

1 July 2003

Biomass, Ocean Nourishment, Photobioreactor

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Technology for Reduction of CO₂

Energy Saving
Energy Conversion
Sequestration/Recycle of CO₂

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Energy Saving
Energy Conversion
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Geological Sequestration
Ocean Sequestration
Biological Sequestration

Technology for Reduction of CO₂

Energy Saving
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Geological Sequestration
Ocean Sequestration
Biological Sequestration
Afforestation
Microalgae
Ocean Nourishment

1. Afforestation

Matured forest never fixes CO₂!

Carbon Neutral
(Recycle)



Biomass Plantation

Capacity and Problems (Global)

Total Amount : 2000GtC (62%Forest, 38%Soil)
Annual Timber Production : 3400Mt (364MtC/yr)
if carbonized (Charcoal) : 218MtC/yr Sequestration (Efficiency 60%)
(16% of CO₂ Emission from Fossil Fuel)

Eligible Area : 744Mha (Carbon Fixation : 2200MtC)

However,

Farm Area necessary for Population Explosion
Jeopardize Local Economy
Cost

Capacity and Problems (Japan)

Total Forestry Area : 25Mha (10Mha in Artificial, 2nd in World)
 Annual Timber Increase : $69 \times 10^7 \text{m}^3$ ($59 \times 10^7 \text{m}^3$ in Artificial)
 equivalent to 8% reduction of domestic CO2 emission
 Therefore, $8.6 \times 10^7 \text{m}^3 / 1\%$ reduction
 or 2.2Mha / 1% reduction (cutting efficiency 70%)

However, most of them are burned at their last stage!!!

Electricity from Woody (xylem) Wastes

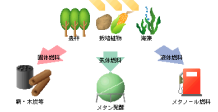
if Flat Fallow Area : 1Mha / 1% reduction (Growth rate $9 \text{m}^3 / \text{ha/yr}$ EU standard)

But impossible!

Wide Area Abroad via CDM

Electricity from Biomass

Sweden : Woody Biomass covers 19% of Primary Energy (9000GWh)
 USA : 7000MW by 550 plants (1% of Electricity)
 Japan : 160MW (Target 330MW in 2010)



Electricity from Waste Woody Biomass

Capacity : 110Mt (6Mtoe=7000GWh in heat) (Oil Consumption : 217.5Mtoe)

Technology : Conventional Power Generation (efficiency 16%)

Gasification (efficiency 45%)

Gas Methanol Hydrogen

Cost : Collection + Transportation + Drying + Chipping + Gasification
 10000JPY/t (35JPY/kWh in electricity)

13.86JPY/kWh (IGCC: Integrated Gasification Combined Cycle)

Economy of Biomass Power Plant

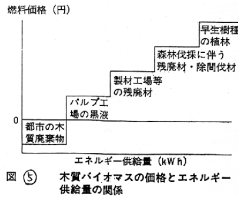


図 ⑤ 木質バイオマスの価格とエネルギー供給量の関係

Chip Price: 1000-6000JPY/t (ave. 2500JPY/t)

1000JPY/t = 2.1JPY/kWh (Price to Grid is 2-3JPY/kWh)

However, no one wants to sell the same timbers

cheaper!!!
 to Obtain 10% Benefit,

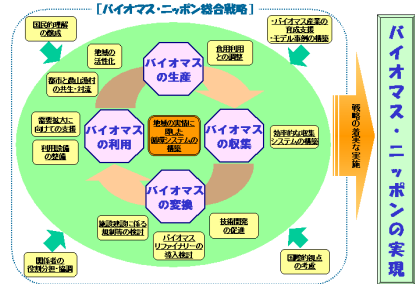
Price to Grid : 12JPY/kWh (Wind Mill, TEPCO) 2000JPY/t

20JPY/kWh (more Government Support) 6000JPY/t

"Biomass Nippon" Strategy

Dec. 2002 by MAFF, METI, ME

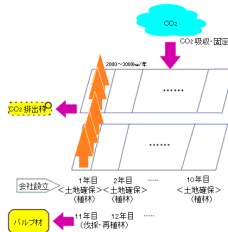
一バイオマス・ニッポン実現に向けて(骨子イメージ)一



CDM : Afforestation Abroad

CDM (Clean Development Mechanism) :
 Developed countries can count on investments in undeveloped countries.

Afforestation in foreign countries!!!



Note: COP8(Oct 2002) did not come to conclusion on CDM regulation.

