DE-FE0032104
Carbon Capture and Utilization for Protein and Fatty Acids

Global Algae Innovations

David Hazlebeck

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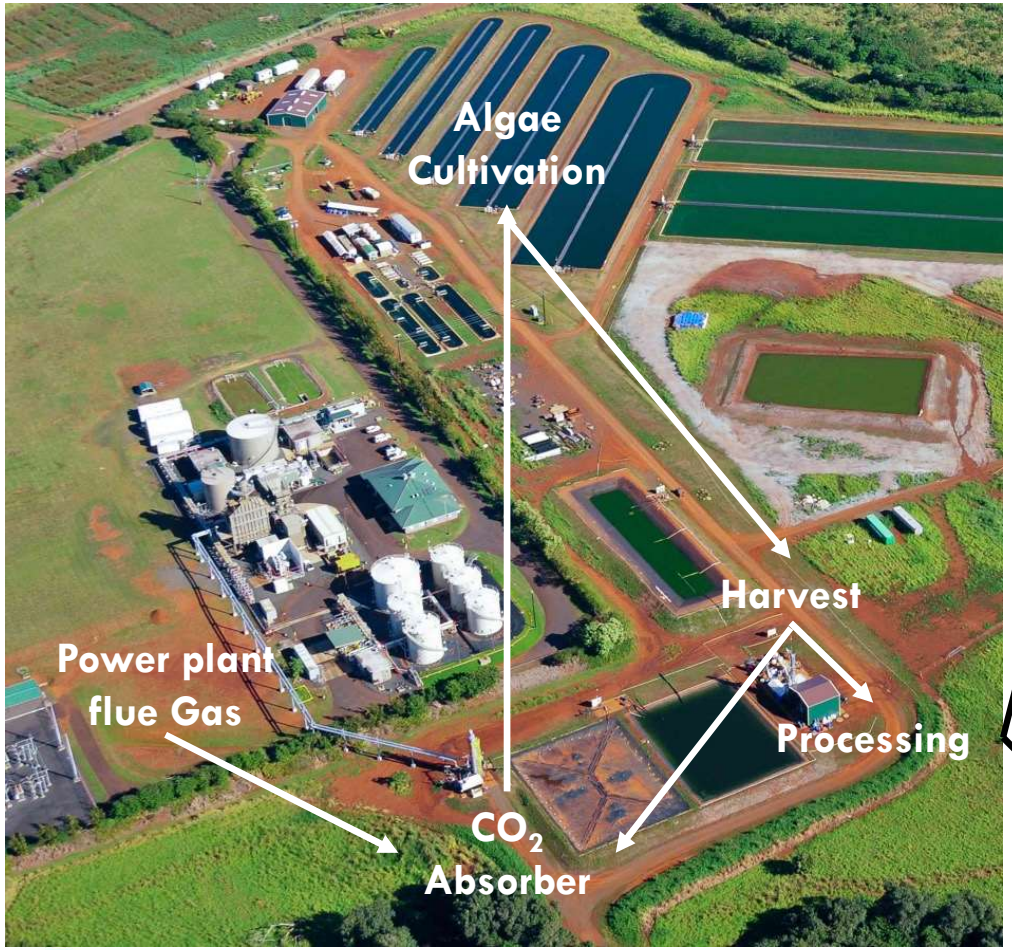
NATIONAL ENERGY TECHNOLOGY LABORATORY

Creating an abundant & sustainable world

Founded in 2013 with the Vision to:

harness the unparalleled productivity of algae to provide food and fuel for the world, dramatically improving the environment, economy, and quality of life for all people. .

Project Summary



GLOBAL ALGAE INNOVATIONS

Consumer Products

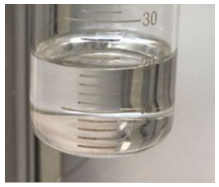
Mono unsat.

Algae Oil

Oil Fractionation

Sat.

