CO_2 Capture and Recycle Using Microalgae

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East Bend Station Demonstration Facility

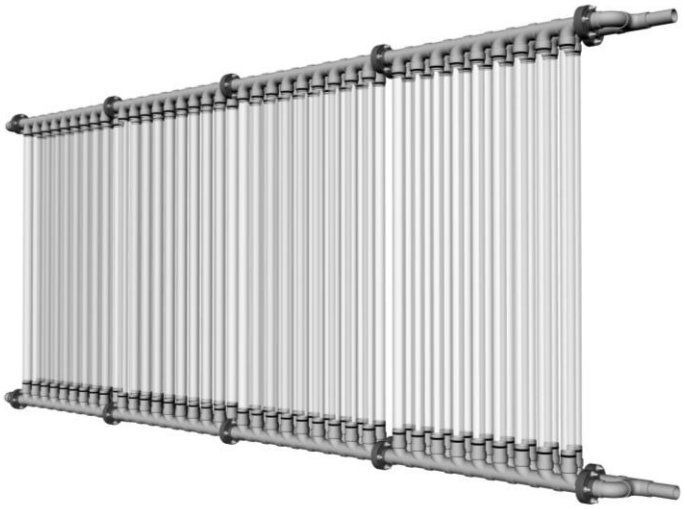
650 MW Scrubbed Unit (SCR, FGD, ESP)

MAIN GOALS

- Define kinetics of process
  - Monitor dissolved CO_2 and O_2 to determine photosynthetic rate
  - Help size large system and next generation design
- Gain understanding of real capital and operating costs
  - Minimize energy consumption
- Measure biomass composition to track heavy metals and other flue gas constituents

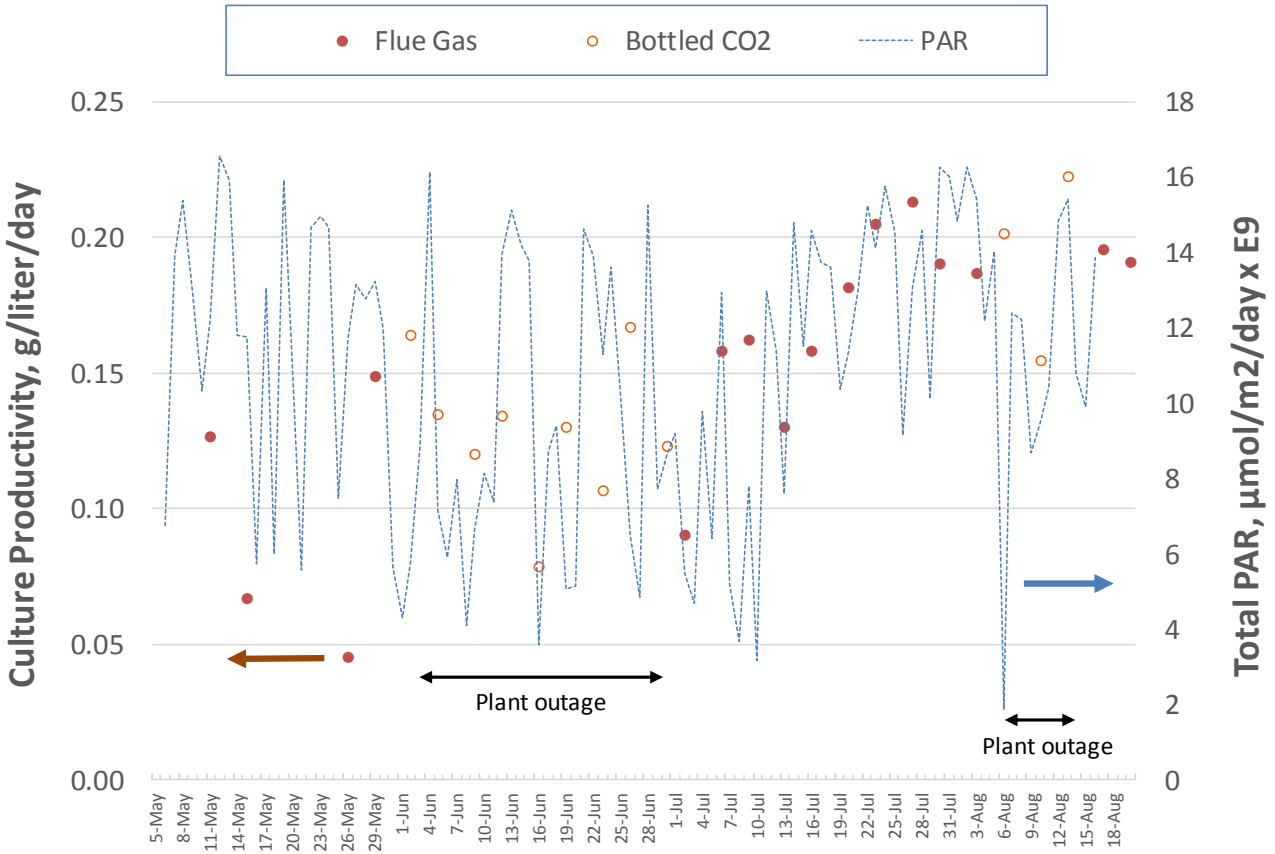
	CO_2 %	NO_x ppm	SO_2 ppm
Average	8.9	53.4	28.0
Minimum	7.2	14.5	6.5
Max.	9.6	97.2	84.3

“Cyclic Flow” Photobioreactor (1150 L) Installed at East Bend (2nd Generation PBR)



