medium and long term

High value products

Astaxanthin

Antiviral substances

Animal feed



High volume products

C1 – C6

BTL

Marine biogas production



# Phytolutions Projects



5 MW  
Destructor station  
1000 m<sup>2</sup>  
bioreactor



1.8 GW  
Coal-fired power plant RWE  
600 m<sup>2</sup> / 1600 m<sup>2</sup> bioreactor



50 MW Biomass  
power plant  
1000 m<sup>2</sup> bioreactor  
Consulting



Heating station  
600 m<sup>2</sup>  
bioreactor

## Reference: RWE Project



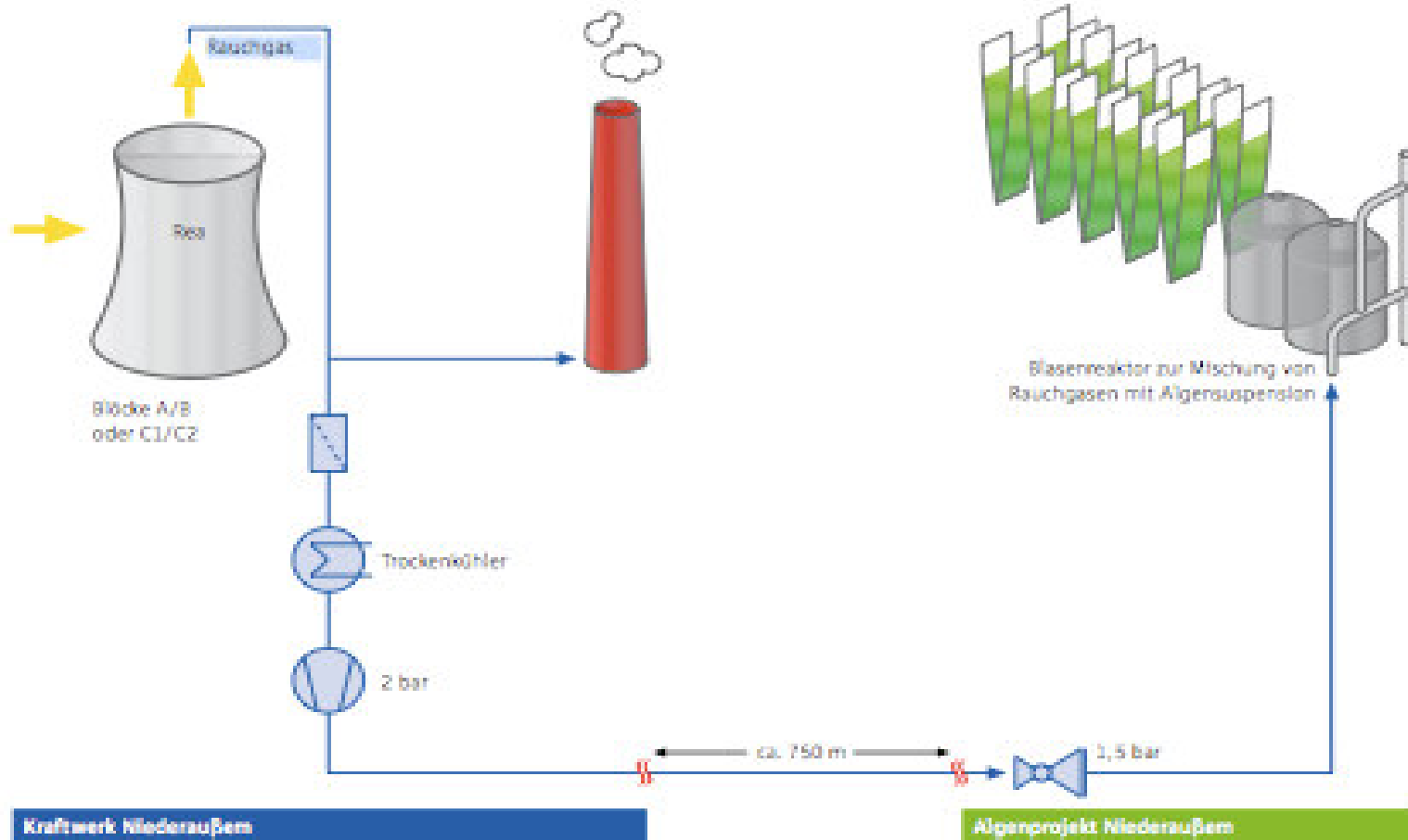
**600 m<sup>2</sup> bioreactor at RWE coal-fired power plant**

**Start of Operation:**  
1.8.08 in Niederaussem

**Objective:**  
Investigation of Options for  
CO<sub>2</sub> Utilization  
Optimization of the complete  
process chain – from algae  
production to the final  
product

**Partners:**  
Jacobs-University, Bremen,  
Forschungszentrum Jülich,  
Phytolutions GmbH, Bremen

# RWE Project

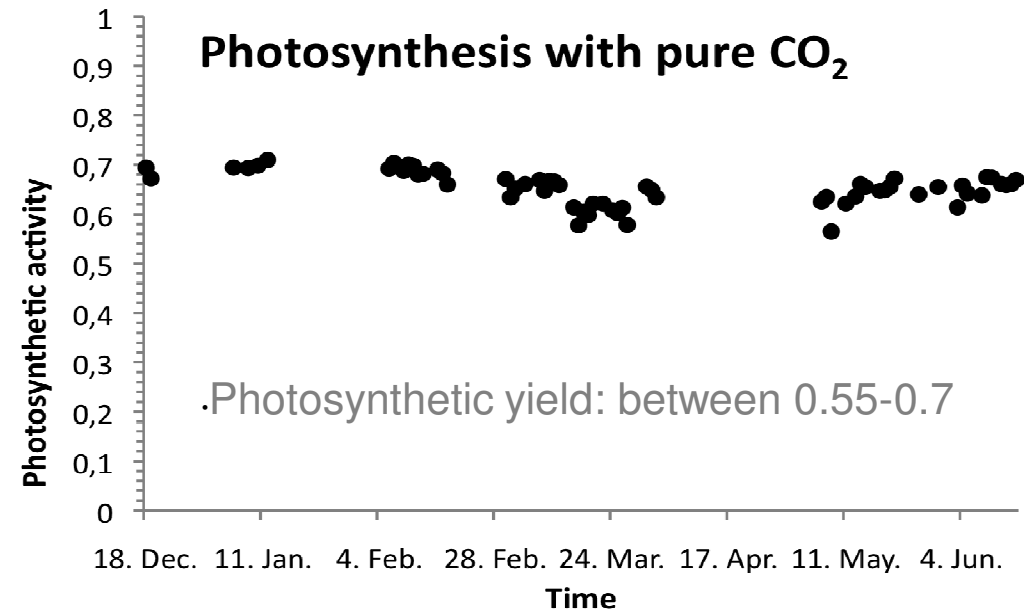
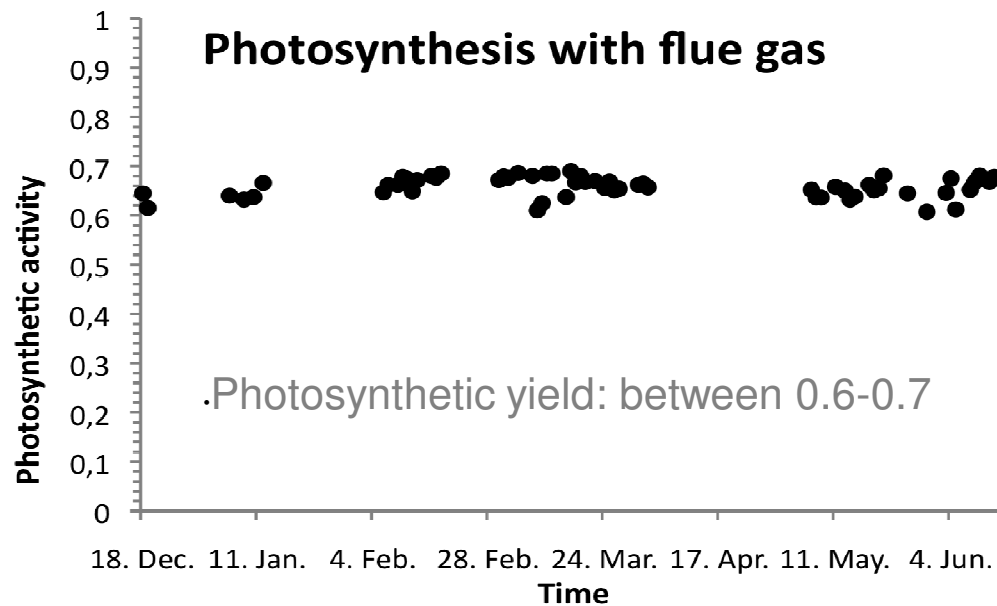


