DOCKETED

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Project Title:	2019-2020 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program
TN #:	225897
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Submitted On: 11/14/2018
Docket Number: 18-ALT-01

Lecture Algae Biofuel

Bio-Fuel and CO2 Capture by Algae

Additional submitted attachment is included below.

Bio-Fuel and CO2 Capture by Algae

Ami Ben-Amotz

NASA

November 20, 2008

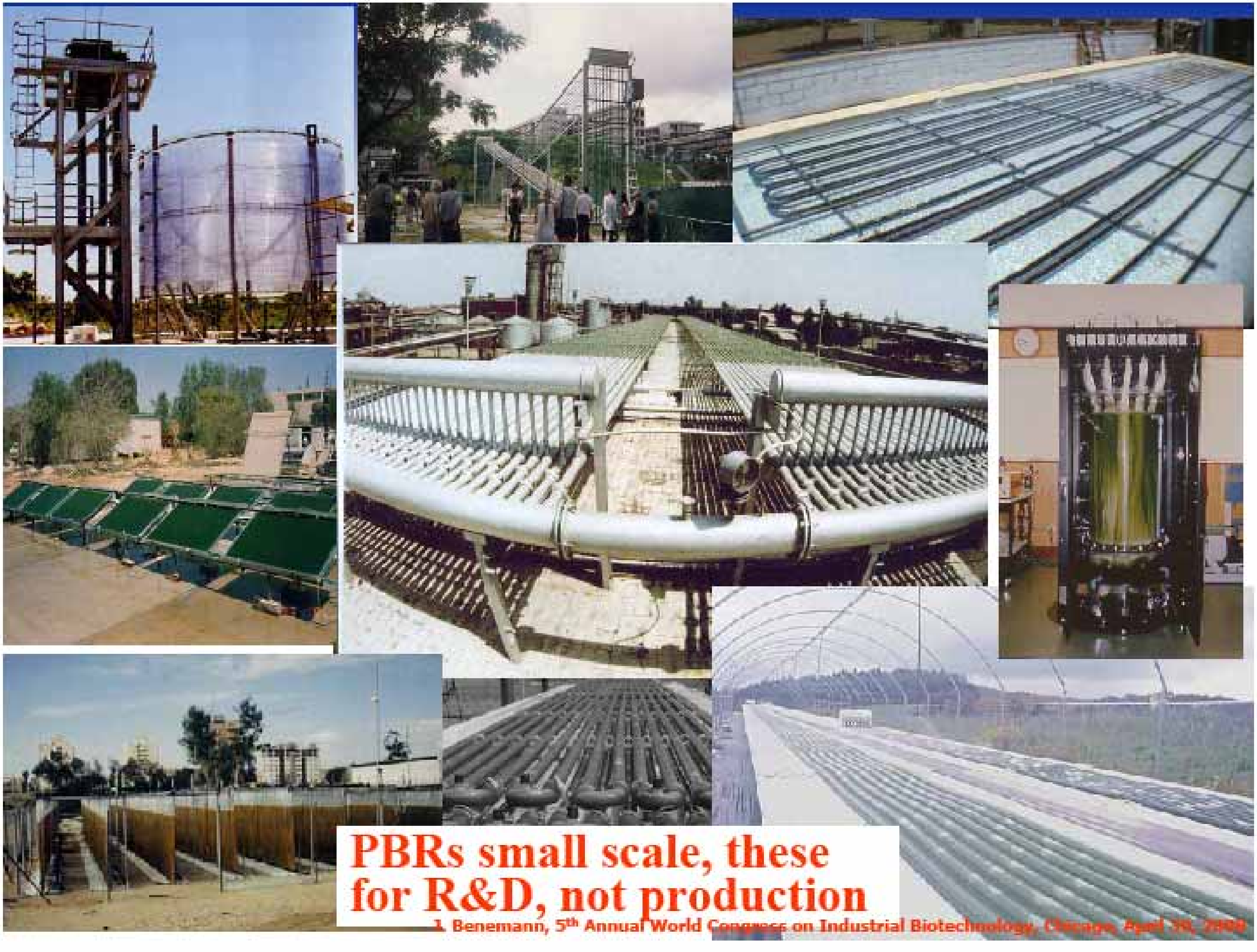
Seambiotic

Microalgal
Applied Phycology

Since 1950 through 2008
almost all commercial algae
production plants
use only open ponds

Commercial Photo-Bioreactors

Examples of Failure & High Cost


PBRs small scale, these
for R&D, not production
J. Benemann, 5th Annual World Congress on Industrial Biotechnology, Chicago, April