East Bend Algae Productivity

Summer 2015

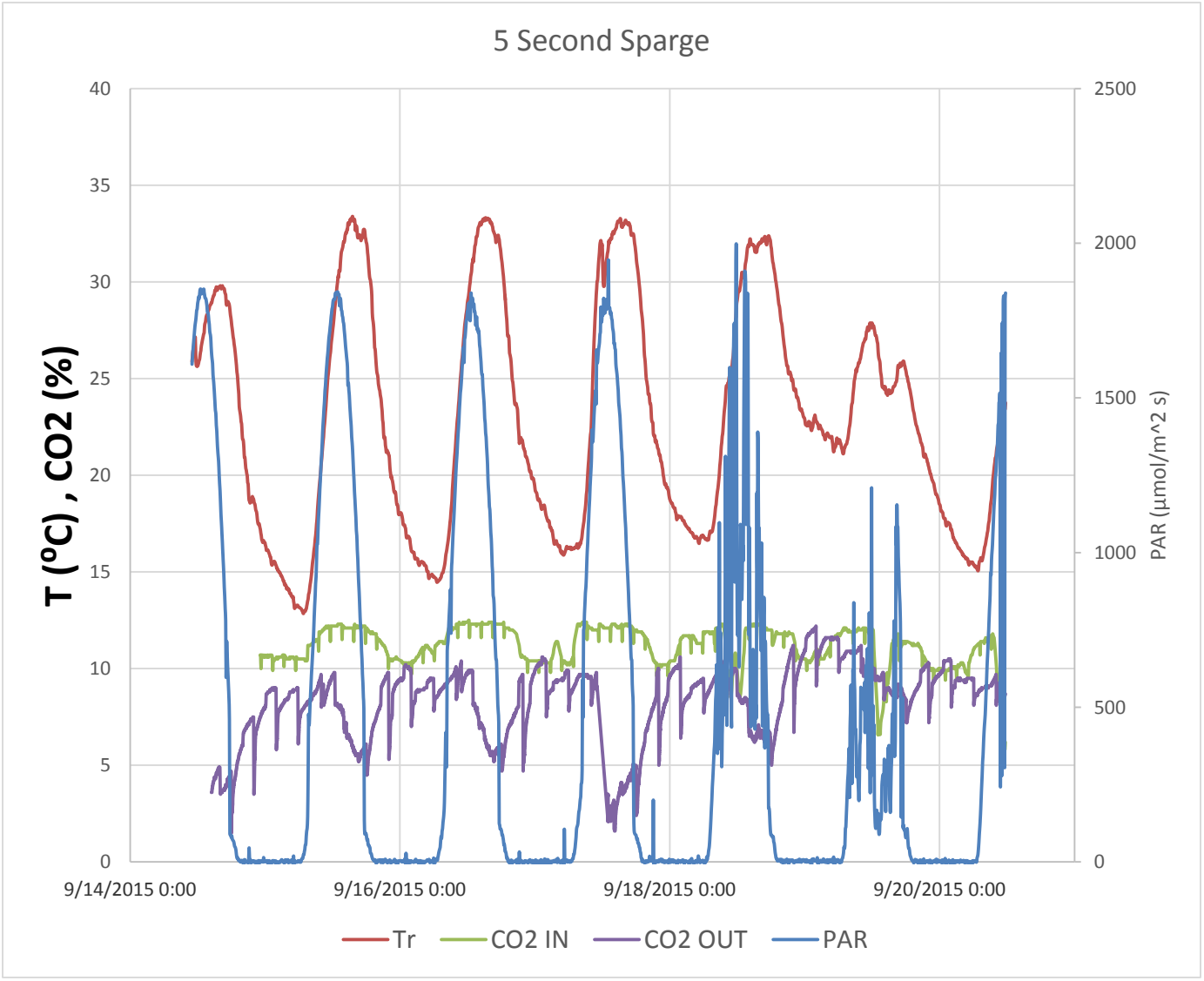


- Algae productivity = 0.165 ± 0.057 g/(L.day), equivalent to ca. 35 g/(m^2.day)

M.H. Wilson, D.T. Mohler, J.G. Groppo, T. Grubbs, S. Kesner, E.M. Frazar, A. Shea, C. Crofcheck, M. Crocker, *Appl. Petrochem. Res.*, 2016, 6, 279-293.

