European Algae Biomass

London, 25-26th April 2012

Opening Address

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Università degli Studi di Firenze, Italy

...troubled times

Will algae save us from environmental and economic disaster?

Will algae save our future?

Yes .. , says the ABO…

ALGAL BIOMASS ORGANIZATION

ALGAL BIOMASS ORGANIZATION LAUNCHES ALLABOUTALGAE.COM TO EDUCATE AND INSPIRE CONSUMERS ABOUT THE POTENTIAL OF ALGAE

Comprehensive website offers information, videos and photos about algae's potential as a feedstock for fuel, food and feed

ORLANDO, Fla. – February 6, 2012 – The Algal Biomass Organization today launched Allaboutalgae.com, a new website designed to showcase the potential of algae-based products to provide sustainable and scalable sources of food, energy and fuel. The website, developed in concert with the National Biodiesel Board provides information, videos and photos all about algae-derived products such as biodiesel, aviation fuel, biochemicals, animal feed and nutritional supplements.

Allaboutalgae.com is the first site designed to showcase algae's potential for everyone – from those just learning about algae to seasoned algae enthusiasts and entrepreneurs looking for the latest information on the industry's progress toward meeting challenges in energy security, food production and sustainability.

ALL ABOUT algae .COM

AB ALGAL BIOMASS ORGANIZATION

HOM FAQ

Products made from algae are the natural solution to the energy, food, economic, and climate challenges facing our world today. Algae have the power to simultaneously put fuels in our vehicles, recycle CO2, provide nutrition for animals and people and create jobs for millions of Americans. Algae? Naturally.

Why Algae:

National Energy Security. As an increasingly thirsty world drives demand for declining supplies of liquid transportation fuels, countries without secure access to oil will be at a disadvantage – economically, politically and militarily. And since the United States imports more than 60 percent of our liquid fuels, it is crucial to our national energy security that we develop long-term, domestic sources of transportation fuels.

Economic Security. Each year, we send about $400 billion US dollars abroad in exchange for the fuel we consume. That's almost one billion dollars a day that could be funneled back into the US economy through domestically-produced renewable fuel, helping us overcome major economic problems.

Climate Change. We must reduce our greenhouse gas emissions and protect and preserve our land, water, air and soil by developing renewable and sustainable energy sources. Liquid transportation fuels account for nearly a third of our fossil-fuel carbon emissions footprint.

Fortunately, there is a solution to these incredible challenges. It comes in the form of the Earth's oldest organisms – algae – which can help address all three of these major issues.

Fortunately, there is a solution to these challenges: algae!

Obama's Energy Plan -- Algae

By Susan Jones

February 24, 2012

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(CNSNews.com) - "The American people aren't stupid," President Obama said on Thursday -- as he insisted that drilling for more oil on U.S. territory is "not a strategy to solve our energy challenge."

President Barack Obama speaks at the University of Miami Field House in Coral Gables, Fla., Thursday, Feb. 23, 2012. (AP Photo/Susan Walsh)

The president's solution? Algae, for one.

There are no quick fixes to the nation's eneergy problem, the president said, dismissing Republican calls for more drilling as a "bumper sticker."

"We're making new investments in the development of gasoline and diesel and jet fuel that's actually made from a plant-like substance -- algae," the president said at a campaign stop in Florida. "You've got a bunch of algae out here, right? If we can figure out how to make energy out of that, we'll be doing all right."

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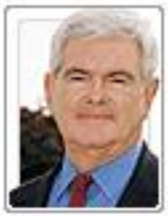

Why Obama is absurd to suggest algae

by Newt Gingrich
03/21/2012

WASHINGTON -- Capitol Hill Republicans mounted an all-out offensive against President Obama's energy initiatives Tuesday, even mocking him for an idea many of them used to like: using algae to create biofuel.

"Over the past few weeks the American people have begun to feel the painful effects of President Obama's energy policy," Senate Minority Leader Mitch McConnell declared in a Senate floor speech that ridiculed an energy plan Obama detailed last week, which included the use of biofuel sources such as algae. "As millions of Americans groaned at the rising cost of a gallon of gasoline, the president took algae as a substitute for gas. Algae as a substitute for gas," McConnell said in apparent disbelief.

This is a classic move of the Left: observe a real world problem (high gasoline prices) and propose a solution that is totally disconnected from the practical realities of the world and has little chance of success (algae).

Algae oil yield?

[Cultivating Algae for Liquid Fuel Production](http://oakhavenpc.org/cultivating_algae.htm)
(*http://oakhavenpc.org/cultivating_algae.htm*)

		Gallons of Oil per Acre per Year
Corn	→	20 - 30
Soybeans	→	50
Sunflower	→	110
Rapeseed	→	130
Oil Palm	→	600
Microalgae	→	5.000-25.000

↓

50.000-250.000 L oil per ha and year

Let's listen to the voice of SCIENCE!

Singh & Olsen, 2011

Perform their LCA of algal biofuels

ARTICLE IN PRESS

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journal homepage: www.elsevier.com/locate/apenergy

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AppliedEnergy

A critical review of biochemical conversion, sustainability and life cycle assessment of algal biofuels

Anoop Singh *, Stig Irving Olsen

Quantitative Sustainability Assessment, Department of Management Engineering, Technical University of Denmark, Lyngby, Denmark

- Assuming an oil concentration of 42% and the 365 t ha^{-1} $year^{-1}$ productivity achievable in AlgaeLink reactors, algae can produce > 150 t oil ha^{-1} $year^{-1}$ (i.e. 250 times than traditional crops)
- Open ponds, with 300 t biomass ha^{-1} $year^{-1}$ and 20-30% oil, give an oil output of 60 to 90 t ha^{-1} $year^{-1}$, which is only (*sic*) from 100 to 150 times greater than oil seed crops.