# RWE Project





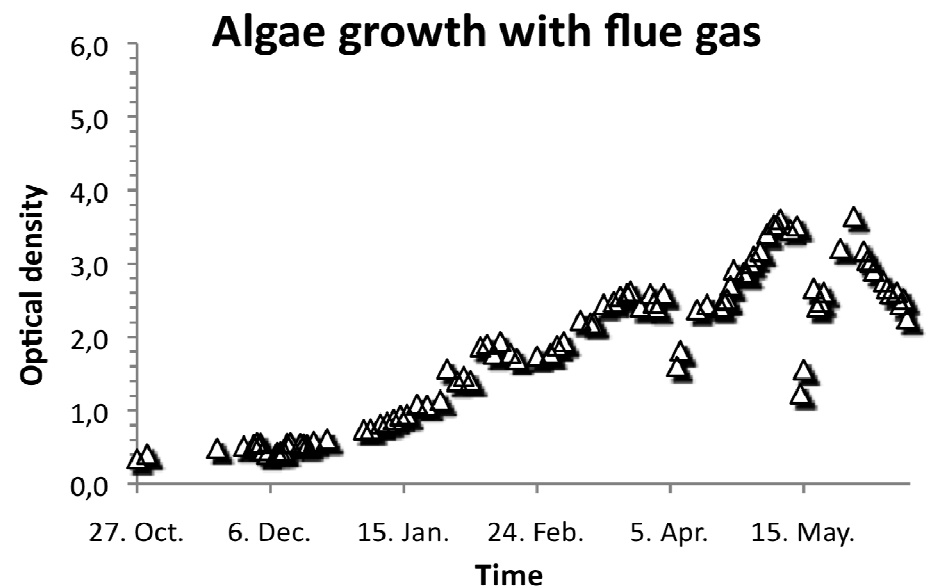
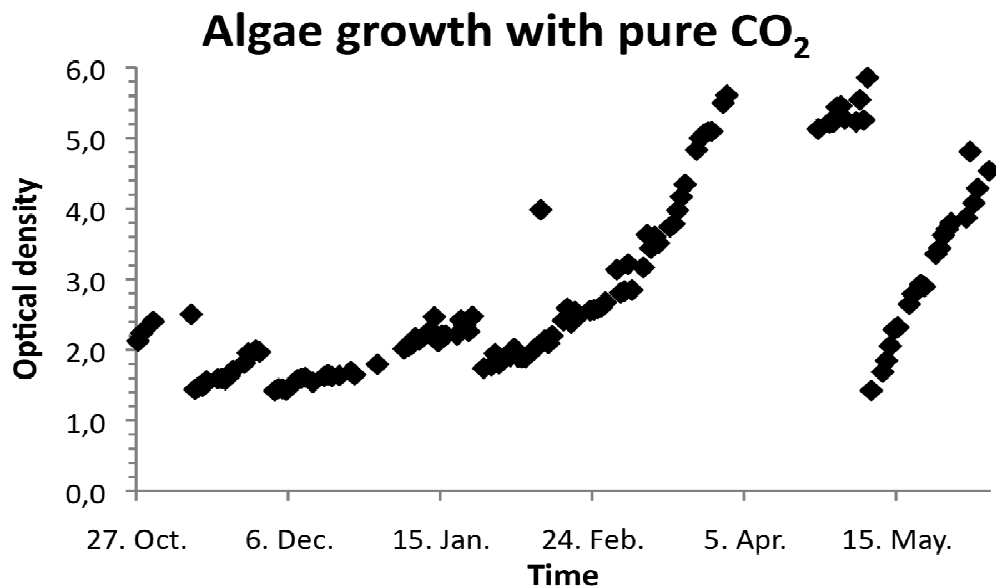
# How photosynthetically active are the algae with flue gas ?



