

BIOSEQUESTRATION USING SOLAR ENERGY

Dr.(Mrs).M.Premalatha
Asst.Professor
CEESAT,NIT,Trichy

Carbon Sequestration

“The Path Forward”



“Pathways to Sustainable Energy”

Energy for the New Millennium

OUTLINE

- **Global Warming – Reasons**
- **Global Warming – Solutions**
- **Biosequestration by solar energy**
 - **Objective**
 - **Background**
 - **Biofixation**
 - **Type of Solar Bioreactor**
 - **Type of Microalgae**
 - **Parameters Affecting Micro Algae Growth**
 - **Design Of Solar – Bioreactor**
 - **Disposal Of Micro Algae Through Biomethanation**
- **Goals – Short, Mid and Long term goals**

STATUS OF CO₂

Pre-industrial Amount : 280 ppm

Present Amount : 382 ppm

Maximum Allowable \leq : 450 ppm

**Rate of Change : +2 ppm/year
(and growing)**

Global Warming - Reasons

- Very high quantity of CO₂
- Thermal Pollution

Global warming-Solution

- So far – Solution of Pollution Problems
 - Concentrate and contain
 - Dilute and disperse

- Hereafter-

- Convert and use it

Energy balance:

$$I/P = O/P + \text{Losses}$$

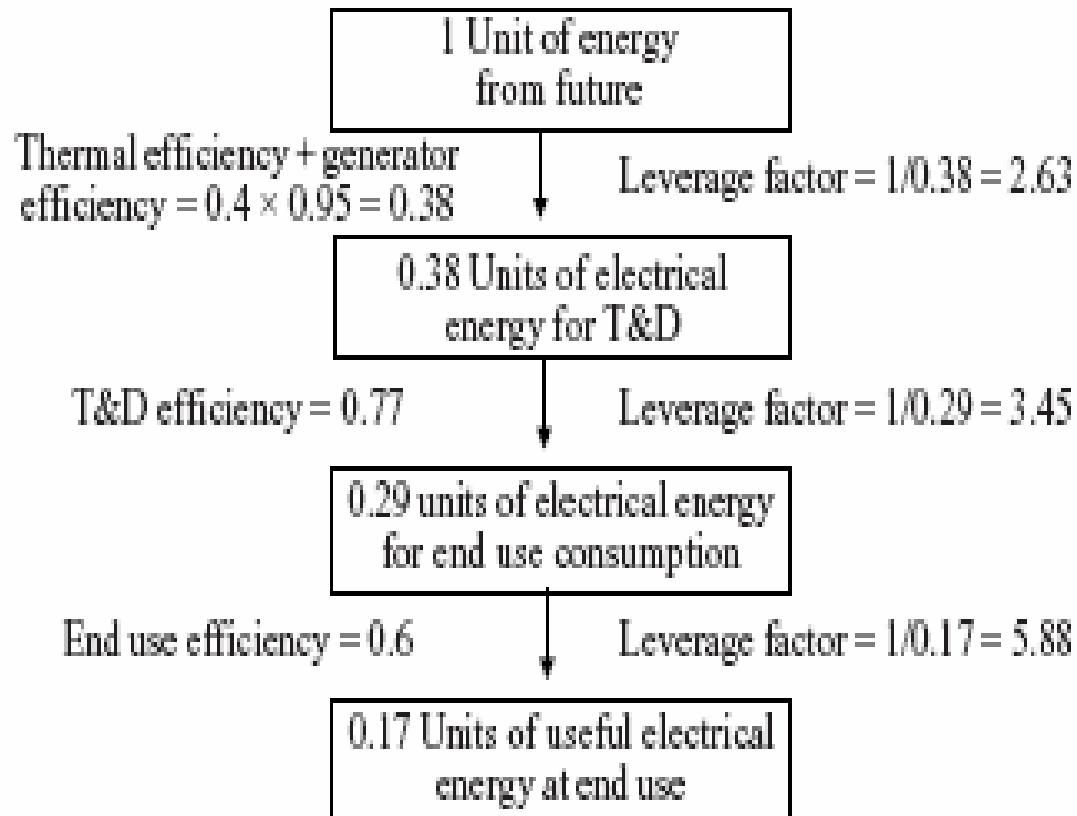
$$S-1 = O/P + O/P1(\text{Heat}) + L1 [\text{CHP}]$$

$$S-2 = O/P + O/P1(\text{Heat}) + O/P2(\text{Cooling}) + L2(\text{CHCP})$$

$$S-3 = O/P + O/P1(\text{Heat}) + O/P2(\text{Cooling}) + O/P3(\text{Micro algae}) + L3(\text{CHCMP})$$