Chlorella, Otto Pulz, Germany

Haematococcus, Algae Technologies, Israel

Dunaliella, Murcia, Spain
US$ 10 million loss

Murcia, Spain

Major problems: predators and contamination

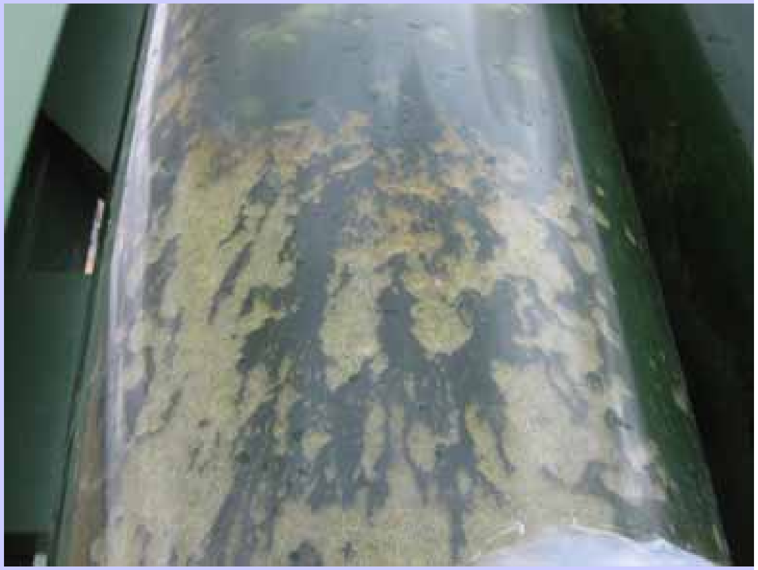
Murcia, Spain
1990

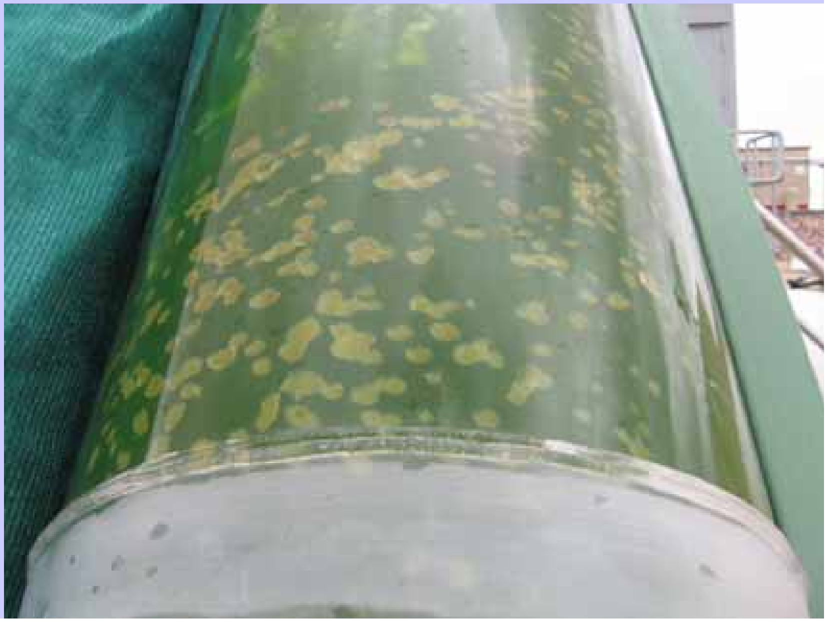
Murcia, Spain
Never worked commercially

GreenFuel Technologies Co, Arizona, USA photo-bioreactors on start

GreenFuel Technologies Co, Arizona, USA

Few weeks later, heavy contamination, difficulty to clean





GreenFuel Technologies Co, Arizona, USA
Bags trial, high cost scale up

GreenFuel Technologies Co, Arizona, USA
US$ 10 million project, 2007

GreenFuel Technologies Co, Arizona, USA

Major problem: summer cooling

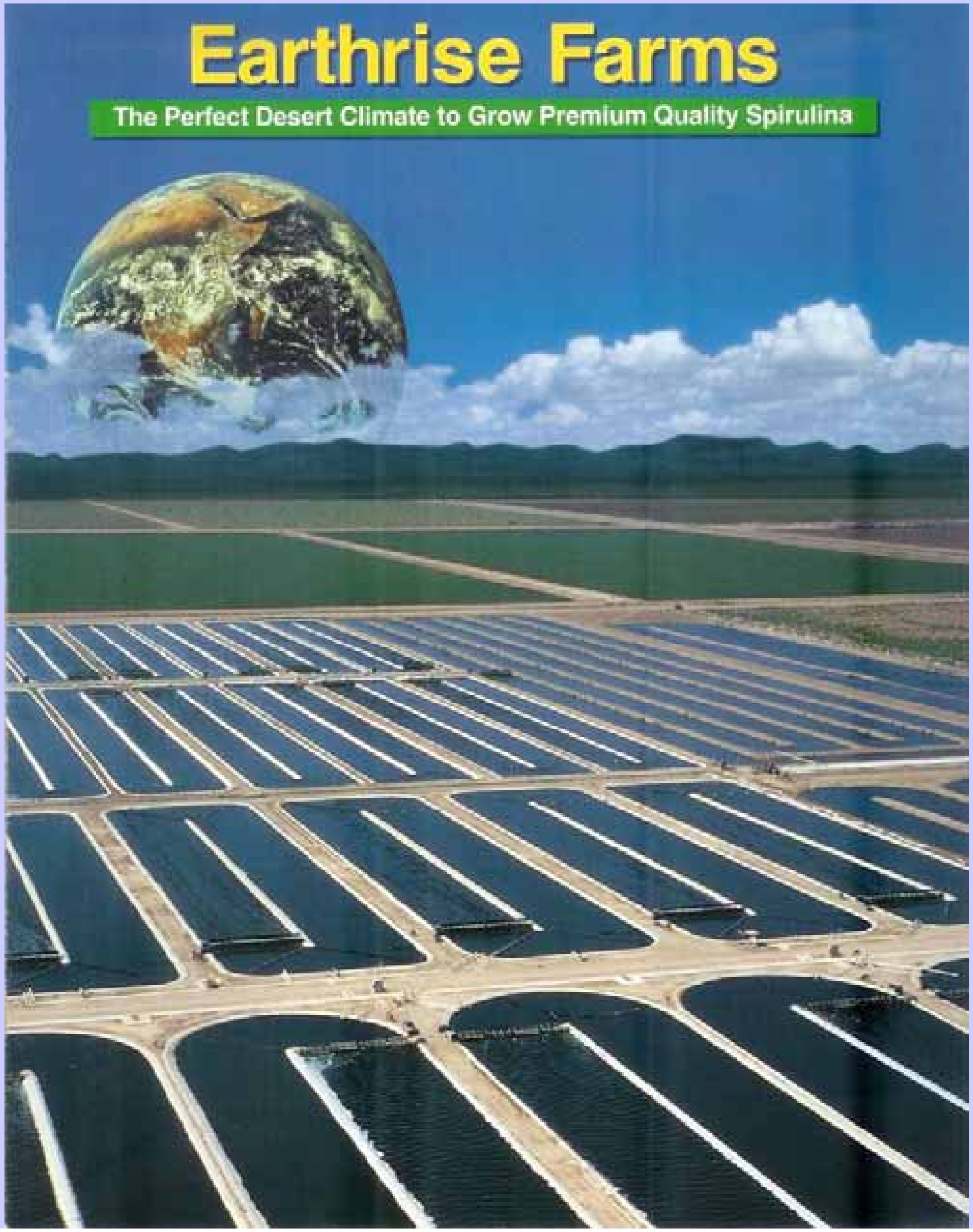
Commercial Algae Open Ponds

Open Ponds
since 1950
Taiwan & Japan

round & oblong open ponds
mostly mixotrophic cultivation

Far East *Chlorella* and *Spirulina* Open Ponds

Earthrise *Spirulina*, Imperial Valley, CA, USA

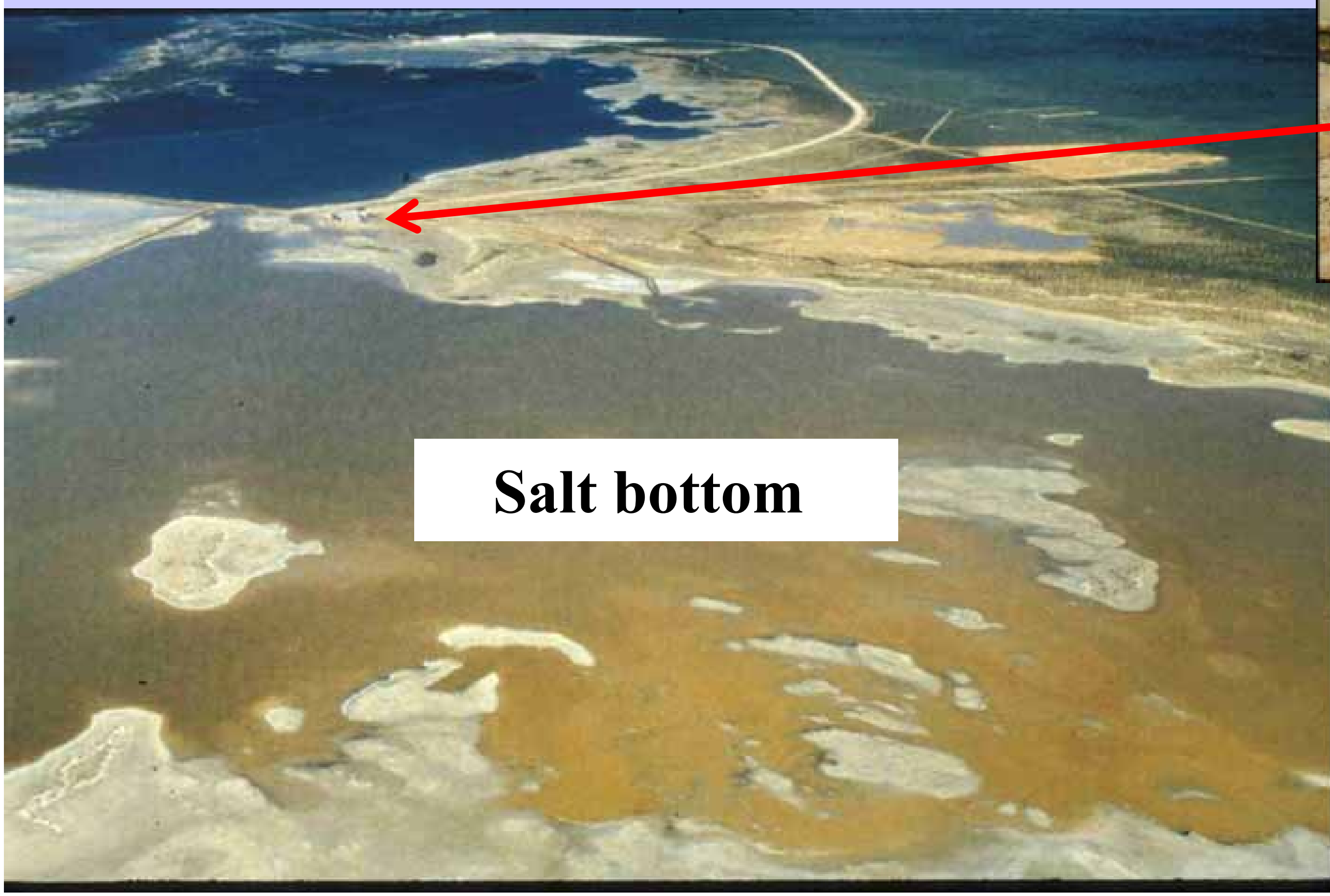


Cyanotech Co
Hawaii, USA

Microbio Resources, Imperial Valley, Calipatria, CA, USA

Cognis *Dunaliella*, Whyalla, Australia

Cognis, Whayalla, Australia
Large Scale *Dunaliella* Cultivation



Algae Cultivation

Dunaliella, Hutt Lagoon, West Australia

Dunaliella

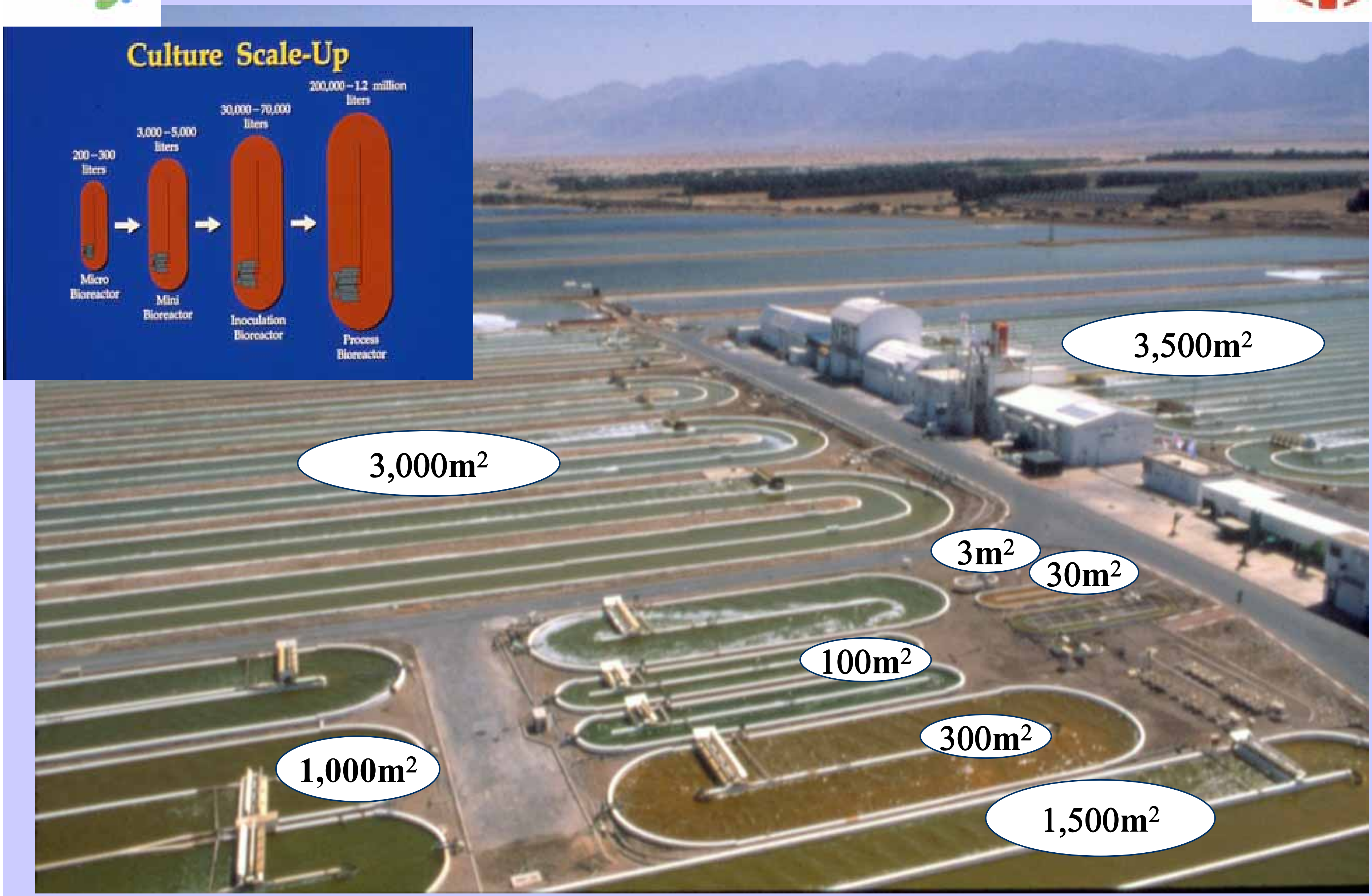
Health Food Supplement Commercial Plant

Intensive Cultivation

NBT Ltd., Nikken Sohonsha Co. (1975)
Dunaliella 10 Hectares Plant, Eilat, Israel

$\int h\nu x\, dt$

Dunaliella Scale Up



Dunaliella Biotechnology

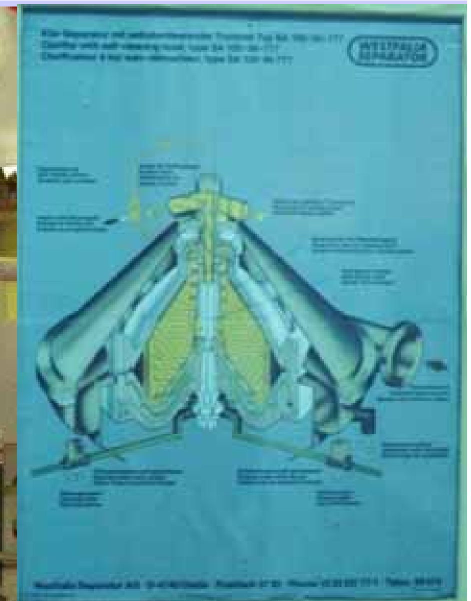
PC Control

Dunaliella

Biotechnology

Processing

Dunaliella Harvesting
Westphalia Ltd., Continuous Centrifuges



Dunaliella Paste (~15%)

Dunaliella Spray Dryer

Dunaliella
Spray Dried β-Carotene Algal Powder

Japan & Far East Market Price
~$4,000/kg algal AFDA
(β-Carotene Health Food)

Japan

Raw algae
Israel

Dunaliella β-Carotene Capsules
100 yen/capsule

300 mg dry powder/cap
20 mg β-carotene
9-cis/all-trans 1:1

Dunaliella Health Food Powder

Door to door marketing by 500,000 sale agents in the Far East

Open Ponds & Closed Bioreactors

The key Questions:

Cost of construction & operation
Light
Contamination
Cleaning
Maintenance
Productivity

Nature Beta Technologies Ltd. (NBT)
Nikken Sohonsha Co
Sharing our know-how

Annual Microalgae Production Costs
NBT *Dunaliella* Plant versus Alternative Bio-Fuel Algal Plant
(10 Hectares Plant Open Ponds)

	Dunaliella NBT Ltd., Eilat, 2008	Alternative Algal Plant 2008(?)
	Cost in US$/year	
Manpower	500,000 (20 workers)	?
Electricity ($0.125/KW)	180,000	?
Fertilizers (N,P,K, Fe) and other chemicals	36,000	?
Domestic Land City Taxes	50,000	?
CO_2 ($500/ton)	150,000	?
Sea Water ($0.25/m3)	200,000	?
Fresh Water	20,000	?
Other supplies and Miscellaneous	30,000	?
Total	1,166,000	?
Yearly production of dry algae biomass	70 tons (2g/m2/day)	?
Cost of 1Kg dry microalgae	$17.00/kg	$0.34/kg ???
Market Price	$4,000/kg algal AFDA (β-Carotene Health Food) Total sale ~$100 million/year	Algae cost for bio-fuel should be below $0.5/kg algal AFDW

How to reduce the Cost of Algae Production?

