

# ***Improving the cost-effectiveness of algal CO<sub>2</sub> utilization by synergistic integration with power plant and wastewater treatment operations***

Department of Energy Cooperative Agreement No: DE-FE0032098



National Energy Technology Laboratory  
Carbon Management Project Review Meeting  
August 15 - 19, 2022



# Project Overview

- **DOE Funding Program DE-FOA-0002403: *Engineering-Scale Testing & Validation of Algae-Based Technologies & Bioproducts (AOI 1)***
  - Upscaling & integrating unit processes for algal carbon capture & utilization
- ***End of Project Objectives & Goals:***
  - BP1 Goal (Oct 2021 - Mar 2023) 180 m<sup>2</sup> cultivation system installed and achieves at least 10 g/m<sup>2</sup>/d productivity with coal flue gas CO<sub>2</sub>
  - BP2 Goal (April 2023 – Sept 2024) Cultivation system has an average productivity of 14.3 g/m<sup>2</sup>/d with coal flue gas CO<sub>2</sub>
  - End Goal: TEA with key performance parameters supporting a required selling price below market value of protein conc. w/ a \$0 CO<sub>2</sub> capture credit

Budget Period	Work	Start	End	Budget
I	Design, Construction and Startup	10/1/2021	3/31/2023	\$1,897,532
II	Testing and Optimization	4/1/2023	9/30/2024	\$601,564

# Project Overview - Participants



**PI: Dr. Lance Schideman**  
**Illinois Sustainable Tech. Center**  
**Prairie Research Institute**  
**University of Illinois**  
Project management and  
integration of wastewater nutrients.

