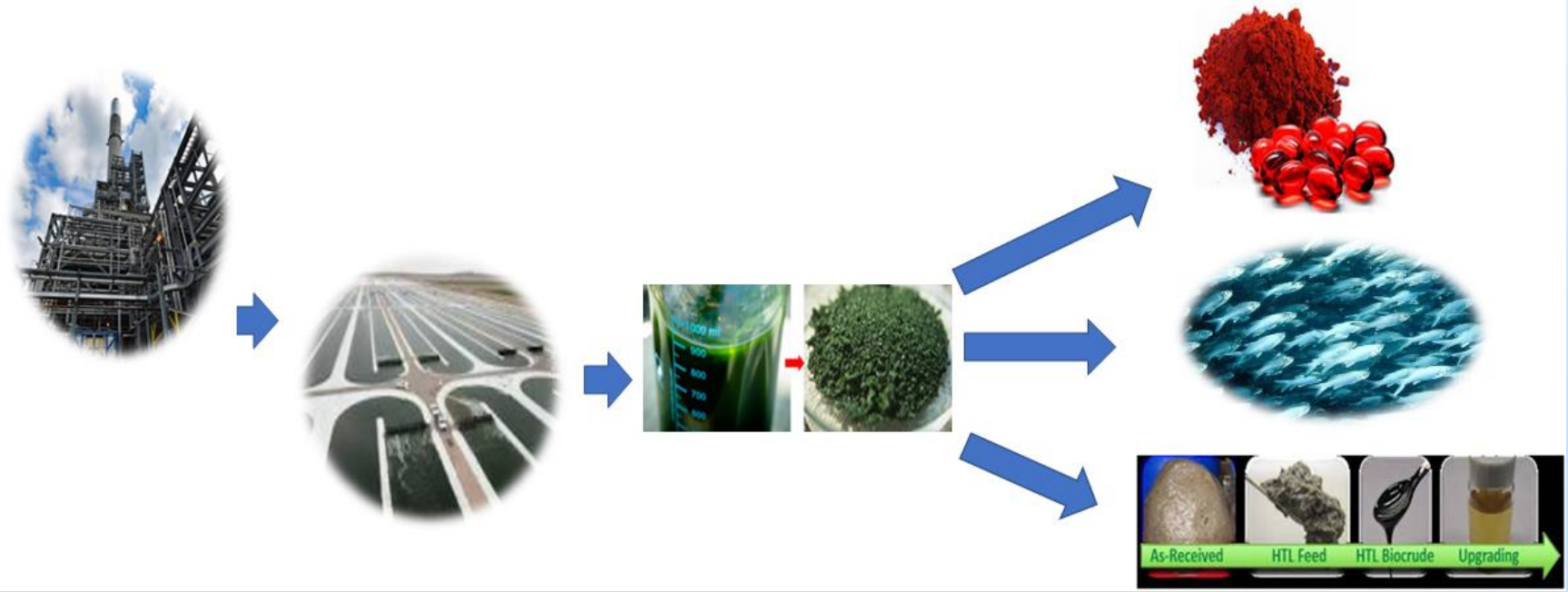
CO2 Conversion to Products Using Algae

Award No: DE-FE0032516

PI: Dr. Fred Harrington

NETL/DOE Federal Project Manager: Naomi O'Neil

Project Kickoff Meeting October 17. 2024



General Project Information

Title: *CO2 Conversion to Products Using Algae*

- Recipient: Helios-NRG, LLC
  - PI: Fred Harrington, PhD, Chief Scientist
  - Business Mgr: Jim Maloney, VP
  - DOE Federal Project Manager: Naomi O'Neil

- **Project Funding:**
  - **Total: $1,248,841**
  - **Government Share: $999,024 Cost Share: $249,817**

