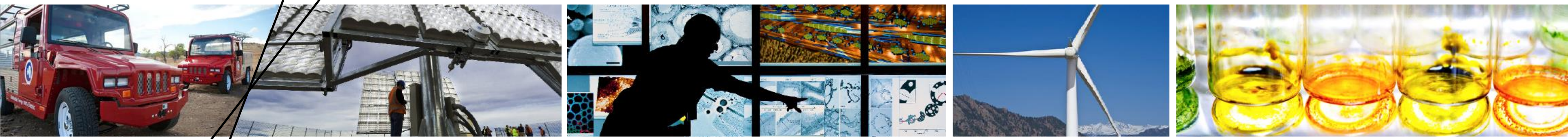
TEA Modeling Perspectives on Algae CO_2 Sourcing



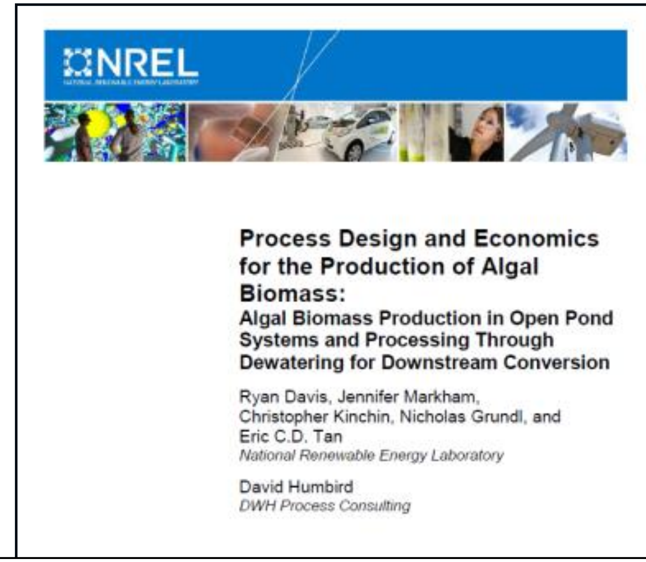
Ryan Davis
National Renewable Energy Laboratory

Algae CO2 Workshop
May 23, 2017
Orlando, FL

Bulk Flue Gas: Logistical/Equipment Challenges

Logistical/equipment challenges:

- On-site: Expensive and logistically challenging to route 4-5 ft FG pipelines around a farm >1,000 acres
  - Flue gas may constrain product options from biomass
- Off-site: Day/night compressor power cycling may be impractical
  - NREL algae farm report: 15 km pipeline = 80 MW max instantaneous power demand – cannot merely turn on and off such a large machine (requires 4-6X current draw at startup)
  - Assumed marginal turndown at night = 75 MW as 24-hr average
  - *Higher power demand to run compressor than the amount of power generated to produce the CO_2*


NREL

Process Design and Economics for the Production of Algal Biomass:
Algal Biomass Production in Open Pond Systems and Processing Through Dewatering for Downstream Conversion

Ryan Davis, Jennifer Markham, Christopher Kinchin, Nicholas Grundl, and Eric C.D. Tan
National Renewable Energy Laboratory

David Humbird
DWH Process Consulting

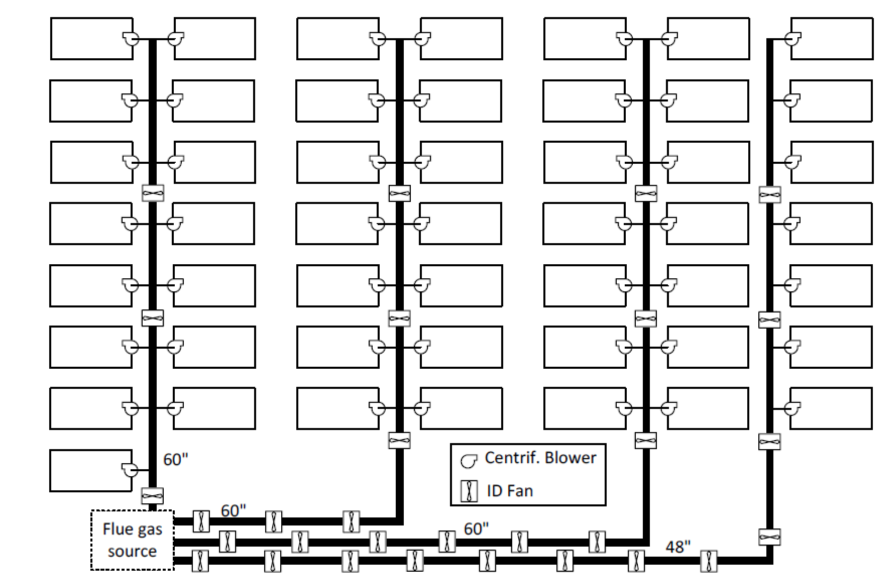
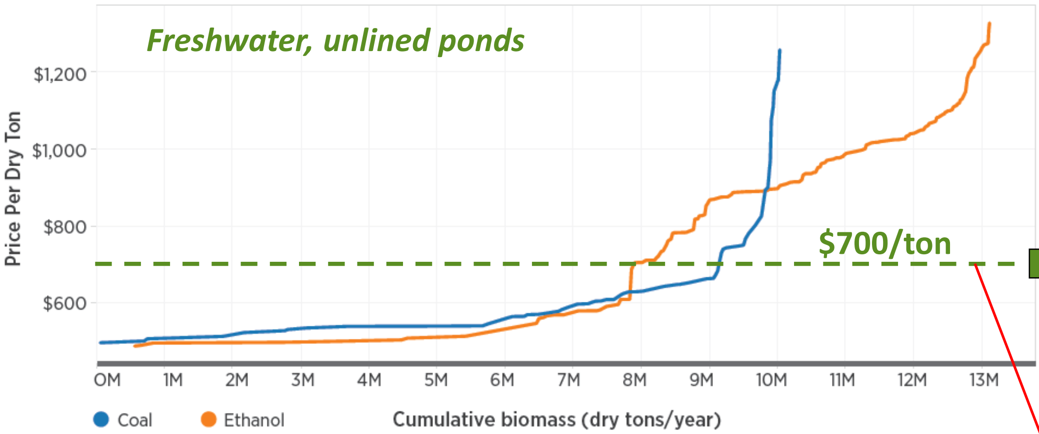