Perspective

Biofpr
Biofuels Bioproducts & Biorefining

Why microalgal biofuels won't save the internal combustion machine

Jan B. van Beilen, University of Lausanne, Switzerland

Received August 24, 2009; revised version received September 24, 2009; accepted September 25, 2009
Published online December 1, 2009 in Wiley InterScience (www.interscience.wiley.com); DOI: 10.1002/bbb.193;
***Biofuels, Bioprod. Bioref.* 4:41–52 (2010)**

Abstract: Proponents of microalgae biofuel technologies often claim that the world demand of liquid fuels, about 5 trillion liters per year, could be supplied by microalgae cultivated on only a few tens of millions of hectares. This perspective reviews this subject and points out that such projections are greatly exaggerated, because (1) the productivities achieved in large-scale commercial microalgae production systems, operated year-round, do not surpass those of irrigated tropical crops; (2) cultivating, harvesting and processing microalgae solely for the production of biofuels is simply too expensive using current or prospective technology; and (3) currently available (limited) data suggest that the energy balance of algal biofuels is very poor. Thus, microalgal biofuels are no panacea for depleting oil or global warming, and are unlikely to save the internal combustion machine.

J Appl Phycol (2009) 21:509–517
DOI 10.1007/s10811-009-9446-5

Let's listen to the voice of SCIENCE!

Biofuels, facts, fantasy, and feasibility

David Alan Walker

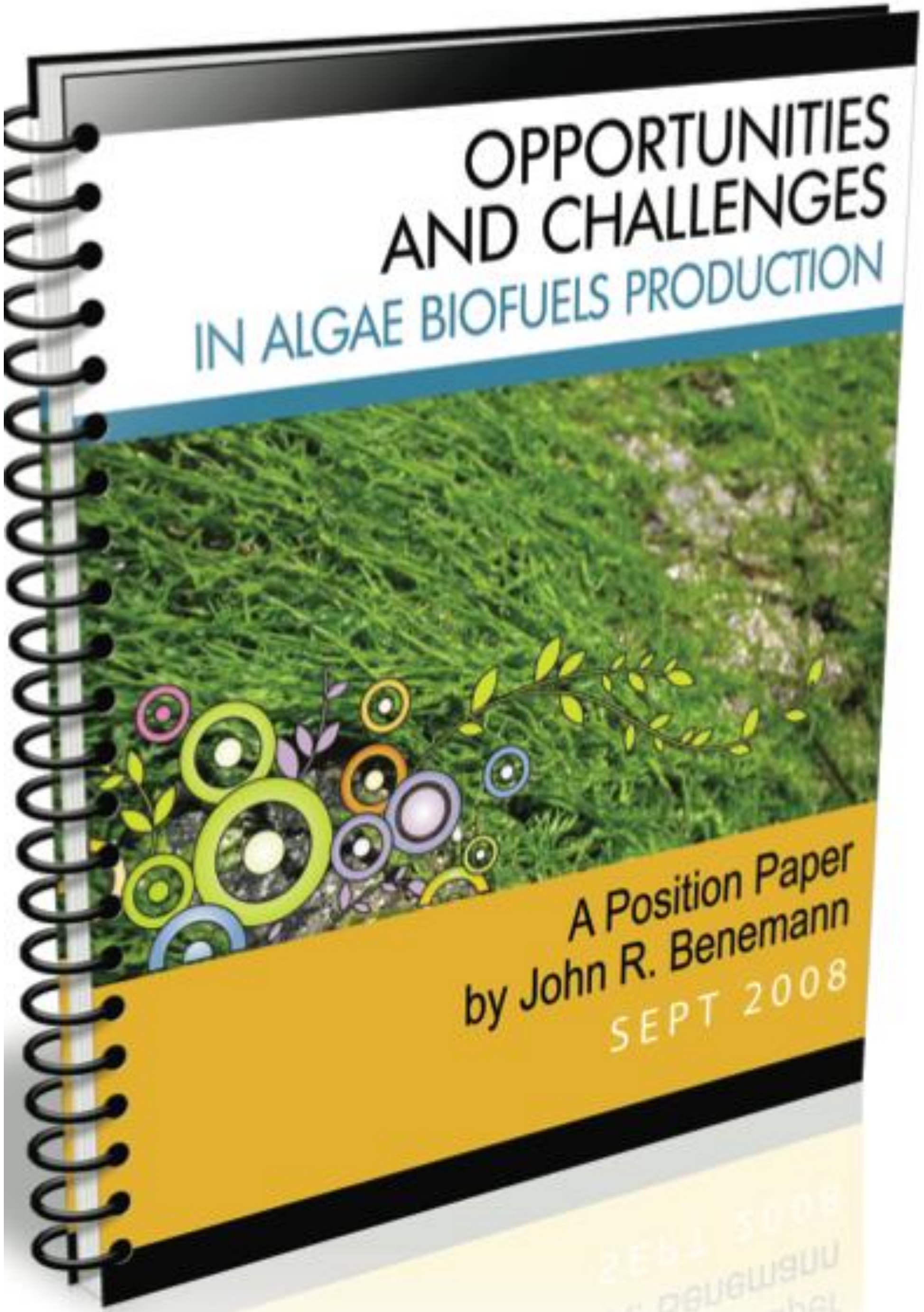
It is frequently claimed that algae are more productive than higher plants.

On the contrary there is much experience which shows that algae are not more, but less productive.

Algae productivities measure/claimed in different cultivation systems

Company/University	Reactor type and volume/surface	Reactor cost	Biomass productivity (t ha^{-1} y^{-1})	Oil productivity (t ha^{-1} y^{-1})	PE (% total solar radiation)	Microalgal species
FLAT PHOTOBIOREACTOR						
Subitec GmbH (Germany)	vertical flat panel (FPA), 180 L	38 € m^{-2} occupied area	120[a]	-	7.28	-
FLEXIBLE FILM PANELS						
University of Florence/F&M Srl (Italy)	disposable panel (GWP- I), 800 L	50 € m^{-2} reactor	40[b,c]	20[b,c,e]	1.53 1.53	*Nannochloropsis*
			50[b,c]	-	3.14	*Tetraselmis suecica*
	disposable panel (GWP- II), 350 L	25 € m^{-2} reactor	54[b,c]		2.21	*Tetraselmis suecica*
Archimede Ricerche Srl (Italy)	disposable panel (GWP- I), 40,000 L		20[b,c]	-	0.97	*Nannochloropsis, Isochrysis, Tetraselmis*
Vertigro Algae Technologies LLC (Texas, USA)	vertical flexible film panel		600[a]	275[a]	18.33 (biomass) 15.63 (oil)	-
Proviron Holding NV (Belgium)	vertical flexible film panel (ProviAPT)	10 € m^{-2} bag	-	-	-	-
Solix Biosystems Inc. (Colorado, USA)	vertical flexible film panel (AGS-4000)	3000 € m^{-2} basin (complete)	-	27[a]	1.68	-
Phytolutions (Germany)	vertical flexible film panel (Phytobag), 25,000 L	15 € m^{-2} reactor	80-120[a]	-	5.22-7.84	-
Photon8, Inc. (Texas, USA)	horizontal flexible film panel (Parallel Film Reactor)	<10 US$ m^{-2}	182[b]	51[b]	5.87 (biomass) 3.06 (oil)	-
HYBRID SYSTEMS						
Diversified Energy Corp. (Arizona, USA)	trough system (Simgae™)	5 US$ m^{-2}	50[a]	10-15[a]	1.41 (biomass) 0.53-0.80 (oil)	-
Phycobiosciences, Inc. (Arizona, USA)	trough system (Super Trough), 133,000 L	6.2-12.3 US$ m^{-2} reactor	-	-	-	-
MBD Energy Ltd (Australia)	horizontal bag (BAGS)	-	-	26[a]	1.88	-
Algenol Biofuels, Inc (Florida, USA)	horizontal bag, 4,500 L	-	-	44[a] (ethanol)	1.91	-
AlgAmerica LLc (Pennsylvania, USA)	horizontal flexible film panel, 2,600 L	30 US$ m^{-2}	-	-	-	-