- **Project Period: 9/1/2024 – 8/31/2026**

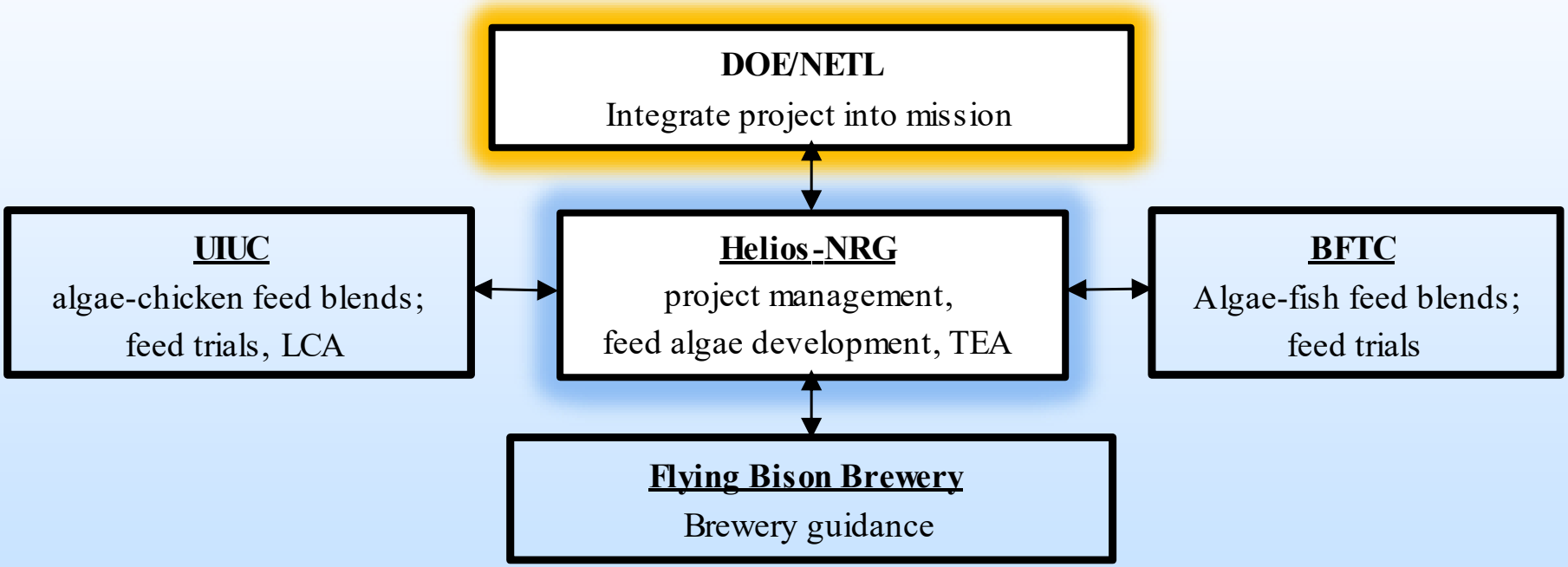
Project Partners

- Bozeman Fish Technology Center

- University of Illinois Urbana-Champaign

- Flying Bison Brewing

Organization Chart



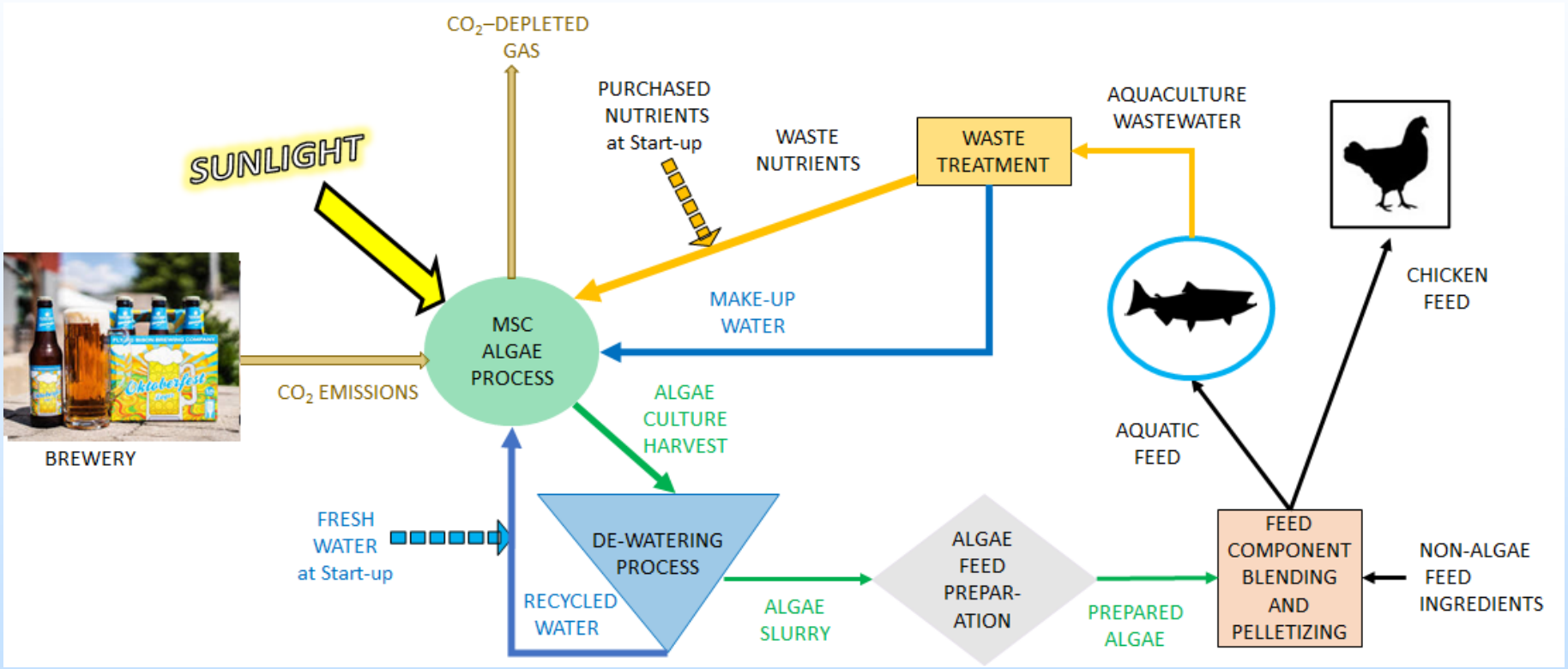
Overall Strategy

- ***For CO_2 capture to be economically viable, a revenue stream is required to offset cost of capture***

- **Develop algae technology for high CO_2 capture efficiency and high productivity from anthropomorphic CO_2 sources**

- **Reduce capture cost via operational efficiency, wastewater credits & product revenue**

Process Schematic at Commercialization



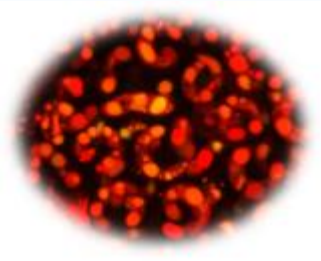
Key Advantages of the Technology

- CO_2 captured as a biomass - avoids gas sequestration
- Sustainable primary energy source (sunlight)
- Capture cost offset by revenue from products
- High productivity + capture efficiency
- Closed system minimizes contamination & water loss
- Continuous scalable process
  - Easier integration with upstream/downstream processes
  - Lower operational cost

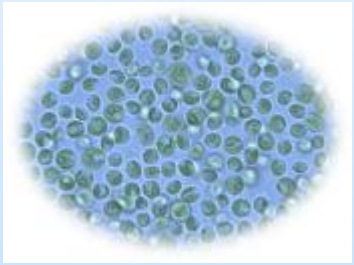
Background

Algae Species Selection

- Species are application dependent
- Primary criteria for CO_2 capture species
  - High growth rates in presence of high levels of CO_2
  - Can utilize wastewater (Municipal and HTL-aqueous)
  - Adapted naturally occurring species – no GMO's
  - Prior Helios experience & well characterized
- Animal feed blend species
  - Product specific
  - Nutritional requirements with algae content
  - Prior Helios experience with a variety of species
- Additional species in portfolio for other specialized applications e.g. nutraceuticals