▶ .Yield above 0.5 means algae are in a good physiological state

**Conclusion: Flue gas has no negative affect on photosynthetic efficiency!**

## How productive are the algae with flue gas during spring?

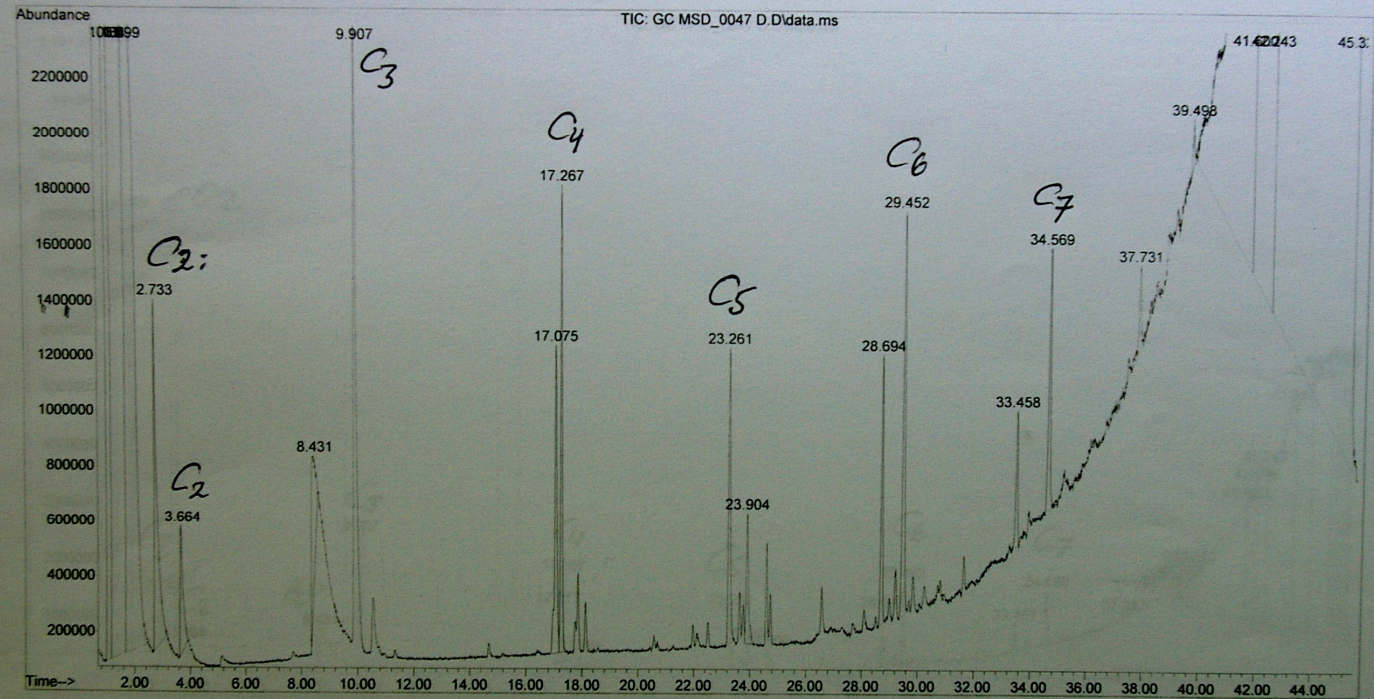


**Conclusions: - Flue gas has no negative effect on productivity  
2.5 x higher productivity (per area) compared to an open pond system!**

# Pyrolysis of microalgae

1/2

File : C:\msdchem\1\DATA\Data 5.08\GC MSD\_0047 D.D  
Operator :  
Acquired : 8 Mar 2009 15:16 using AcqMethod Tracer.M  
Instrument : GC MSD  
Sample Name: 1&4 10 ul  
Misc Info :  
Vial Number: 1



## Clients and energy projects with algae

Client	CO2-source	Location	Time frame
E.ON	Coal fired pp	D, Bremen	2004-2007
RWE	Peet fired pp	D, Niederaußem	2008 - 2013
SeeOTwo	Biomass pp	A, Vienna	2009 - 2011
Brewa	Waste material pp	D, Bremen	2010 - 2012
Vituki	Water treatment	H, Budapest	2010
Arcelor	Steel	D, Bremen	Planung 2011
Pfleiderer	MDF-Werk	D, Thüringen	Planung 2011
Cemex	Cement	D, Beckum	Planung 2011

# Astaxanthin

Status:

Production of Astaxanthin in 2010

Market:

€ 50 Mio.

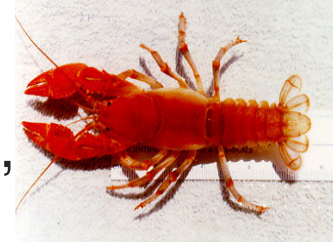
Status

EWOS, NO

Skretting, Nutreco, NI

Biomar, DK

Emsland Alleraqua, (Shrimpsfutter) D,



# Bioactive substances from microalgae

Phytolutions has a patented production system for antiviral substances

Market: > € 150 Mio

Dairy industry, cosmetic industry



# Feed

Status: algal cultures for life feed, pastes and concentrates

Market: € 150 Mio.

Ostrea Sverige Oyster production,

German Shrimps(feed)



# Oyster Production in Namibia





## Feed algae

*Nannochloropsis*

*Isochrysis*

*Tetraselmis*

*Rhodomonas*

*Thalassiosira*

*Phaeodactylum*

*Pavlova*

...

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## Biodiversity-Project – Namibia

Collect and secure algal species

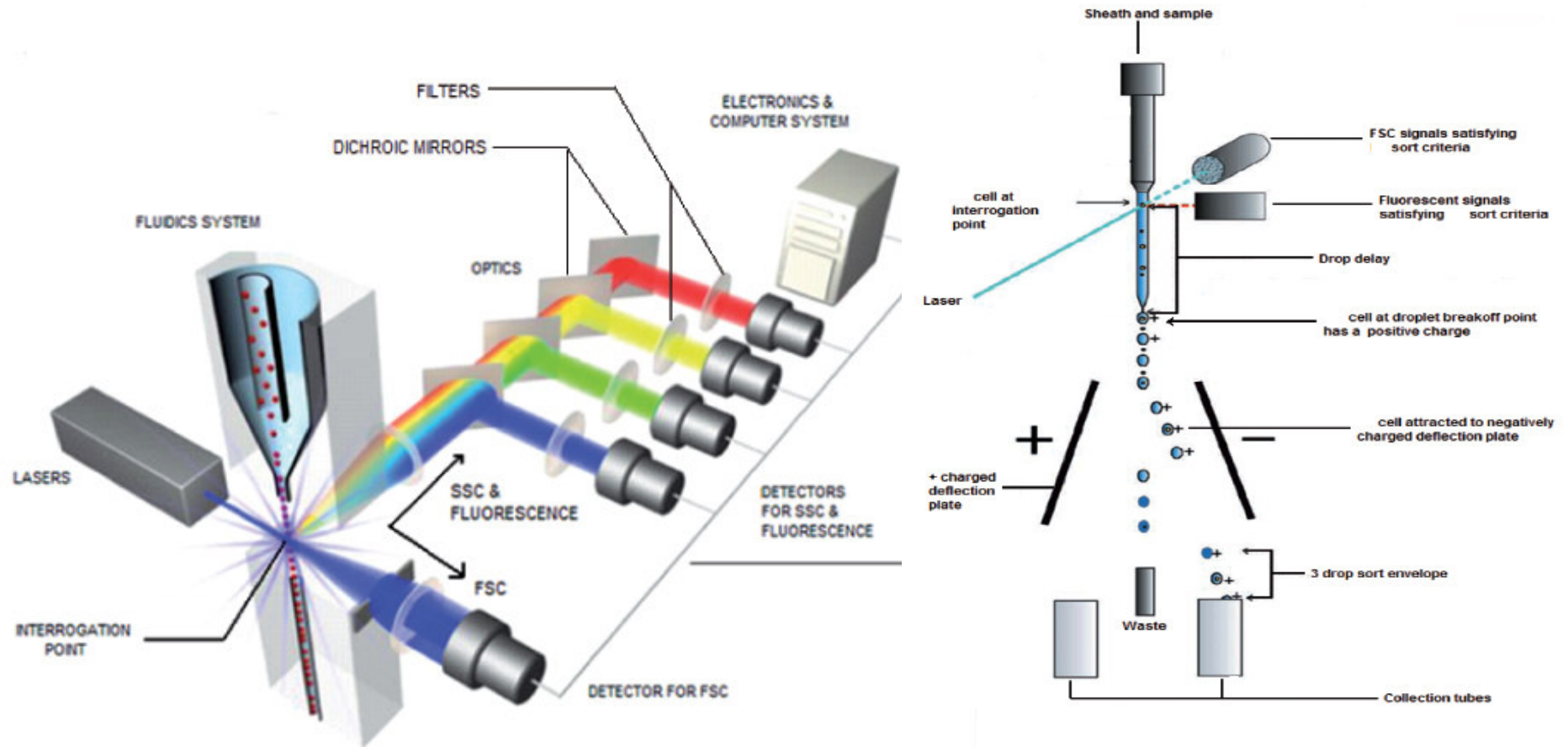
Establish a library that can be handled easily