Company/University	Reactor type and volume/surface	Reactor cost	Biomass productivity ($t\ ha^{-1}\ y^{-1}$)	Oil productivity ($t\ ha^{-1}\ y^{-1}$)	PE (% total solar radiation)	Microalgal species
OPEN SYSTEMS						
University of Florence (Italy)	advanced raceway pond, 500 m^2 (25 m^3)	-	-	10[a]	0.81	-
Institute of Microbiology, Academy of Sciences (Czech Republic)	inclined pond, 700 m^2 (Trebon); 100 m^2 (Kalamata)	-	34[b] 77[b]	-	2.88 (Trebon) 2.22 (Kalamata)	*Chlorella*
VERTICAL COLUMNS						
AlgAmerica LLc (Pennsylvania, USA)	column, 400 L	1,080 US$ unit	-	-	-	-
University of Florence (Italy)	annular column, 120 L	1,000 € unit 400 € m^{-2} IS (5 m^2) 5000 € m^{-2} occupied area (0.2 m^2)	73[b,c]	-	3.16	*Tetraselmis suecica*
Enalg SpA (Italy)	annular column		10,000[a]		434	-
Bio Fuel Systems (BFS) S.L (Spain)	annular column	-	-	250	16.36	-
TUBULAR SERPENTINE PHOTOBIOREACTOR						
University of Almeria (Spain)	horizontal serpentine, 4,000 L	-	-	16[b]	0.93	*Scenedesmus almeriensis*
AlgaeLink NV (The Netherlands)	horizontal serpentine, 97 m^3	160 € m^{-2} oc[illegible]	160[a] (The Netherlands) 300[a] (Australia)	-	9.12 6.84	*Tetraselmis*
Institute of Microbiology, Academy of Sciences (Czech Republic)	horizontal serpentine, 65 L	1,000 € m^{-2} 131 € m^{-2} occupied area (6.88 m^2)	33[b,d]	-		*Arthrospira*
University of Almeria (Spain)	vertical serpentine, 2,800 L	-	73[b]	-	2.28	*Nannochloropsis*
TUBULAR MANIFOLD PHOTOBIOREACTOR						
GFT Corp. (Massacchussets, USA)	triangular airlift reactor	-	-	80[a]	6.33	-
	3D Matrix	-	358[b]		14.58	-
Mycrophyt sas (France)	vertical serpentine, 5,400 L	-	35[b]	-	1.33	*Neochloris oleoabundans*



COST

Currently the plant gate production cost for the lowest cost algal biomass produced is that of Spirulina, which can be estimated at about $ 5,000 per metric ton.