H-1903



H-0322

MSC process for Carbon Capture

Concept developed using proprietary model

- Various MSC tank designs developed & tested
- Efficient culture circulation and gas/liquid contacting
- Predictable operation - automated dynamic control
- Top lit closed system with scalable, low-cost seals
- High productivity & capture efficiency

Stability demonstrated in ~100-day outdoor test

Integrated MSC operation validated at NCCC

- Performance exceeded project targets

MSC and Controls	Location	Sim. Flue Gas Contaminant	Nutr-WW Replacement	Normalized Algae Prod	Avg CO_2 Capture
1st Gen Manual Control	Outdoor	N/A	N/A	139%	81%
		SO_X/NO_X + 5HM	80%	141%	76%
2nd Gen Automated Control	Outdoor	N/A	N/A	142%	77%
	NCCC'22	NCCC Flue Gas	N/A	123%	87%
3rd Gen Dynamic Control	Outdoor	N/A	N/A	161%	94%

Fish Feed Background

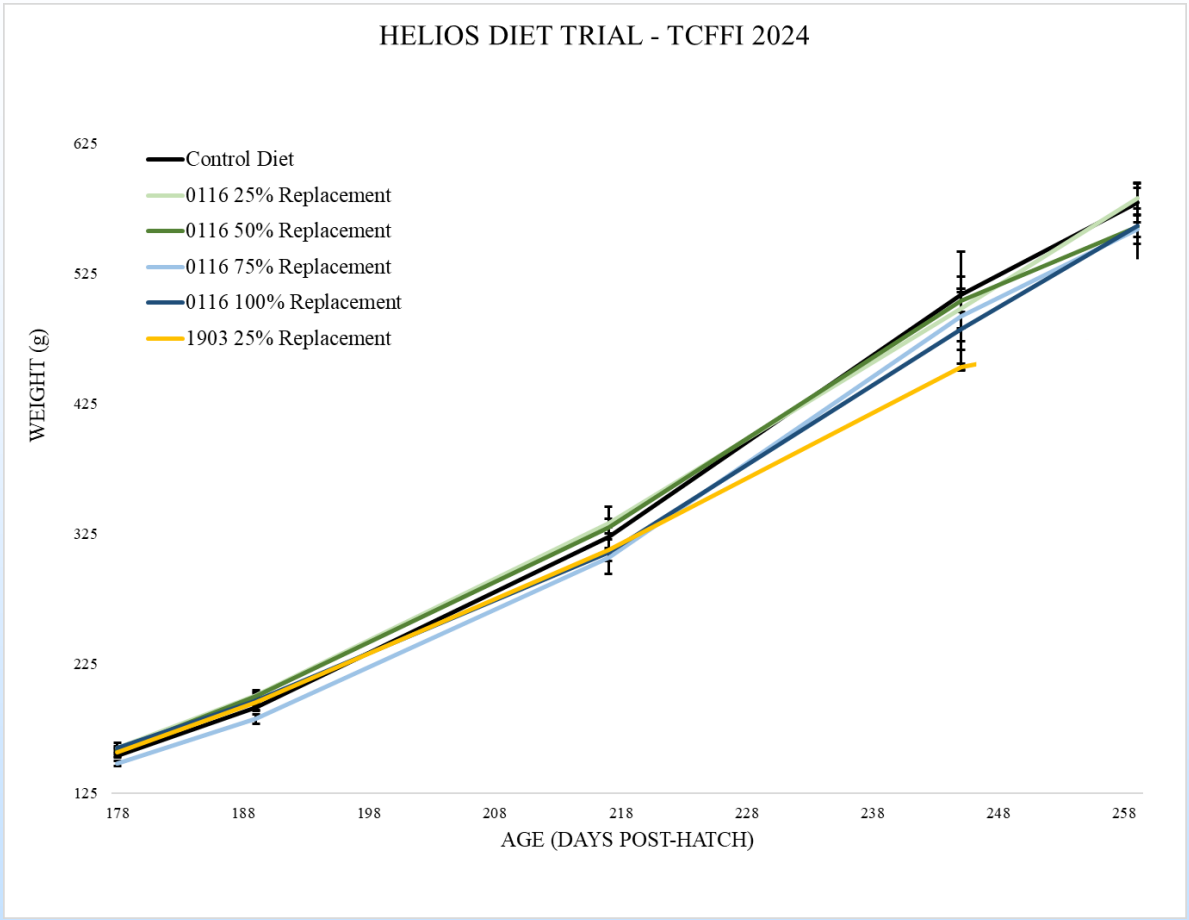
Use of Algae in Fish Feeds

- Algae has the potential to provide key nutrients
  - protein and amino acids;
  - fat and long chain fatty acids;
  - astaxanthin, beta carotene and vitamins
- Algae blended feed produced for digestibility and growth tests

Algae qualification for aquaculture feed blends

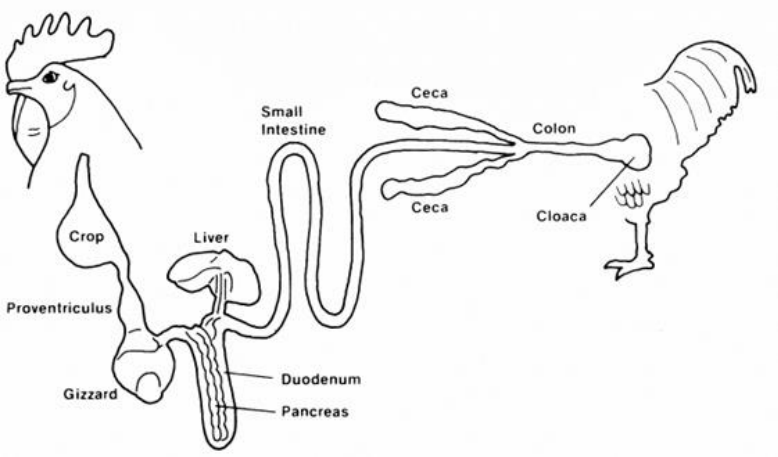
- Feed produced with 0-100% of fish meal replaced with algae
- Two algae species tested: H-1903 and H-0116
- Feed trials conducted in Recirculating Aquaculture System
- Successful long-term tests demonstrated viability

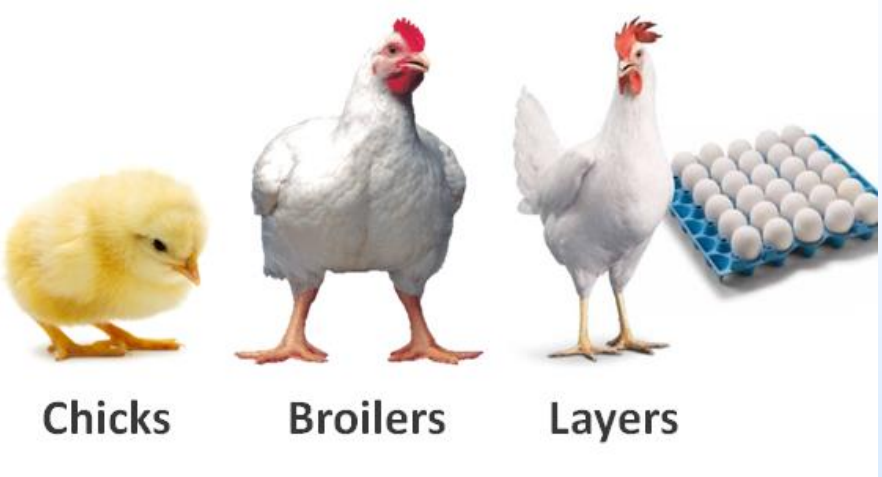
Algae qualification for aquaculture feed blends



- Monitored fish growth, health, water quality during test
- Comparable growth rate with algae-based feeds