Electric Power Stations

Burn: oil, gas, coal and mix

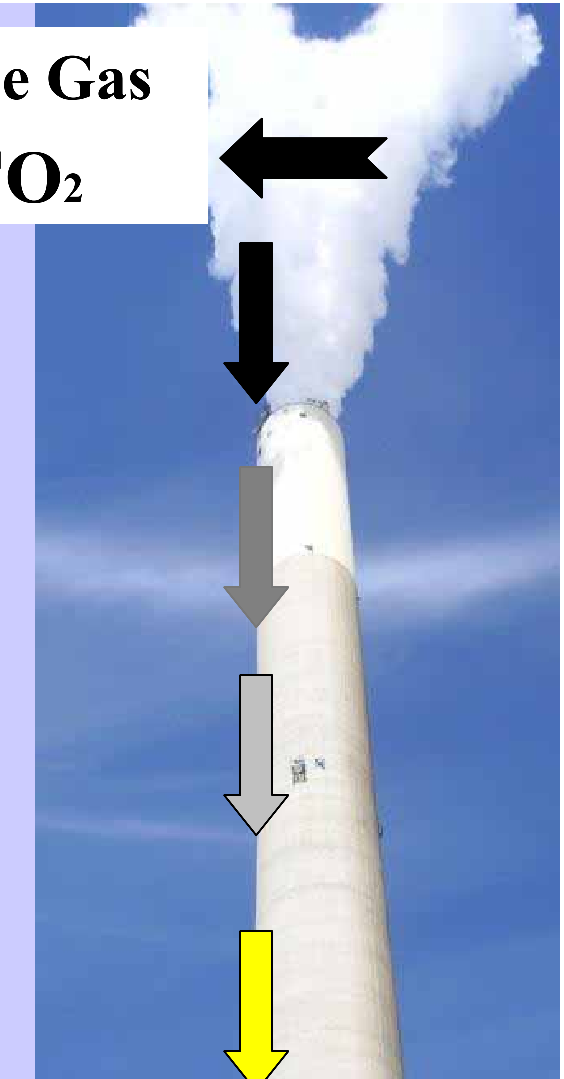
Use: sea water for cooling

Average mid-large station emits ~ 4,000 ton CO_2 per hr

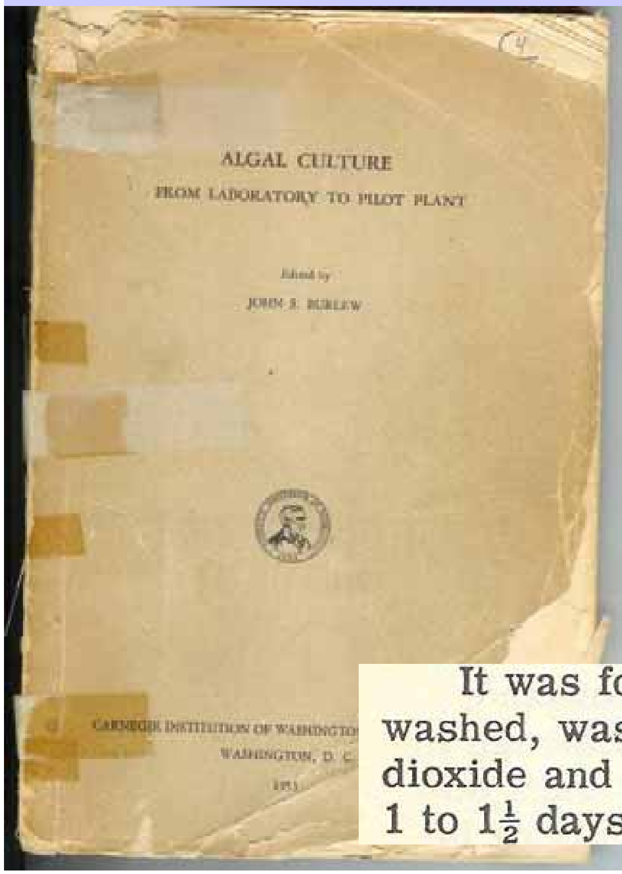
CO_2 emission, 4-14%, plus NOx, plus minerals, plus?

Algae ?

Flue Gas
CO_2



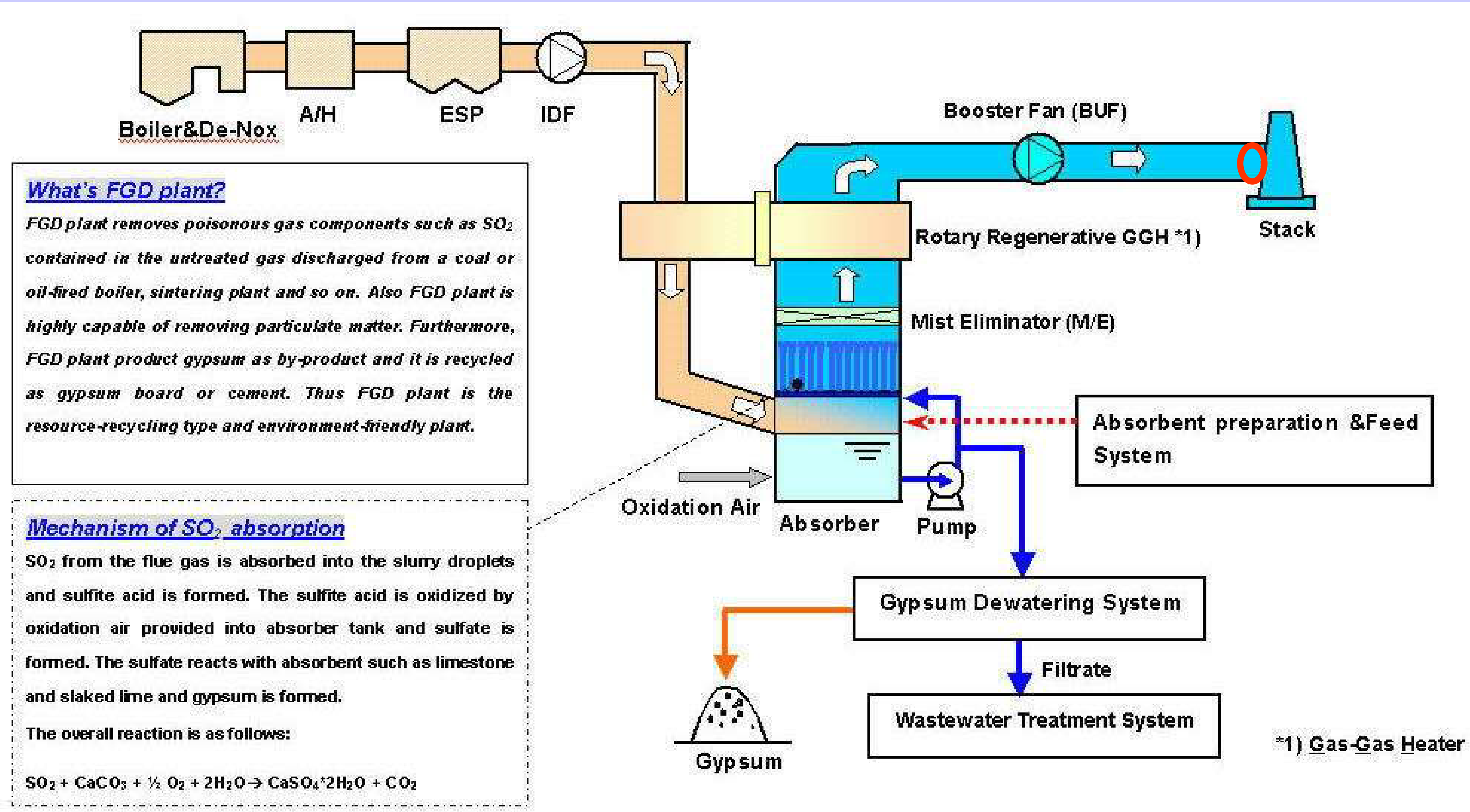
The "Algal Bible":
"Algal Culture, From Laboratory to Pilot Plant"
John S. Burlew (Ed.), 1953:
"Flue Gas is Toxic to Algae"! SO_2 & H_2S toxicity



It was found that the carbon dioxide (from cylinders filled here), if unwashed, was extremely toxic to the algae because of the presence of sulfur dioxide and hydrogen sulfide, which resulted in the death of the cultures in 1 to $1\frac{1}{2}$ days. The gas had to be washed by passing through alkaline per-

Flue GasDesulphurization (FGD, SO_2 Scrubbing)

FGD the art technology used for removing sulfurdioxide-of-is the current state (l to generate from the exhaust flue gases in power plants that burn coal or oi ($_2$SO neratorsthe steam for the steam turbines that drive their electricity ge



Flue Gas Desulphurization (FGD SO_2 chemistry)
Scrubbing with a basic solid or solution

SO_2 is an acid gas and thus the typical sorbent slurries or other materials used to remove the SO_2 from the flue gases are alkaline.

The reaction is taking place in **wet scrubbing** using limestone, $CaCO_3$ to calcium sulphite, $CaSO_3$ that can be expressed as:

$$\mathbf{CaCO_3\ (solid) + \underline{SO_2\ (gas)} \rightarrow CaSO_3\ (solid) + CO_2\ (gas)}$$

When wet scrubbing with a $Ca(OH)_2$ (lime slurry), the reaction also produces $CaSO_3$ (calcium sulphite) and can be expressed as:

$$\mathbf{Ca(OH)_2\ (solid) + SO_2\ (gas) \rightarrow CaSO_3\ (solid) + H_2O\ (liquid)}$$

When wet scrubbing with a $Mg(OH)_2$ (magnesium hydroxide slurry), the reaction produces $MgSO_3$ (magnesium sulphite) and can be expressed as:

$$\mathbf{MgOH_2\ (solid) + SO_2\ (gas) \rightarrow MgSO_3\ (solid) + H_2O\ (liquid)}$$

Some FGD systems go a step further and oxidize $CaSO_3$ (calcium sulphite) to produce marketable $CaSO_4.2H_2O$ **(gypsum):**

$$\mathbf{CaSO_3\ (solid) + 1/2\ O_2\ (gas) + 2H_2O\ (liquid) \rightarrow \underline{CaSO_4.2H_2O\ (solid)}}$$