Expand approach to other regions

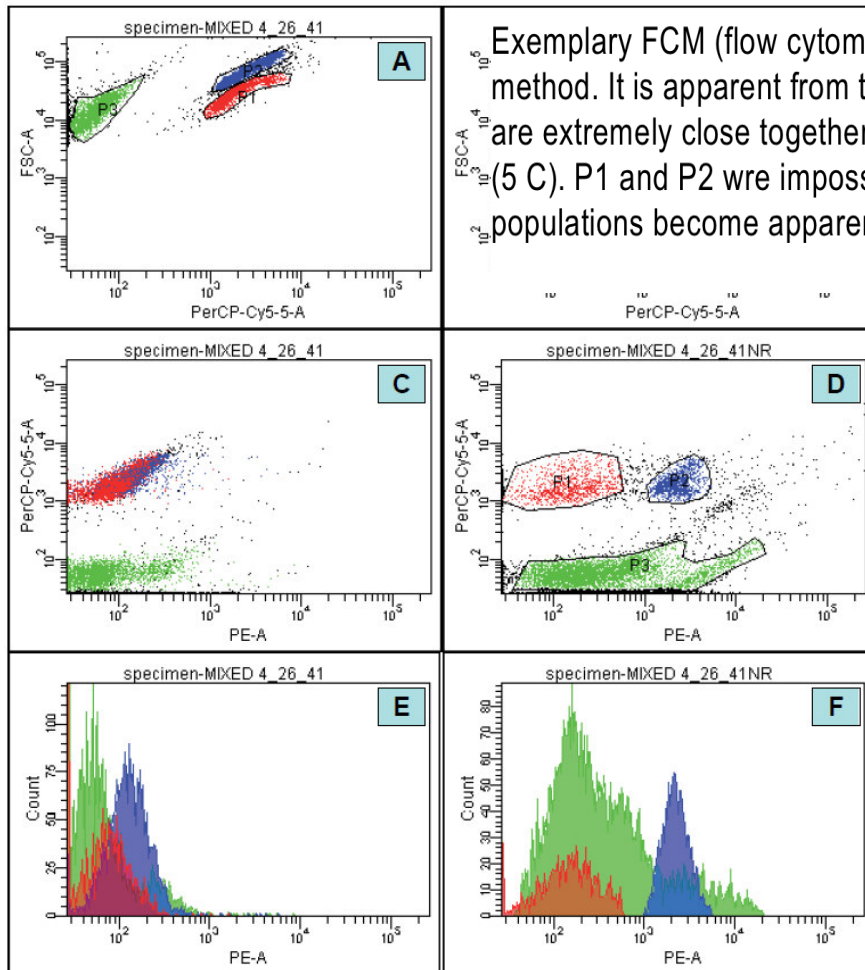
Use library to screen for high value ingredients

Sell licenses to customers, provide services

# Flow cytometry



# Flow cytometry on microalgae



Exemplary FCM (flow cytometry) data on a mixed culture of microalgae illustrates the potential of this method. It is apparent from this sample that, although distinguishable, Population 1 and 2 (P1,P2) are extremely close together, making gating and subsequent sorting of individual populations difficult (5 C). P1 and P2 were impossible to separate. After staining with Nile red however, three separate populations become apparent and are easily gated and sorted.

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## What makes a library precious ?

1. 30 % of new small molecules derived from algae and related sources
2. Screening for lipids, pigments, or antiviral-substances etc.
3. Interest of cosmetical and pharmaceutical Industry

## Future Trends and Applications

**Hepatotoxic substances/toxins lead to liver failure**  
***Use a specific antibody (CD30) to target toxin to liver cancer cells = therapeutic substance***

**Surface active or antibacterial substances from algae**  
***Modify and attach antibiotic substance = new surface „desinfektant“***  
***(food industry)***

## We do algae: from green to red...



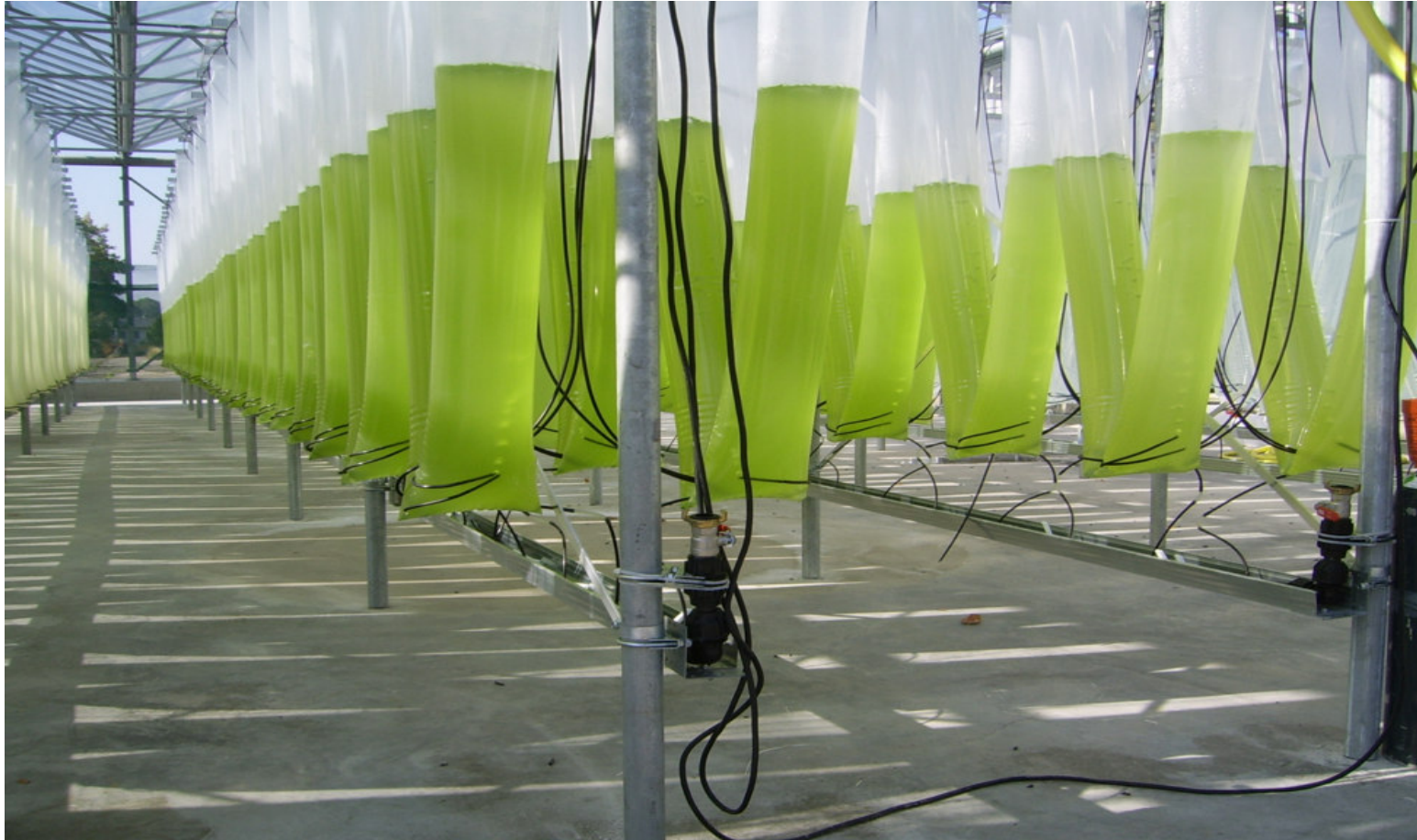
- Rhodomonas Nannochloropsis Isochrysis Thalassiosira
- and Tetraselmis, Haematococcus, Dunaliella, Scenedesmus, Chlorella, Phaeodactylum ....

