Development of Scaleable Algae Production System for Biological CO2 Sequestering and Production of Bio-Fuel

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PT MEDCO DOWNSTREAM INDONESIA

ENERGY DEMAND IN ASIA IS RISING

- China
- India
- Indonesia
- More than 60% is relying on Coal Burning
- Indonesia is planning construction of 10 GW coal-fired electric generator plant to meet growing demand of electricity
- 10 GW means about 150 million tons of coal to be burned every year
- Annual CO2 emission from the plant is 500 million tons to be dumped to the atmosphere, unless CO2 sequestering is applied

PRESENTLY THE BURDEN OF ABSORBING CO2 EMISSION FROM THE POWER RESTS ON THE FORESTS

- IS THERE ANY ALTERNATIVE?
- MICRO ALGAE PRESENTS AN ALTERNATIVE WHILE SERVES AS A NEW SOURCE OF RENEWABLE ENERGY
- WHY?
  - Micro algae growth rate is 100 times faster than land-based plants
  - The chlorophyll within the micro algae absorbs CO2 by the help of sun energy to convert it to sugar and other nutrients, and produces oxygen that is released to the atmosphere in exchange of CO2.
  - Micro algae growth cycle is doubling every 24 to 48 hours
  - Micro algae can produce lipids (oil) (20 to 65 % by weight); carbohydrates/sugars (10 to 40%) and protein (20 to 40%)
  - There are more than 100,000 species of algae in the sea and fresh water to choose from to produce any specific product.
  - Some species (Nannochloropsis and Bryococcus Braunii) contains more than 60% oil

SOME COMPARISONS OF OILS PRODUCED BY PLANTS

Type of plant	Oil content (% of dry weight)	Oil yields (annual)
Jatropha	30-35	600 L/ha
Oil palm	25-30	5.830 L/ha
Microalgae	35-80	58.700-136.900 L/ha

ADVANTAGES OF MICROALGAE COMPARED TO LAND-BASED PLANTS

- Does not compete with food production
- Uses much less space (10 to 100 times less)
- Each hectare of land can produce more than 60,000 liters of oil annually, or 12,000 gallons, or 300 barrels.
- It can absorb more CO2 gas per hectare than land-based plants
- Each ton of dry algae is equivalent to 788 kg of Carbon/coal or 2.9 tons of CO2 gas.
- The production of Algae in the vicinity of a power plant has mutiple benefits:
  - Can absorb CO2 gas form the exhaust of the power plant, including Nox and Sox gases
  - These gases are food for algae, the more is absorbs gas, the more it grows
  - The algae can become a renewable source of energy producing bio-fuel, bio-ethanol, even hydrogen.
  - The algae is also a renewable source of organic feed-stock for animals and fish, or fertilizer
  - Also feedstock to produce bio-polymers/plastics (bio-degradeable) as well as materials for pharmaceuticals.

INDONESIA AS A MARITIME COUNTRY

- A Tropical country with lots of sunshine and solar energy
- Large coastal area: 81,000 km2 of coastal line, ideal for algae cultivation and production on a large scale basis
- Most of industrial installlations that produce major CO2 emissions lays near or on the coastal area (power plants, steel production, petro-chemical and gas plants), makes CO2 sequestering by algae veru natural
- Indonesia is also second largest coal production (and exports) in Asia, next to Australia, and will depend mostly on coal for electric production in the foreseable future

PURPOSE OF RESEARCH

- Focus on developing large-scale algae production system
- Design and engineering of Photo-Bioreactor (PBR) which can be produced at low cost on a large scale basis with production cost of $500K per hectare for the first generation (presently lowest cost available commercial system is $1M per hectare).
- Design should maximize efficiency of the algae production, including:
  - **Photonic efficeincy**
  - **Direct injection of CO2 gas capability**
  - **Dissolved oxygen removal to prevent oxy-toxicity to the algae**
  - **Complete monitoring and control of process variables such as flow-rate, pH, salinity, macro and micro nutrients**
  - **Dark-light zone cycling to prevent photo-saturation effect and hysteresis**
  - **Spectrum shifting to increase photo efficiency**
  - **Light filtering to maximize PBR material life-time under full outdoor conditions**
  - **Capable of producing algae density of at least 5gms/liter at harvest point**
- Final research outcome is to produce a prototype of a modular PBR that covers 200m2 area with 50,000 liters volume which can be scaled-up for system covering 1 ha of area by simply adding similar module units, with volume capacity of 2,500,000 liters.