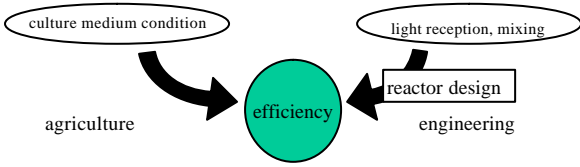
Cost of Foreign Afforestation for Carbon Fixation

Organization	Site	Biomass	Investment (JPY)	Area (ha)	Carbon Fixation	Cost (JPY/tC)
Tokyo Electric Power	Australia, Tasmania	eucalyptus	1800mil. (total)	10000/10yrs	3tC/ha	6000
Tohoku Electric Power	Australia, APFL Ltd.	eucalyptus	8000mil. (total)	26000/10yrs	5tC/ha	61500
Kansai Electric power	Australia, Perth	eucalyptus	400mil. (total)	1000/20yrs	235KtC (total)	1700
Mitsubishi Paper Mills	Australia, Tasmania	eucalyptus	6300mil. (total)	25500/15yrs	130KtC/yr	3200
Japan Int. Forestry Center	Indonesia, LombokIsl.	neem	-	3000/10yrs	4.5tC/ha	4000
Idemitsu Kosan	Australia, Ebenezzer	eucalyptus	25mil. (total)	135/5yrs	6820tC (total)	3700

Coal with Carbon Credit

Elements associated with Efficiency

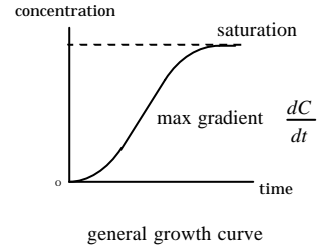
- sunlight reception
- mixing (global, local)
- culture medium condition (temperature, pH, salinity, etc)



Growth Curve

Maximum Efficiency = Growth Rate

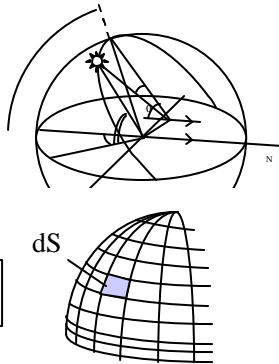
$$V \frac{dC}{dt} \quad V = \text{reactor capacity}$$



general growth curve

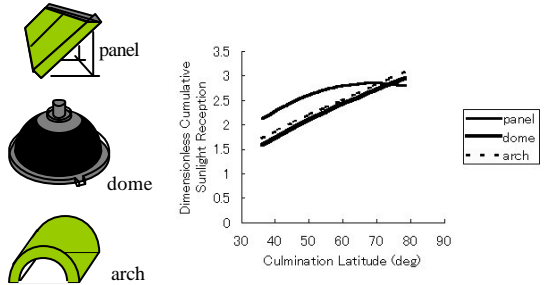
Light Reception

modelling of the movement of the sun with respect to season and daytime



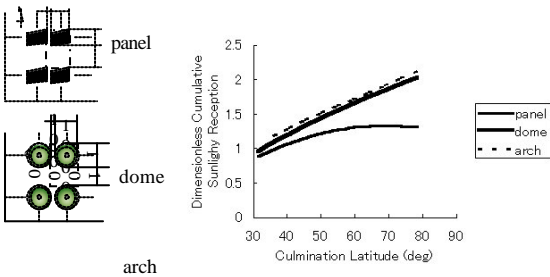
Comparison of Various Reactors in Reception in a Day

(at unit land area of **single reactor**, the north latitude 35 deg.)

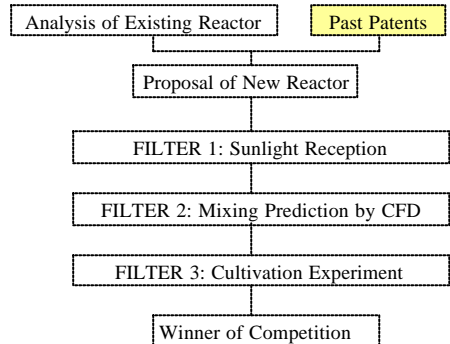


Comparison of Various Reactors in Reception in a Day

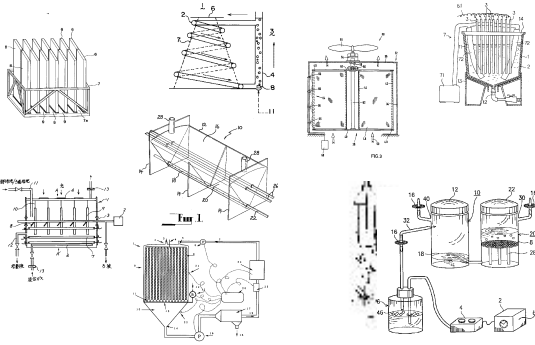
(at unit land area for **mass production**, the north latitude 35 deg.)