Figure 17. Layout of flue gas piping and fans for the 50-module system

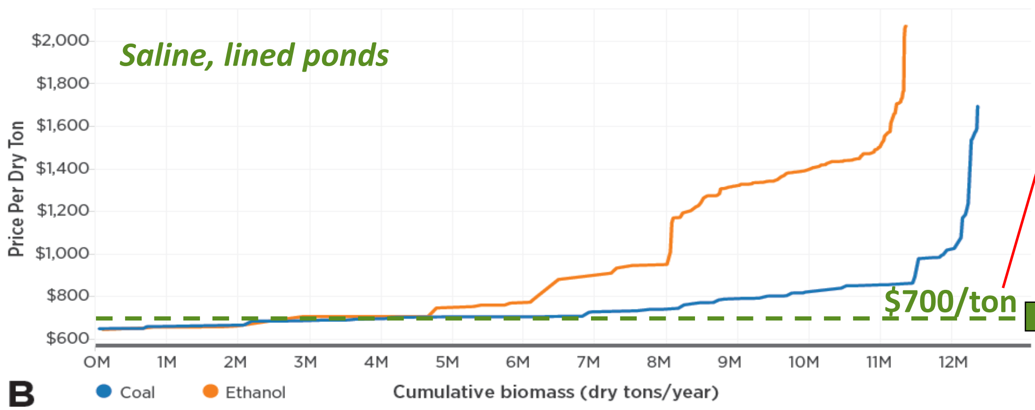
Bulk Flue Gas: Scalability Challenges

Figure 7.33 | Minimum selling price per dry ton vs. cumulative total biomass for each co-location strategy using *Chlorella sorokiniana* at future productivities[9]



Note: The biomass does not reflect any co-location with natural gas, because the power required to move sufficient CO_2 for the high-productivity scenario brought the cost of CO_2 above the $40/ton commercial purchase price.

Figure 7.35 | Minimum selling price per dry ton vs. cumulative total biomass for each co-location strategy using *Nannochloropsis salina* at future productivities for *(A)* minimally lined ponds and *(B)* fully lines ponds.[11]



Note: The biomass does not reflect any co-location with natural gas, because the power required to move sufficient CO_2 for the high-productivity scenario brought the cost of CO_2 above the $40/ton commercial purchase price.

- BT report projected cost curves for "future" productivities (~25 g/m^2/day) constrained by flue gas pipeline delivery costs
- *BT study assumed 82% CO_2 utilization efficiency in ponds – scalability would become significantly more limited if CO_2 utilization were low

17.1 MM ton/yr total

= 1.2 – 2.7 BGY fuels (CAP/HTL)

$700/ton = max reasonable limit for $3/GGE fuels (current MYPP pathways require <$200/ton to achieve $3/GGE, but introducing coproducts/biomass blending will improve MFSP)

11.5 MM ton/yr total

= 0.8 – 1.8 BGY fuels (CAP/HTL)

***https://energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf**

Alternatives to Bulk Flue Gas

- Carbon capture
  - Significantly less costly and logistically challenging for on-site delivery to ponds (8X lower pipeline distribution costs)
  - Relaxes constraints on flat unoccupied land availability directly co-located with power plant
  - May extend the CO_2 transport range significantly and expand the BGY fuel potential (*key to make a case for national scalability)
  - **However, currently challenged by LCA based on high energy demand for CC (gen-1 MEA) – need to establish gen-2 details**

Scenario	GHG Emissions g CO_2e / MJ RD_e[a]	Fossil Energy Use MJ/ MJ RD_e	Petroleum Use MJ/MJ RD_e	
Revised 2022 Target				
CAP	56	0.71	0.083	MEA CC @ 0.64 MJ_e/kg CO_2 = 45% GHG ↓
HTL	51	0.62	0.027	
Revised 2022 Target				
CAP	39	0.55	0.081	Co-located flue gas transport = 59% GHG ↓
HTL	38	0.50	0.025	

http://www.ipd.anl.gov/anlpubs/2016/07/128907.pdf

- Carbonate scrubbing
  - Allows for 24-hour CO_2 storage, minimizes CO_2 outgassing losses
  - But, requires high alkalinity/high pH
  - Demonstrate scalability for large >1,000 acre farm?