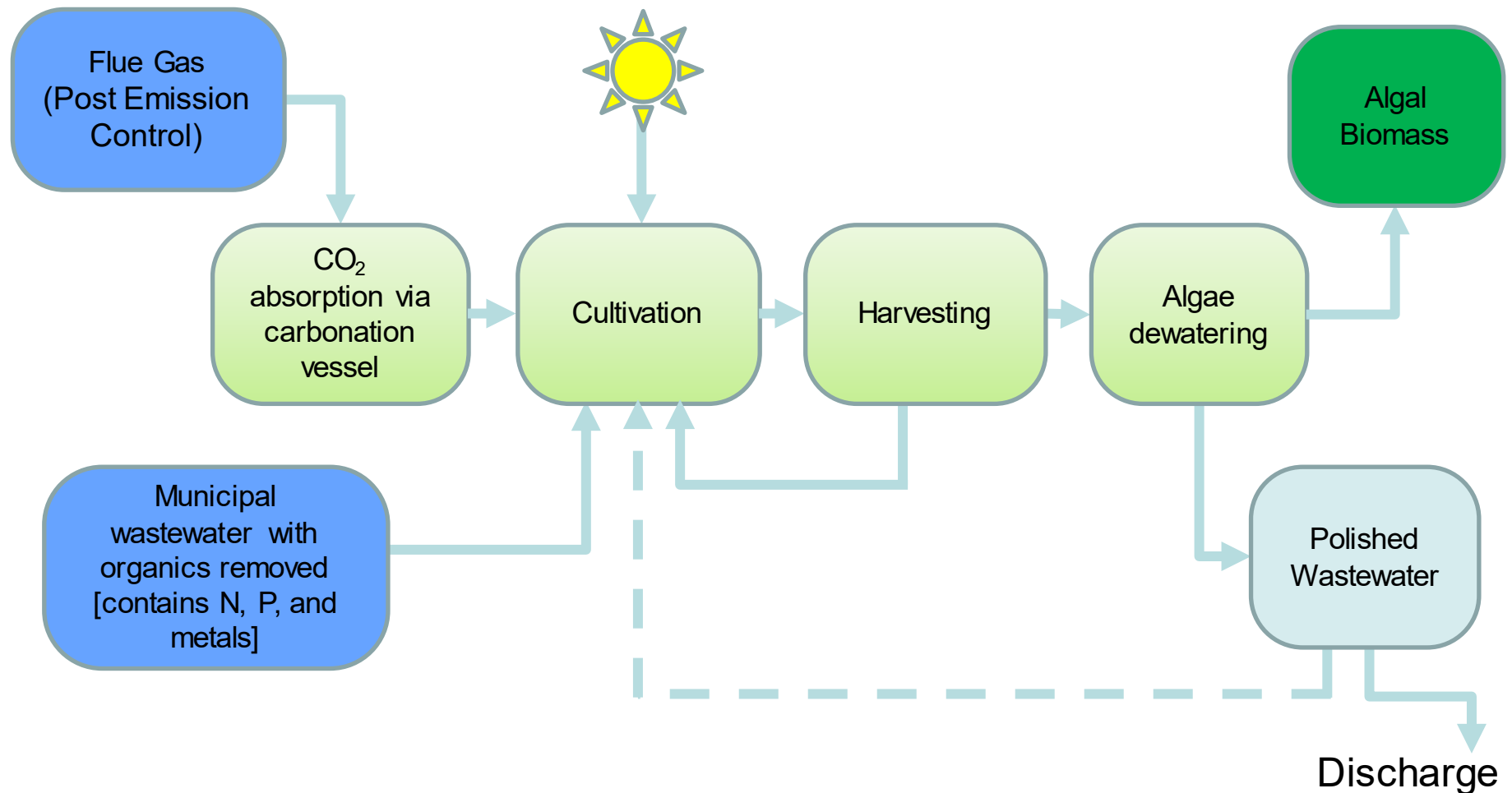


**Global Algae Innovations:**  
Design and construction of  
algae cultivation system

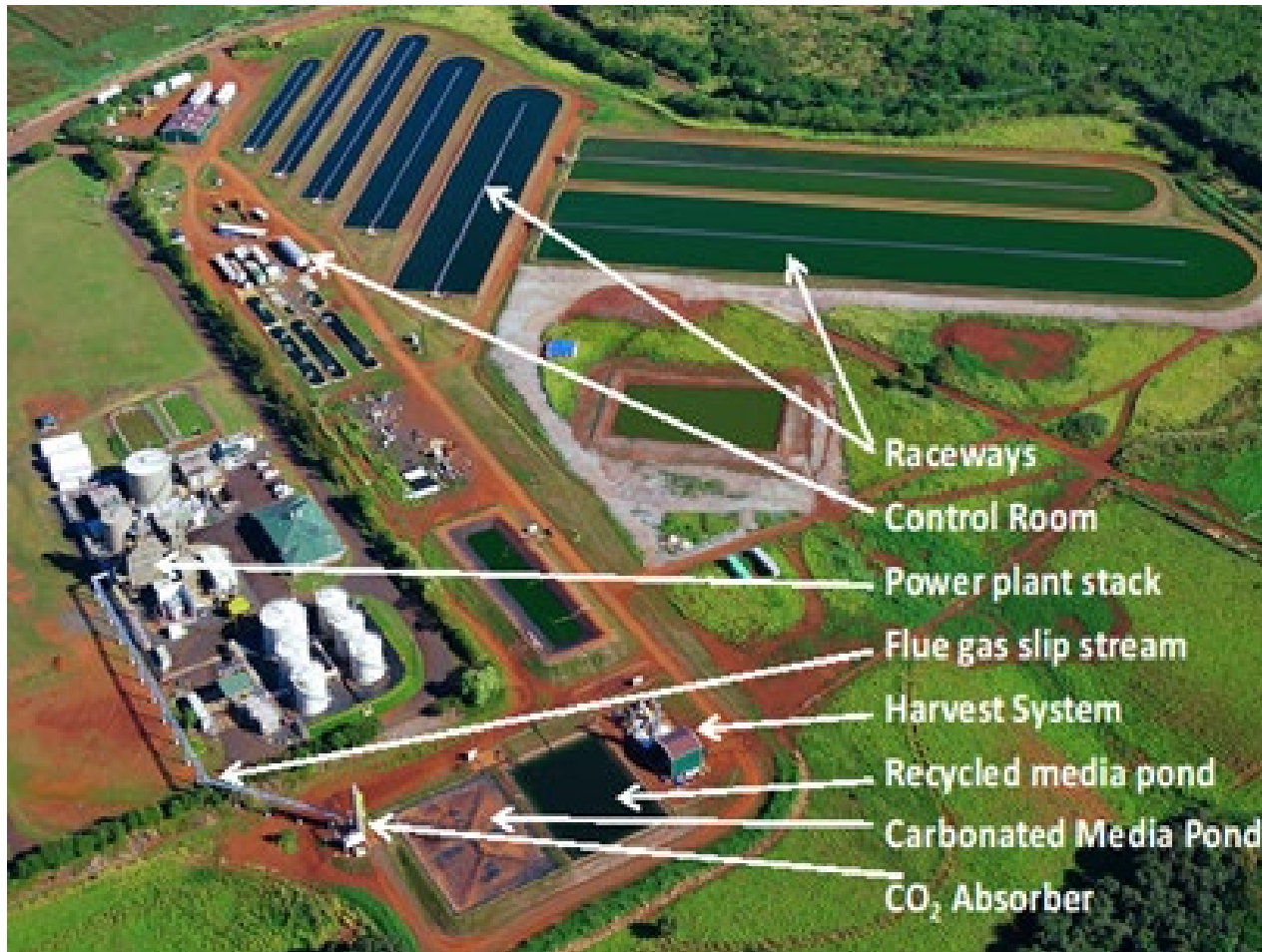


**City Water Light and Power:**  
Host Site

# Technology Background- Block Flow Diagram



# Technology Background

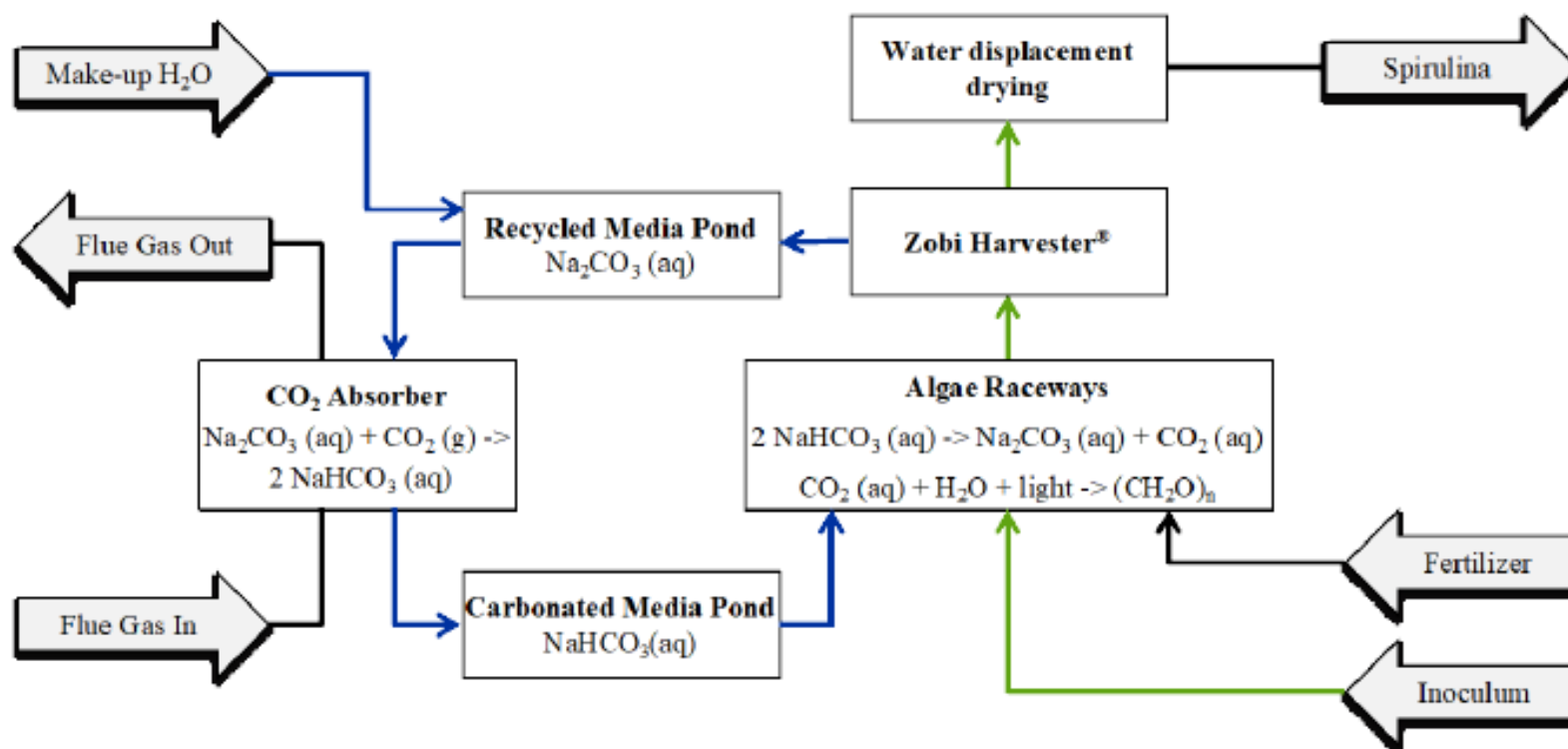


GAI's 8-wet acre  
Kauai Algae Farm  
- CO<sub>2</sub> from a  
naptha-fueled  
power plant



# Technology Background- CO<sub>2</sub> Capture Process Integration with Algae Cultivation

Previous  
CO<sub>2</sub>  
Absorber  
Column  
by GAI



# Technical Approach

**Project Strategy:**  
Combine Key  
Advantages from  
Previous Projects

Top Tier Algae Cultivation  
System from GAI

First Demonstration with GAI  
System Using Coal Flue Gas

Improvement of Economics  
with Use of Wastewater  
Nutrient Inputs and  
Higher Value Co-Products

# Technical Approach

Task / Subtask	Milestones