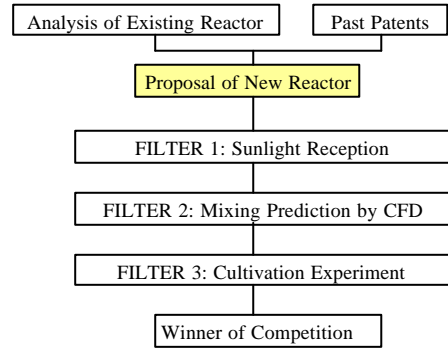
Invention Process of New Reactor



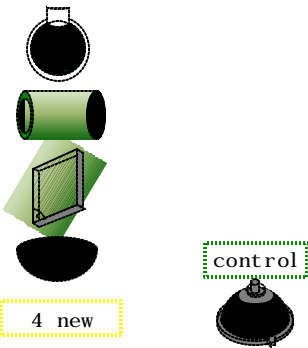
Investigation of Past Patents



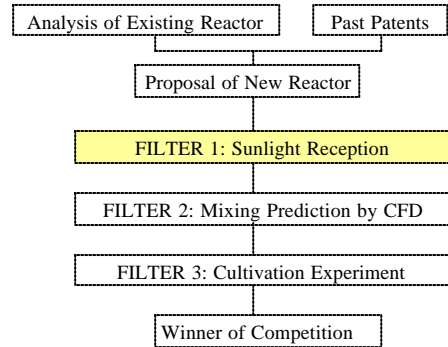
Invention Process of New Reactor



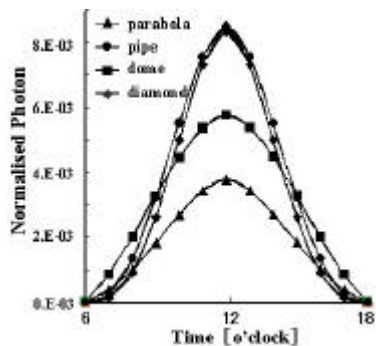
Proposal of New Reactor



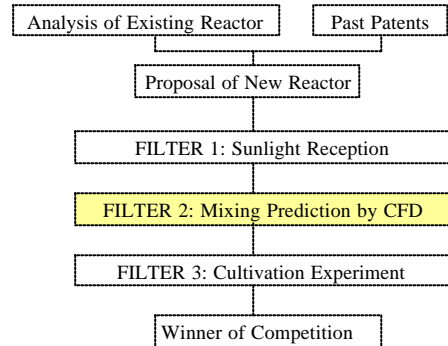
Invention Process of New Reactor



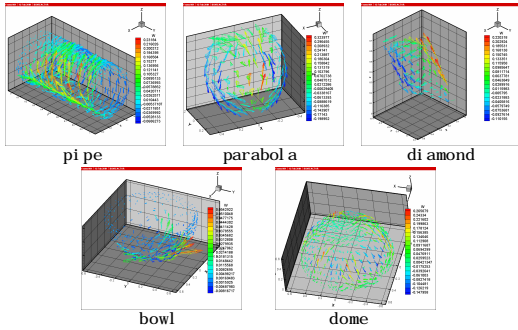
FILTER 1: Sunlight Reception



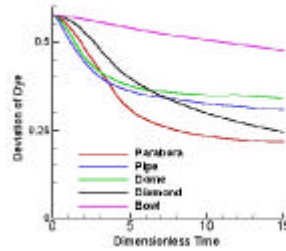
Invention Process of New Reactor



FILTER 2: Mixing Prediction by CFD



Assessment of Global Mixing by CFD: 1

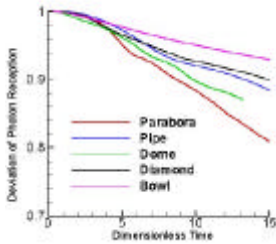


diffusion equation :

$$\frac{\partial C}{\partial t} + u_j \frac{\partial C}{\partial x_j} = \frac{\partial}{\partial x_j} \left(\frac{n_j}{S_j} \frac{\partial C}{\partial x_j} \right) + \Gamma$$