...from small to large





...and larger



## In-door and out-door



## A short history: 10 years ago-flat panel bioreactors



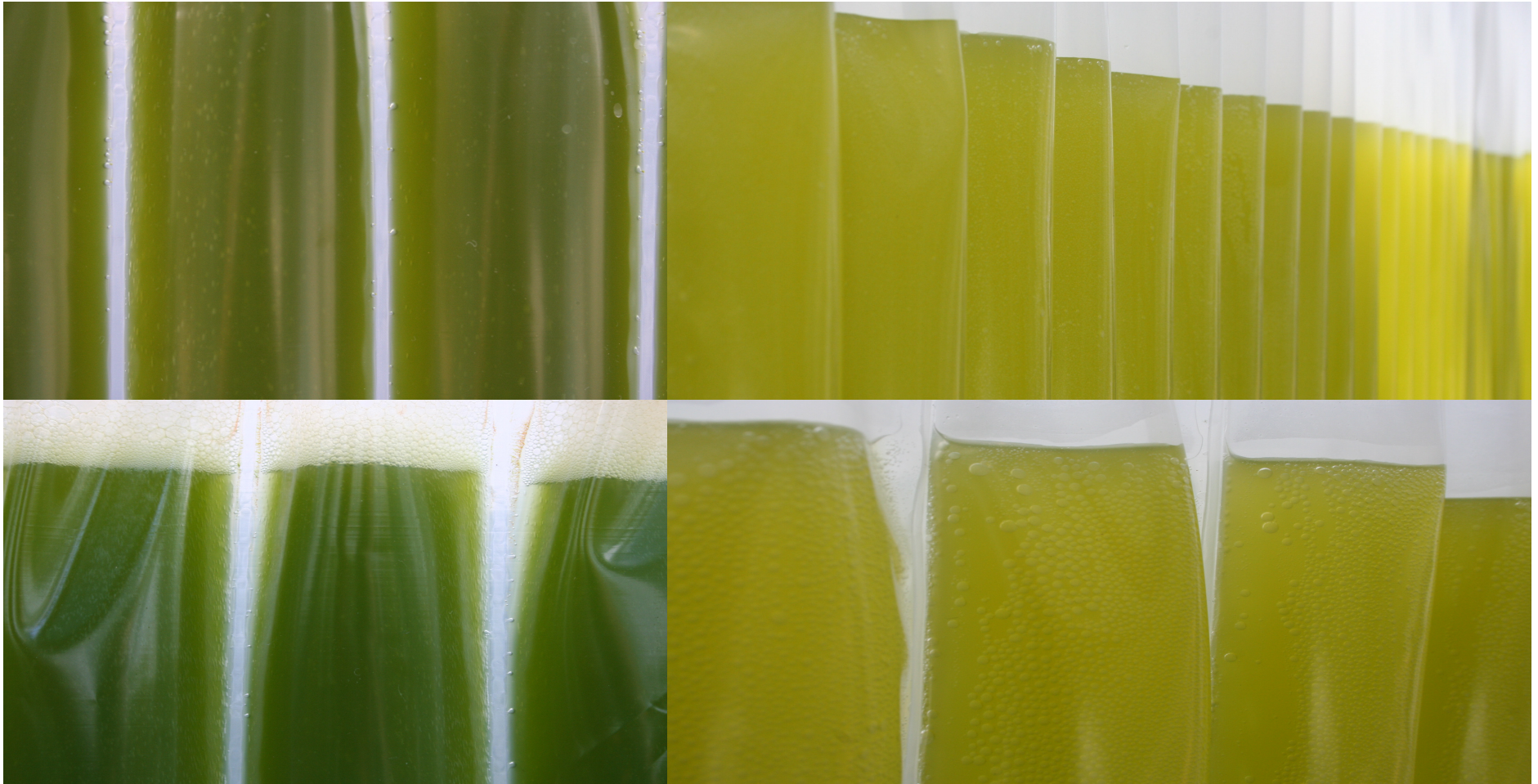
# Klötze-Modules



# phytobag system



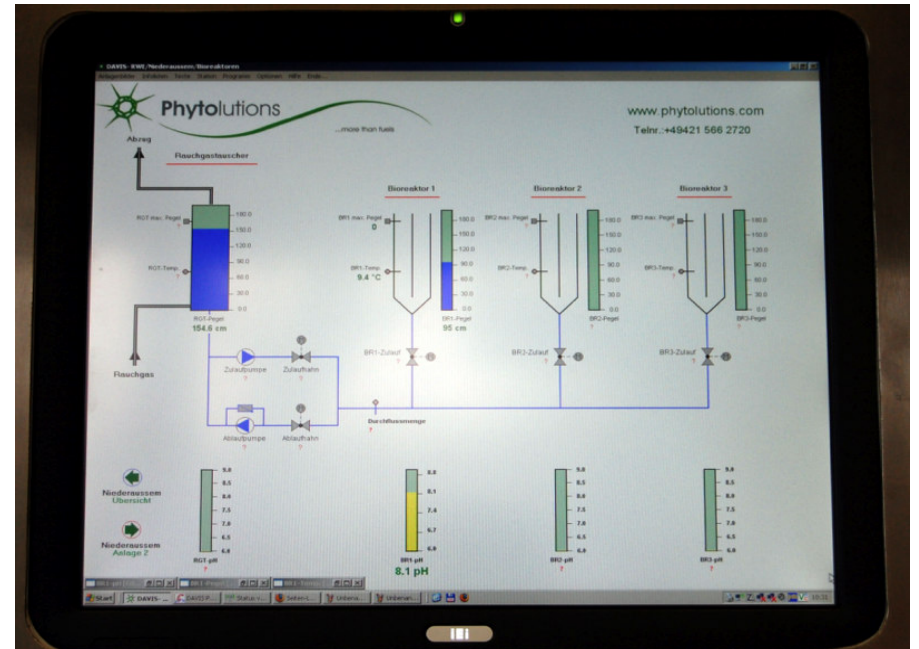
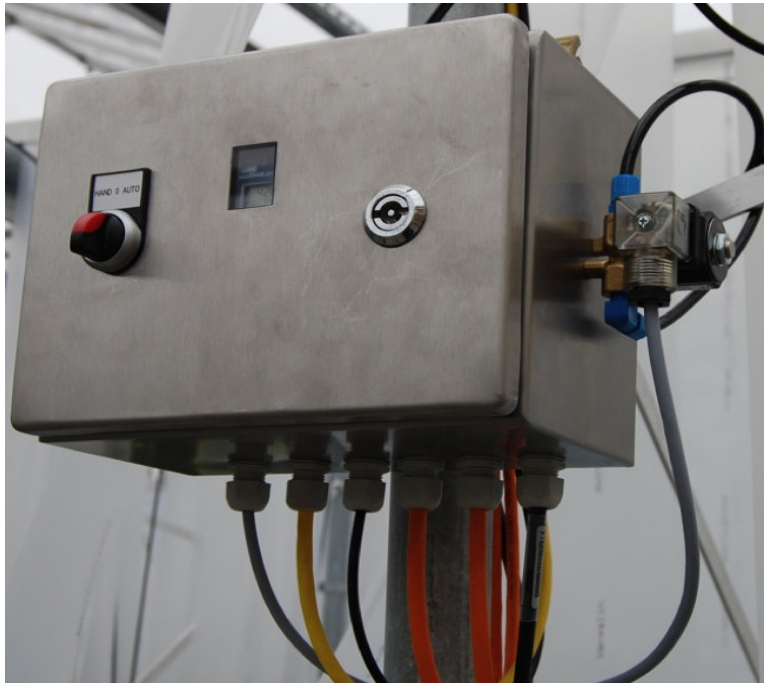
# Culturing microalgae in a phytobag



# phytoharvester



# phytocontrol unit





# Closed bioreactors

	Phytolutions	IGV	Subitec	Solix Biofuls
<b>Production system</b>	<b>Closed PBRs</b>	<b>Closed PBRs</b>	<b>Closed PBRs</b>	<b>Closed PBRs in open ponds</b>
<b>Average annual solar radiation at production sites (kWh m<sup>-2</sup>)</b>	<b>941-980</b>	<b>1061-1100 (941-980)<sup>c</sup></b>	<b>1061-1100</b>	<b>1350-1450</b>
<b>Biomass concentration (kg m<sup>-3</sup>)</b>	<b>2-4</b>	<b>3-6</b>	<b>1-7</b>	<b>1-10</b>
<b>Volumetric productivity (kg m<sup>-3</sup> d<sup>-1</sup>)</b>	<b>0.2-0.24</b>	<b>0.2-0.3 (0.12-0.22)<sup>c</sup></b>	<b>0.8-1.0</b>	<b>0-0.7</b>