1/1.1	Submit Updated Project Management Plan (PMP)
1/1.2	Submit Initial Technology Maturation Plan (TMP)
2	Cultivation system installed & operational achieving > 10 g/m <sup>2</sup> /d productivity with coal flue gas CO <sub>2</sub>
3	Absorber system installed and operational and achieves at least 75% carbon capture efficiency
4	Harvesting and drying system installed and operational and produces algae powder with less than 10% moisture content
5	Algae protein meal with at least 50% protein
6	Demonstrate ability to replace at least 50% of nutrients in algal inoculation cultures
7	Interim TEA and LCA confirming costs for baseline performance
8.	Integrated system has average CO <sub>2</sub> capture efficiency of >80%,
8	Cultivation system has an average productivity of 14.3 g/m <sup>2</sup> /d with coal flue gas CO <sub>2</sub>
9	Demonstrate ability to use power plant waste heat to extend algae growing season and increase cold weather productivity
10	Determine projected value of algal biomass based on live chicken digestion tests
11	Final TEA incorporating averages of key performance parameters projects a required selling price that is less than the market price of the protein concentrates at a scale of 5000-acres with \$0 credit for CO <sub>2</sub> capture and mitigation
12	Final LCA incorporating averages of key performance parameters projects at least a 50% reduction in GHG for the target products

Completed Milestones shaded in light blue



# Project Overview

Site plan at CWLP host site for this Algae project and other related projects



# Project Achievements

- Algae Production System Design Substantially Complete
  - Zero Discharge Design
- Procurement of Major Equipment Complete
- Delivery Ongoing
- Construction Contractors Scheduled
- Algae pilot raceway pond area totaling in 180 m<sup>2</sup>