$C_0(L) = \text{RandomNumber}$
 $\Gamma = 0$
C:alga number
 ↓
 standard deviation
 ↓
 winner is **Parabola**

Assessment of Global Mixing by CFD: 2

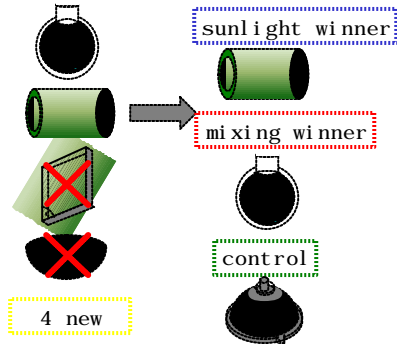


diffusion equation :

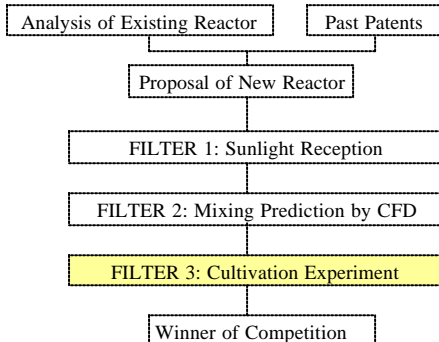
$$\frac{\partial C}{\partial t} + u_j \frac{\partial C}{\partial x_j} = \frac{\partial}{\partial x_j} \left(\frac{n_j}{S_j} \frac{\partial C}{\partial x_j} \right) + \Gamma$$

$C_0(L) = 0$
 $\Gamma = I = I_0 \exp(-kcx)$
C:integrated PFD
 ↓
 standard deviation
 ↓
 winner is **Parabola**

Result of FILTER 2



Invention Process of New Reactor



FILTER 3: Cultivation Experiment

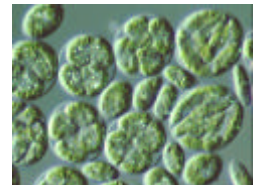
Reactors **parabola** **pipe** **Biodome**

date :12-24 January 2001

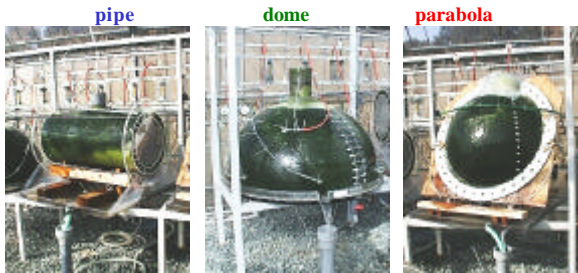
site :Yamaha Motor Co., Iwata City, Shizuoka

algae :*Chlorococum littorale*

by the courtesy of Marine Biotechnology Institute



FILTER 3: Cultivation Experiment

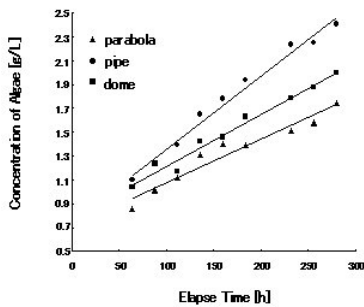


Dimensions and Conditions

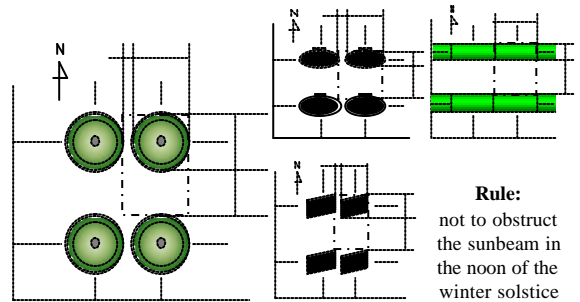
	capacity (L)	occupation (m ²)	air flow rate (L/min)	temperature (deg)	pH
parabola	70	2.21	31	25	7.0-8.0
pipe	70	0.90	31		
Biodome	130	2.74	60		

- MC Culture Medium: artificial seawater
- Initial Alga Concentration : 1 .0g/L
- Align Direction: South (Axis: west-east)