Jet fuel, diesel, and gasoline



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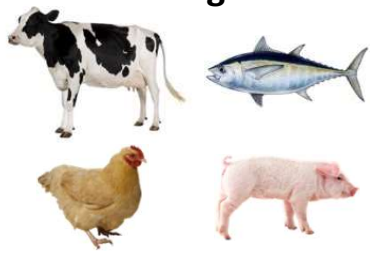
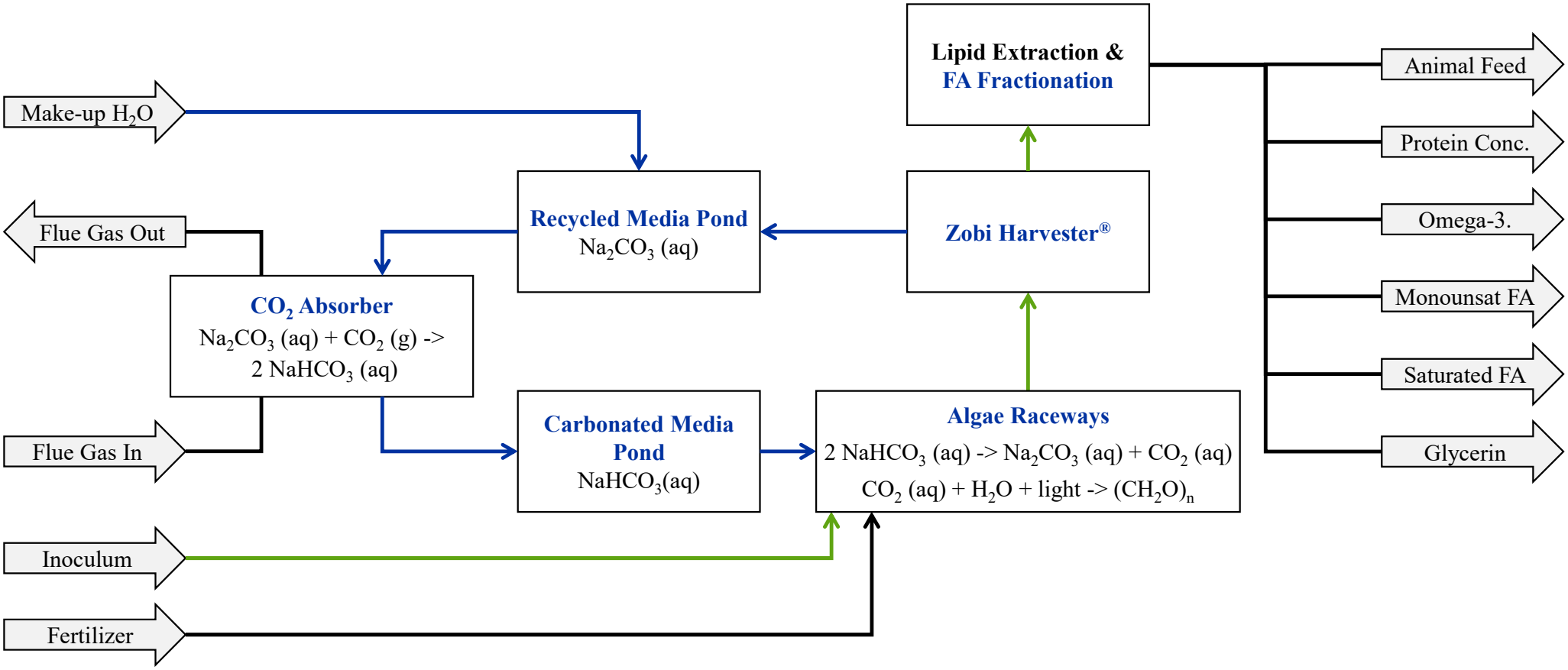
Protein Meal

Food Ingredients

Feed Ingredients



Simplified Block Flow Diagram



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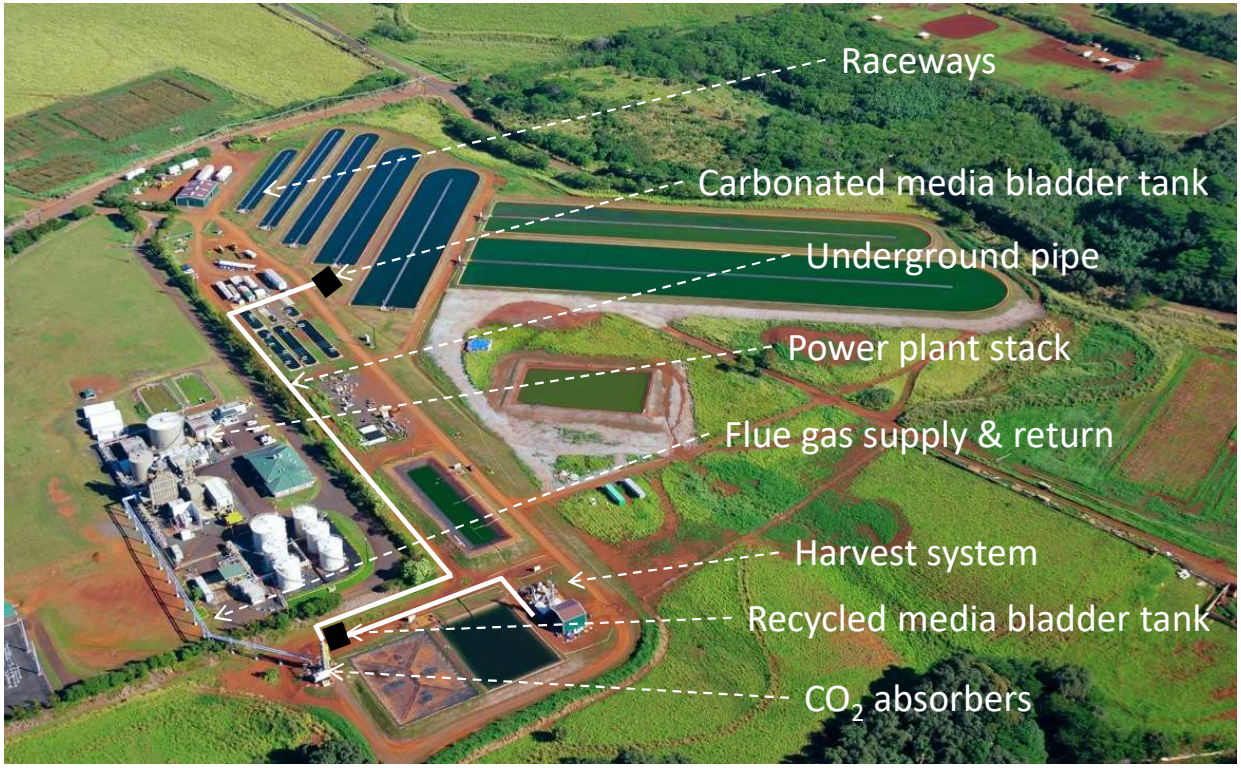
New absorber and tanks integrated into the Kauai Algae Farm