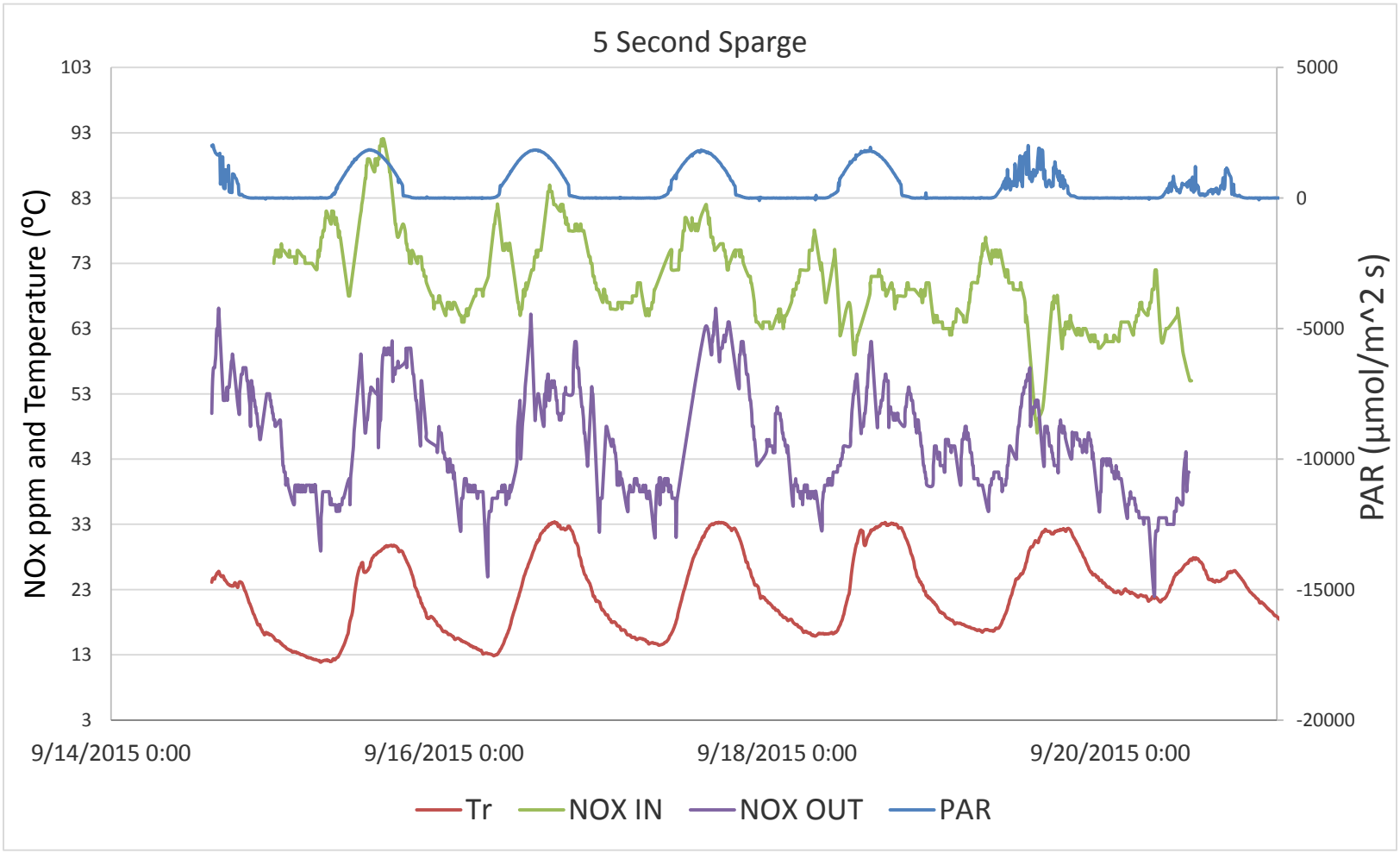
CO_2 in *versus* CO_2 out

Av. CO_2 capture efficiency during daylight hours = 44%



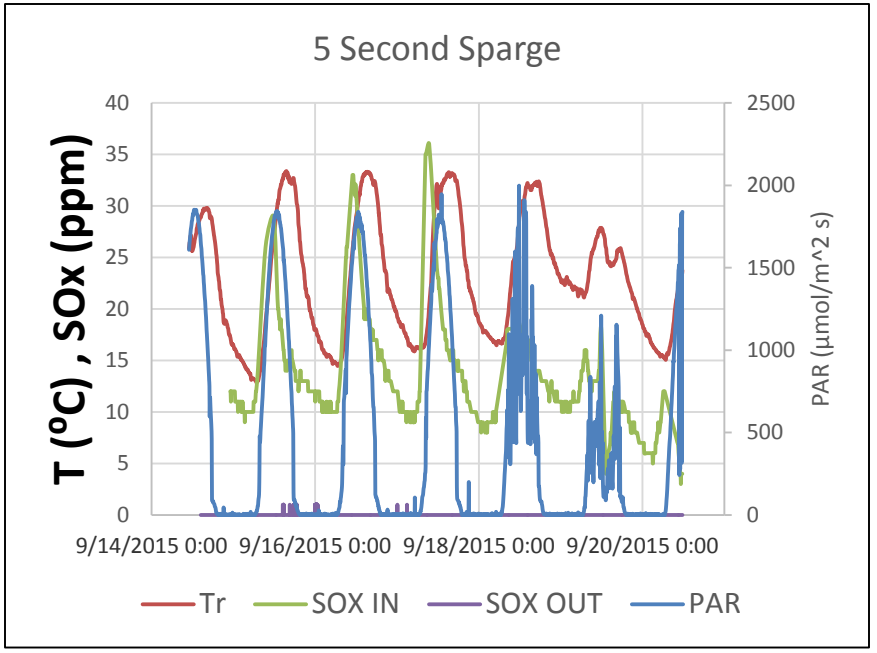
NOx in *versus* NOx out

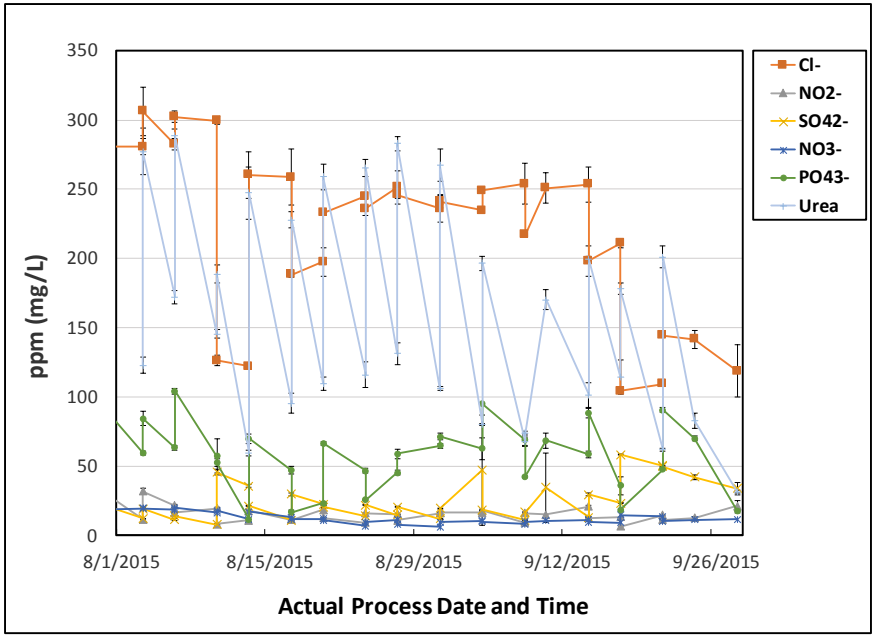
Av. NOx removal efficiency = 41.5%



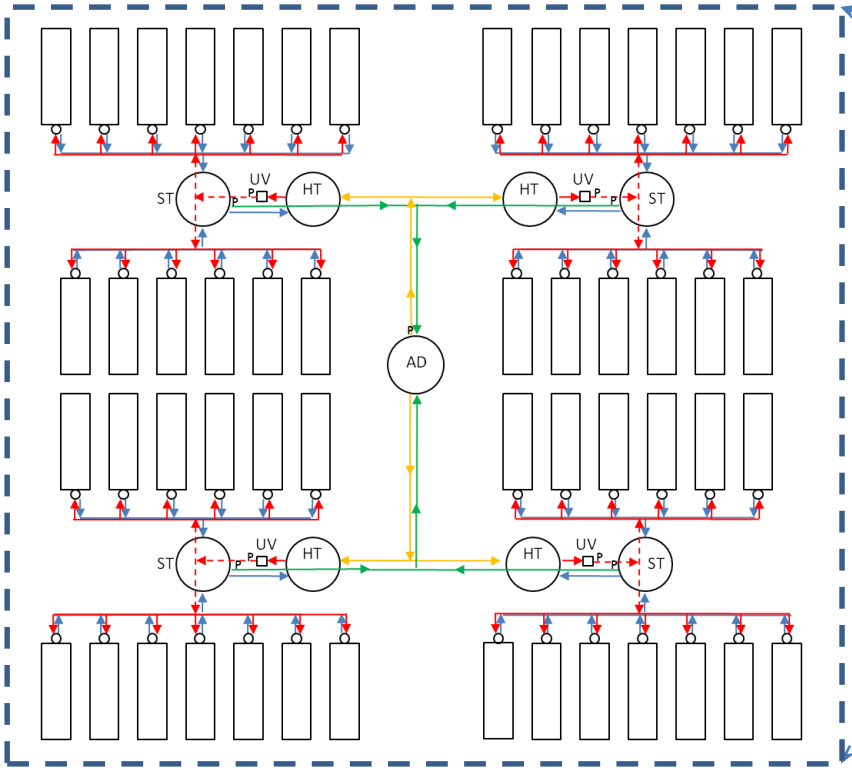
SOx in *versus* SOx out

- Inlet SO_2 = ca. 10-30 ppm
- 100% SO_2 removal efficiency
- No accumulation of sulfate ions in culture medium over 5 month operating period

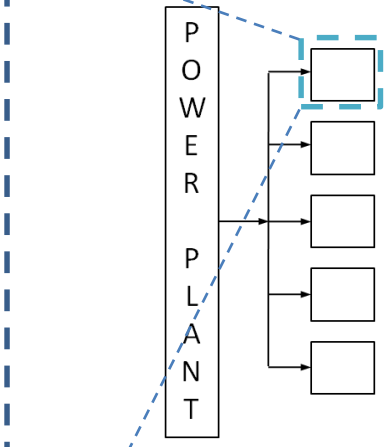




Life Cycle Analysis



Schematic of a section of the algae system consisting of 52 PBR modules, 4 settling tanks (ST), holding tanks (HT), and UV sterilizers (UV).