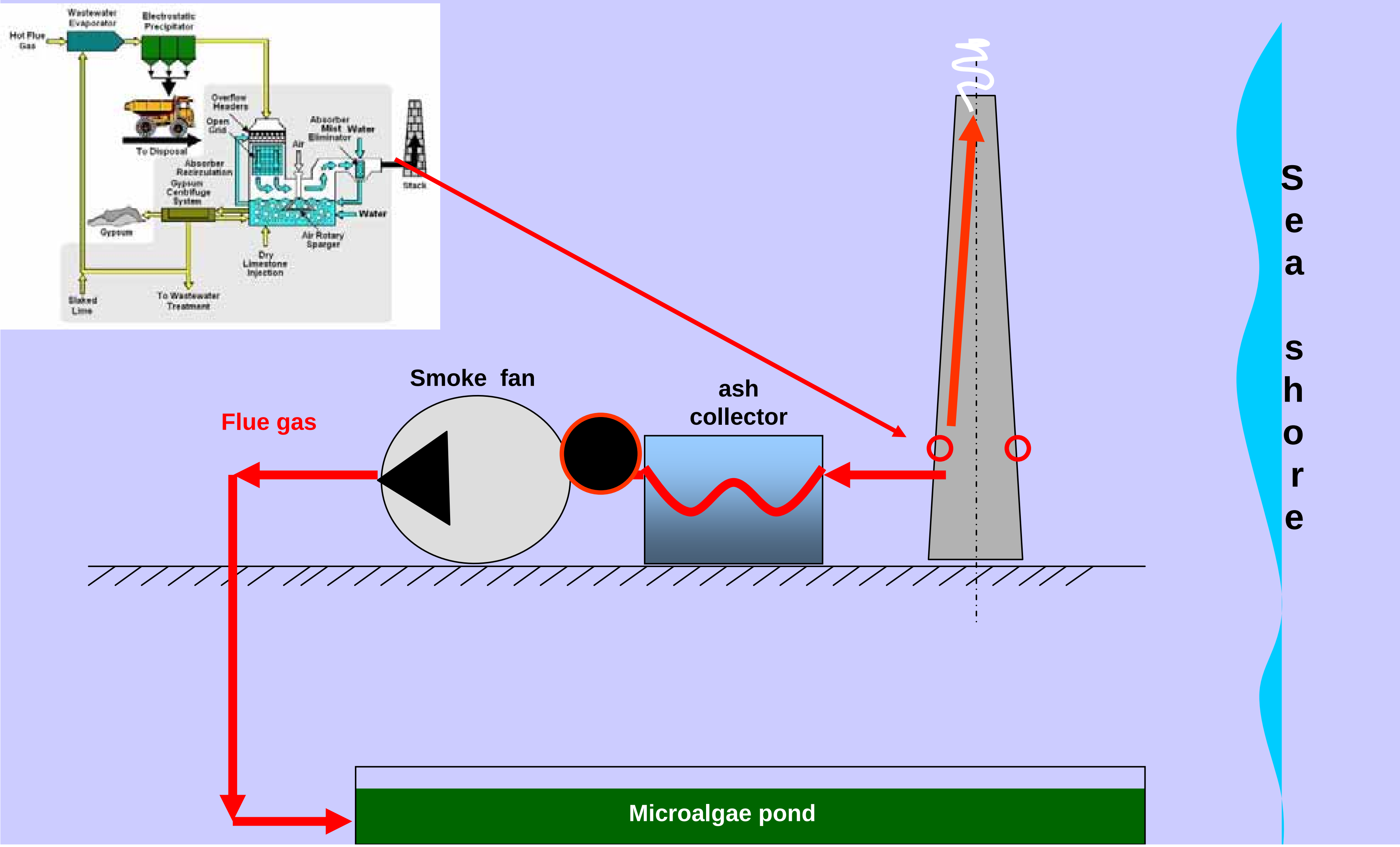
Israel Electric Corporation
Four Power Plants all coal
One is FGD Plant (Ashkelon)

Seambiotic Algae Pilot Plant
Within the IEC Power Plant area, Ashkelon, Israel

IEC Power Plant Ashkelon, Israel
Only one FGD chimney (out of 8 in Israel)

IEC CO_2- Generation Basic Scheme

"Please make holes in the smokestack for algae"



Israel Electric Corporation
The connections to the chimney
(FGD 2 units)

FGD Power Station, Ashkelon, Israel (431 ton CO_2 /hr, 10,344 /day)

Ruthenberg Power Station, Units III&IV.			**Unit Nominal Load 550MW**				
I. Coal		**LHV =**	**6170**	**kcal/kg**			
	C,% =	65.26	H_2O,% =	10.99			
	H,% =	4.53	Ash,%=	8.85			
	S,% =	0.63	N,% =	1.25			
	O,% =	8.49					
II. Theoretical Flue Gas Composition.			Excess Air=	100.00%			
	V^0=	6.74	V^0_{CO2}=	1.22	@6%O_2	Alfa =	1.4
	V^0_{H2O}=	0.748	V^0_{N2}=	5.33			
	V^0_{SO2}=	4.41E-03	V^0dry=	6.55			
	$Vgas^{alfa}$=	8.743	$Vgas^{6\%O2}$=	10.04			
III. Real Gas Composition		(Gas temperature 140 -50 C, density 1.3 kg/m3).					
Unit Load		**550MW**		**341MW**		**181MW**	
Excess Air		***1.21***		***1.44***		***1.7***	
	Calculated		**Measured**	Calculated		Calculated	
	Before FGD	After FGD		Before FGD	After FGD	Before FGD	After FGD
Gas Volume, Nm^3/kg fuel	8.743	10.04		10.318	11.59	12.10	13.52
CO_2,%	13.93	12.13	**13.30**	11.802	10.51	10.07	9.01
O_2,%	16.19	14.10	4.7-5.12	6.04	5.37	8.19	6.10
N_2,%	0.11	0.10	-	74.41	66.25	74.90	67.03
H_2O,%	7.31	22.31	-	7.71	19.33	6.81	19.19
SO_2,ppmv	504.23	-	56-70	427	-	364.37	-
H_2S,%	~0		-	~0		~0	~0
NO_x,ppmv	297.00	300	190-200	292	260	249	223
SO_3,mg/Nm^3	~5		-				
CO,mg/Nm^3	287		**~250**	243		208	186
$CH_{condensable}$	No data			No data		No data	No data
Sulfur	~0			~0		~0	~0
Particles,mg/Nm3	46						

Flue Gas Processing
Inside the FGD Chimney

Analysis of the FGD Flue Gas Mist
Many Minerals at Low pH
(variety of coals)

אמינולאב בע"מ שרותי מעבדה אנליטיים לתעשיה, מזון, רפואה, חקלאות, מחקר ואיכות הסביבה
סניף ראשי -קרית ויצמן, ת.ד 4074 נס ציונה 70400 טל: 08-9303333 פקס: 08-9303300
סניף צפון -היוצרים 19, ת.ד 1033 כרמיאל 20100 טל: 04-9586916 פקס: 04-9582154

14/03/2007
דו"ח מס': C1695

לכבוד
מר משה כהן
סימביוטיקס בע"מ
מגדלי עזריאלי 1) בניין עגול(
תל אביב 67021
טל: 050-6709692
פקס: cmosheo@gmail.com

הנדון: **תעודה לתוצאות בדיקה**

מס 'אמינולאב: 10559.07-C
תאור הדוגמה : נוזל FGD-Farm
נדגם ע"י: הלקוח
סוג הדיגום: לא ידוע

תאריך קבלה: 05/03/2007

תוצאות הבדיקה:

הבדיקה	יחידות מידה	תוצאה	הערות
סריקת מתכות מלאה ב -ICP			1
כסף -Ag	mg/L	<0.05	
אלומיניום -Al	mg/L	3	
ארסן -As	mg/L	<0.1	
בורון -B	mg/L	<0.1	
בריום -Ba	mg/L	0.07	
בריליום -Be	mg/L	<0.05	
סידן -Ca	mg/L	5	
קדמיום -Cd	mg/L	<0.05	
קובלט -Co	mg/L	<0.05	
כרום -Cr	mg/L	0.06	
נחושת -Cu	mg/L	31	
ברזל -Fe	mg/L	23	
כספית -Hg	mg/L	<0.05	
אשלגן -K	mg/L	0.6	
ליתיום -Li	mg/L	<0.05	
מגנזיום -Mg	mg/L	1	
מנגן -Mn	mg/L	0.2	
מוליבדן -Mo	mg/L	<0.05	
נתרן -Na	mg/L	<0.5	
ניקל -Ni	mg/L	1	
זרחן -P	mg/L	1	
עופרת -Pb	mg/L	2	
גופרית -S	mg/L	6347	

נבדק ע"י: ליליה איסאקוב חתימה: ____________

אושר ע"י: דר 'צדוק שאבי -מנהל המחלקה חתימה: ____________

Mist (H_2O)
Flue Gas
13% CO_2
NOx
Minerals
Low pH

אמינולאב בע"מ שרותי מעבדה אנליטיים לתעשיה, מזון, רפואה, חקלאות, מחקר ואיכות הסביבה
סניף ראשי -קרית ויצמן, ת.ד 4074 נס ציונה 70400 טל: 08-9303333 פקס: 08-9303300
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/03/2007
דו"ח מס': 1695

מס 'אמינולאב: 10559.07-C

תוצאות הבדיקה:

הבדיקה	יחידות מידה	תוצאה	הערות
סלניום -Se	mg/L	<0.05	
סטרונציום -Sr	mg/L	0.1	
טיטניום -Ti	mg/L	0.2	
ונדיום -V	mg/L	<0.05	
אבץ -Zn	mg/L	72	

הערות לבדיקה:
(-) = אין הערות.
1. סריקת מתכות -תוצאה סלולה בסימן "<" -לא נמצאו עקבות בדוגמה בגבול הרגישות המצוין.

אבטחת איכות:

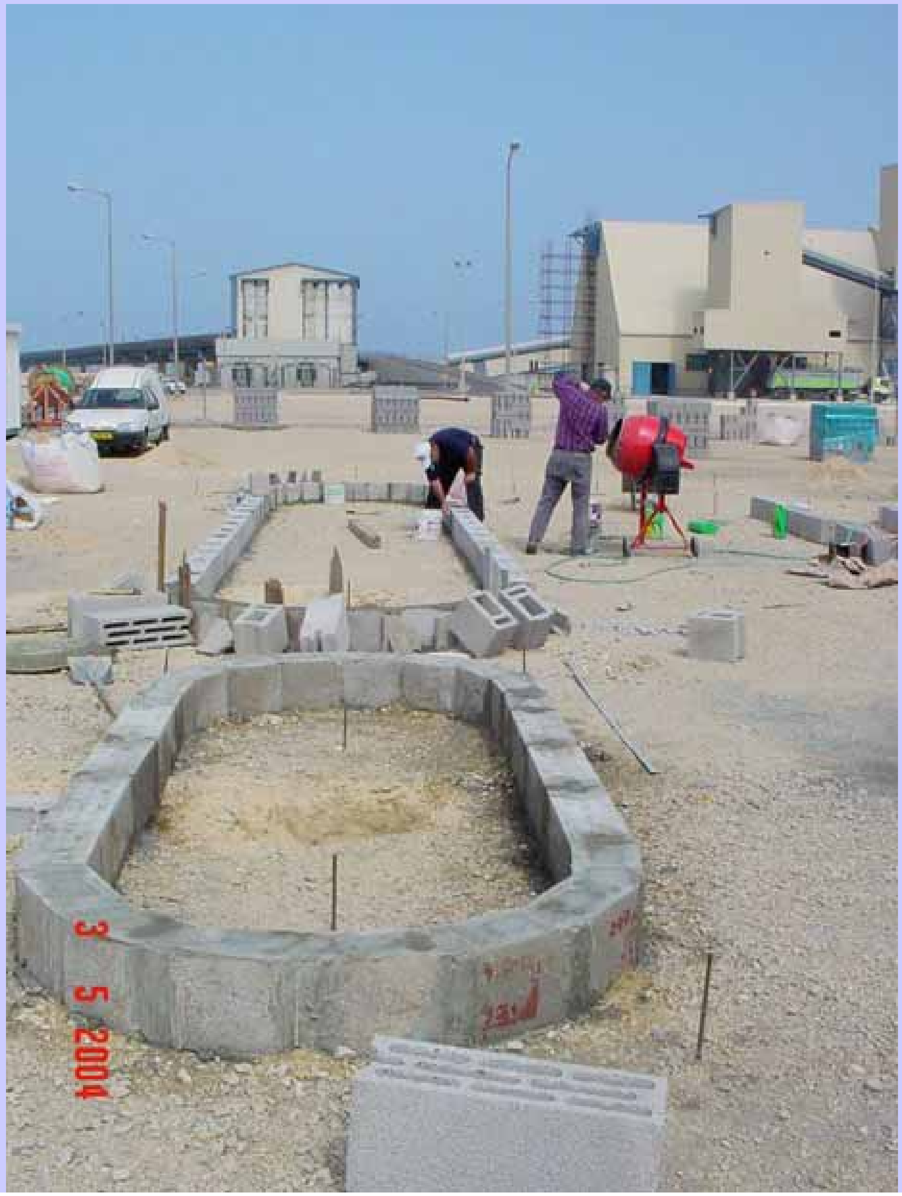
הבדיקה	שיטה/ תקן	הערות
סריקת מתכות מלאה ב -ICP	SOP# CW-041	-

השמטות/ חריגות:
המעבדה מפעילה מערכת איכות מתועדת לפי ISO/IEC 17025 והיא פועלת בהתאם לנהלי עבודה מתועדים.