J. Benemann (2008)

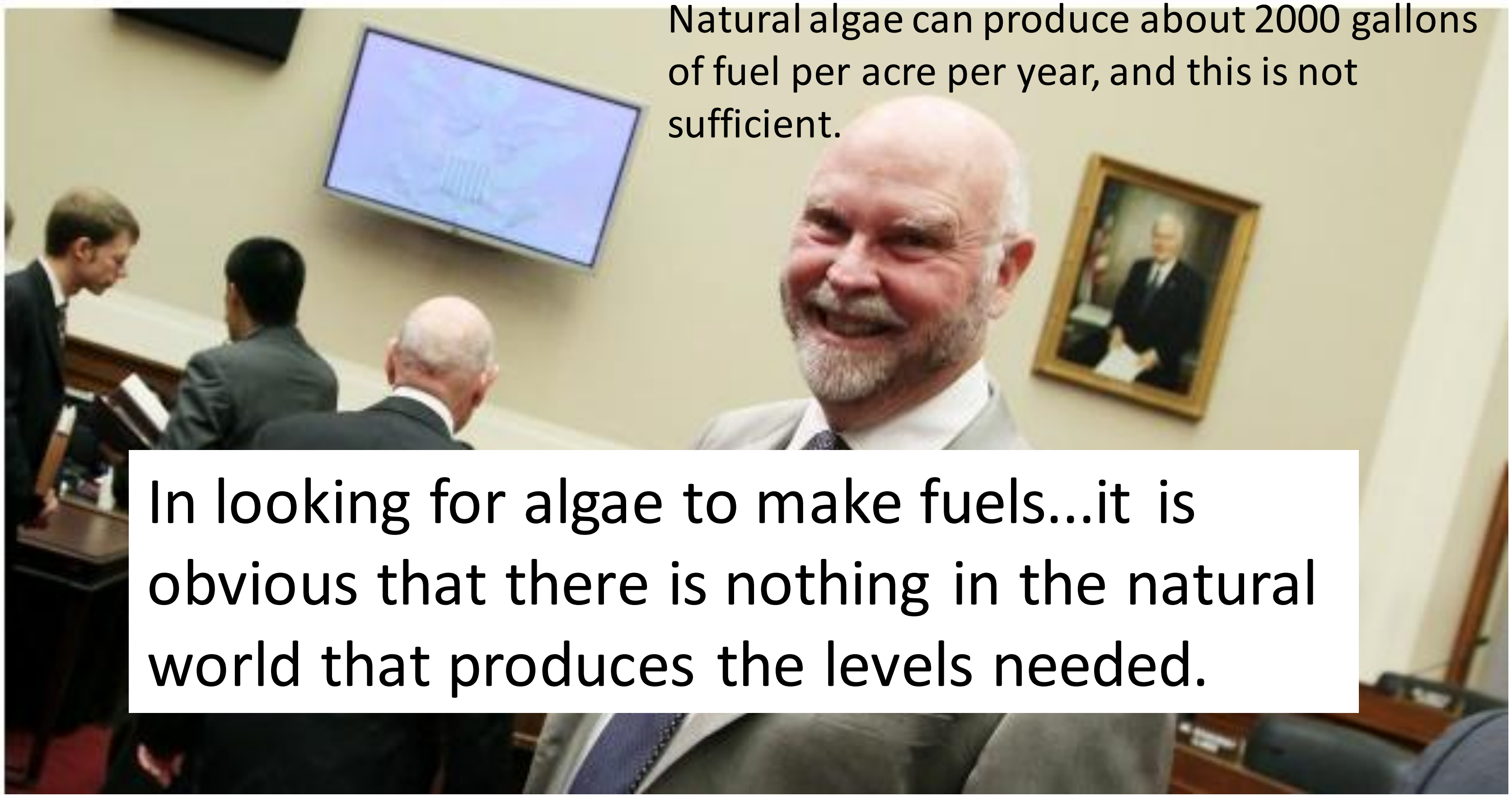
PRODUCTIVITY

Assuming a currently achievable biomass yield of about 50 mt/ha-yr with a 25% oil content, the oil yield would be about 14,000 litres of oil per hectare per year. Given the capital and operating costs, a tripling in outputs of what is currently possible is required..

J. Benemann (2008)

Trouble in the algae lab for Craig Venter and Exxon

Posted By Steve LeVine ■ Friday, October 21, 2011 - 1:20 AM ■ [+] Share



Natural algae can produce about 2000 gallons of fuel per acre per year, and this is not sufficient.

In looking for algae to make fuels...it is obvious that there is nothing in the natural world that produces the levels needed.

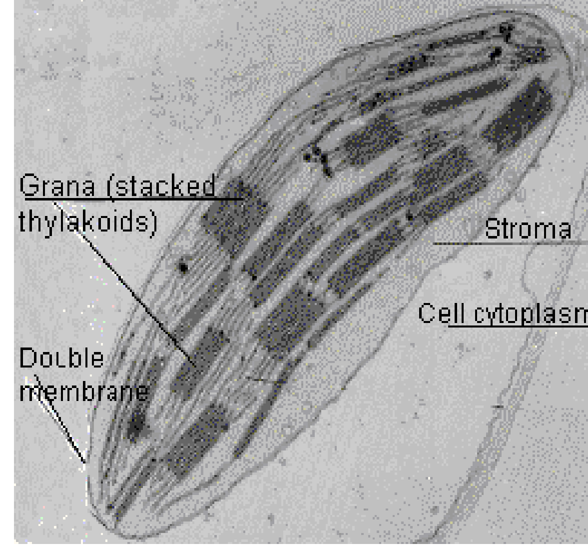
Craig Venter: Algae fuel that can replace oil will not come from nature

By Katie Fehrenbacher Oct. 23, 2011, 8:20pm PT 2 Comments

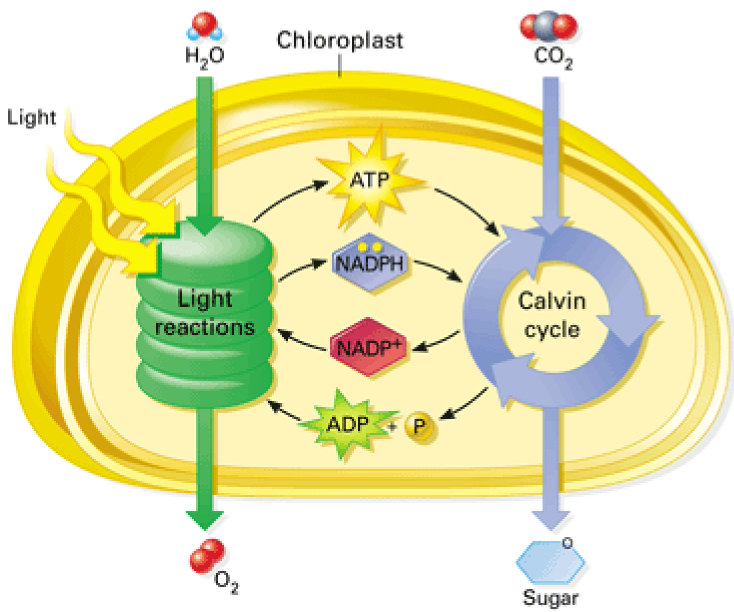
ALGAE PHOTOSYNTHESIS

There are limitations…

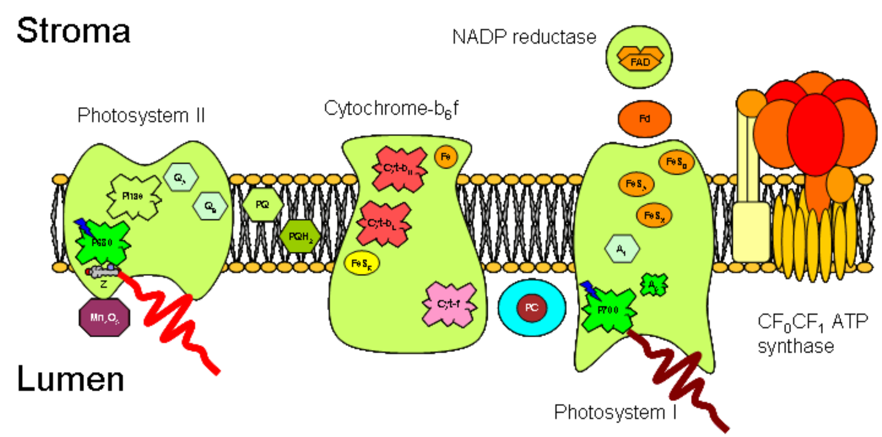
The algal chloroplast and photosynthetic efficiency



www.texaseducator.com/…/myourses/chloro3.gif



1mkturin.wordpress.com



faculty.ksu.edu.sa/mmi/Pictures%20Library

ALGAE PHOTOSYNTHESIS

The numbers (efficiencies) :