Global Warming – Solution-1

- CHP (Decentralised Power)



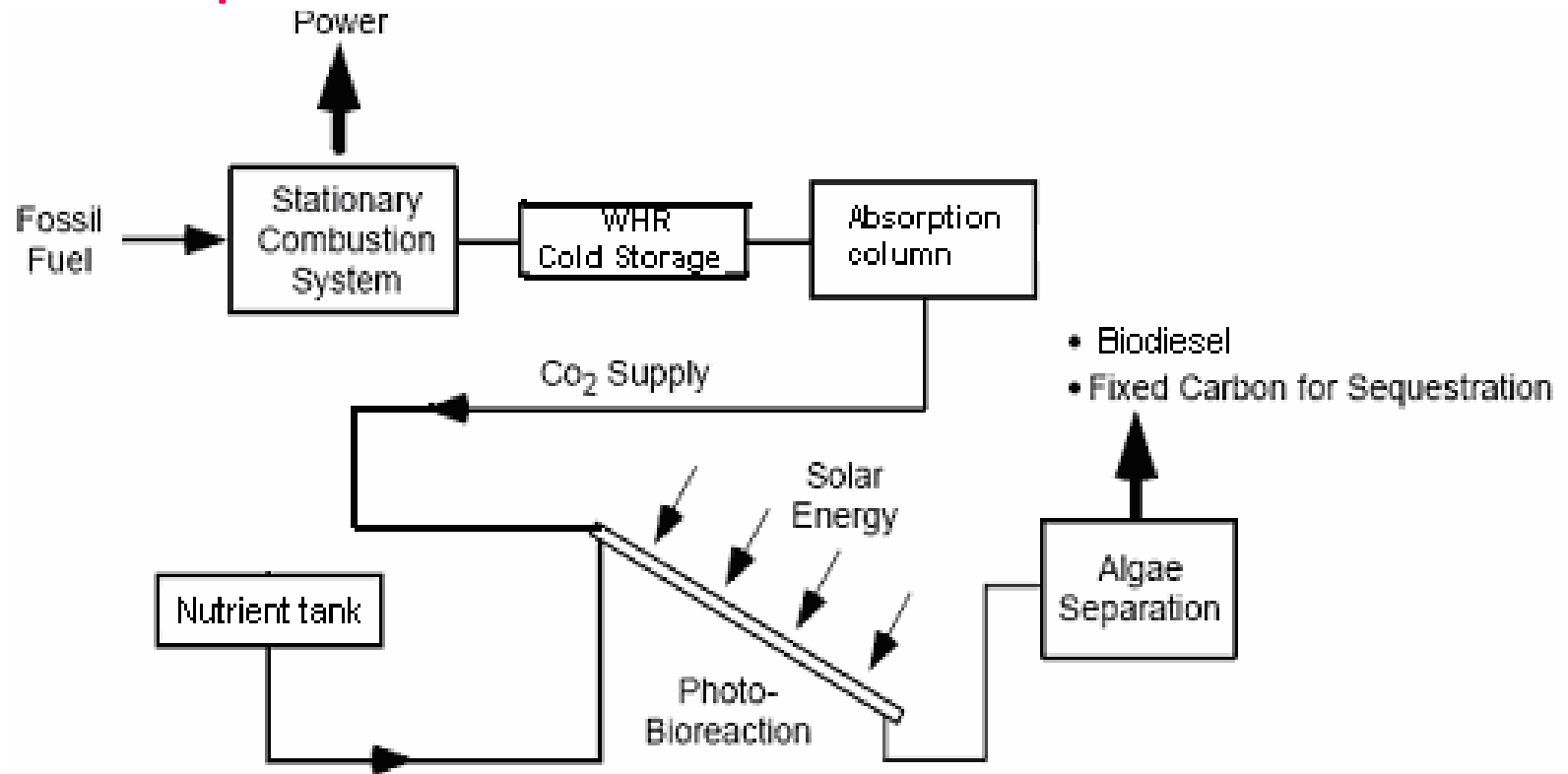
Global Warming – Solution-2

- CHCP

Cold Storage near power plants
(Centralized Food Processing)