נבדק ע"י: ליליה איסאקוב חתימה: ____________

אושר ע"י: דר 'צדוק שאבי -מנהל המחלקה חתימה: ____________

Ponds on Construction



Ponds on Construction

PVC Liner

FGD Gas
From the Chimney to the Algae Ponds

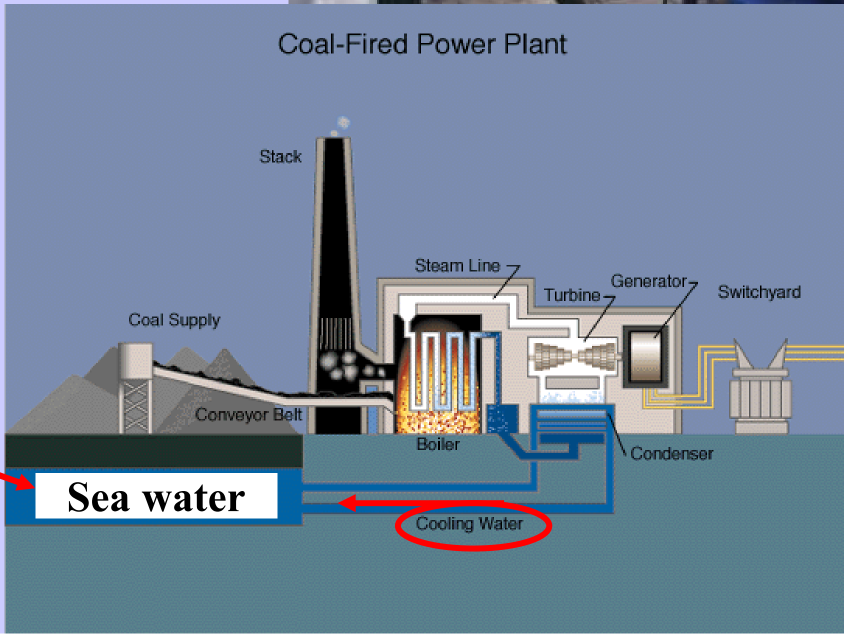
IEC Power Plant

Free Seawater Supply ~ 450,000 m^3/hr

(Filtered & Chlorinated)

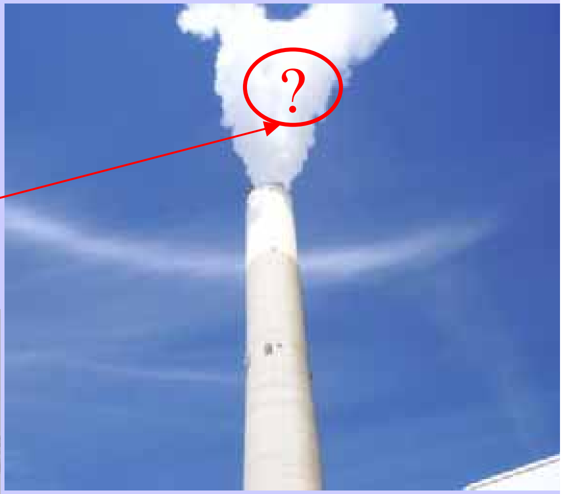
Production Cost
Manpower
Electricity ($0.125/KW)
Fertilizers (N,P,K, Fe) and other chemicals
Domestic Land City Taxes
CO_2 ($500/ton)
Free Sea Water
Fresh Water
Other supplies and Miscellaneous
Total
Yearly production of dry algae biomass
Cost of 1Kg dry microalgae ?

The Pumps

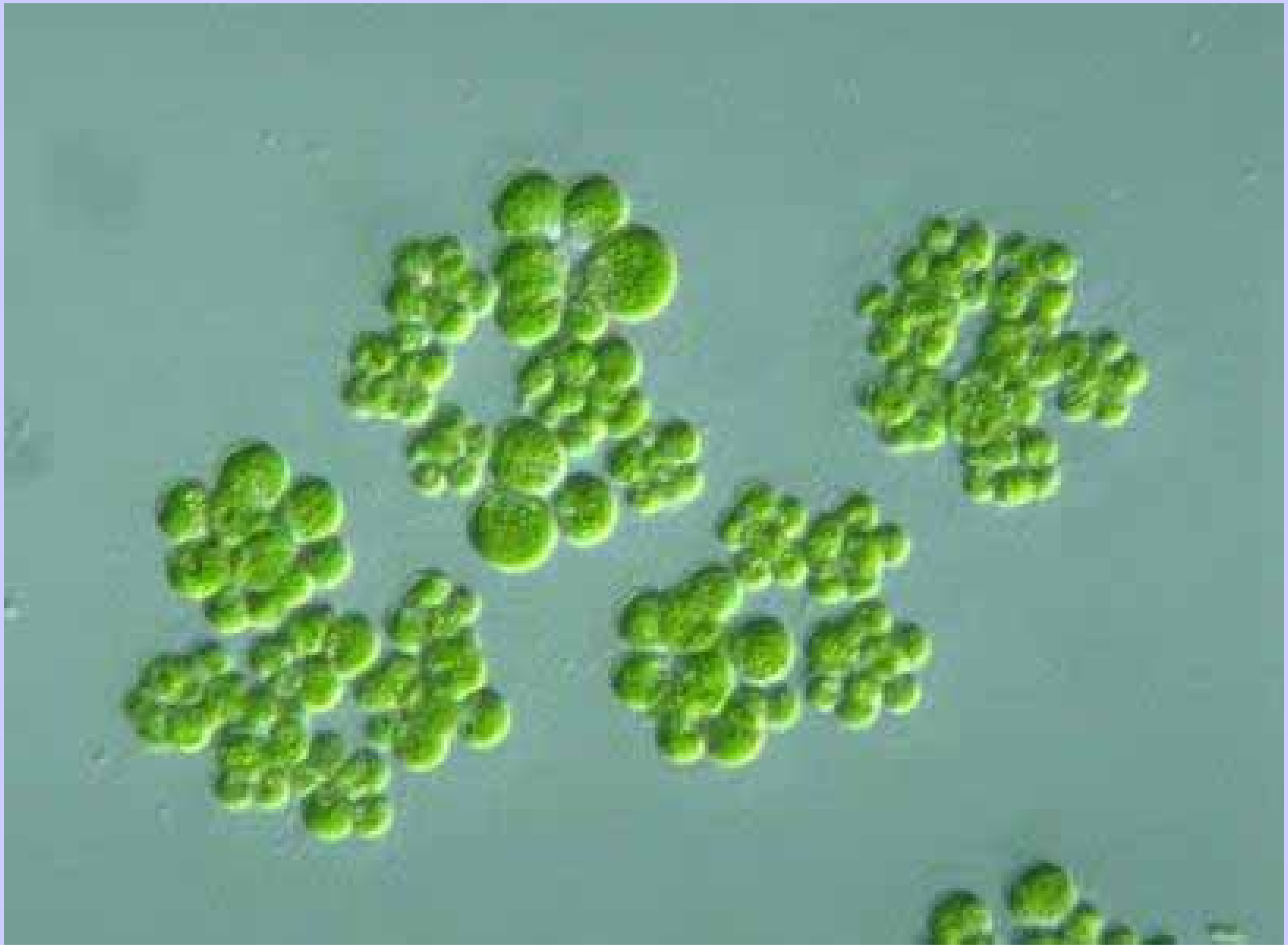


IEC Power Plant
Flue gas
Free NOx
N fertilizer(?)

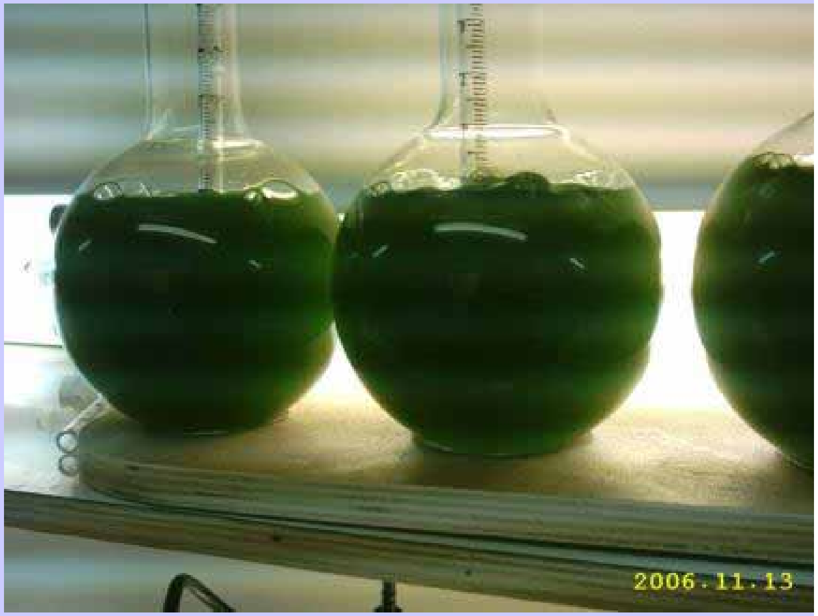
Production Cost
Manpower
Electricity ($0.125/KW)
Fertilizers (N,P,K, Fe) and other chemicals
Domestic Land City Taxes
CO_2 ($500/ton)
Free Sea Water
Fresh Water
Other supplies and Miscellaneous
Total
Yearly production of dry algae biomass
Cost of 1Kg dry microalgae ?



Nannochloropsis
Eustigmatophyceae
Bio-Fuel or High W3 FA, EPA



Stock Algae Cultures in house



Stock Algae Cultures outside

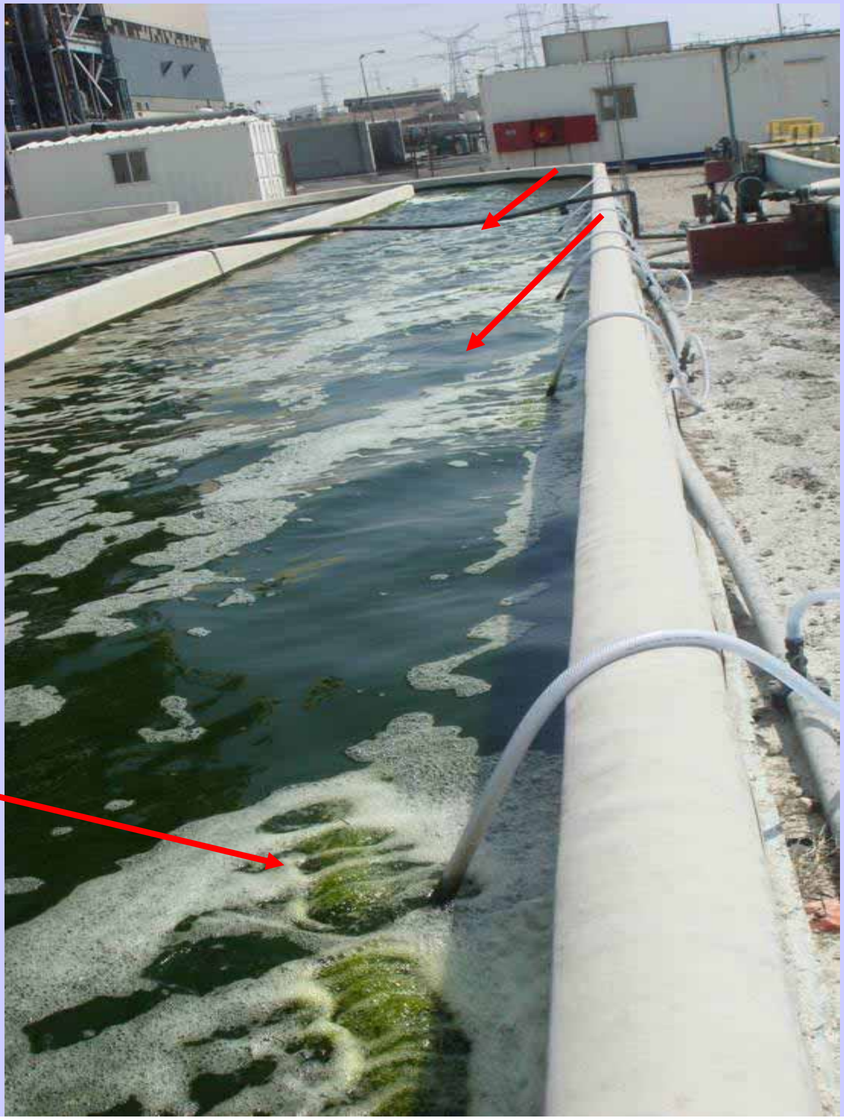
Scale-Up Cultivation of *Nannochloropsis sp*

Coal Burning FGD Flue Gas

Superior Algal Growth!