METHODOLOGY

1. Photo-bio reactor with the followong features:
   i. Type: Vertical PBR constructed of thin transparent polymer film tubes, interconected continuously to allow continuous algae culture until harvesting point
      a) 10 times more efficient than open-pond type
      b) Continuous growing cycle and maximizing light exposure to the algae growth media
      c) Simple fabrication and assembly
      d) Maximizing volume per unit area
      e) Optimum photo efficiency of absorption by algae cells and maximizing productivity/growth
      f) Ease of CO2 injection with controllable flow rate and ease of oxygen removal
      g) Application of "air-lift" principle for thorough algae light exposure while producing dark-light short cycles
      h) Monitoring and control of all variables: flow-rate, pH, temperature, salinity, photo intensity
2. PBR material selection, candidates: polycarbonate, HD PE, PVC; initial selection: PC
3. CO2 injection system: sparger at bottom of each column to create "air-lift" and creating dark-light cycling for the algae particles
4. Oxygen removal: by sparging mixture of CO2 and N2 gas and by diffusion through membrane
5. Flow control of growing media and gasses to control the effective residence times
6. Nutrient and pH control for maximizing growth rate
7. Sea-water intake: Pre-filtering to remove particles, and sterilization prior to use in system

METHODOLOGY (2)

8. Algae growth enhancements: applying succesfully tried methods on land-based plants using proven proprietary nano-trechnology methods. Doubling growth rates is possible
9. Photo-synthesis enhancements: enhancing the chlorophyll to increase rate of assimilation, absorb more CO2 and produce more brix. Proven method for land-based plants/leaves.
10. Algae harvesting: use low cost methods instead of costly centrifuge and filtering, using alternative methods: floculation and flotation.
11. Product extraction:
    i. Lipid/oil by sovent extraction to produce bio-diesel
    ii. Carbohydrate and sugar: enzymatic extraction followed by fermentation to produce bio-ethanol
    iii. Protein and minerals for animal feed and fertilizer
12. PILOT TESTING: It is planned to set-up pilot testing for CO2 sequestering at the Medco Downstream bio-ethanol plant in Lampung and produce algae products for various applications