Global Warming – Solution-3

- Biosequestration



Recovery and sequestration of CO₂ from stationary combustion system by photosynthesis of micro algae

OBJECTIVE

- **To simulate different designs of bio-solar reactor using CFD to maximize micro algae production**
- **To design, fabricate and test an economical bio-solar reactor.**

CO₂ Emission

- Yearly CO₂ emitted by thermal power plants is uniformly distributed in atmosphere (no stratification of CO₂ in the atmosphere) between 1-6 km above mean sea level.
- 50% of yearly CO₂ emitted is absorbed by photosynthesis, sea surface and rock weathering.
- 1 kWh electrical energy produces 0.90 kg CO₂ in the atmosphere from coal.

CO₂ FIXATION BY SOLAR BIOREACTOR

Photosynthesis



- Carbon dioxide, CO_2 , water, H_2O , and radiant energy from the sun are used.
- Glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, and oxygen, O_2 , are produced.
- The radiated energy falls within the visible light spectrum

ALGAE PHOTOSYNTHESIS

- Natural photosynthesis in plants and microorganisms absorb about 10^{11} tons CO_2/yr .
- However, the efficiency of solar energy conversion in plant production under optimal growth conditions is only 5 to 6%.
- Under field conditions, only 1~2% for sugarcane, 0.15% for forests.
- Photosynthesis is much more efficient in micro algae than in terrestrial plants.
- Algae can utilize the high concentrations of nitrate and phosphate nutrients contained in municipal and agricultural effluents for the fixation of CO_2 emitted from power stations or steel plants.

Microalgae

- Marine green alga *Tetraselmis suecica*
- The photosynthetic efficiency is 9~10% (optimal) or 4.6~5.1% (field). The CO₂ utilization efficiency is close to 100%.
- Good for ambient air (0.035% CO₂), pure CO₂, and stack gases (15% CO₂).
- Maximal growth rate with 20% CO₂ in a mineral nutrient medium at an NaCl conc. of 1.5%
- Growth rate is still 50% of the maximal even at 9% NaCl.
- Hot spring alga *Chlorella* sp. Optimal growth temp. in the ranges 35 to 40°C

Photosynthesis and Algae Growth

- Using the input elements of photosynthesis, we can look at algae growth and ways to optimize the quantum yield.

$$\Phi = \frac{\text{yield of photochemical products}}{\text{total number of quanta absorbed}}$$

- Carbon Dioxide
- Water
- Radiant energy

Solar Radiation and Photosynthesis

- Goal was to find if solar radiation that naturally occurs inhibits the photosynthesis

Radiation and Wavelengths	
PAR	400-700 nm
UV-A	315-400 nm
UV-B	280-315 nm

Solar Radiation Effects on Quantum Yield

- *Valonia utricularia* algae was exposed solar radiation for about 15 minutes during the noon hour.
- The yield dropped from about 0.7 to 0.5 when exposed to PAR alone, or PAR and UV-A.
- The yield dropped to 0.4 when exposed to the total solar radiation.

UV Spectra Shifting Possibilities

- **Most of the dyes in the experiment were absorbing the near-UV radiation and blue region.**
- **This region, as well as the UV region, has adverse effects on algae growth.**
- **Dyes have been suggested to be used as UV shifters to absorb the appropriate solar radiation and shift it into part of the spectrum that will be beneficial for algal growth.**
- **A shift, instead of a filter, of near-UV rays to the usable spectra could even further optimize algae growth.**

AVAILABILITY OF SOLAR ENERGY

- Above the atmosphere, we get 1368 W/m^2 of radiated power from the sun, across all wavelengths
 - This number varies by $\pm 3\%$ as our distance to the sun increases or decreases (elliptical orbit).
- At the ground, this number is smaller due to scattering and absorption in the atmosphere
 - about 63%, or $\sim 850 \text{ W/m}^2$ with no clouds, perpendicular surface
 - probably higher in dry desert air

PHOTOSYNTHETIC EFFICIENCY

- **Only 25% of the solar spectrum is useful to the photosynthetic process**
 - uses both red and blue light (reflects green),
 - doesn't use IR or UV
- **70% of this light is actually absorbed by leaf**
- **Only 35% of the absorbed light energy (in the useful wavelength bands) is stored as chemical energy**
 - the rest is heat
 - akin to photovoltaic incomplete usage of photon energy
- **Net result is about 6%**