Results



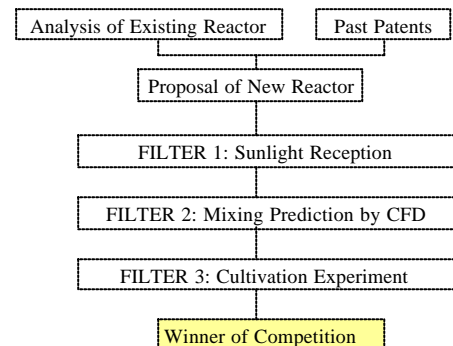
Land Occupation



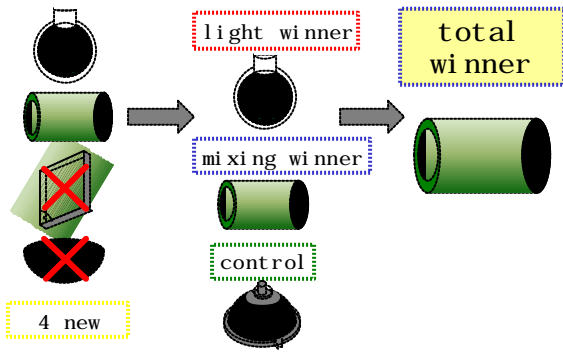
Assessment of Efficiency

	growth rate per apparatus (g/day)	growth rate per volume (g/L/day)	growth rate per land area (g/m ² /day)
parabola	6.05	0.086	2.73
pipe	10.25	0.146	11.39
Biodome	12.38	0.095	4.52

Invention Process of New Reactor



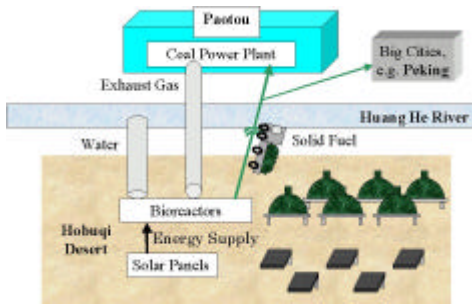
Winner of Competition



Design of CO2 Recycle System



Schematics of Proposed System



Botryococcus braunii.

Annual Energy Balance per 1km²

		MWh/km ² /year
A	Operation	20,000
B	CO ₂ Supply	240
C	Water Supply	15
D=A+B+C	(covered by solar energy)	20,255
E	Transportation of Algae	250
F	Gross Production	82,000
G=F-E	Net Production	81,750

Annual CO₂ Fixation per 1km²

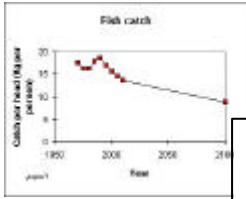
H	Energy Production in Electricity (MWh/km ² /year)	19,800
I	CO ₂ Emission per Unit Electricity (tCO ₂ /MWh) Chinese Coal Power Plant	14.7
J=HI	CO ₂ Fixation per Unit Area (tCO ₂ /km ² /year)	291,000

Cost of CO₂ Fixation

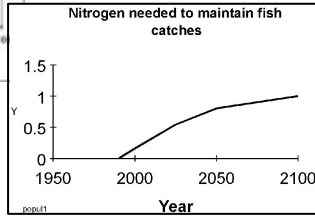
		US\$mill/km ² /year
K	Initial Cost (US\$mill)	556.9
L	Annual Balance (US\$mill)	-12.0
M=K/20-L	Annual Balance with Redemption (US\$mill)	39.8
N=M/J	CO ₂ Fixation Cost (US\$/tCO ₂)	137

50000JPY/tC (afforestation 400-60000JPY/tC)

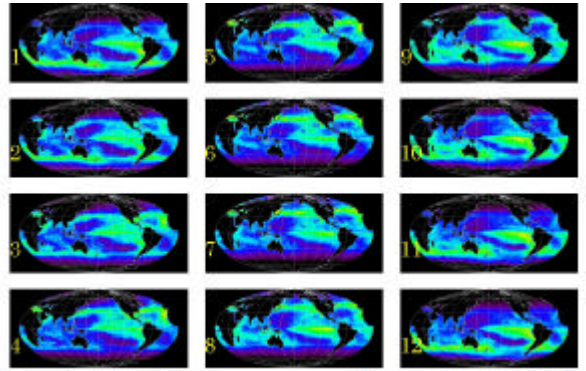
3. Ocean Nourishment



Additional nitrogen needed to keep fish catch per head of population constant, assuming new primary production in the ocean is 4.5 Gt C per year in 1990. The current level of nitrogen manufactured is about 80 Mt per year.