Total solar radiation (TSR) at sea level	→ 100%
PAR (suitable radiation)	→ 45%
Maximum photosynthetic efficiency (PE) on PAR	→ 27%
Maximum (theoretical) PE on TSR	→ 12%
Maximum PE under optimal conditions outdoors	→ 5%
Maximum PE under real conditions	→ 2.5%
Actual best average in industrial plants	→ 1.5%

With 17.4 MJ m^{-2} = 13 g m^{-2} d^{-1} ≈ 50 t ha^{-1} $year^{-1}$

Mass culture of algae for energy farming in coastal deserts - Calabria, Italy, 1979-1983

Balloni W., Florenzano G., Materassi R., Tredici M. R., Soeder C.J. and Wagener K. (1982)

Board mixed ponds

Productivity during a continuous cultivation period of 18 months

52 t ha^{-1} $year^{-1}$

With the marine microalga *Tetraselmis*

The GREEN WALL PANEL

Developed at Florence University and commercialized by **Fotosintetica &Microbiologica Srl**

Necton S.A.
Olhão -Portugal

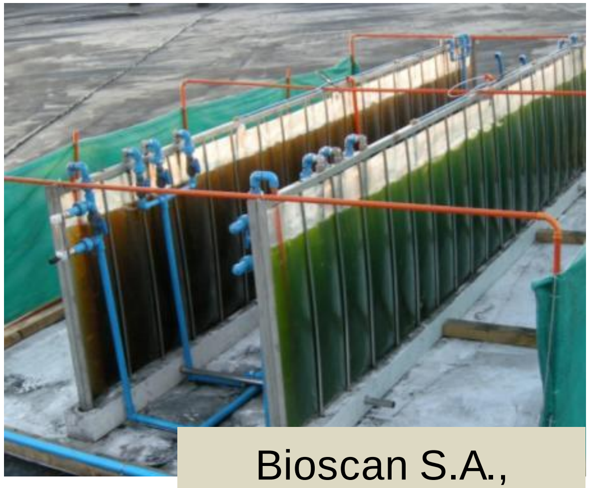
Archimede Ricerche S.r.l.
Imperia, Italy

ENI S.p.A
Gela (CL) -
Italy

Enel S.pA.
Brindisi, Italy

Bioscan S.A.,
Antofagasta, Chile

GWP –



Bioscan S.A.,
Antofagasta, Chile

Extrapolated productivity
(Southern Italy)

60-70 t ha^{-1} year

C.R.E.A.R. CENTRO RICERCA ENERGIE ALTERNATIVE E RINNOVABILI

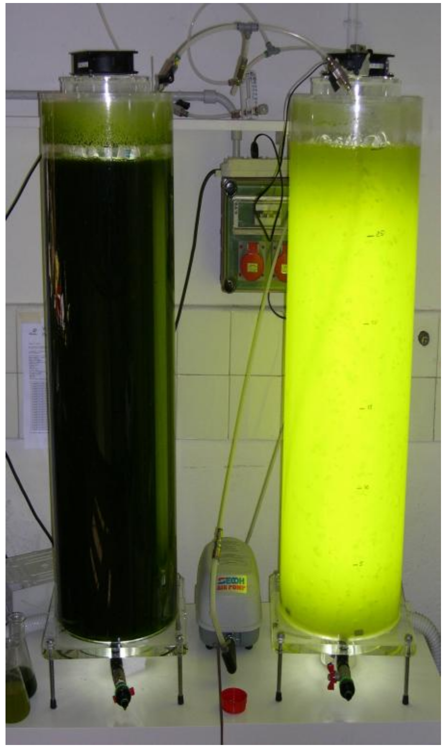
F&M Fotosintetica & Microbiologica S.r.l.