Overview of Poultry Nutrition





GE → DE → ME

DE → feces E

ME → urine E

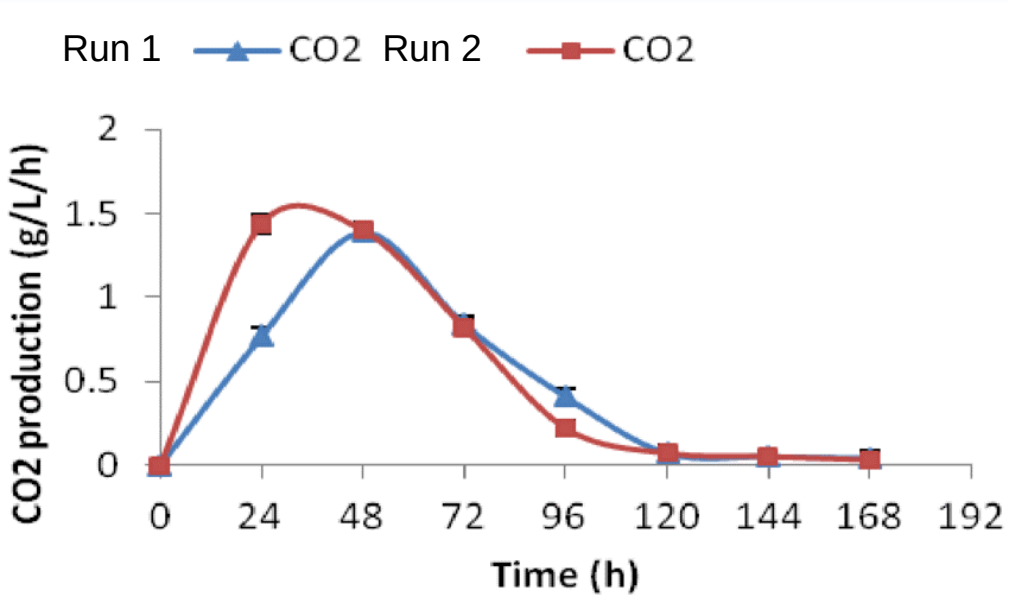
Dietary Components

- -Carbohydrates (mostly starch)
- -Protein
- -Fat
- -Minerals & Vitamins

Brewery Fermentation Off-gas CO_2

- Commercial fermentation processes produce a waste gas stream with 70-90% CO_2 that is currently vented to the atmosphere
- Capture and conversion of this CO_2 is the objective of the current project

Fermenter Off-gas CO_2 for Algae Culture



- CO_2 production is time dependent
- Lack of toxic contaminants (e.g. acid gases, heavy metals) makes this attractive for high value algae cultivation
- Bio-contamination will need to be understood & addressed

Project

Objectives

- **BP1:**
  - **Quantify nutritional profiles for the 2-feed applications**
  - **Define algae compositions matching nutritional needs**
  - **Select specific algae strains that are best for meeting nutritional needs**
  - **Preliminary tests using fermenter off-gas**
  - **Produce/characterize test quantities of algae blended feeds**

- **BP2:**
  - **Algae field test using CO_2 captured from brewery off-gas**
  - **Produce feeds & conduct test campaigns**
  - **Refine TEA**
  - **Refine LCA**

Work Plan

- Task 1: Project Management and Planning
- Task 2: Community Benefits Plan

BP1:

- Task 3: Poultry feed nutrient requirements & algae replacement viability
- Task 4: Fish feed nutrient requirements & algae replacement viability
- Task 5: Tailor algae for nutritional needs
- Task 6: Optimize algae-based feed blends

BP2:

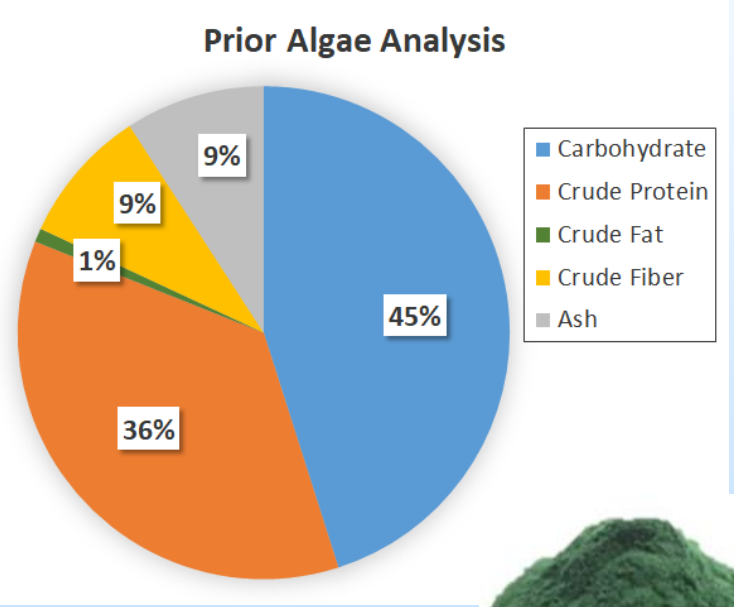
- Task 7: Algae culturing on brewery off-gas; field test
- Task 8: Produce algae blended feed and conduct live feed tests
- Task 9: Refine Techno-economic Analysis (TEA)
- Task 10: Refine Life Cycle Analysis (LCA)

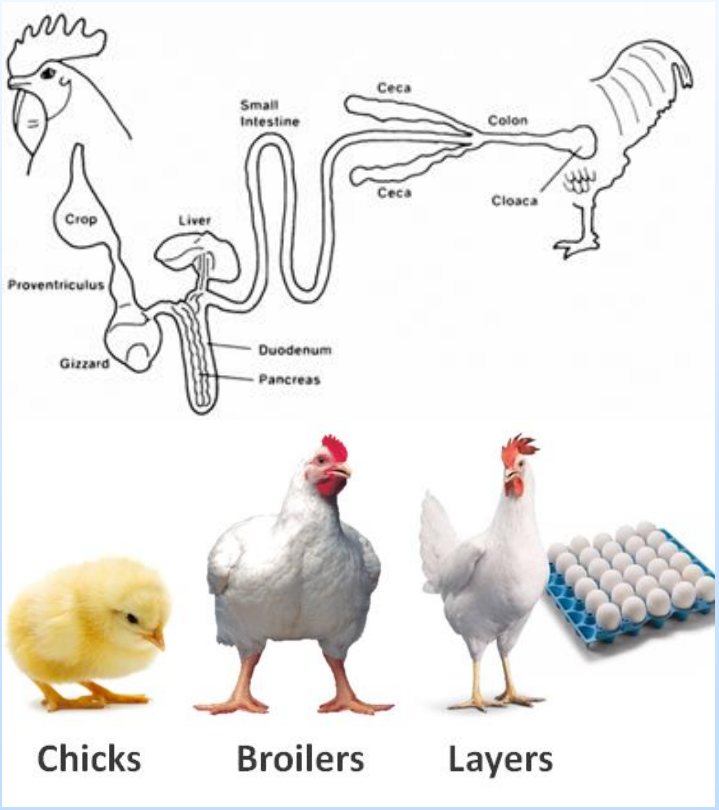
BP-1 Tasks

- **Task 2 - Community Benefits Plan**
  - **Prepare and advertise for internship/part-time position with local colleges with emphasis on underrepresented groups**

Task 3 - Assess poultry feed nutrient requirements and algae feed component replacement viability

- Quantify nutritional profile requirements for poultry feed
- Select algae to match key ingredients in poultry diets





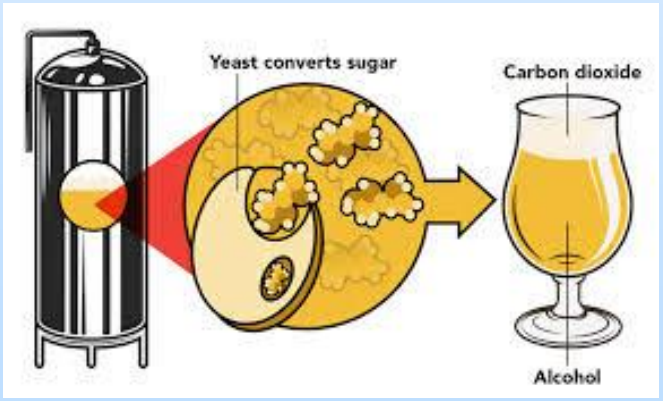
Task 4 - Assess fish feed nutrient requirements and algae feed component replacement viability