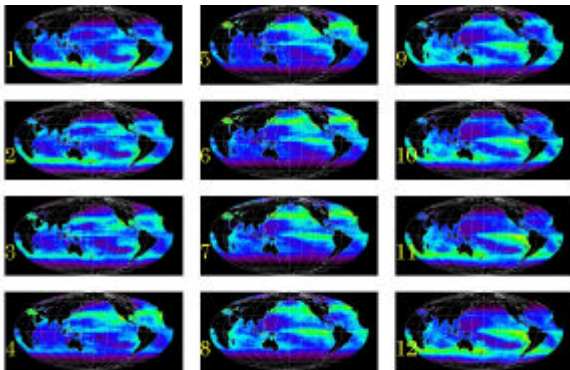


Fish catch (FAO 1994) per head of population. Predictions are based on an assumed constant catch after 1990



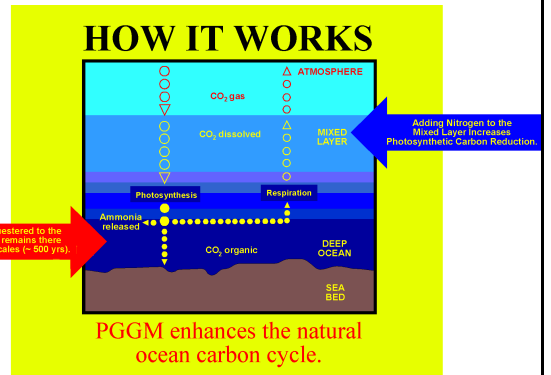
Primary Productivity (1999)

L.Asanuma/JAMSTEC/NASDA



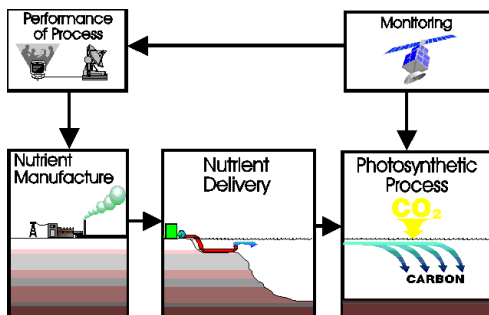
Primary Productivity (1998)

L.Asanuma/JAMSTEC/NASDA



Jones and Otaegui (1997)

Design of Pilot Plant



Jones and Otaegui (1997)

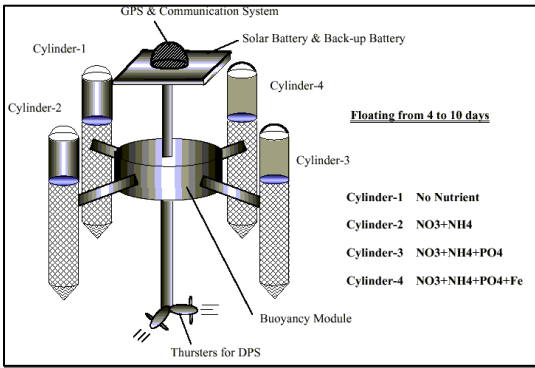
Research Project " Ocean Nourishment in Asia "

Objectives

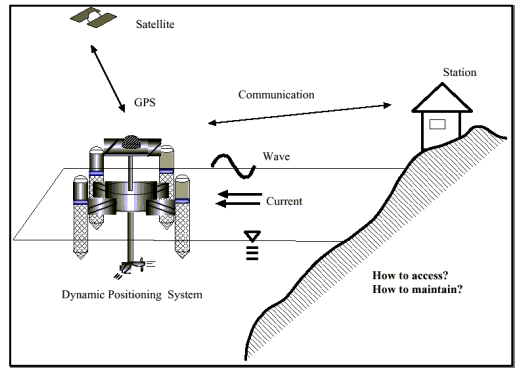
1. To Measure Carbon Flux Sinking to Deep Ocean and to Calculate Efficiency
2. To Estimate Benefits in Fish Catch via Food Web
3. To Assess Impacts to Ocean Ecosystem

Research Team

- Ocean Biologists
- Ocean Chemists
- Ocean Physicists
- Ocean Engineers



Offshore Mesocosm Experiment



Offshore Mesocosm Experiment

Capacity and Cost

- Amount of CO₂ sequestration per Ammonia 1ton
 - Redfield Ratio : 20t
 - CO₂ emission by operation : -2t
 - Deep-Sea Sequestration Efficiency 70% : 12.6t
- Cost : \$19/tC (2200JPY/tC)
- Capacity : 5MtC/yr by 5 Pilot Plants