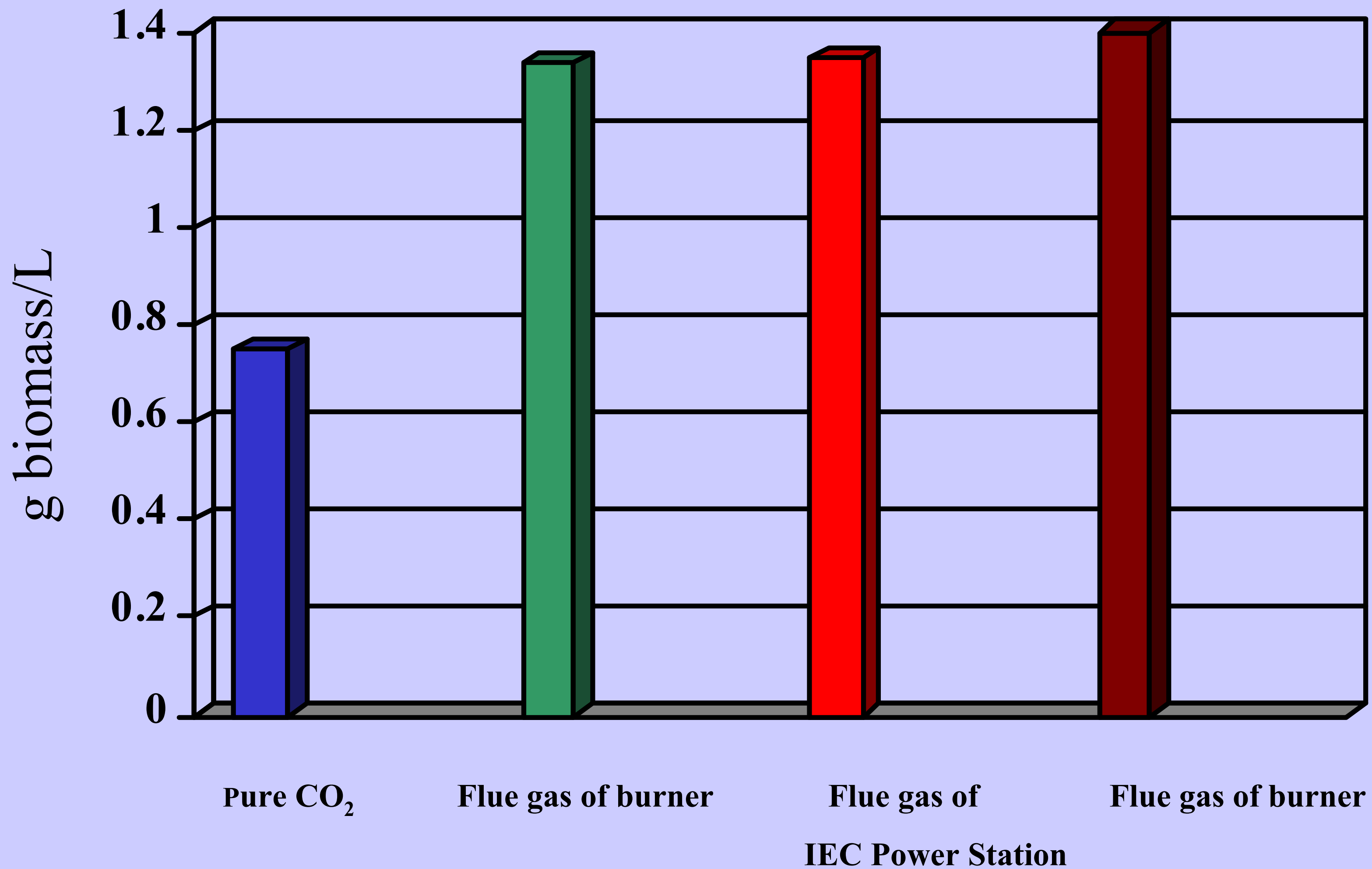
Algal density at depth of 20 cm ~ 1g algae/L

Production Cost
Manpower
Electricity ($0.125/KW)
Fertilizers (N,P,K, Fe) and other chemicals
Domestic Land City Taxes
*Free FGD CO_2
Sea Water ($0.25/m3)
Fresh Water
Other supplies and Miscellaneous
Total
Yearly production of dry algae biomass
Cost of 1Kg dry microalgae ?



Nannochloropsis Grows better on Coal FGD Flue Gas than on Pure CO_2

1. Pure CO_2
2. Flue gas
3. Flue gas from the Power Plant
4. Flue gas



Coal FGD Mist Minerals Content
"Coal Extract" superior to "Soil Extract"

Seambiotic

דיגום: 05/08/2008 00:00 תנאי שמירת חדוגמא וחחובלח:

תאור בדיקה	יחידת מידה	תחום מותר	תוצאה
כספית (Hg) ב-AA	מ"ג/ליטר		<0.001
סריקת מתכות ב-ICP	-		ראה רשימה
כסף (Ag) - ב-ICP	מ"ג/ליטר		<0.010
אלומיניום (Al) - ב-ICP	מ"ג/ליטר		0.733
ארסן (As) - ב-ICP	מ"ג/ליטר		<0.020
בורון (B) - ב-ICP	מ"ג/ליטר		7.69
בריום (Ba) - ב-ICP	מ"ג/ליטר		0.028
בריליום (Be) - ב-ICP	מ"ג/ליטר		<0.005
סידן (Ca) - ב-ICP	מ"ג/ליטר		8.60
קדמיום (Cd) - ב-ICP	מ"ג/ליטר		<0.005
קובלט (Co) - ב-ICP	מ"ג/ליטר		<0.010
כרום (Cr) - ב-ICP	מ"ג/ליטר		<0.010
נחושת (Cu) - ב-ICP	מ"ג/ליטר		<0.010
ברזל (Fe) - ב-ICP	מ"ג/ליטר		0.381
כספית (Hg) - ב-ICP	מ"ג/ליטר		<0.010
אשלגן (K) - ב-ICP	מ"ג/ליטר		0.092
ליתיום (Li) - ב-ICP	מ"ג/ליטר		<0.010
מגנזיום (Mg) - ב-ICP	מ"ג/ליטר		1.40
מנגן (Mn) - ב-ICP	מ"ג/ליטר		0.012
מוליבדיום (Mo) - ב-ICP	מ"ג/ליטר		<0.010
נתרן (Na) - ב-ICP	מ"ג/ליטר		3.21
ניקל (Ni) - ב-ICP	מ"ג/ליטר		<0.010

דיגום: 05/08/2008 00:00 תנאי שמירת חדוגמא וחחובלח:

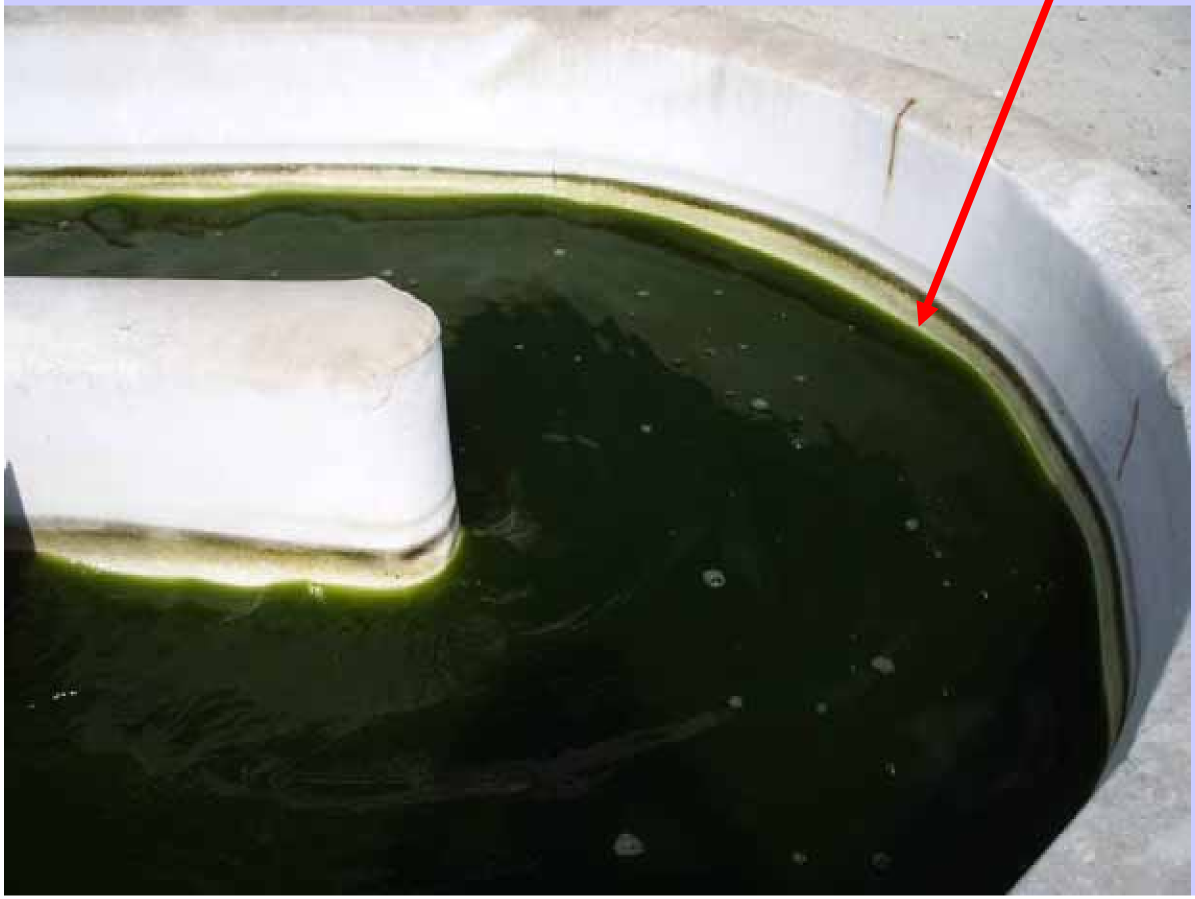
תאור בדיקה	יחידת מידה	תחום מותר	תוצאה
זרחן (P) - ב-ICP	מ"ג/ליטר		0.011
עופרת (Pb) - ב-ICP	מ"ג/ליטר		<0.010
גופרית (S) - ב-ICP	מ"ג/ליטר		29.0
אנטימון (Sb) - ב-ICP	מ"ג/ליטר		<0.020
סלניום (Se) - ב-ICP	מ"ג/ליטר		<0.020
סיליקון (Si) - ב-ICP	מ"ג/ליטר		0.568
בדיל (Sn) - ב-ICP	מ"ג/ליטר		<0.020
סטרונציום (Sr) - ב-ICP	מ"ג/ליטר		0.020
טיטניום (Ti) - ב-ICP	מ"ג/ליטר		0.023
ונדיום (V) - ב-ICP	מ"ג/ליטר		<0.010
אבץ (Zn) - ב-ICP	מ"ג/ליטר		0.539