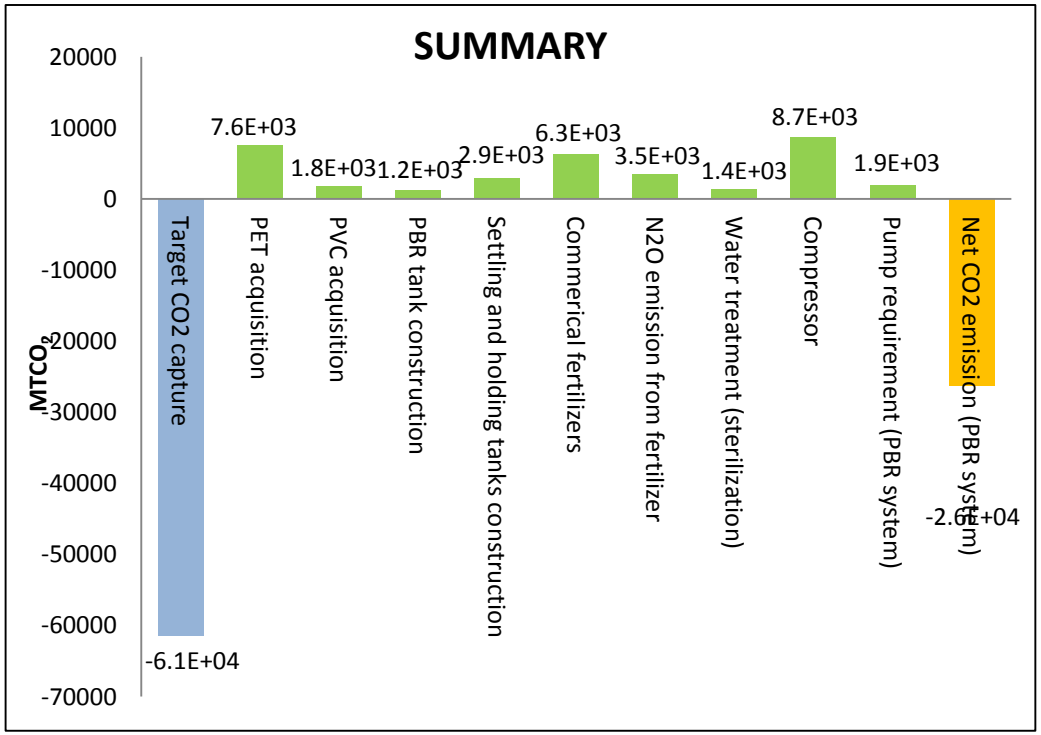
A schematic of the algae system (260 PBR modules; 260 individual feed tanks, feed pumps, and compressors; 20 individual settling tanks, holding tanks, and UV sterilizers)

- A life cycle assessment (LCA) was developed for an algae system based on UK's cyclic flow PBR, **mitigating 30% of the CO_2 emitted by a 1 MW coal-fired power plant**.
- Operation of the algae system included cumulative process requirements and energy consumption associated with algae cultivation, harvesting, dewatering, nutrient recycling, and water treatment.

Life Cycle Analysis: Results

- CO_2 emission associated with the gas compressor was 8.7 x 10^3 metric tons, due to the large amount of flue gas (4422 m^3/h) being compressed at full capacity for 12 h per day.
- PBR feed pumps emitted a lesser amount of CO_2 (1.9 x 10^3 metric tons) on account of the cyclic flow operation mode.
- The PBR system was able to capture 43% (2.6 x 10^4 metric tons) of the target CO_2 emission (6.1 x 10^4 metric tons).
- The LCA results demonstrate that a PBR algae system can be considered as a CO_2 capture technology.

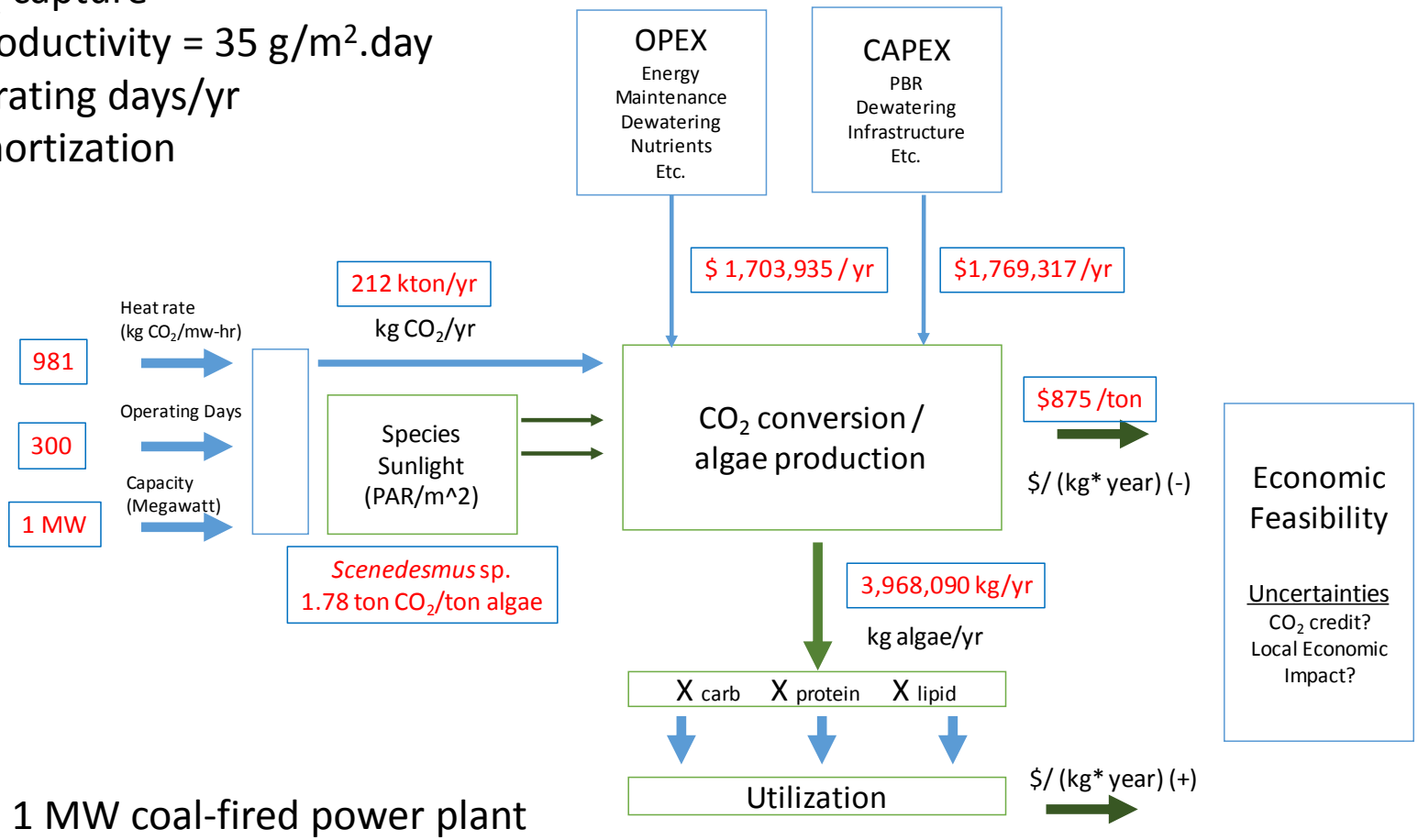
POWER PLANT		
Capacity	1	MW
CO_2 emission	22.76	ton/day
CO_2 capture	30	%
CO_2 emission mitigated	6.83	ton/day
Operation	300	day/year
ALGAE		
Strain	*Scenedesmus acutus*	
Growth rate	0.15	g/L/day
Culture density at harvest	0.8	g/L (dry weight)
Algae required for 30% CO_2 capture	3.88	ton/day