# Project Achievements- Construction Mobilization & Algae Production Equipment Procurement/Delivery



Absorber Stand



Zobi Harvester®

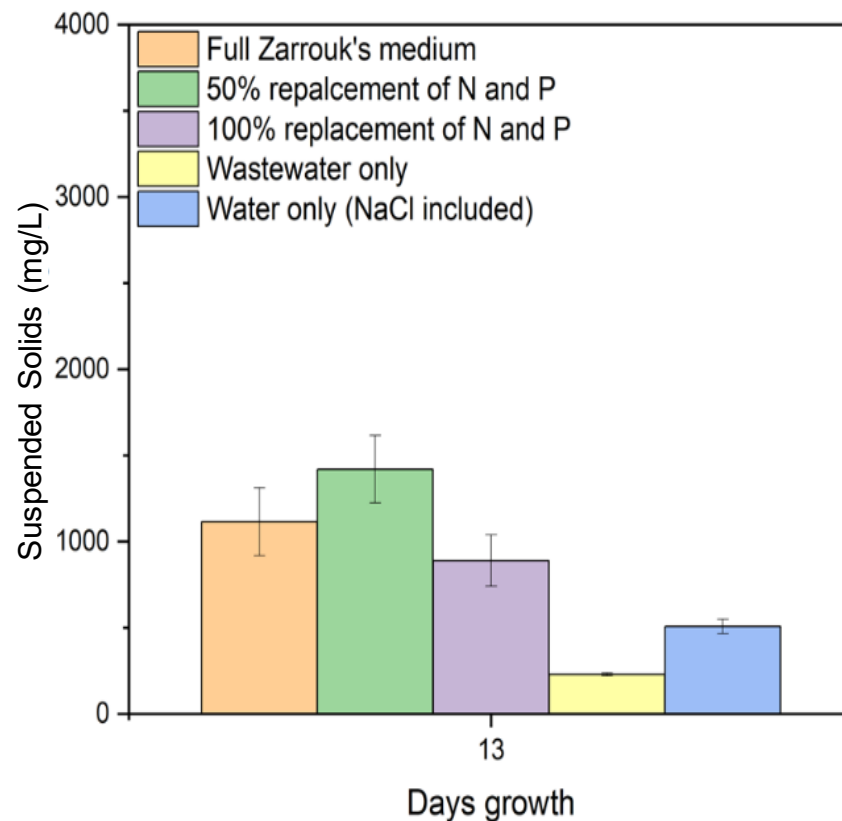
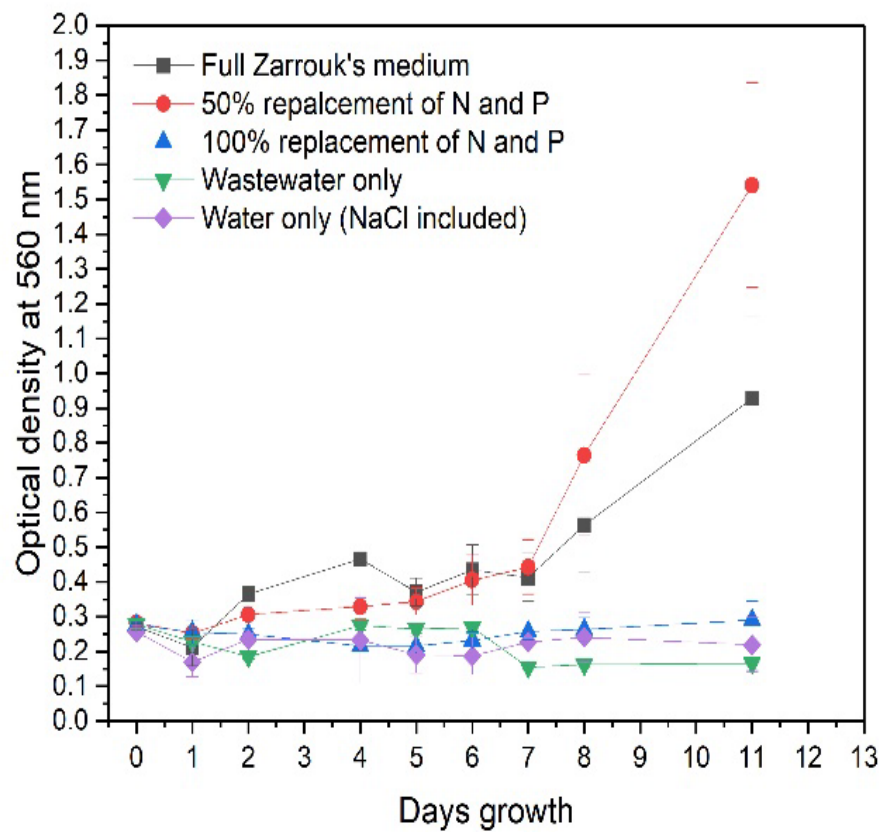