PARAMETERS AFFECTING MICRO-ALGAE GROWTH

- **ABIOTIC FACTORS**
- **BIOTIC FACTORS**
- **OPERATIONAL FACTORS**

Abiotic Factors

- Light (Quality and Quantity)
- Temperature
- Nutrient concentration
- Oxygen
- CO₂ and pH
- Salinity
- Toxic Chemicals

Biotic Factors

- Pathogens (Bacteria, Fungi and viruses)
- Competition by other algae

Operational Factors

- solution, nutrient levels, and the size of the cell population Shear produced by mixing
 - Dilution rate
 - Depth
 - Harvest frequency
 - Addition of bicarbonate
 - Level of bicarbonate available for photosynthesis
 - pH of the growth
-
- Greenshift Industrial Design Corporation (GIDC) has acquired technology that uses a blue-green algae that grows in the environment of hot flue gases found in smokestack.

SOLAR - BIOREACTOR

- Open Type

- Variables

Size, Shape, Material used for construction,
Type of agitation, inclination

TYPE OF MICRO-ALGAE

Species	Effect	Reference
Coccolithophorids	40% lipid 60% total biomass	Fernandaz et al, 1994
<i>Dunaliella salina</i>	Oil production by biomass pyrolysis producing oil 20% less expensive than fossil oil (Cell rate of growth assumed is too high)	Ginzburg, 1993
<i>E.huxleyi</i>	High methane production	Wu and Colleagues, 1999

EFFECT OF FLUEGAS ON MICRO ALGAE

Coal Power Plant Flue Gas Data

	Stack Temp., °F	Stack CO ₂ , %	Stack O ₂ , %	Stack SO ₂ , ppm	Stack NO _x , ppm	Flue Gas Flow Rate, KSCFM
Average	239.5 (115.3°C)	12.1	5.5	422.9	123.6	1712.6
High	251.9 (122.2°C)	12.4	6.6	450.5	142.4	1768.3
Low	228.4 (109.1°C)	11.8	4.7	399.3	106.2	1487

- Effect of different flue gas constituents on micro algal growth rates and carbon dioxide fixation.
- Typical power plant flue gases have carbon dioxide levels ranging from 10%–15%.
- At the typical carbon dioxide percentages, micro algae show no signs of significant growth inhibition.
- Furthermore, studies have shown that micro algae respond better to increased carbon dioxide concentrations, outgrowing (on a biomass basis) micro algae exposed to only ambient air (Maeda et al., 1995; Brown, 1996).

DESIGN OF SOLAR BIOREACTOR

- **Open system - economical for large scale system**
- **Plug Flow or Mixed flow Reactor**

$$t = V / V.F.R$$

where t = time corresponding to exponential growth phase

- **V = volume of the tank**
- **V.F.R = Volumetric flow rate of microalgae removed**
- **Find out algae produced per kg of CO₂ removed**
- **Find out the effect of height on diffusion of CO₂ into the tank**
- **Hence calculate surface area required**

- **Direct or Indirect addition of CO₂**
- **Solar radiation availability**
- **Required solar radiation for selected micro organism**
- **Providing suitable collector for radiation**
- **Scale up or Scale down ?**

DISPOSAL OF MICRO ALGAE THROUGH BIOMETHANATION

- **Continuous Stirred Tank Reactor (CSTR)**
- **Plug Flow Reactor (PFR)**

New Design

- **Combination of both CSTR and PFR**

RESEARCH REQUIRED

- Selection of high growth rate micro algae
- Selection of optimal growth conditions
- Selection of solar-bio reactor
- Selection of low- pressure drop absorption column
- Method of removal of micro-algae
- Best reactor for methane production from micro algae
- CFD simulation of bio-solar reactor
- Designs of Solar bio reactor
- Various operating condition
- Various biodigester for biogas production

GOALS

- Short term - Energy policy

Improving energy efficiency every year

- Mid term - Environmental policy

Improving renewable energy use every year

- Long term - Integrated energy &
Environmental policy

Design any process considering waste utilisation efficiency besides process efficiency

SWOT

- Strength - Developing Country
- Weakness - Policies (PV), R&D(I.T),
Non-uniform pricing of energy,
Cost of carbon credits
- Opportunity - Developed country (Kyoto),
Renewable energy availability
- Threat - Impacts of Global Warming,
Energy crisis

Thank you