GLOBAL ALGAE INNOVATIONS

CO_2 supply system advantages

- 24 hour per day CO_2 capture
- Storage of CO_2 to account for variable demand
- Very low energy: 2.5” water pressure drop on flue gas
- No ground level flue gas emissions, i.e., can be permitted
- Eliminates need for gas distribution or controls to raceways
- Low cost, $25-50/ton captured, stored, and delivered to the raceways
- High capture efficiency, 70-90%
- High utilization efficiency, 90-100%

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Project Objectives

1. Complete field testing that demonstrates parameters listed in the state table for carbon capture and utilization efficiency; cultivation and processing; and product suitability.
   - Verify no issues with product contamination or build up of growth inhibitors
   - Demonstrate high efficiency carbon capture from dilute flue gas
   - Determine winterization efficacy and cost
   - Validate process at engineering scale
2. Accurately quantify economic and environmental benefits of the target products through techno-economic analyses (TEA) and life cycle analyses (LCA) informed by the field testing results that: (a) validate the net decrease in CO2 emissions; and (b) validate required selling price for the products with a carbon price of $0/ton.
   - Verify economics and life-cycle justify continued investment for scale-up
3. Achieve a 10% increase in peak or average algae productivity over the baseline
   - Improves overall economics

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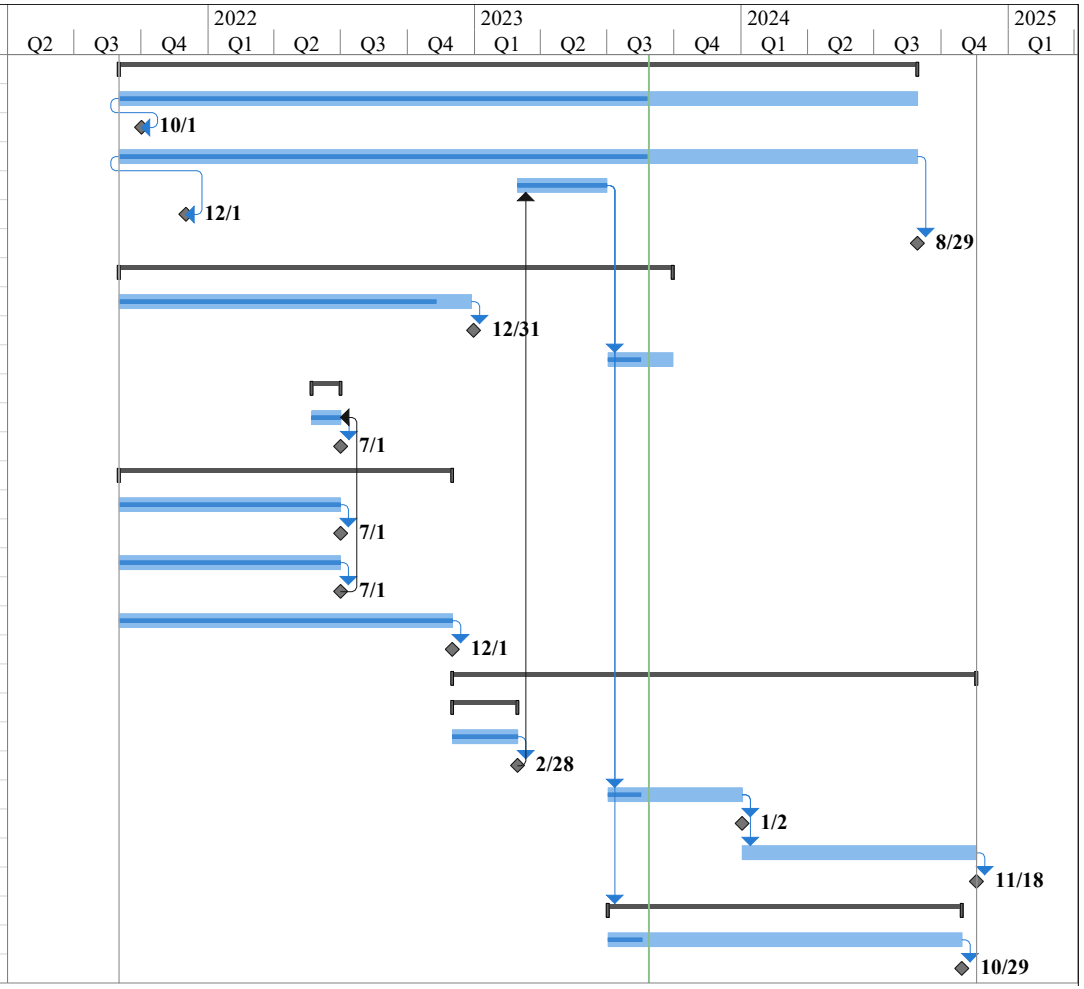
Schedule of Project Activities