Tanks for Algae Propagation  
& Nutrient Media Supply

# Project Achievements

Demonstrated good growth of target strain of *Spirulina* with 50% of nutrients provided from a municipal wastewater source

- Working to acclimate cultures to higher proportion of wastewater





# Animal Feed Product Testing

## Animal Feed Rationale

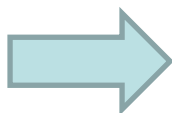
- Large Market Economic Demand: Scales with CO<sub>2</sub> capture
- Global Animal Feed Market > 800 Million Tons/yr

## University of Illinois - Department Animal Sciences

- Conducting feed characterization
- In-vitro and live animal feed testing- Poultry and Cattle
- Estimation of animal feed market value

## Industrial Advisory Board Feedback

- Representatives from animal feed industry



Animal Feed Testing and  
Regulatory Collaboration

# High-Value Spirulina Algal Product: *C-PhycoCyanin (C-PC)*



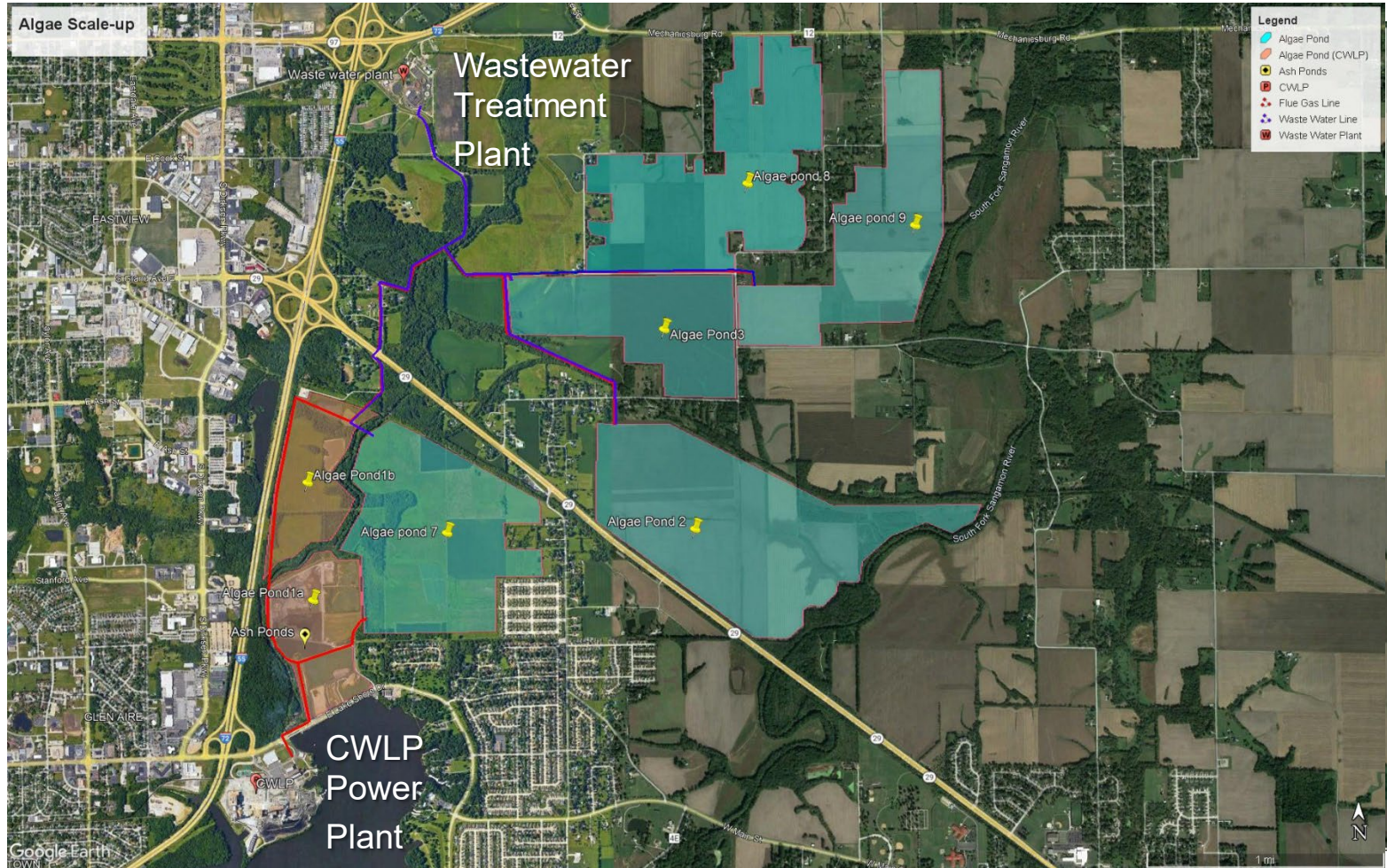
- **C-PC value depends on purity (A620/A280)**
  - Value ranges from \$300/kg to >\$100,000/kg
  - Grade 1: 0.50-1.50 (Food level) (Used as a Dye);
  - Grade 2: 1.50-2.50 (Cosmetic level) (Used as a Dye);
  - Grade 3: 2.50-3.50 (Reagent level) (Used as Dye and Biomarker);
  - Grade 4: Above 4.00 (Analytical level) (Medical Applications)
- **Extraction & purification methods need optimization**