<b>Areal productivity (kg m<sup>-2</sup> d<sup>-1</sup>)</b>	<b>0.022-0.027<sup>a</sup></b>	<b>0.035-0.04<sup>a</sup> (0.019-0.026)<sup>c</sup></b>	<b>0.016-0.02<sup>a</sup></b>	<b>0-0.025<sup>a</sup></b>
<b>Contamination risk</b>	<b>Low</b>	<b>Low</b>	<b>Low</b>	<b>Low</b>
<b>Investment cost (€/m<sup>-2</sup>)</b>	<b>20<sup>b</sup></b>	<b>~100</b>	<b>150<sup>b</sup></b>	<b>Not specified</b>

# Competitors

## Open Pond

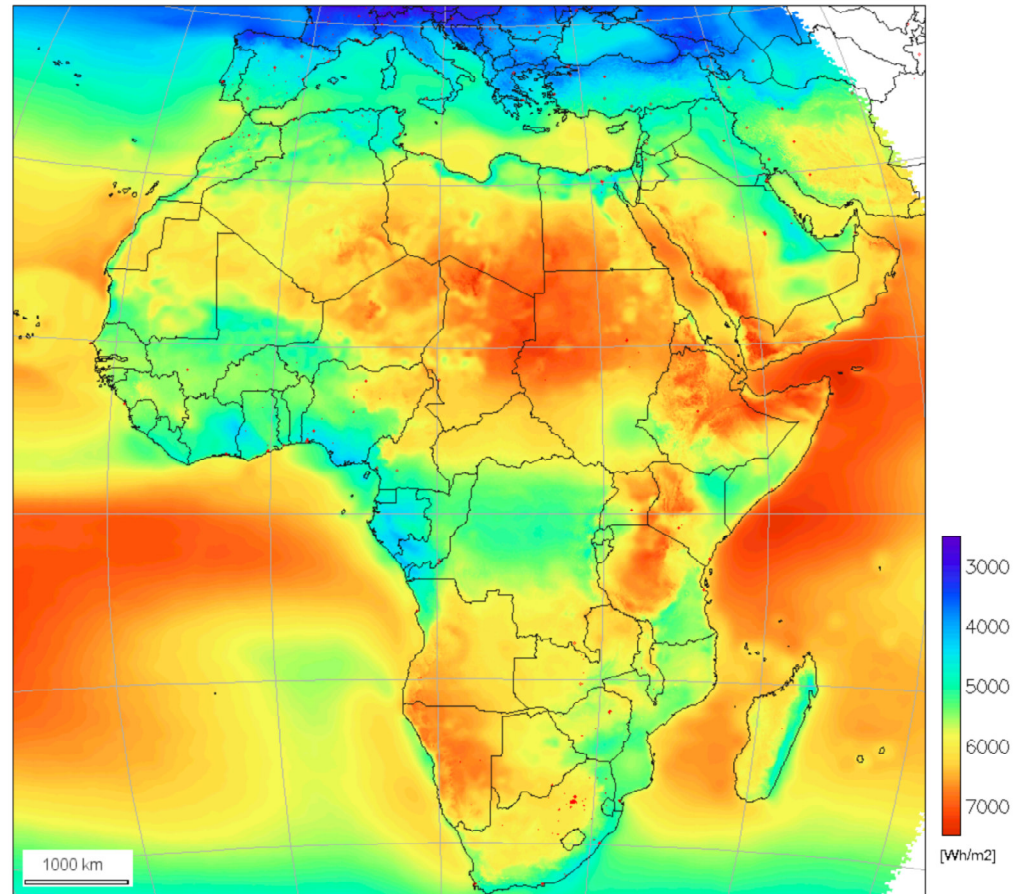
	Sapphire Energy	Seambiotic	Petroalgae	Cyanotech
Production system	Closed PBRs/ Open ponds	Open ponds	Open ponds	Open ponds
Average annual solar radiation at production sites (kWh m <sup>-2</sup> )	>1950	>1850	>1950	>1950
Biomass concentration (kg m <sup>-3</sup> )	0.14-0.5c	0.14-0.5c	0.14-0.5c	0.1-0.5c
Volumetric productivity (kg m <sup>-3</sup> d <sup>-1</sup> )	0.01-0.07c	0.01-0.18b	0.01-0.07c	0.028-0.046c
Areal productivity (kg m <sup>-2</sup> d <sup>-1</sup> )	0.01-0.02a	0.027ab	0.01-0.02a	0.01-0.02a
Contamination risk	High	High	High	High
Investment cost (€/m <sup>-2</sup> )	7-10	7-10	7-10	7-10