Task	Task Name
1	**Management**
1.1	Project Management Plan
D1.1	PMP update
1.2	Technology Maturation Plan
	Transition to BP2
D1.2	Initial TMP
D1.2	Final TMP
2	**Initial TEA and LCA**
2.1	Update TEA & LCA
M2.1	Basline TEA & LCA
2.2	NETL format for TEA & LCA
3	**Risk mitigation tests**
3.1	Productivity test
M3.1	Retire productivity risk
4	**Design, install, checkout**
4.1	Raceway upgrades
M4.1	Racway upgrades operational
4.2	Absorber
M4.2	Absorber operational
4.3	Fractionation subsystem
M4.3	Fractionation operational
5	**Integrated tests**
5.1	**Shakedown**
5.1	Integrated system
M5.1	System operational
5.2	Perfromance target testing
M5.2	Achieve performance params
5.3	Long-term integrated tests
M5.3	Performance params verified
6	**Final TEA and LCA**
6.1	Update TEA & LCA
M6.1	Final TEA & LCA



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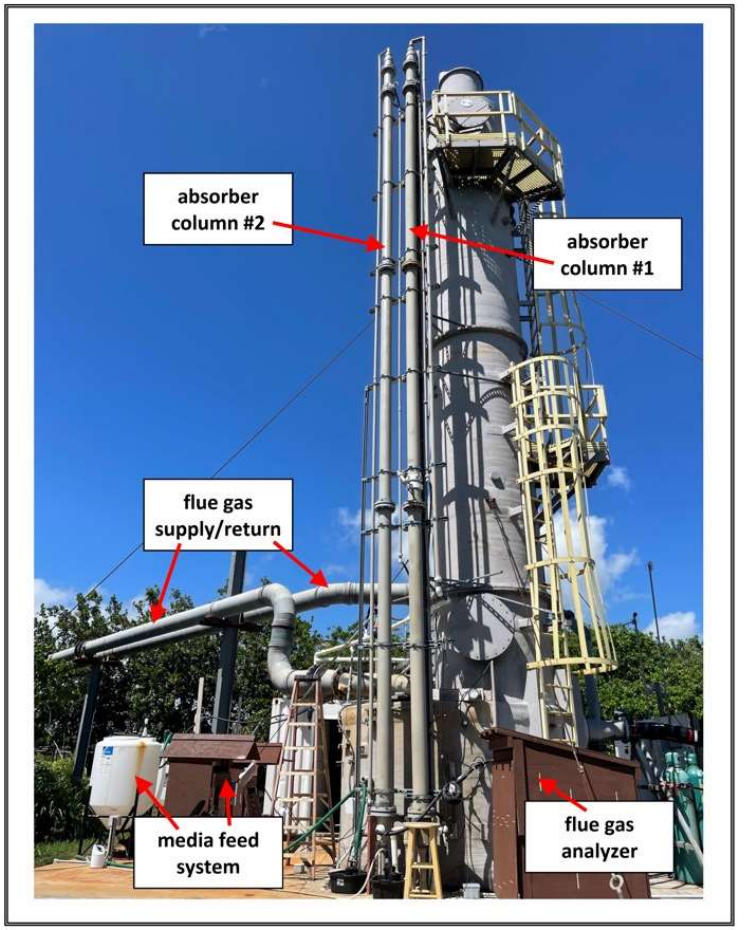
CO_2 Capture and Supply System

- Add a second 6” diameter absorber in series to simulate taller column along with associated pumps, tanks and instruments (Complete)
- Parametric study with flue gas for capture efficiency using existing slip stream piping (Complete)
- Integrated operation with algae cultivation (Underway)
  - Utilize currently installed raceways and Zobi harvester
  - Add water bladder tanks for recycled media and carbonated media ponds
  - Add pumps and lines to connect the absorber, raceways and harvester with the water bladder tanks



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Absorber integrated with harvesting and cultivation through new bladder tanks, pumps and piping

Recycled Media

Carbonated Media

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Raceway improvements and oil fractionation system

- Upgrade the 0.2 acre, 0.3 acre and 3.2 acre-raceways (Complete)
  - Modify the raceways to improve scalability and productivity when operating with Global Algae's proprietary cultivation technology
- Design and install an oil fractionation system to separate the algal oil into omega-3, monounsaturated and saturated fatty acids. (Complete)
  - Send samples to commercial vendors winterization and vacuum distillation testing
  - Work with vendors to design an engineering-scale test system based on the sample testing and data needed for commercial scale design