- **Define nutritional requirements for fish**
  - Profile for an ideal feed with crude nutrient and micro-nutrients to meet nutritional demands

- **Select algae to match key ingredients in fish diets**
  - Algae to provide nutrients in formulated feeds to allow reduction of less sustainable ingredient such as fish meal, oils and/or antioxidants.

Task 5 - Tailor algae for nutritional needs

- Grow algae under conditions to maximize feed nutritional value
- Technology for use of fermenter off-gas in algae cultures
  - Variable flow and CO_2 concentration in off-gas
  - Blend with air to obtain concentration optimal for growth
  - Investigate bio-contaminants in off-gas & mitigation protocols



Task 6 - Optimize algae-based feed blends

- **Develop process to improve algae utilization**
- **Manufacture and characterize fish feed**
  - Produce test batches of feed and conduct initial feed assessments
  - Determine *in vivo* nutrient uptake by fish using algae with preferred post-processing technique
  - Quantify protein, amino acids, fat, and gross energy digestibility

Task 6. Optimize Algae-based Feed Blends (Poultry)

Algae Processing

- Develop process to improve algae utilization in feeds
- Manufacture and characterize poultry feed

Precision-fed Rooster Assay

Individual Amino Acid Digestibility
Total Metabolizable Energy Values

BP-2 Tasks

- **Task 2 – Community Benefits Program**
- **Task 7 – Algae culturing on brewery off-gas; field test**
- **Task 8 – Produce algae blended feed and conduct live feed tests**
  - **Fish feed production and live feed test**
  - **Poultry feed production and live feed test**
- **Task 9 – Refine Techno-economic Analysis (TEA)**
- **Task 10 – Refine Life Cycle Analysis (LCA)**

Project schedule/milestones

Project Timeline - (Gantt Chart)			Budget Period 1				Budget Period 2			
Task Number	Task Description	Assigned Resource	Sep - Nov 2024	Dec 24 - Feb 25	Mar - May 2025	Jun - Aug 2025	Sep - Nov 2025	Dec 25 - Feb 26	Mar - May 2026	Jun - Aug 2026
1	Project Managment	Helios & UIUC								
2	Community Benefits Plan	Helios				★			★	
2.1	DEIA: Diversity, Equity, Inclusion, and Accessibility									
2.2	Environmental Equity: Justice40 Initiative									
2.3	Workforce: Invest in Job Quality & Continuity									
3	Poultry feed requirements and algae components	UIUC & Helios								
3.1	Qualify poultry profile requirements									
3.2	Algae components matching polutry profile			★						
4	Fish feed requirements and algae components	BFTC & Helios								
4.1	Qualify fish profile requirements									
4.2	Algae components matching fish profile			★						
5	Tailor algae for nutritional needs	BFTC & UIUC & Helios								
5.1	Species selection and culture									
5.2	Algae for feed production blend optimization									
6	Optimize algae-blends for feed	BFTC & UIUC & Helios				★				
6.1	Algae process for improved utilization in feed blends									
6.2	Manufacture and characterize fish feed									
6.3	Manufacture and characterize poultry feeds									
7	Algae culture on brewery offgas	Helios								★
8	Production of feed and feed tests	BFTC, UIUC & Helios								
8.1	Fish feed and live fish tests									★
8.2	Poultry feed and live poultry tests									★
9	TEA	Helios								
10	LCA	UIUC & Helios								

★ Milestones

Decision points and success criteria

Decision Point	Date	Success Criteria
Go/No Go End of BP1	8/31/2025	Culturing of algae for feed blend grown on template brewery offgas
Go/No Go End of BP2	8/31/2026	Benefits of algae blended ingredients quantified

Thanks to DOE, NETL and our Partners

Acknowledgement

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