*(Guan S.C., 2016)*

Extraction method	C-PC extraction yield (mg/g)	C-PC purity (A620/A280)	Residue yield (%)	Time (h)	Energy Input	Cost (\$/L)
Freeze-thaw	65.8	0.475	63.2	5	Medium	2.8
Shear	54.5	0.415	48.7	0.3	Medium	0.3
Lysozyme	67.6	0.361	62.6	10	Low	7.5



# Scale-Up Potential- 21<sup>st</sup> Century Power Plant Project



- Large scale algae cultivation of >1500 ac. is possible in the vicinity of Springfield, IL by utilizing a combination of land from local utilities and private farmland.
- Would require a network of flue gas & water pipelines (Approx. 5-10 miles each).

# Summary

- Project Summary: Construction Underway
- Key Project Advantages:
  - Incorporate Wastewater Nutrients to Improve Economics
  - Demonstrate State-of-the-Art Algae Production System with Coal Power Plant Flue Gas and Wastewater Nutrient Inputs
- Project Targeting Algae Product Market Development
  - Live Animal Testing to Support High Volume Product Markets
    - Use of Algae for Animal Feed Avoids Losses Associated with Biofuel Conversion Process
  - Improve Phycocyanin Pigment Extraction Methods for High Value Product Markets

## **Appendices:**

- 1. Organizational Chart**
- 2. Gantt Chart**

# Project Participants and Roles

PRIME CONTRACTOR  
University of Illinois (UI)  
PI: Dr. Lance Schideman

Responsibilities:

- Project management
- Routine operation of the integrated algae cultivation system after start-up
- Analysis of water and air samples from the integrated cultivation system for process performance quantification
- Algae biomass characterization and testing for animal feed applications
- Techno-economic and Life-cycle analysis

Intellectual Property:

- Methods for integrating wastewater treatment operations with algae cultivation

INDUSTRIAL ADVISORY BOARD

Managers and Design Consultants from the Power and Wastewater Industries

Responsibilities:

- Host site supplying coal flue gas (CWLP)
- Advise on current industry drivers/issues
- Review plans for integration with existing infrastructure facilities
- Review comment on project results

SUBAWARDEE - Global Algae Innovations [GAI]

Responsibilities:

- Design & construction of integrated algae cultivation system including raceway ponds, carbon capture, dewatering and drying
- Startup and training staff for routine operations of the integrated algae cultivation system
- Commercialization strategy
- Baseline data for techno-economic and life-cycle analysis

Intellectual Property:

- Flue-gas adapted algal strains
- Patents and other proprietary knowledge for the integrated algae cultivation system components

# Gantt Chart

## Project Management Plan (PMP)

Fri 10/1/21 - Mon 11/1/21