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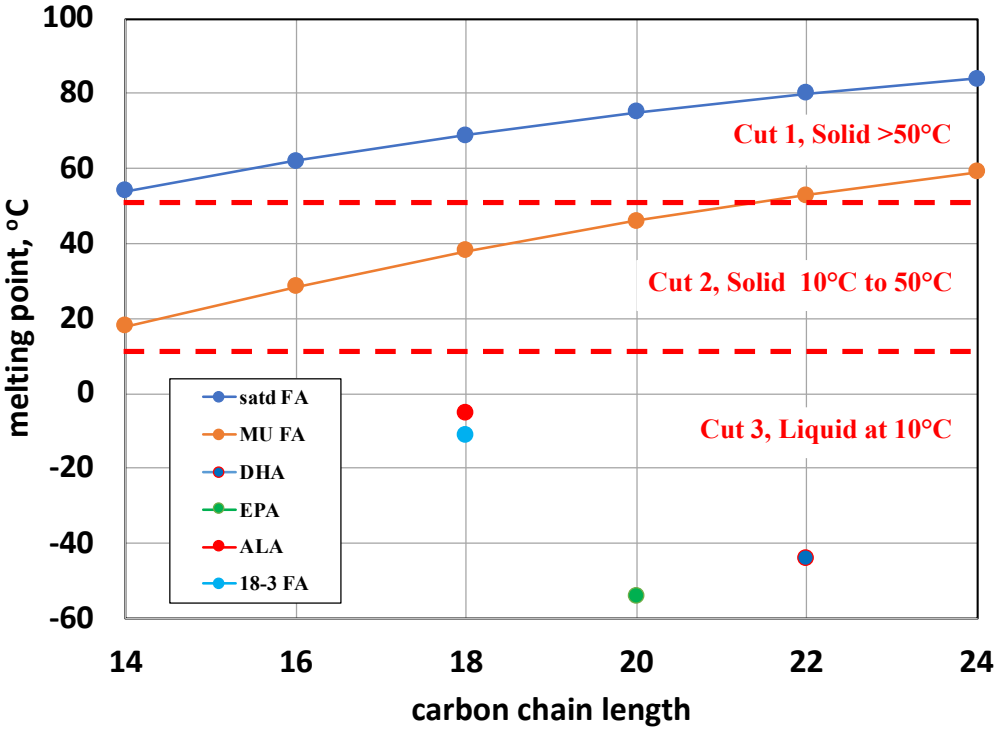
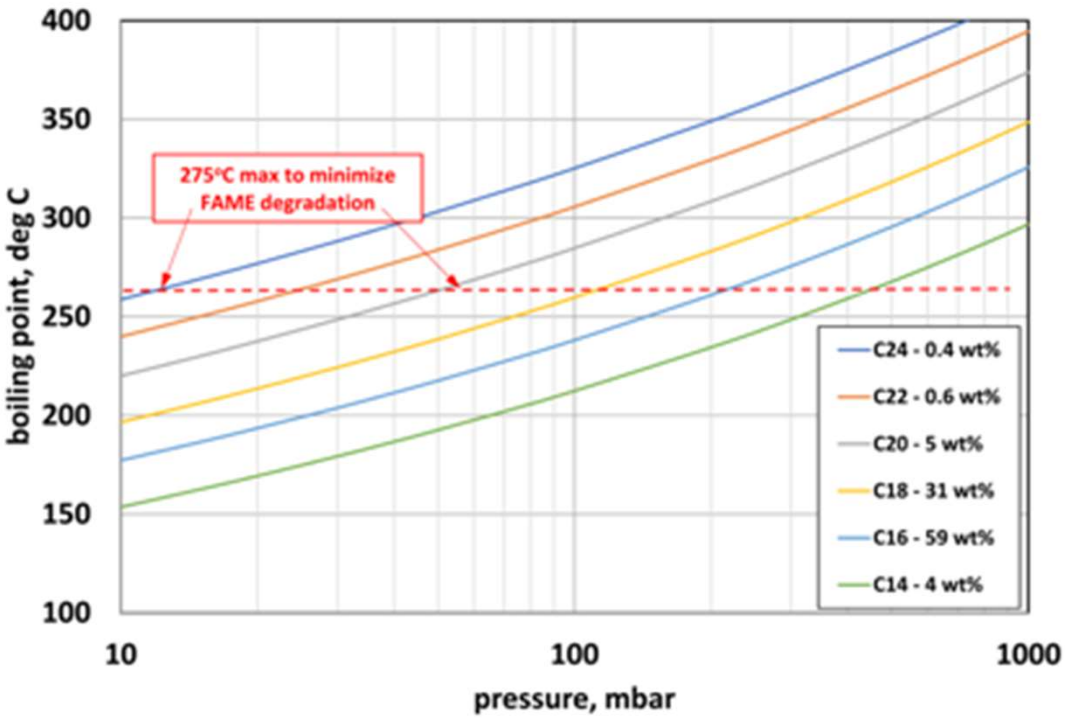
Lipid Fractionation

Winterization (new equipment)



Vacuum Distillation (vendor site)



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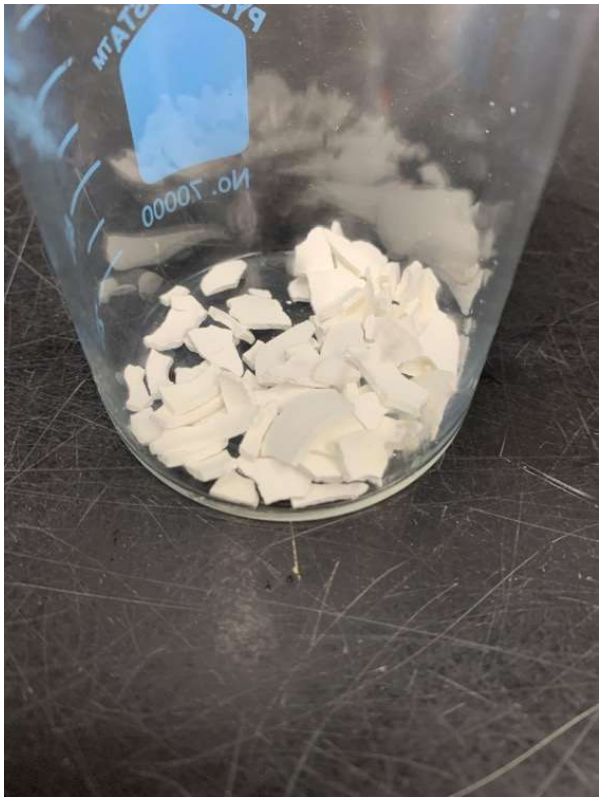
Separation Into Solid and Liquid Lipids