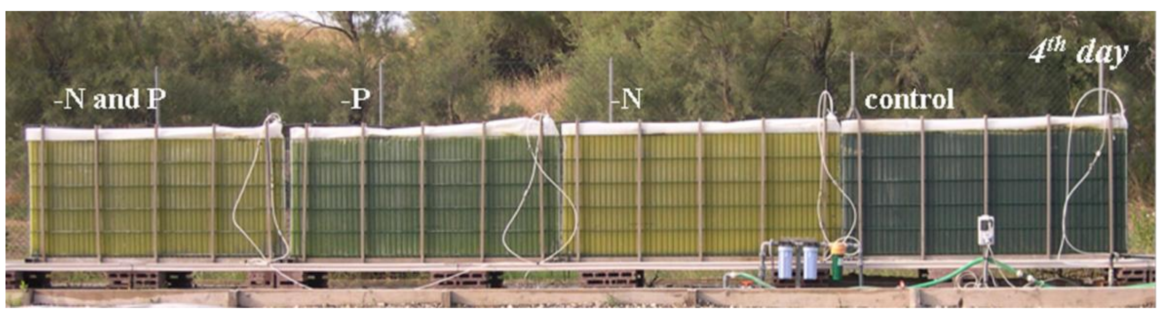
SSOG

Università degli Studi di Firenze

Dipartimento di Biotecnologie Agrarie

MAMBO project: algae oil production in different cultivation systems

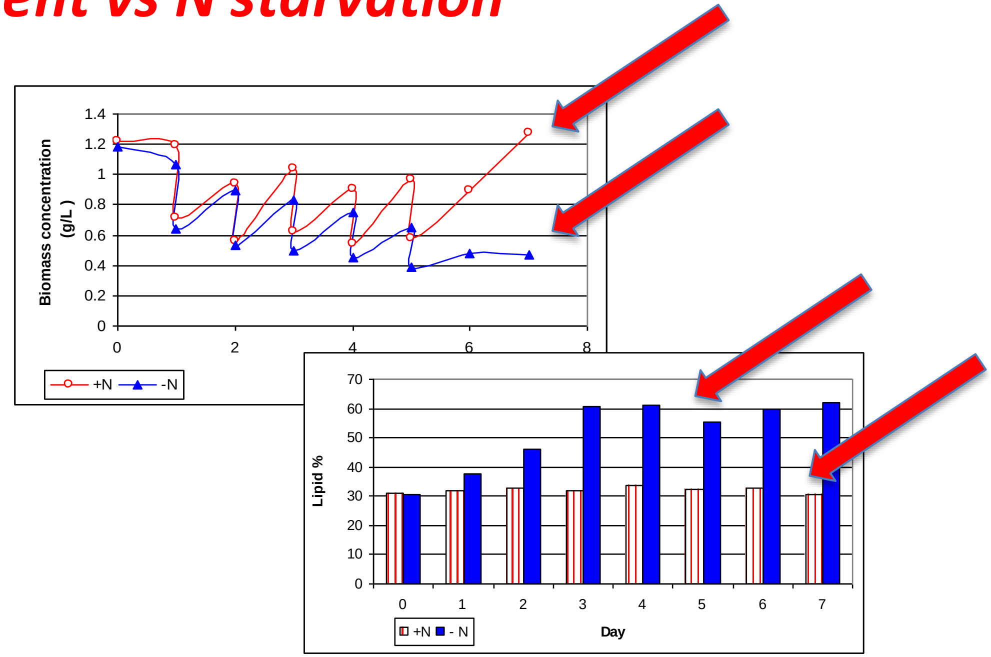


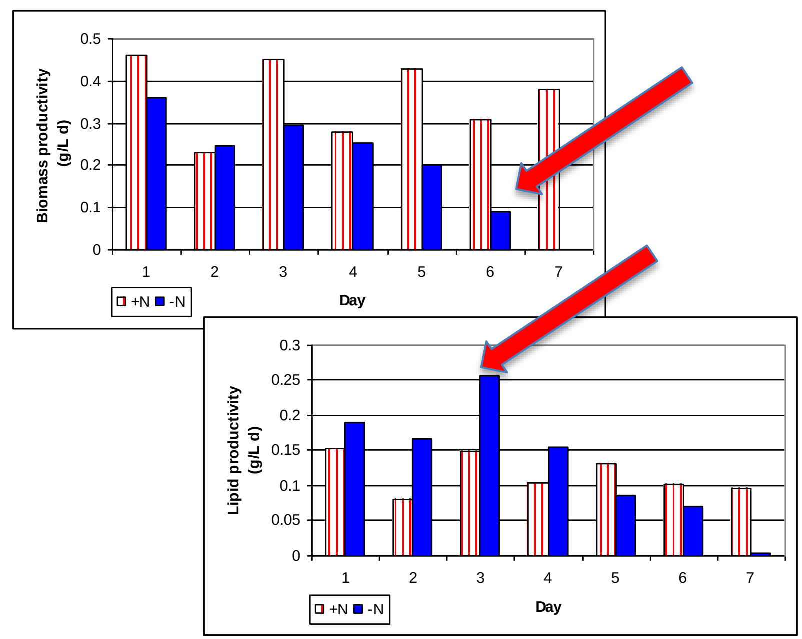


I Experiment
Rosignano - Livorno

N sufficient vs N starvation

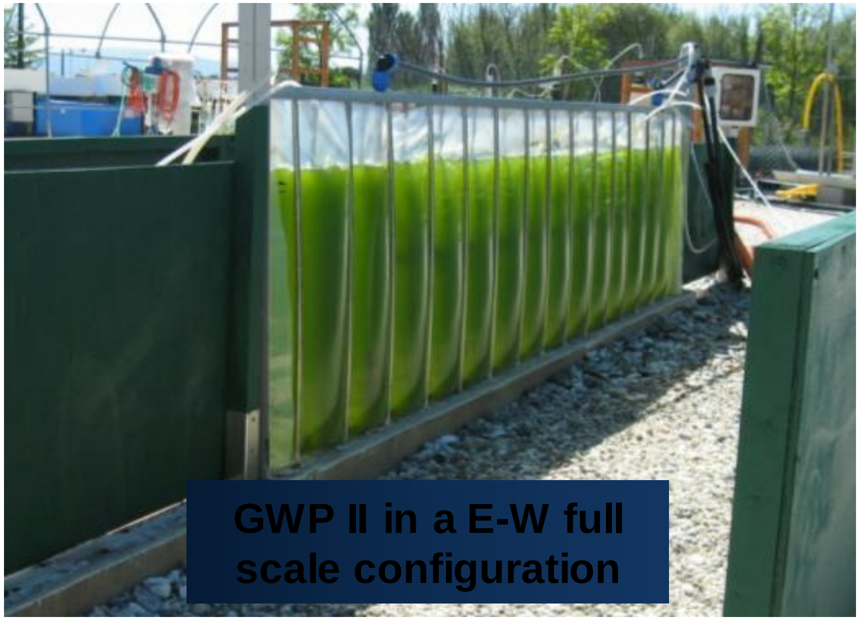
Experimental period: July 2006
Location: Rosignano (LI)
Starvation: - Nitrogen
Culture system: GWP 110 L
Dilution rate: 40% (daily)
Light: Natural
Light path: 4.4 cm
Orientation: S-W N-E
Average irradiance: 15. 7 MJ m^{-2} d^{-1}
Average irradiance on the reactor:
Average temperature (Max - Min): 30.5°C- 25.8°C





Oil production by *Nannochloropsis* under nitrogen starvation

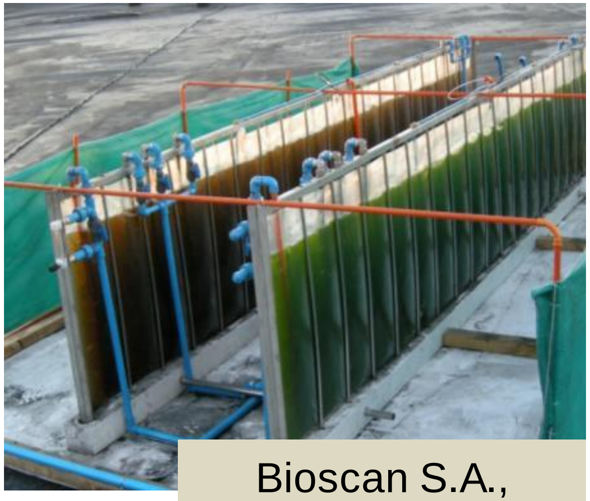
5-9 g oil m^{-2} d^{-1}



4-5 g oil m^{-2} d^{-1}

- 13 t oil ha^{-1} $year^{-1}$ in Tuscany
- 18 t oil ha^{-1} $year^{-1}$ in Tunisia

GWP – an economic and energy analysis



Bioscan S.A., Antofagasta, Chile

Production cost of *Nannochloropsis* and *Tetraselmis* biomass (Bassi & Tredici, 2008)