Techno-economic Analysis

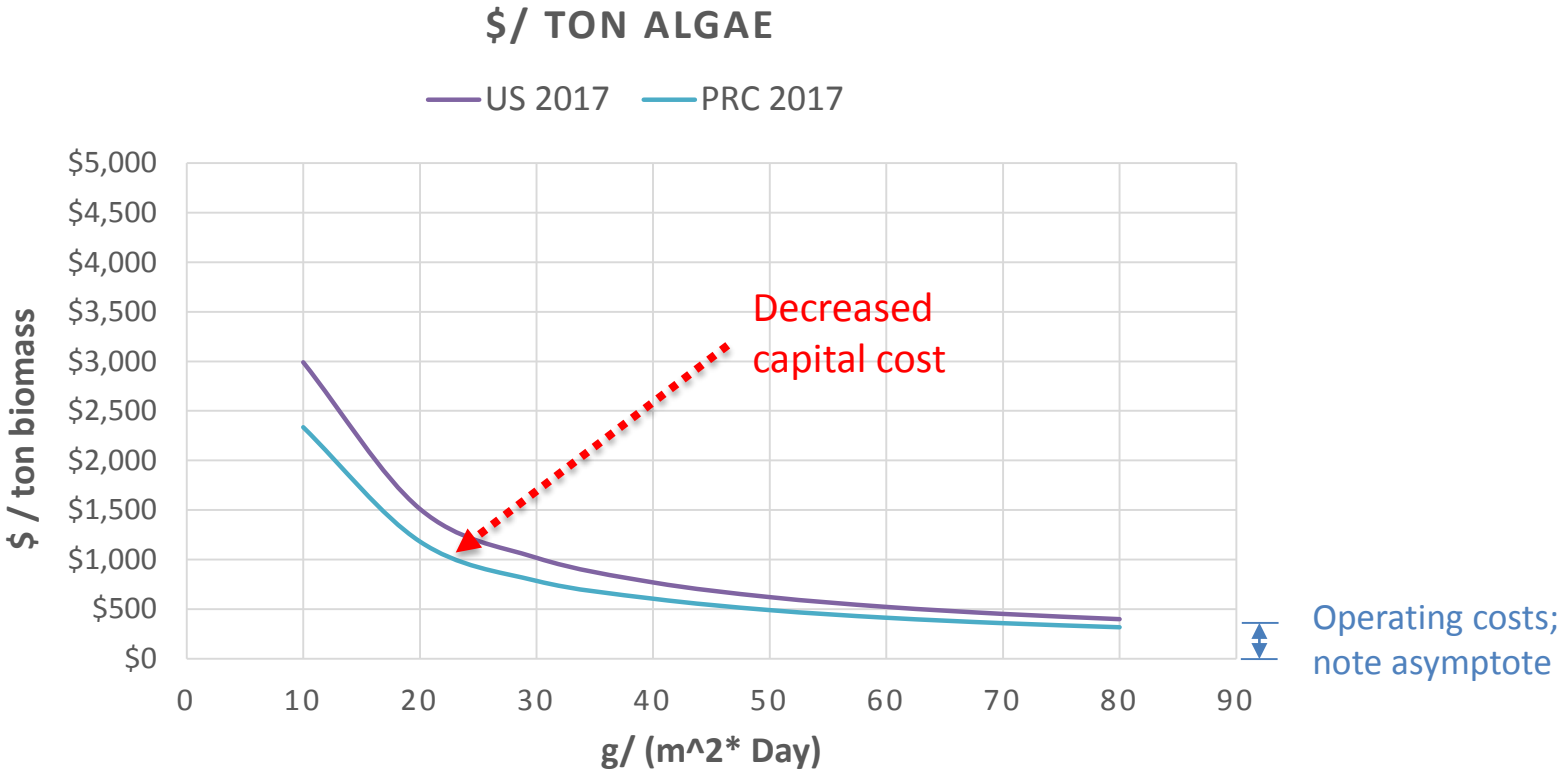
US Scenario (best case):

- 30% CO_2 capture
- Algae productivity = 35 g/m^2.day
- 300 operating days/yr
- 30 yr amortization