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Testing

- Performance testing
  - Parametric testing of the absorber, key independent variables are gas flow, liquid flow, starting pH; samples at multiple locations to validate the mass transfer model (TSD and GAI) (Complete)
  - Measure key performance parameters for raceway improvement (GAI) (Complete)
  - Parametric testing of oil fractionation using winterization and/or distillation to optimize throughput and separation efficiency based on the maximum net value from the algal oil (TSD and GAI) (Simulant complete, algal oil later in BP2)
  - Parametric testing of polyol and polyurethane production to achieve product properties that validate the estimated sale price (UCSD and Algenesis) (Later in BP2)
- Integrated tests (~ten 7-day long tests) (Underway, starting 2nd test)
  - Cultivate on power plant CO_2 with full media recycle (GAI)
  - Harvest algae and extract oil (GAI)
  - Convert monounsaturated oil to polyols (UCSD)
  - Convert polyols to polyurethane samples or products (Algenesis)
- Long-term integrated test (7-day test every 2 months for a year) (later in BP2)
  - Integrated test as described above to obtain annual averages

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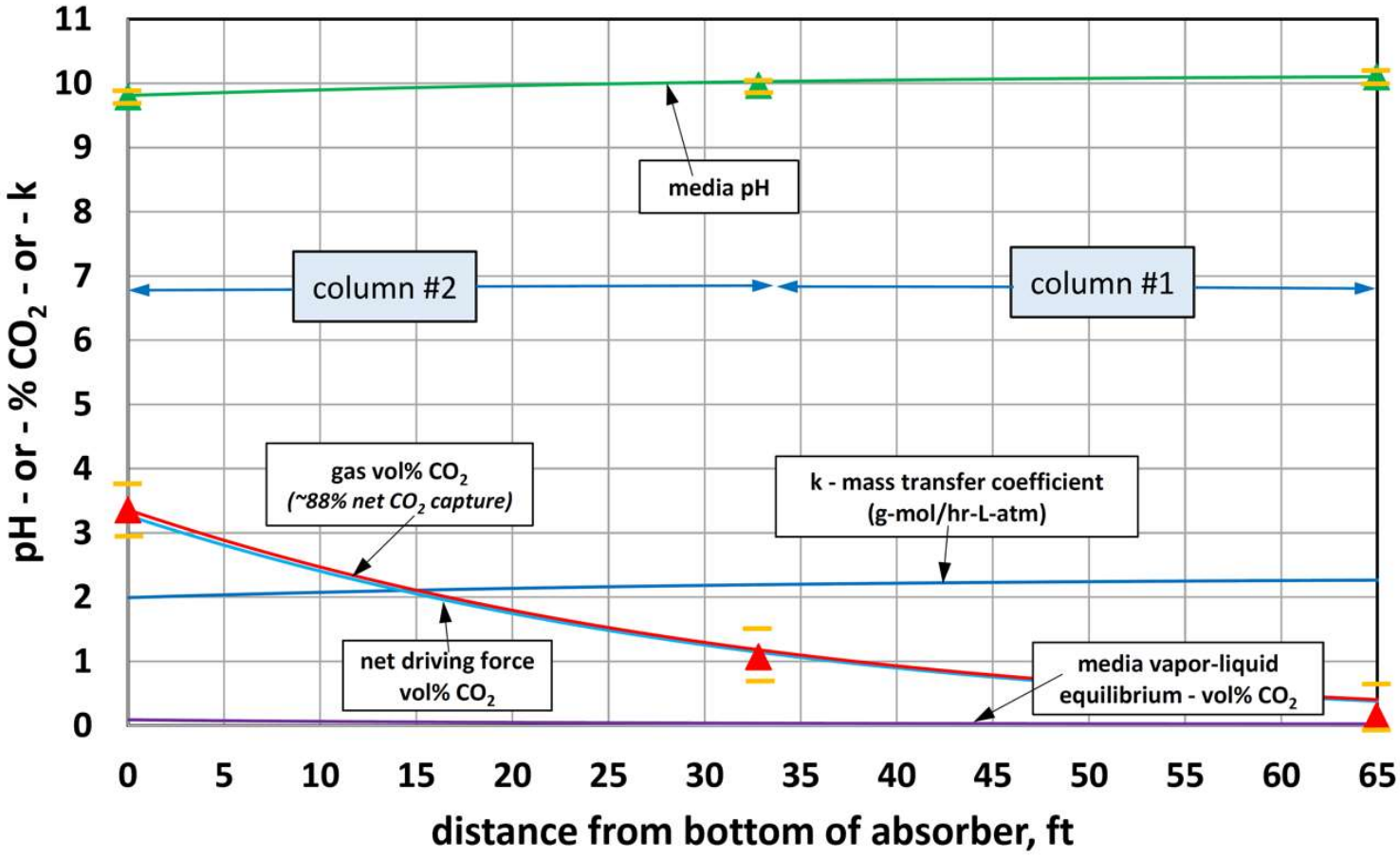
Absorber Test Results
Consistent with Process Model Predictions