- 400 ha
- 360 days
- Solar radiation 15 MJ m^{-2} d^{-1}
- 20 g m^{-2} d^{-1}

Tabella 9 - Totale Costi Operativi: 400 ha ponds

	Costi Operativi IPOTESI 1 € ha^{-1}	Costi Operativi IPOTESI 2 € ha^{-1}	Costi Operativi IPOTESI 2 € ha^{-1}
Energia			
a) Rimescolamento	1.080	1.080	1.080
b) Carico mezzo, pompaggio nutrienti, reintegro evaporazione.	1000	1000	1000
c) Distribuzione flue gas o CO_2	360	360	270
d)Sedimentazione e flocculazione	70	70	70
e) Centrifugazione	444	444	444
f) Costruzioni	100	100	100
Materie Prime			
a) Nutrienti	0	36.202	36.202
b) Flue-gas o CO_2	0	0	43.200
c) Flocculante	1.020	1.020	1.020
d) Acqua mare	367	367	367
e) Lavoro	7.400	7.400	7.400
Costi esercizio	**11.841**	**48.050**	**91.202**
m) Spese generali (15% costi esercizio)	1776	7.207	13.680
n) Manutenzione; Tasse; Interessi (5% Subtotale dei costi capitale)	10.800	10.800	10.800
Costi Operativi	**24417**	**66.057**	**115.682**

Tabella 5 - Totale Costi Capitali ed ammortamento per un impianto di 400 ha di vasche.

	Costi Capitali (€ ha^{-1})
a) Preparazione terreno	24.000
b) Geomembrana PVC	105.000
c) Posa in opera geomembrana	50.000
d) Sistema di filtrazione	5.097
e) paddle wheels	6.233
f) Sump e diffusori	2.645
g) Sistema distribuzione CO_2	400
h) Fornitura e distribuzione acqua	7.692
i) Sistema distribuzione nutrienti	1.128
l) Sedimentatore	900
m) Centrifughe	9.750
n) Costruzioni e viabilità	2.625
o) Rete elettrica	400
Subtotale	**216.000**
l) Ingegneria (10% subtotale costi capitale)	21.600
m) Contingencies (10% subtotale)	21.600
COSTI CAPITALI TOTALI	**259.200**
Durata impianto (anni)	15
Ammortamento annuale	**17.280**

Tabella 10 - Costo di produzione della biomassa in impianto a vasche da 400 ha

	Ipotesi 1 (flue- gas + wastewater)	Ipotesi 2 (flue- gas+nutrienti)	Ipotesi 3 (CO2+nutrienti)
	24.417	66.057	115.682
Costi Operativi (€ ha^{-1} $anno^{-1}$)	23.956	79.574	145.631
	24.094	93.617	176.187
Ammortamento costi capitali (€ ha^{-1} $anno^{-1}$)	17.280	17.280	17.280
TOTALE	**41.700**	**64.700**	**114.330**
Produzione biomassa (Kg ha^{-1} $anno^{-1}$)	45.000	45.000	45.00
Produzione biomassa (Kg ha^{-1} $anno^{-1}$)	60.000	60.000	60.000
Produzione biomassa (Kg ha^{-1} $anno^{-1}$)	75.000	75.000	75.000
	0.92	**1.84**	**2.94**
Costo di produzione biomassa (€ Kg^{-1})	**0.68**	**1.61**	**2.71**
	0.55	**1.47**	**2.57**

Ipotesi 1: CO_2 da flue gas e nutrienti da reflui
Ipotesi 2: CO_2 e nutrienti acquistati

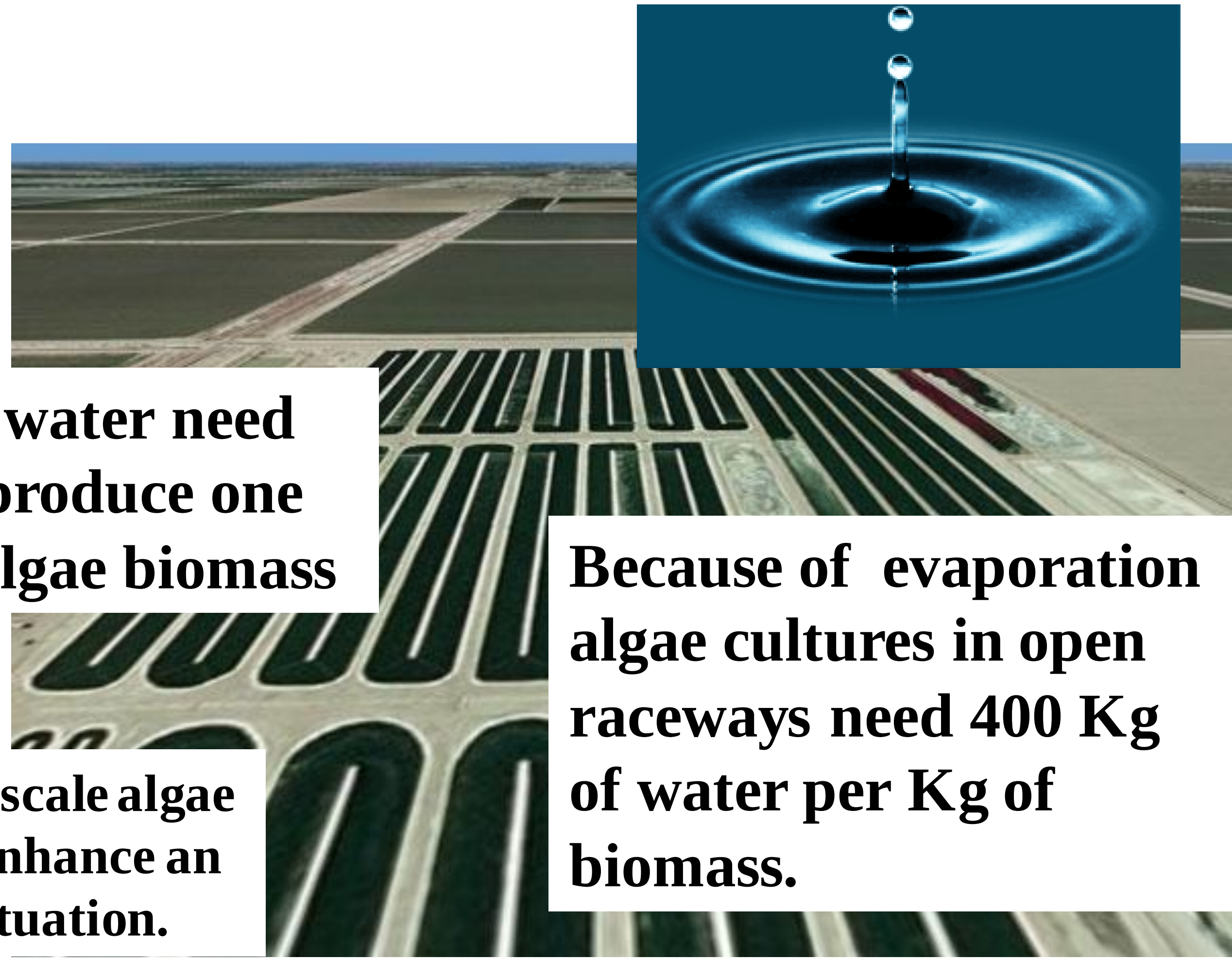
	(Florence-Italy)		(Tunis-Tunisia)	
	($GJ\ ha^{-1}\ yr^{-1}$)	%	($GJ\ ha^{-1}\ yr^{-1}$)	%
OUTPUT	**661**	**100**	**1260**	**100**
TOTAL INPUTS	**1151**	**100**	**1496**	**100**
E.E materials	**504**	**44**	**504**	**34**
• *GWP–II reactor*	409	0,36	409	0,27
• *piping+fittings*	45	0,04	45	0,03
• *machinery*	13	0,01	13	0,01
• *buildings*	12	0,01	12	0,01
• *0ther*	24,6	0,02	24,6	0,02
Fertilizers	**204**	**18**	**388**	**26**
• *N*	175	0,15	334	0,22
• *P-P_2O_5*	21,72	0,02	41	0,03
• *K_2O*	6,6	0,01	12,58	0,01
Operation Energy	**443**	**38**	**604**	**40**
• *mixing*	160	0,14	228	0,15
• *cooling*	134	0,12	174	0,12
• *medium pumping*	12	0,01	12	0,01
• *harvesting*	4	0,00	6	0,00
• *centrifugation*	113	0,10	162	0,11
• *labor*	5	0,00	7	0,00
• *plant decommissioning*	12,8	0,01	14,8	0,01
Net Energy Ratio (NER)	**0.57**		**0.84**	