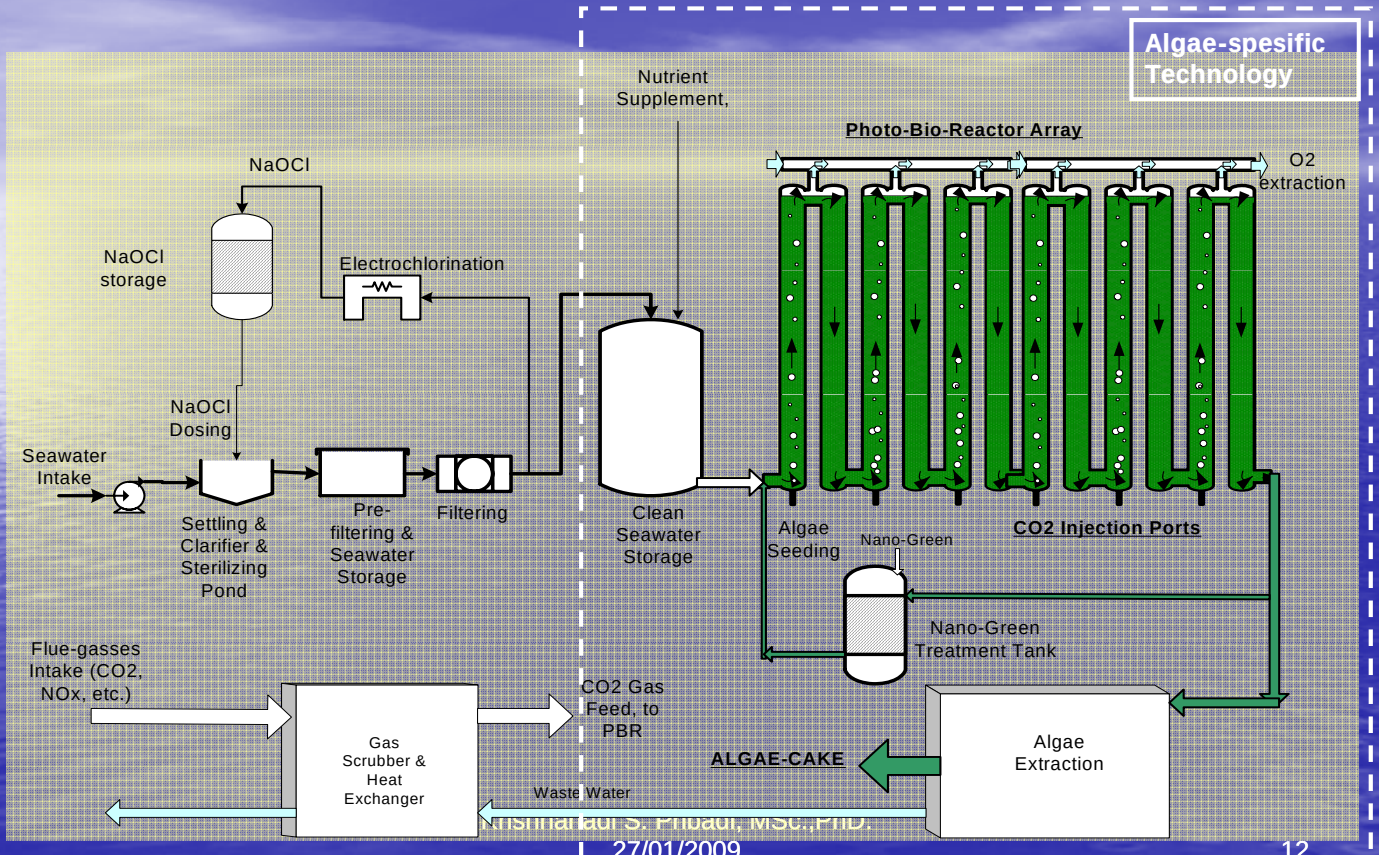
BENEFITS OF RESEARCH PROGRAM

1. Poduction of low-cost Photo-bioreactor that can be mass-produced for applications in Indonesia
2. Significatly reduce GHG CO2 emisiions from power plants and industries
3. Provide a renewable source of energy from microalgae as a viable alternative to fossil fuels tha does not compete with food prodcution in land-based agriculture
4. Provide renewable source of feedstock for animal feed and fertilizer that can siginificantly contribute to food production in oland-based agriculture and fishery
5. Source for bio-materials (bio-polymers) and cellulose source that can replace wood for producing pulp for paper, thereby reducing the number of trees to be cut to produce paper
6. The creation of new jobs and down-stream industries using algae products