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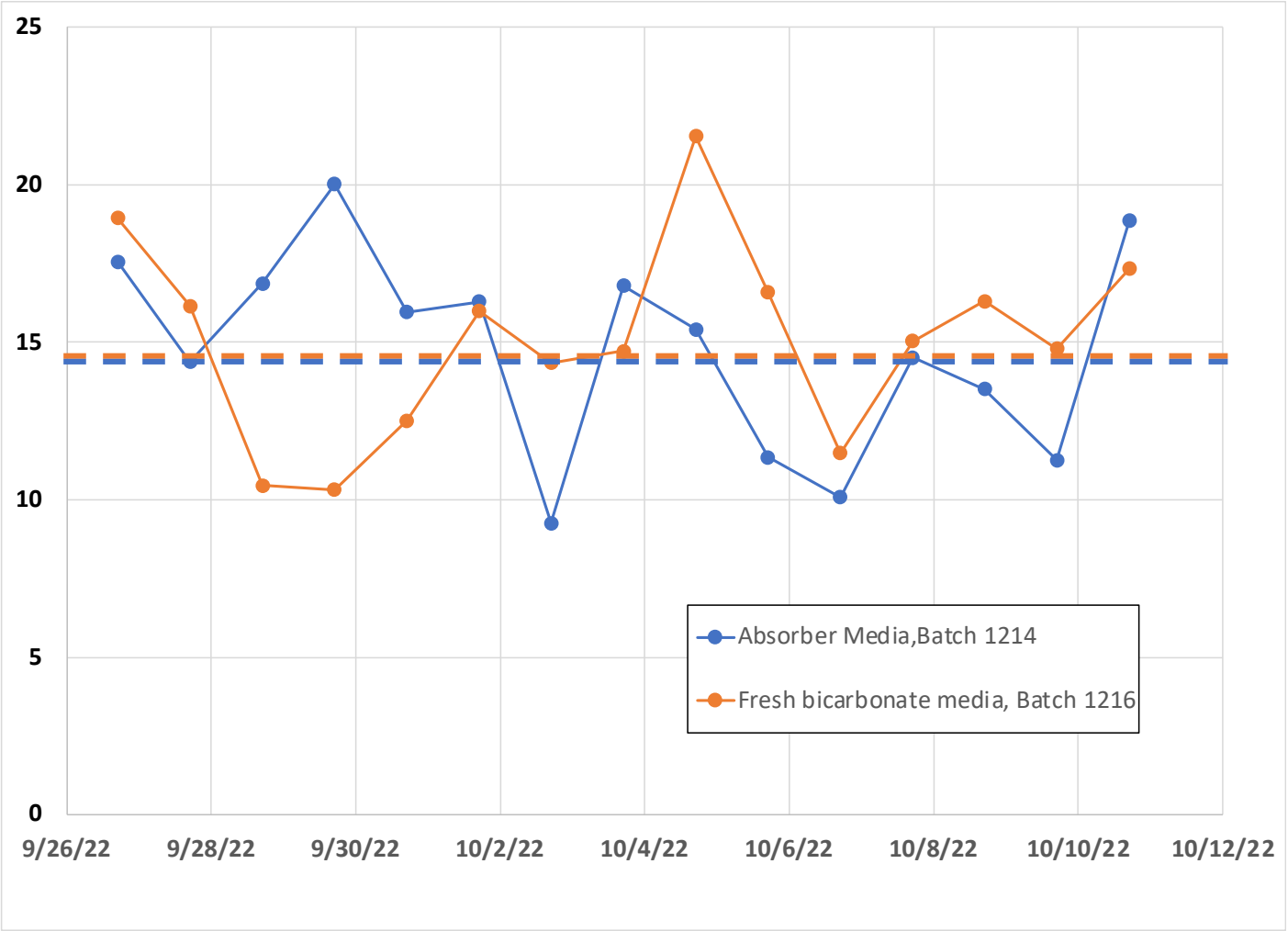
Productivity is the Same with CO_2 from Fresh Bicarbonate and CO_2 Absorbed from Flue Gas