EROI of major energy sources

Middle East oil	**10 – 30**	(fossil fuel quality varies)
Tar sands	**1.5**	
Hydro-power	**45 - 90**	
Coal	**25**	(according to accessibility)
Nuclear	**5 – 20**	(according to assumptions)
Wind	**4 – 50**	
Solar	**1 -10**	
Corn ethanol~	**1**	(therefore subsidised)
Algae in GWP ~	**1**	

The fundamental issue in biofuels production is **WATER** and the **ENERGY-WATER NEXUS**

Algae cultivation is all about water management:



Huge amounts of water need to be handled to produce one kilogram of dry algae biomass

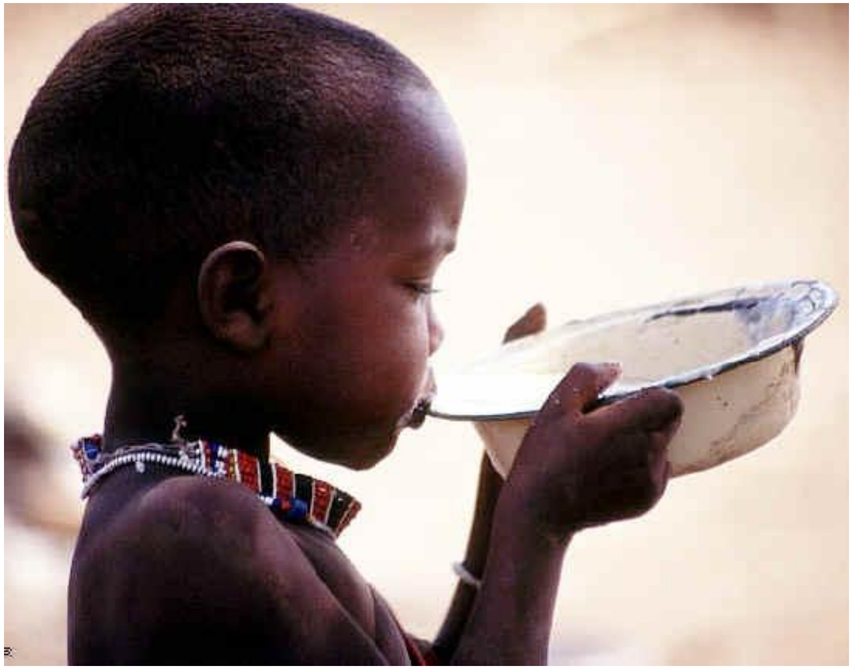
Because of evaporation algae cultures in open raceways need 400 Kg of water per Kg of biomass.

In many countries large-scale algae cultures risk to further enhance an already stressed water situation.

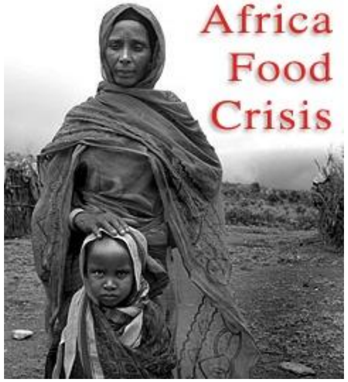
The rapidly growing population puts unsustainable pressure on resources

The FAO, IFRI and IEA forecast by 2030:

1. a 50% increase in the demand of food;
2. a 40% increase in the demand of energy.



Producing that food and energy (if ever possible) will impact heavily on shrinking water resources.



Key Topics:

European Market Insight

Potential and Future Outlook for Emerging Markets

Investment from an Investor's Perspective

An insight into the key aspects of Environmental Law & Regulation that affect the operation of the industry.

An analysis of the Current Cultivation Methods used, focusing on: Cost, Technology, Efficiency and Scalability.

An in depth comparison of Harvesting & Oil Extraction techniques.

Algae Production: Case Study Examples

Cutting-Edge Research & Development Activities

Algae Potential in CO2 Sequestration & Wastewater Treatment

Algae Supply Chain Analysis

Life Cycle Analysis of Algae Biofuel

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