13.3 % CO_2
200 ppm NOx
Minerals
Low pH

Natural Selection of Microalgae

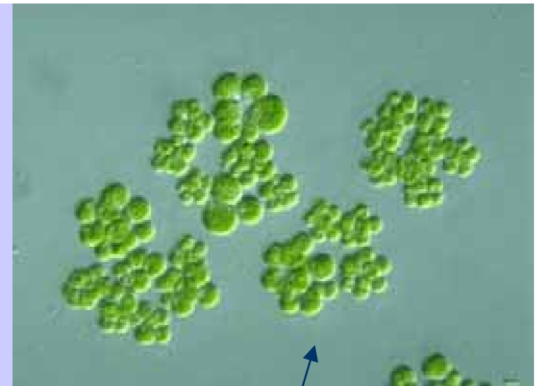
by season and by the coal

Spring-Summer Diatoms (brown/black)



Diatoms

Self Selected algae by the specified coal FGD flue gas (spring-summer algae)



Coal FGD Algae Selection 2005-2008

***Dunaliella*, Chlorophyceae**

***Tetraselmis*, Chlorophyceae**

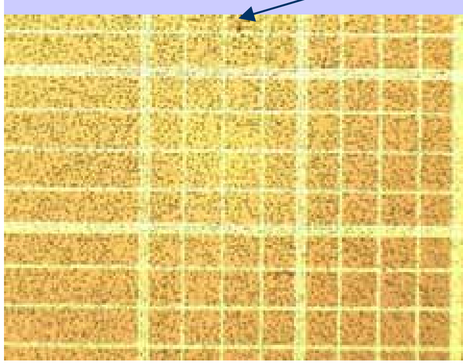
***Nannochloropsis*, Eustigmatophyceae**

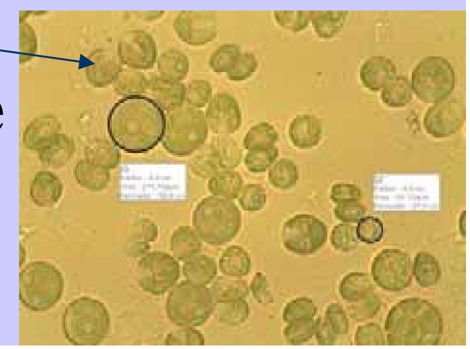
***Nannochloris*, Chlorophyceae**

***Chlorococcum*, Chlorophyceae**

***Skeletonema*, Bacillariophyceae**

***Navicula*, Bacillariophyceae,**





Average Yearly Productivity
of
unicellular marine algae
on
FGD flue gas
in
open ponds
~20 g x m2 x day-1

Photosynthetic Limitation of Long Term Algal Productivity

Max Theoretical Algal Productivity

25 $g/m^2/day$

Environment Factor	Reduction	(%)
Solar light	-------	100
Scattering and reflecting properties of surface	10%	90
Absorption spectrum (depth of culture)	50%	45
Photosynthetic efficiency (25%)	75%	11.3
Light saturation (7-95%)	60%	4.5
Respiration, photo-respiration, excretion	5%	4.3
Photo-inhibition	10%	3.8
Temperature	20%	3.1
====================================	=============================	
	Productivity	
Mean daily solar intensity	4,000 kcal/ m^2/day	
Energy productivity at 3% efficiency	120 kcal/ m^2/day	
Algal biomass productivity (5 kcal/g)	**25 g/m^2/day**	

Dunaliella **Productivity NBT, 2 g/m2/day**

Flue gas Algae Productivity, 20 g/m^2/day

(Terrestrial plants productivity is up to 5 g/m^2/day)

Feasible Harvesting

Low Cost Algal Harvesting?

Seambiotic

Algae Centrifuges of Lower Cost

Basket Centrifuge

Decanter Centrifuge

Auto-flocculation (Diatoms)

Harvesting by Floc-Filtration

Seambiotic

Dunaliella induced Flocculation

Dunaliella Biopolymer-Flocculation

Co-Bio-Flocculation
Nannochloropsis & diatoms

Annual Microalgae Production Costs NBT *Dunaliella* Plant versus Seambiotic/IEC FGD Plant (10 Hectares Plant)		
	Dunaliella **NBT Ltd., Eilat**	**Seambiotic/IEC Plant** **(estimated)**
	Cost in US$/year	
Manpower	**500,000** **(20 workers)**	**120,000** **(8 workers)**
Electricity ($0.125/KW) & residual energy	180,000	**30,000**
Fertilizers (N,P,K, Fe) and other chemicals	36,000	**36,000**
Domestic Land Taxes	50,000	**10,000**
CO_2	150,000	**5,000**
Sea Water	200,000	**5,000**
Fresh Water	20,000	**10,000**
Other supplies and Miscellaneous	30,000	**20,000**
Total	**1,166,000**	**236,000**
Yearly production of dry algae biomass	**70 tons** **(2g/m2/day)**	**700 tons** **(20g/m2/day)**
Cost per 1Kg dry microalgae	**$17.00**	**$0.34**
Market Price	**$4,000** **β-Carotene Health Food**	**For Bio-Fuel cost should be below** **$0.5/kg algal dw**

From the Algae
to
Bio-Fuel

Seambiotic made algae available in large quantity

Seambiotic

Seambiotic frozen algae stock

7 tons/1,000m^2/year

Seambiotic

Seambiotic

Extraction and Processing of lipids and carbohydrates

to bio-diesel & bio-ethanol & protein

Algal paste (a few tons) were shipped frozen or dried

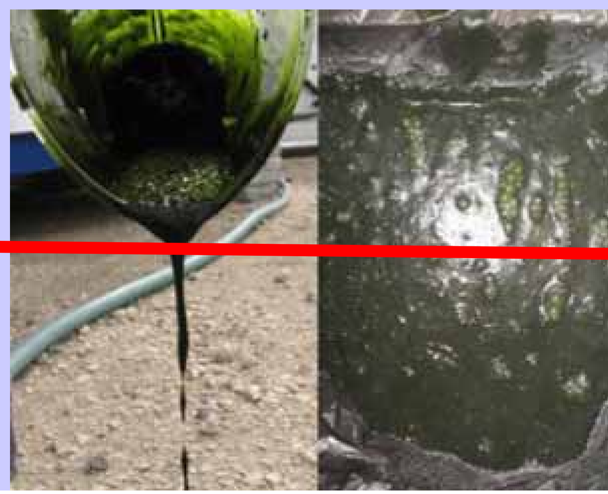
from

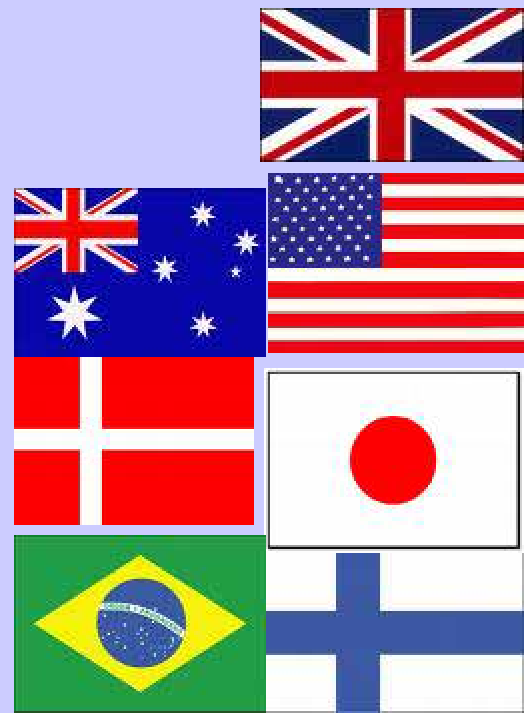
Seambiotic Ltd., Israel

to

processing trials

Israel





Nannochloropsis, Bio-Diesel

Seambiotic & Inventure

Nannochloropsis Bio-Diesel (marine algae smell)

Certificate of Analysis

Inventure

Certificate of Analysis

Customer: Seambiotic — Date : 4/29/2008

B/L# : NA — Time :

P.O.# : NA — Batch# : SEA42908

Quantity : Received unkown microalgae for processing

Product Certified: Algae biodiesel

Results from Certification Sample

	Method	Minimum	Maximum	Results
Flash Point, deg C	(ASTM D 93)	130.0		>130
Kinematic Viscosity, cSt @ 40C	(ASTM D 445)	1.9	6.0	3.5
Cloud Point, deg C	(ASTM D 2500)	-2.0		< -2
Specific Gravity @ 60f	(ASTM D 1298)	0.85	0.90	0.880
Acid Number, mg KOH, gm	(ASTM D 664)		0.5	0.20
Free Glycerin	(ASTM D 6584)		0.02	<0.01
Total Glycerin	(ASTM D 6584)		0.24	0.20
Appearance	(Visual)	B&C		B&C

Tested by ______________
Q/C control

Inventure Chemical, Inc.
1741 First Ave. S, third floor
Seattle, WA 98134
Phone# (206)-753-0258
www.inventurechem.com

Inventure

Certificate of Analysis

Customer: Seambiotic — Date : 4/29/2008

B/L# : NA — Time :

P.O.# : NA — Batch# : SEA42908

Quantity : Received unkown microalgae for processing

Product Certified: Algae biodiesel

Results from Certification Sample

	Method	Minimum	Maximum	Results
Flash Point, deg C	(ASTM D 93)	130.0		>130
Kinematic Viscosity, cSt @ 40C	(ASTM D 445)	1.9	6.0	3.5
Cloud Point, deg C	(ASTM D 2500)	-2.0		< -2
Specific Gravity @ 60f	(ASTM D 1298)	0.85	0.90	0.880
Acid Number, mg KOH, gm	(ASTM D 664)		0.5	0.20
Free Glycerin	(ASTM D 6584)		0.02	<0.01
Total Glycerin	(ASTM D 6584)		0.24	0.20
Appearance	(Visual)	B&C		B&C

Tested by ______________
Q/C control

Inventure Chemical, Inc.
1741 First Ave. S, third floor
Seattle, WA 98134
Phone# (206)-753-0258
www.inventurechem.com

Algae Bio-Ethanol

Inventure

Certificate of Analysis

Customer: GreenFuel Technologies

Date : 02/07/07

B/L# : NA

Time : NA

P.O.# : NA

Batch# : GFT011007

Quantity : Processed de-fatted alege pulp, material evaoprated to concentrate
Initial 2000 grams of algae
* material not distilled

Product Certified: Algae ethanol

Results from Certification Sample

	Method	Minimum	Maximum	Results
Flash Point, deg C	(ASTM D 93)	Report		25.0
Ethanol %/wt	GC	Report		79.3*
Methanol %/wt	GC		0.50	NA
Acid Number, mg KOH, gm	(ASTM D 664)		0.5	0.46
Specific Gravity @ 60f	(ASTM D 1298)	0.75	0.87	0.87
Appearance	(Visual)	B&C		B&C

Tested by

G/C

Inventure Chemical Technologies LLC
2244 Port of Tacoma Road
Tacoma,WA, 98401
Phone# (253) 284-4302
Fax# (253) 284-4303

From the Algae

through lipids

Acid Transesterification

to

"Protein"

Seambiotic

Dried Algae

Diatoms

Nannochloropsis

Nannochloropsis High Value Protein, (essential amino acids)

University of Alabama,
Drs' Rusty Sutterlin & Thomas Mawhinney

Seambiotic

Units	W/W%	W/W%
Dept #	Insolubles	Solubles
Taurine	0.00	0.01
Hydroxyproline	0.00	0.00
Aspartic Acid	0.00	0.03
Threonine	0.00	0.00
Serine	0.00	0.00
Glutamic Acid	0.14	1.94
Proline	0.04	1.13
Lanthionine	0.00	0.05
Glycine	0.02	0.66
Alanine	0.04	1.24
Cysteine	0.01	0.01
Valine	0.03	1.26
Methionine	0.00	0.02
Isoleucine	0.01	0.43
Leucine	0.04	1.80
Tyrosine	0.02	0.64
Phenylalanine	0.03	0.95
Hydroxylysine	0.04	1.42
Ornithine	0.00	0.16
Lysine	0.03	0.44
Histidine	0.00	0.04
Arginine	0.01	0.07
Tryptophan	< 0.04	0.42
Total	0.46	12.72
Crude Protein*	8.73	41.80

** Percentage Nitrogen X 6.25. W/W%= grams per 100 grams of sample.*
Results are expressed on an "as received" basis unless otherwise indicated.