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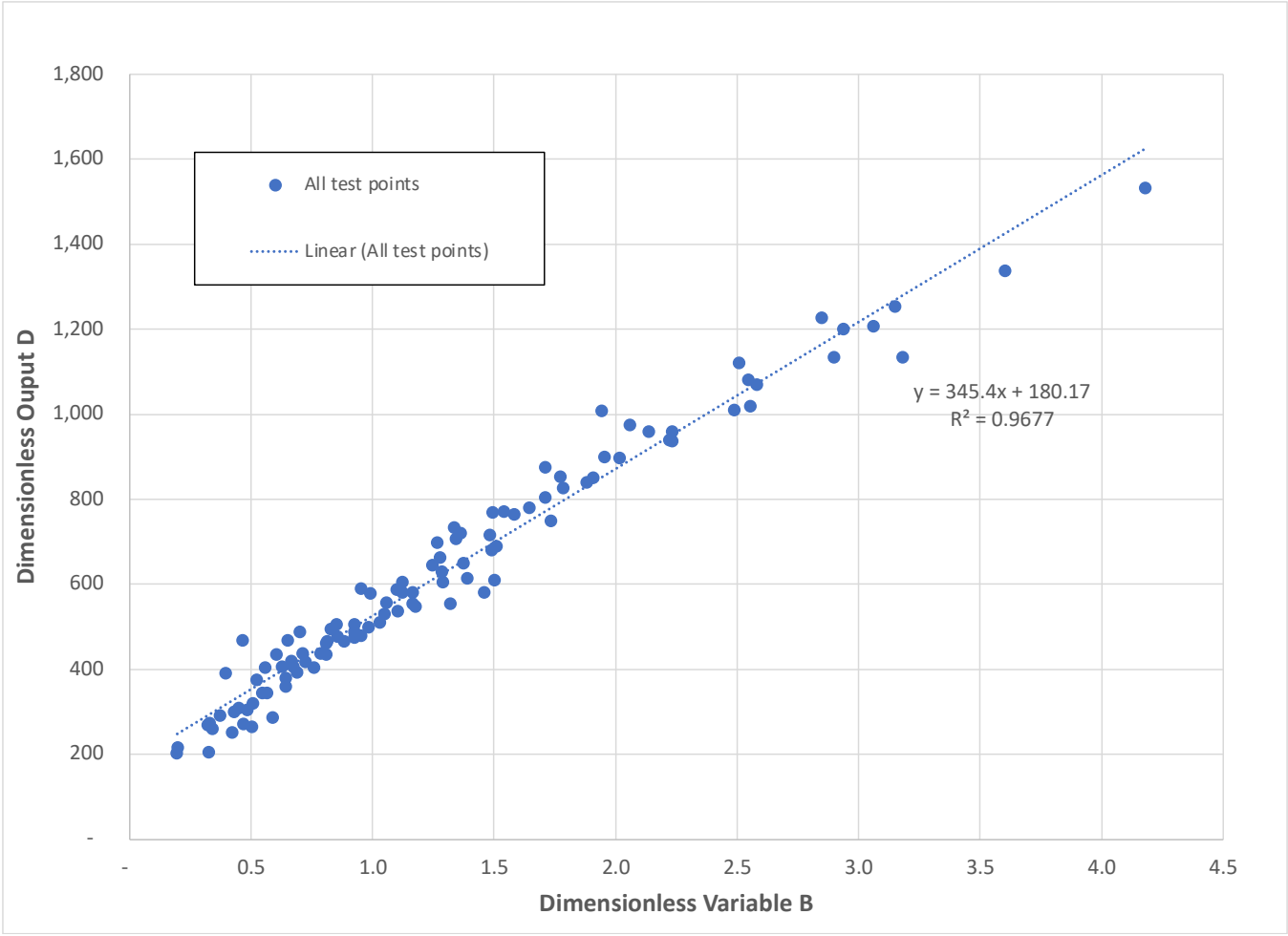
Developed a Single Dimensionless Input Parameter to Combine all of the Input Variables (19 data sets)



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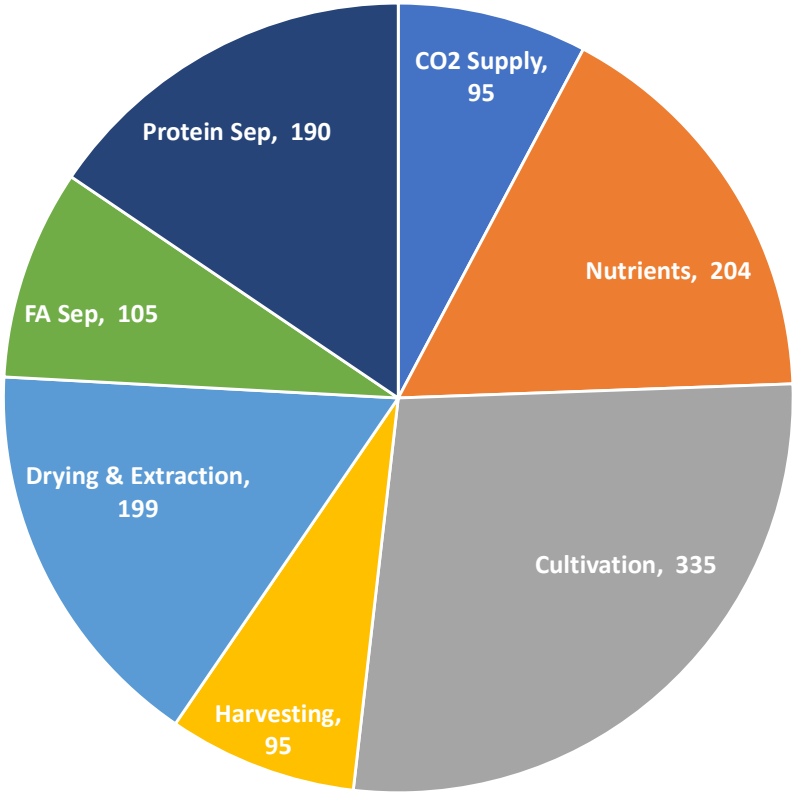
Costs and product values updated to 2023 $



Product	% of AFDW	Value ($/mt)
Protein concentrate	12%	1800
M. unsat. fatty acid	17%	2300
Sat. fatty acid	17%	1400
Omega-3	6%	4200
Glycerin	5%	1100
Protein meal	43%	570
Composite price	**100%**	**1400**

Projected cost $1224/mt (2023$, 8% unlevered IRR)

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Scale Up Plan

Current 8-acres

3.2-acre

Intermediate-scale
(grading permit issued last week)

12 to 25-acre

5,000-acre farm

200-acre

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