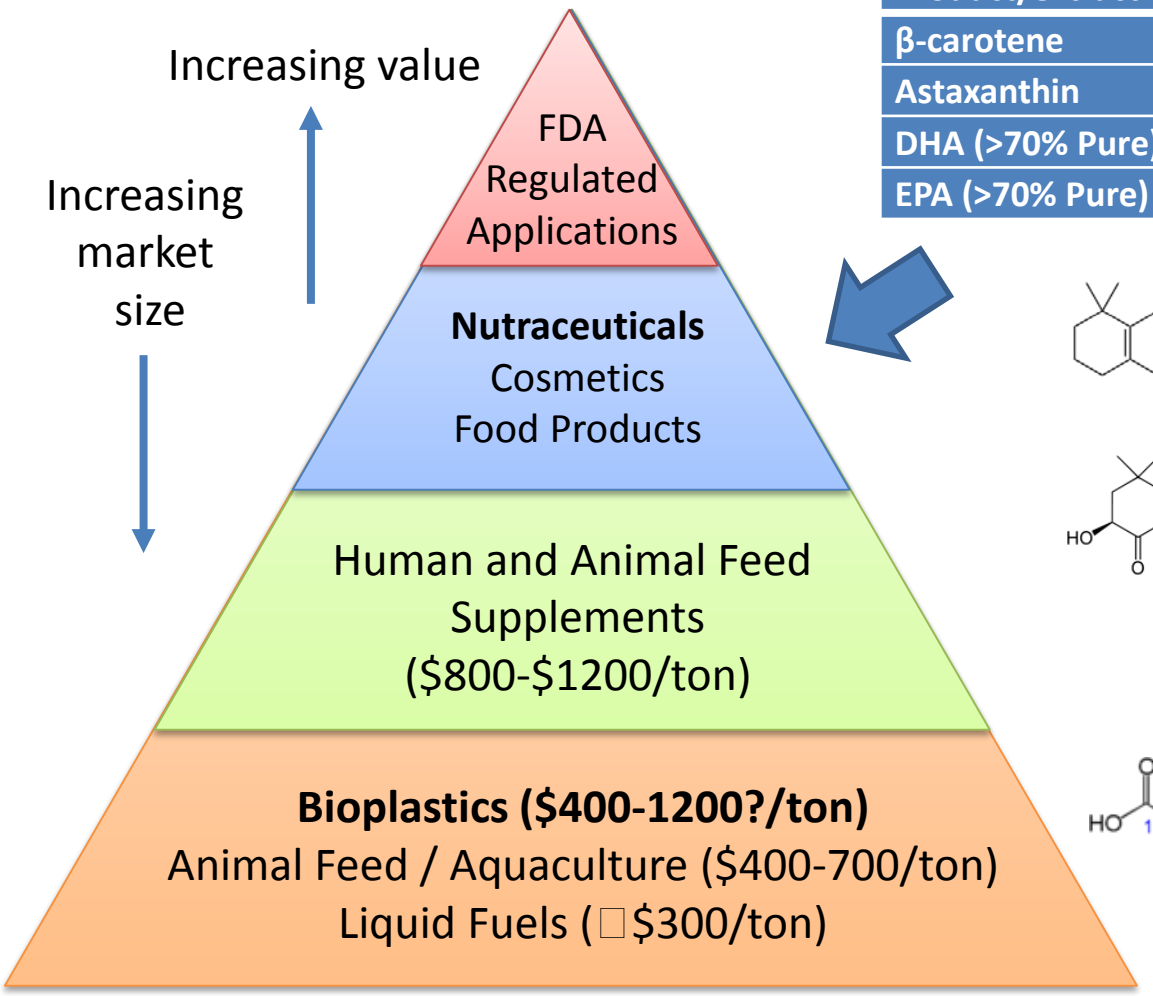
Base case: 1 MW coal-fired power plant
Estimated min. algae production cost = **$875/ton**
(biomass dewatered to 10-15 wt% solids)

Techno-economic Analysis (cont.)

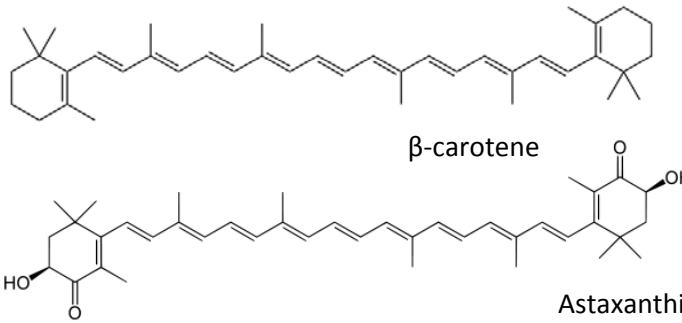


- Asymptote relates to operating costs
- Cost in PRC lower due mainly to lower labor costs (PBR installation and operation)

Algal Biomass Utilization

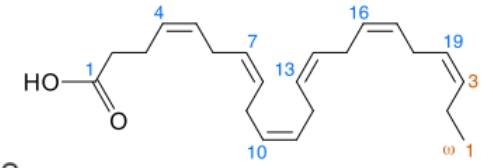


Product/extract	Selling price	Wt% in algae
β-carotene	$300-3000/kg	14%
Astaxanthin	$2500-7150/kg	3%
DHA (>70% Pure)	~$12,540/kg	7.8%
EPA (>70% Pure)	~$12,540/kg	4%