Flue Gas Microalgae Gross Chemistry

Protein (food & feed)

20-50%

Cellular Lipids (bio-diesel)

TG, DG, MG, Polar & Neutral

8-50%

Cellular Carbohydrates (bio-ethanol)

20-50%

***Chlorophyceae*: Starch (α (1→4) glucose units**

Most other classes: Chrysolaminarin (β (1→3) glucose units

Microalgae
Commodity Market Potential Value

33% Protein (feed), US$ 1.0/kg = $ 0.3

33% Lipids (bio-diesel), 1.2 US$/L = $ 0.4

33% Carbohydrates (bio-ethanol), US$ 1.0/L = $0.3

Total ~ US$ 1.0/kg algae

Lower CAPEX
Large Scale Algae
Open Ponds

Capital Costs
Dunaliella Plant versus Alternative Bio-Fuel Algal Plant
(10 Hectares Plant Open Ponds)

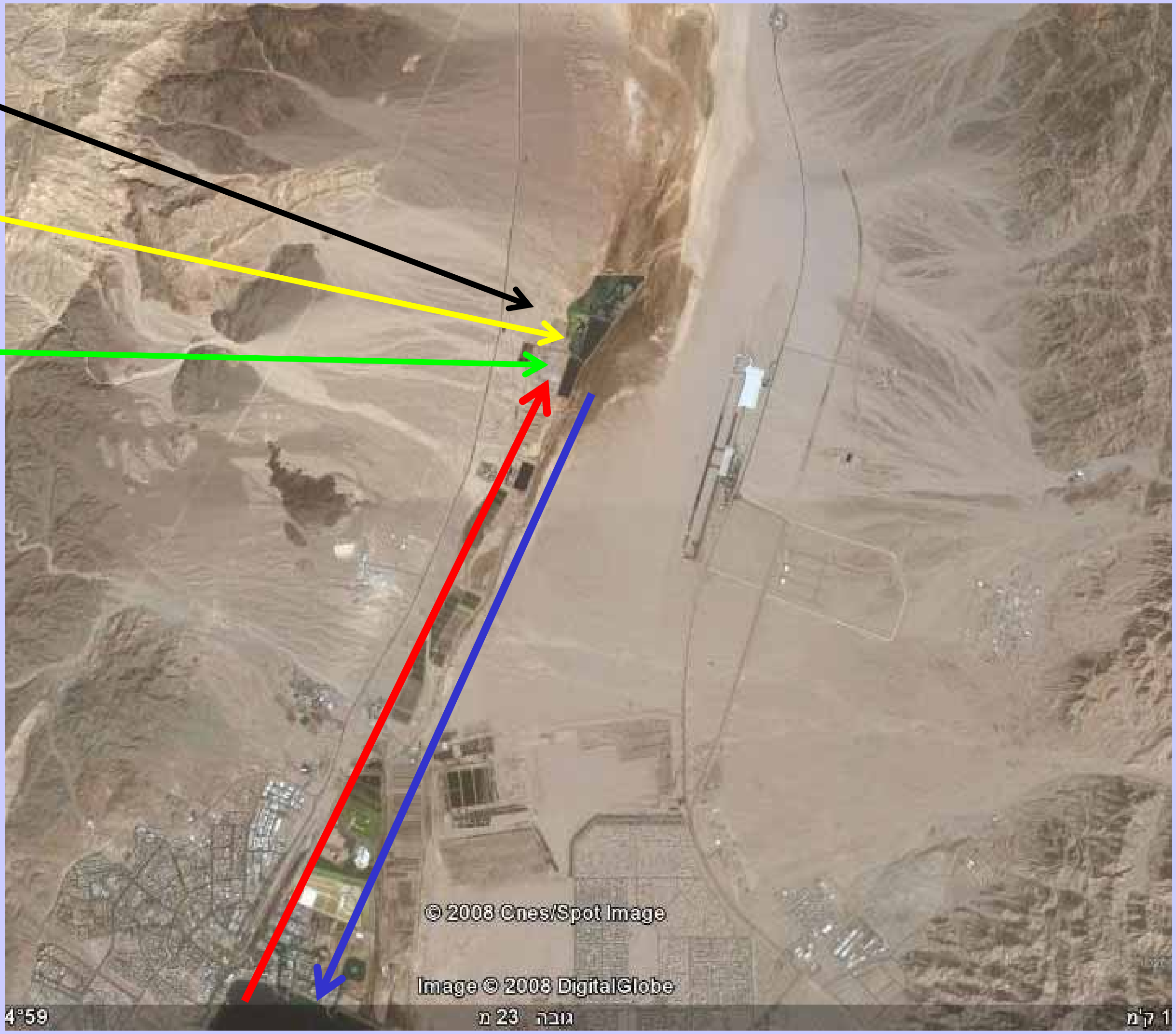
Category	Health Food *Dunaliella* NBT Ltd., Eilat, 2008 Capital Cost in US$	Category	Alternative Algal Plant Capital Cost in US$
Land	0	Land	0
Seawater Pumps and Underground Pipes, 4,000 m^3/day (1 km from the sea), ~$100/m*	200,000*	Sea water and piping, outsourcing,	30,000
Centrifuges, 4 x SS Clarifiers, 1,500m^3/day	2,000,000	Flocculation	200,000
Ground Work & Liner, PVC Food Grade & Cloth, $15/$m^2$	1,500,000	Ground work & Clay, Salt	150,000
Pressurized CO_2 Containers , 2 x 15 tons, $50,000/unit, piping	150,000	Flue gas and piping, outsourcing	50,000
Spray Drier, 300L/hr, plus LP Gas Container $250,000/unit	450,000	Drying? Power plant, outsourcing	?
Infrastructure, air, pipes, pumps, containers paddle wheels, sensors, control , power room, PC room	1,000,000	Infrastructure?	200,000?
Buildings: office, laboratory, processing, maintenance, control	1,000,000	Buildings	500,000
Others, including recycling salt, $0.3ML	300,000	Others	300,000
Total	**6.600,000**	**Total**	**1,430,000(?)**
Capital Cost, US$/$m^2$	66.0	Capital Cost, US$/$m^2$	14.3(?)

Capital Costs

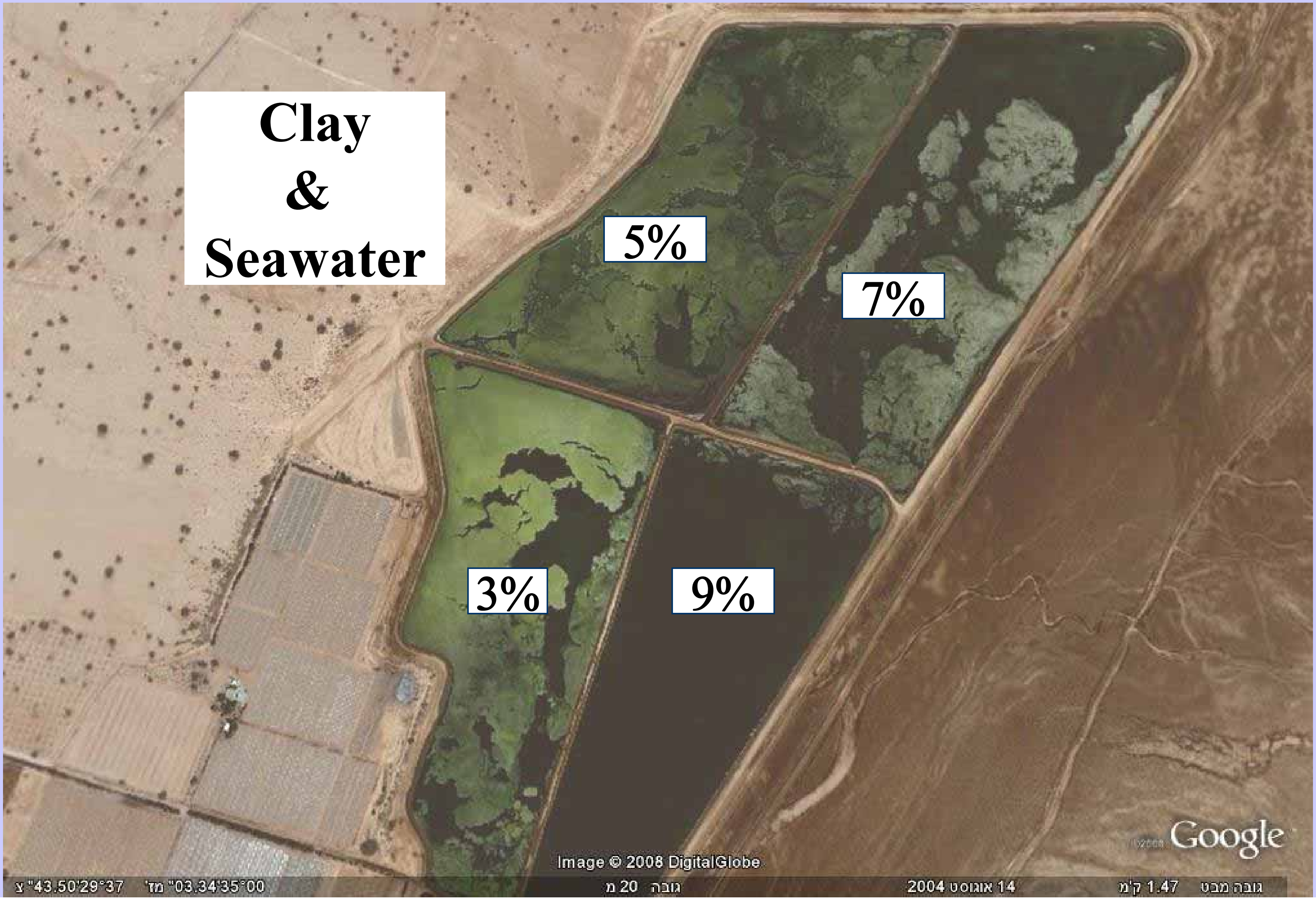
Bio-Fuel Microalgae Plant Land & Outsourcing

Desalination & Seawater pipe, 700,000m^3/day

Category
Land, *Desert Land ?*
Seawater Pumps and Underground Pipes, Outsourcing: *Desalination Plant, Salt Industry*
Centrifuges, 4 x SS Clarifiers, 1,500m$^{3/}$day
Liner, *Clay, Salt*
Pressurized CO_2 Containers , 2 x 15 tons, $50,000/unit
Spray Drier, 300L/hr, plus LP Gas Container $250,000/unit
Infrastructure, air, pipes, pumps, containers paddle wheels, sensors, control , power room, PC room, $1ML
Buildings: office, laboratory, processing, maintenance, control, $1ML
Others, $0.3ML
Total
Capital Cost, US$/m^2



Salt Water Clay Ground Ponds
200 Hectares Desert Arava Valley, Israel



NASA

Intensive Culture Mixing
&
Algal Productivity

Salt

Algae

Economic Feasibility?

Salt at US$25/ton is feasible

Algae at US$1,000/ton??

Seambiotic

ISRAELI ELECTRIC CO

Seambiotic

Small Israeli company of 6 employees

Major Achievements (2005-2008):

1. Applying the know-how of health food algal biotechnology to algal bio-fuel
2. Direct use of electric power plant coal burning flue gas
3. Direct use of electric power plant turbine cooling sea water
4. Continuous production of microalgae, ~7 tons/1,000m^2/year
5. Production of high lipid *Nannochloropsis* to 50%/AFDW
6. Processing collaboration of the algal mass to bio-diesel, bio-ethanol and protein
7. Supply of mass of algae to many algae companies
8. Reducing CAPEX and APEX of algal biotechnology
9. Scale up to 5 hectares pond area in 2009
10. Open to cooperation and collaboration