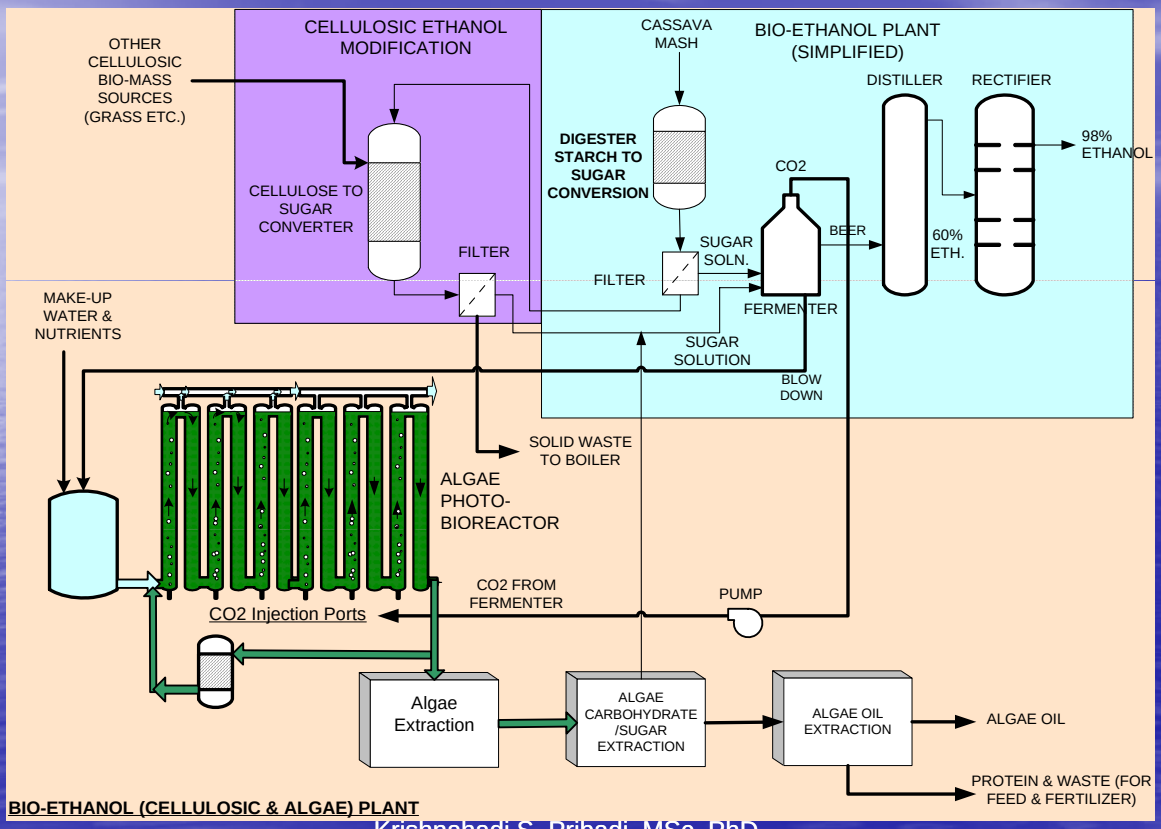
Algae Development Program Schedule

DESCRIPTION	YEAR 1												YEAR 2											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Start-up Preparations																								
Design & Engineering of PBR																								
Procurements, Equipment & Materials																								
Laboratory Set-up																								
Mold Fabrication																								
PBR Fabrication Prototype I																								
Prototype I Integration & Testing																								
Redesign																								
Mold Fabrication																								
PBR Fabrication Prototype II																								
Prototype II Integration & Testing																								
Prototype Field Installation																								
Instrumentation & Process Control Design																								
System Integration and Testing																								
Harvesting Method Investigation																								
Harvesting Method Testing																								
Algae Product Testing																								
Bio-Fuel/Algae Oil Extraction																								
Medium Scale PBR Construction (1 Ha)																								
Medium Scale Pilot Operational Testing																								

DIAGRAM OF ALGAE PRODUCTION SYSTEM



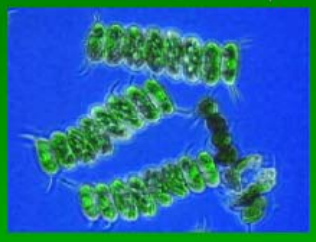
APPLICATION FOR CO2 SEQUESTERING BIO-ETHANOL PLANT



PRINCIPLES OF ALGAE PRODUCTION

EXAMPLE OF OPEN-POND RACEWAY ALGAE CULTIVATION (FLORIDA, USA)

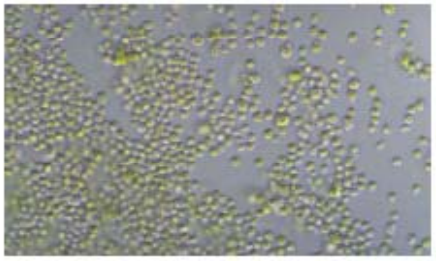
Algal Species List (some)



- *Scenedesmus dimorphus*
- *Neochloris oleoabundans*
- *Nannochloropsis salina*
- *Phaeodactylum tricomnutum*
- *Isochrysis galbana*
- *Euglena gracilis*
- *Botryococcus braunii*
- *Dunaliella tertiolecta*
- *Nannochloris* sp.
- *Spirulina* sp.

CHLORELLA, A MULTI-PURPOSE ALGAE

- Used Chlorella, a type of green algae
- Easy to grow
- Extremely high levels of photosynthetic efficiency
- The Chlorella maintains a fast rate of cell division.



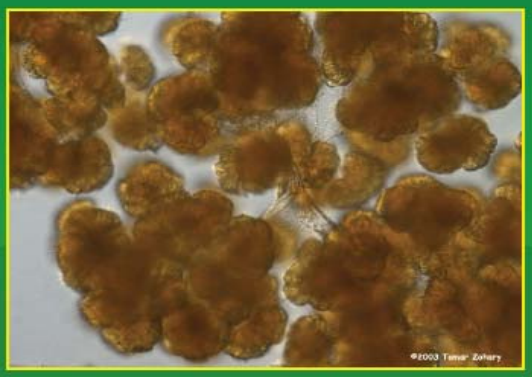
BOTRYOCOCCUS BRAUNII (Bb)
ALGAE WITH HIGH HYDROCARBON CONTENT

Bb

- *Botryococcus braunii*, or Bb, is a source of biological hydrocarbons.
- Up to 75% of Bb's dry weight is a hydrocarbon that can be used for diesel.

Botryococcus braunii Kützing

- Brown resting stage that often gives rise to massive rust-colored algal "blooms" on the surface of lakes.
- In this stage, 75% of the total dry weight may be accounted for by branched-chain hydrocarbons.
  - Wake & Hillen 1980



ALGAE DERIVED PRODUCTS

- Mature, oil-rich algae can be processed into a number of commercial products:
  - Biodiesel (oil)
  - Ethanol
  - Animal Feed (Fodder)
  - Food
  - Cosmetics
  - Pharmaceuticals
  - Plastics (Biodegradable)

POTENTIAL APPLICATION WITH FLOATING VERTICAL PBR IN THE COASTAL AREA

THANK YOU