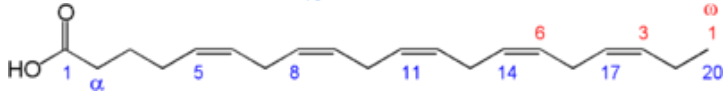


β-carotene

Astaxanthin

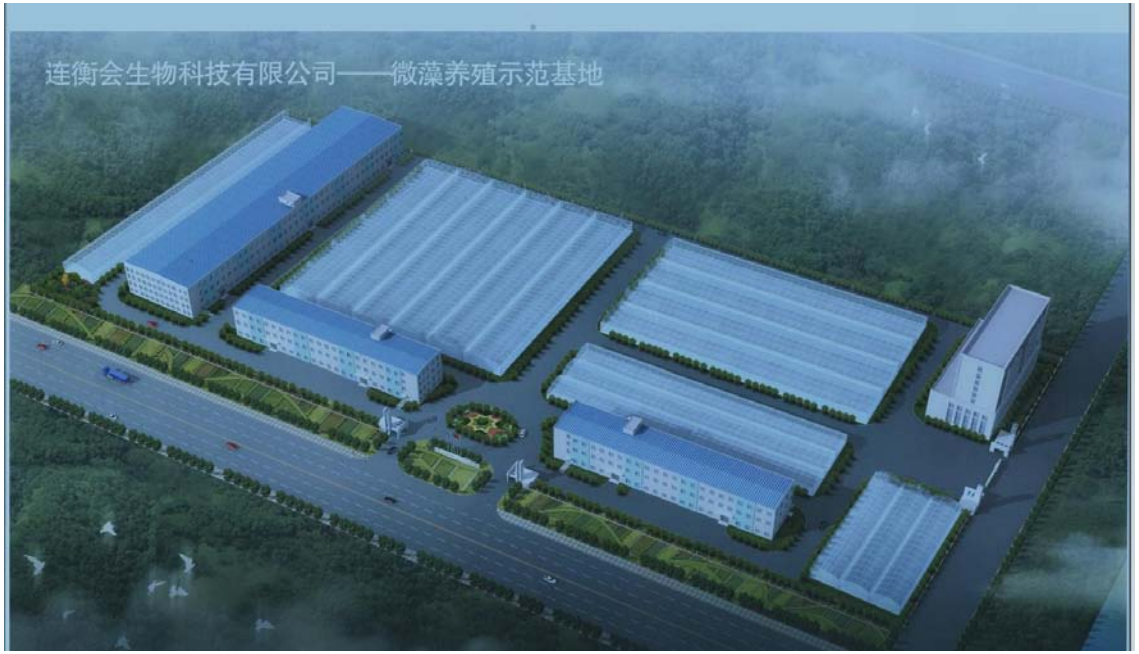


DHA

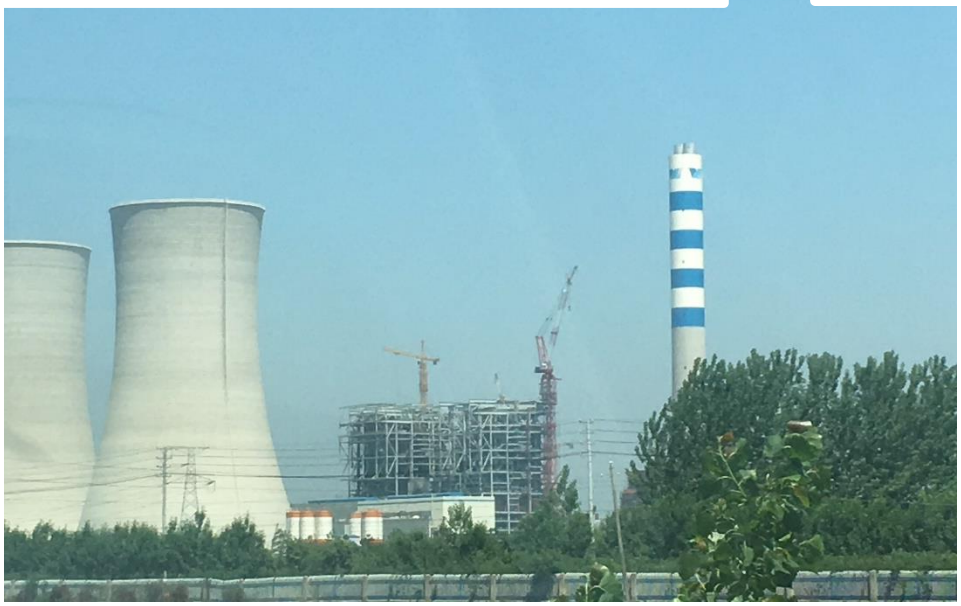


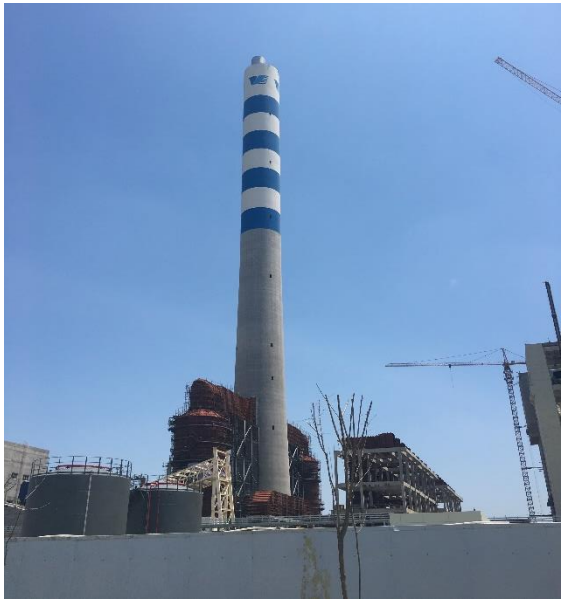
EPA

Lianhenghui Demonstration Project – Zhengzhou, China



Lianhenghui Demonstration Project





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