# Global horizontal irradiation



Global horizontal irradiation (1985-2004)  
(annual average of daily sums, Gh)

EUROPEAN COMMISSION  
DIRECTORATE GENERAL  
Joint Research Centre



PVGIS (c) European Communities 2002-2006  
Helioclim-1 (c) Ecole des Mines de Paris/ARMINES 1985-2005

<http://re.jrc.ec.europa.eu/pvgis/>

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## Summary:

We provide algal production systems and solutions

We are putting emphasis on biodiversity and collection of algae

We are looking for partners with aquaculture background and interest

Phytolutions interacts closely with Jacobs University – desire to establish an academic network

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1 ha = 0,5 – 1,0 mio. Euro

Thank you very much for your attention !

Contact: Theodor Fahrendorf  
Phytolutions GmbH  
Fon: +49 421 566272 14

[www.phytolutions.com](http://www.phytolutions.com)  
[t.fahrendorf@phytolutions.com](mailto:t.fahrendorf@phytolutions.com)



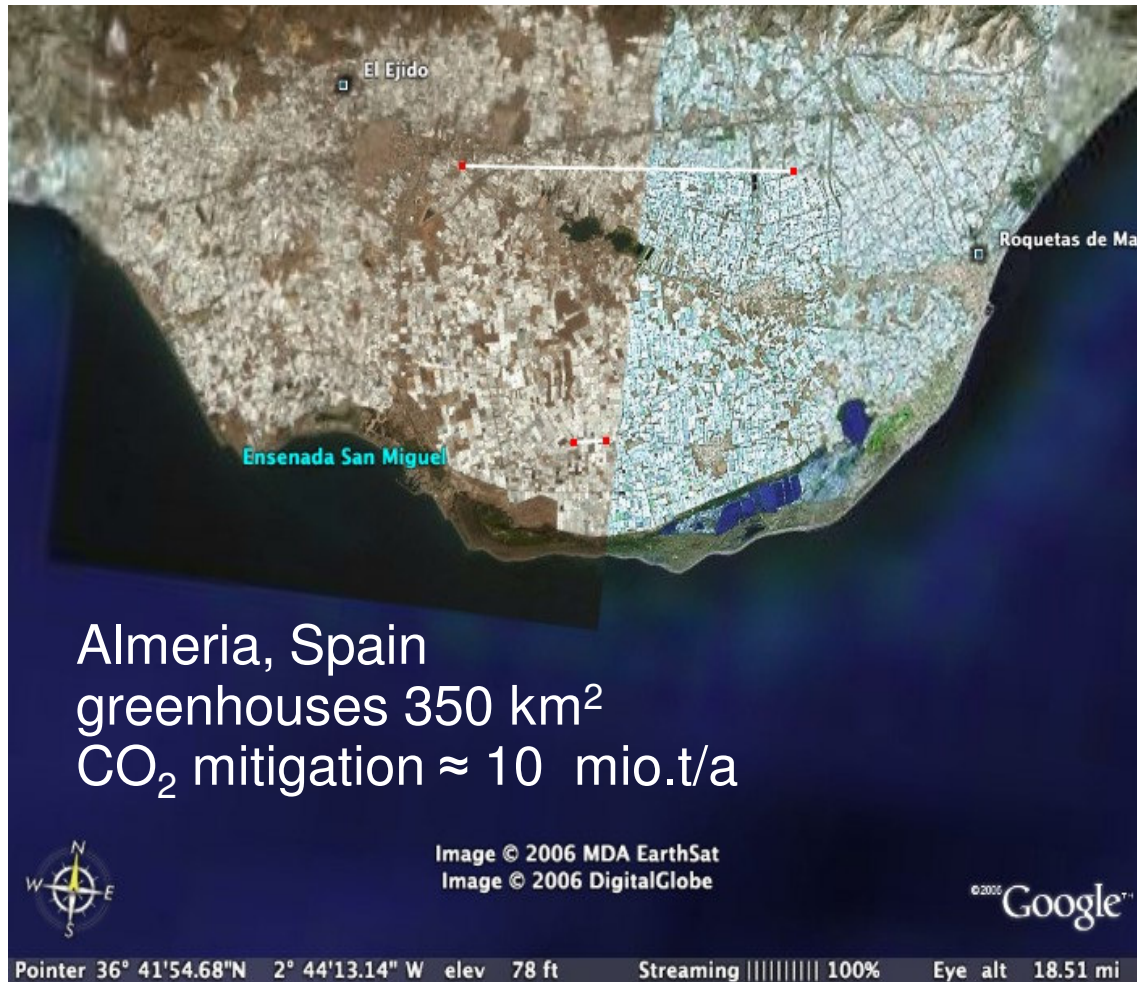
Cultivation of marine microalgae at power-plants for the production of biofuels and basic chemicals

Image © 2007 TerraMetrics

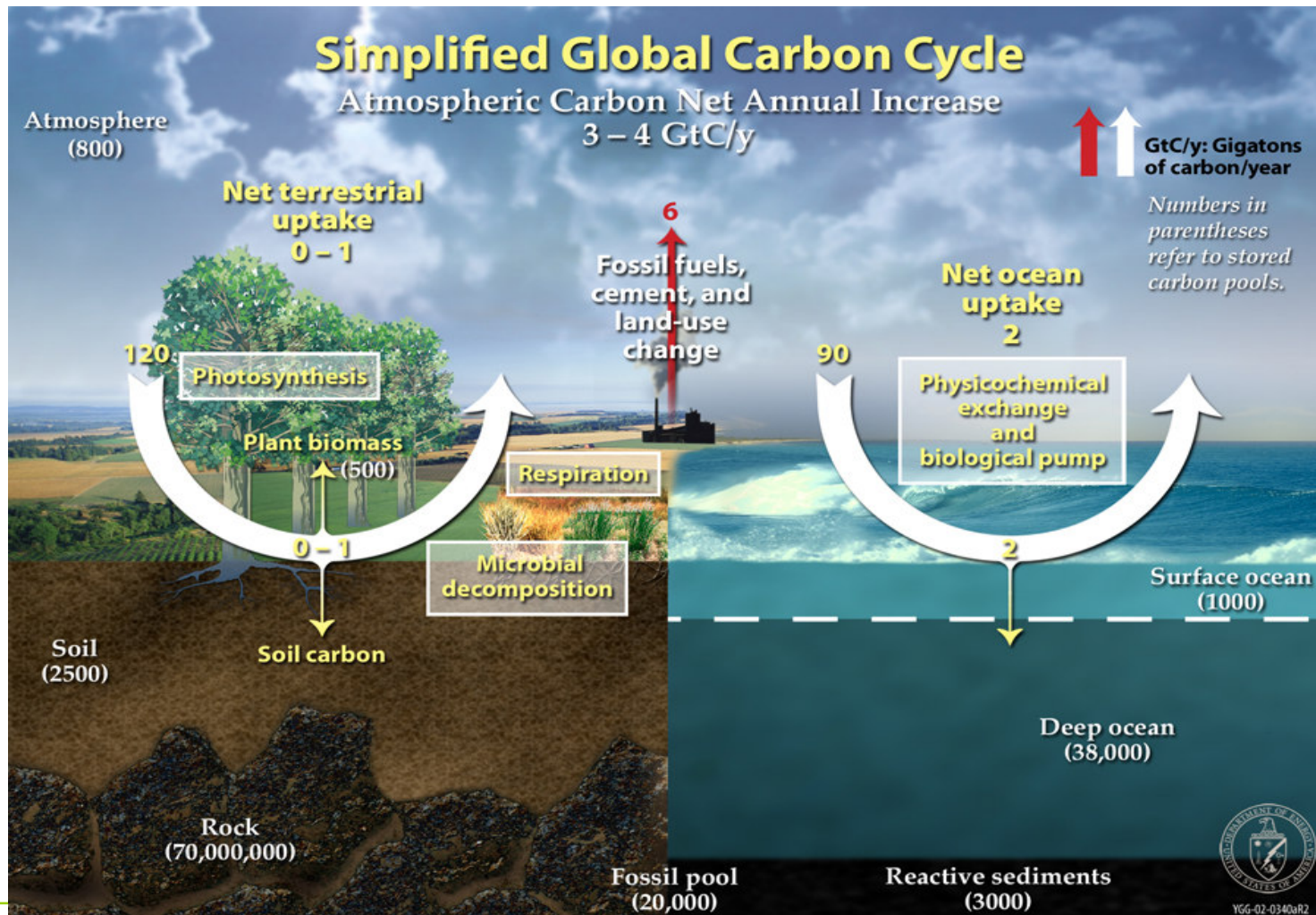
Image NASA

©2007 Google™

# What space do we need ?



# Global Carbon Cycle

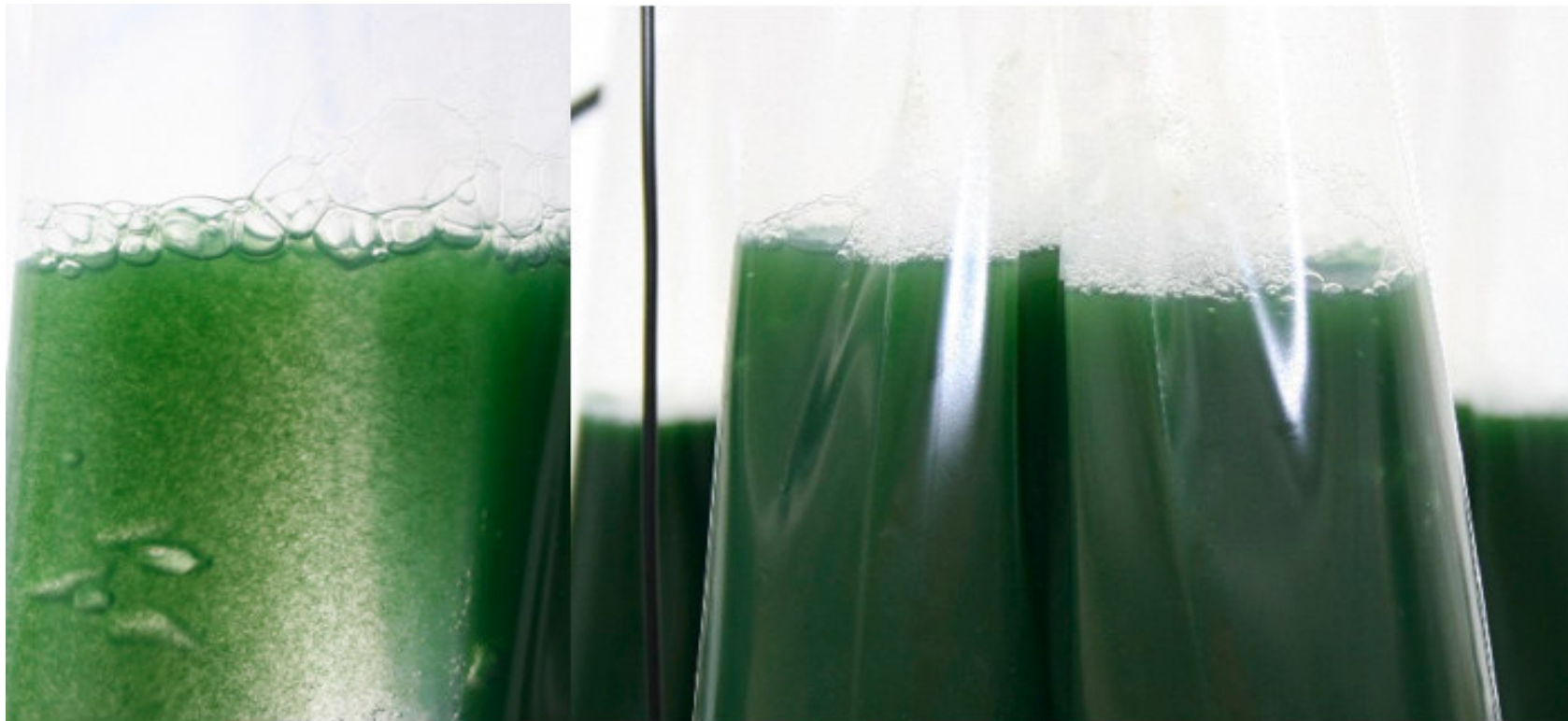




# Aquaculture



# *Spirulina platensis*



## Production of *Haematococcus pluvialis*



# Microalgae use Nutrients from Biogas plant



# Microalgae and Biogas

