

DOE Bioenergy Technologies Office (BETO) 2019 Project Peer Review

PILOT-SCALE ALGAL OIL PRODUCTION

DE-EE0007965

March 5, 2019

David Hazlebeck

Global Algae Innovations

Goal Statement

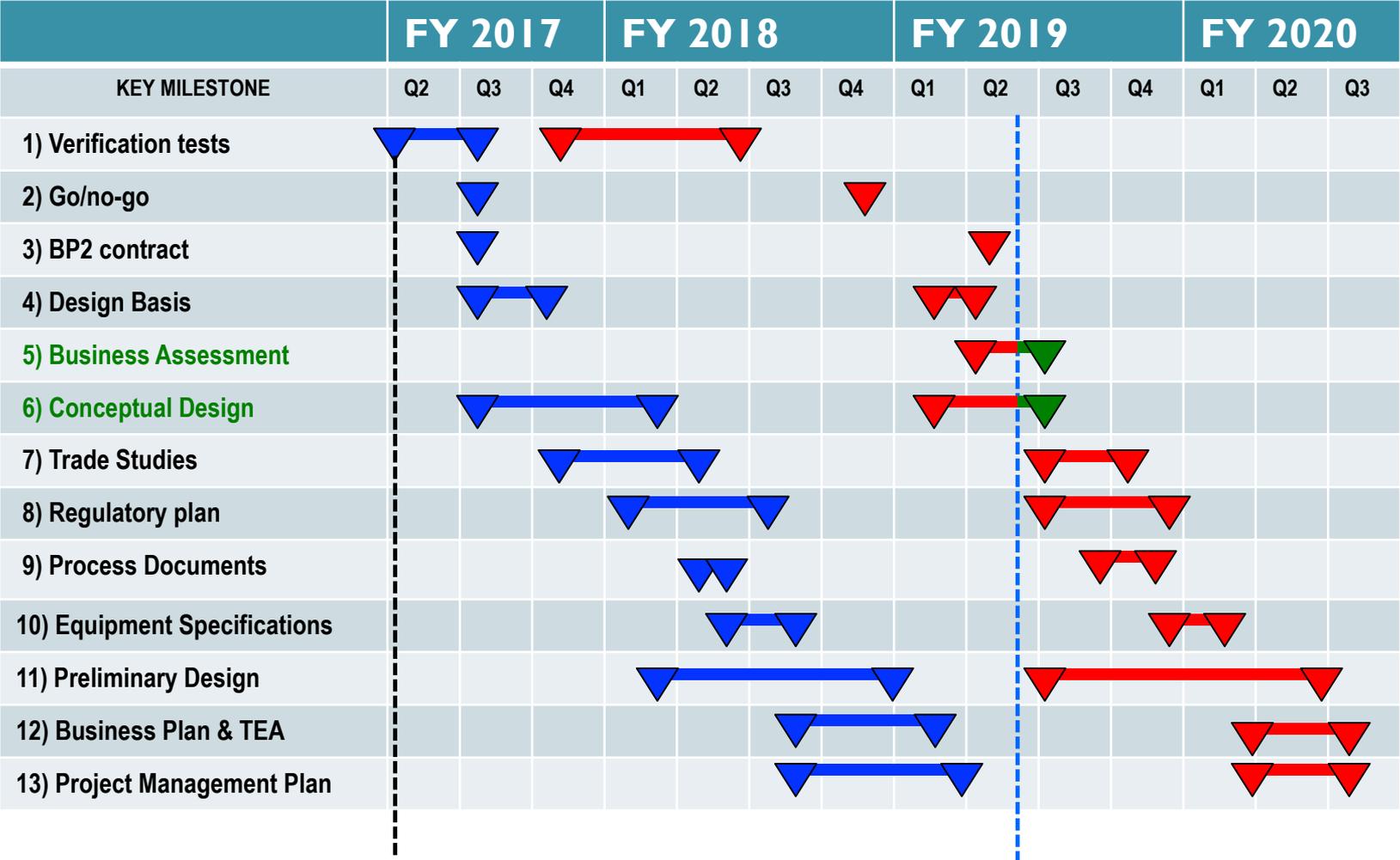
The goal is to scale-up open-raceway algae biofuel process that is economically viable and sustainable, including

- preliminary planning and design of a pilot-scale facility
- technoeconomic analyses for a full-scale facility based on the design effort that verify the process is economically viable and sustainable
- a business plan for financing and operation of the pilot-scale facility that enables long-term economical operation for algal oil production

Relevance to bioenergy industry

- First pilot-scale facility for an advanced open-raceway algal oil process will provide approach for many scale-up issues
- Economic viability by incorporating order-of-magnitude improvements relative to conventional technology throughout the entire process
- Pilot-scale profitable with same intermediates as commercial-scale facility, so will produce large quantities of algae oil and algae meal
- Provides commercial drive and funding for continued improvements

Key Milestones



START DATE
(Conditional)

TODAY

	Original Project Costs (Estimated)			Project Spending & Balance		Final Project Costs
Budget Periods	DOE Funding	Cost Share	Contingency	Spending to date	Remaining Balance	Funding Needed to Complete
BP1 Verification	353	353	0	854	0	0
BP2 Conceptual Design	175	175	0	30	320	0
BP2 Preliminary Design	533	533	0	0	1066	0
BP2 Project Management Plan	175	175	0	0	350	0

Quad Chart Overview

Timeline

- Start Date: Jan 2017
- Original end date: Dec 2018
- Revised end date: Dec 2019
- Verification & contracting 22 months longer than anticipated
- 20% complete

Budget

	2017	2018	2019 +
DOE	350	3	883
Cost Share	311	191	734
Partners			
• TSD		11%	
• UCSD		8%	
• TBD Civil		15%	

Barriers

- Aft-H. Overall Integration and Scale-Up
- Aft-A. Biomass Availability and Cost
- Aft-B. Sustainable Algae Production

Other Barriers addressed:

- Aft-D. Sustainable Harvesting
- Aft-E. Algal Biomass Characterization, Quality, and Monitoring
- Aft-F. Algae Storage Systems
- Aft-I. Algal Feedstock On-Farm Preprocessing
- Aft-J. Resource Recapture and Recycle

Partners

TSD
UCSD
Civil Engineering Firm
State of California
Imperial Valley Economic
Development Corp
Imperial Irrigation District

1- Project Overview - FOA

DE-FOA-0001232: Project Development for Pilot and Demonstration Scale Manufacturing of Biofuels, Bioproducts, and Biopower (PD2B3)

Topic Area 1: Algal Biomass – at least 25,000 gal/year

Demonstrate future plans for conversion to biofuel

At least 50% of carbon in products as biofuel

TEA supports BETO target of \$3/GGE

Qualify as advanced biofuel

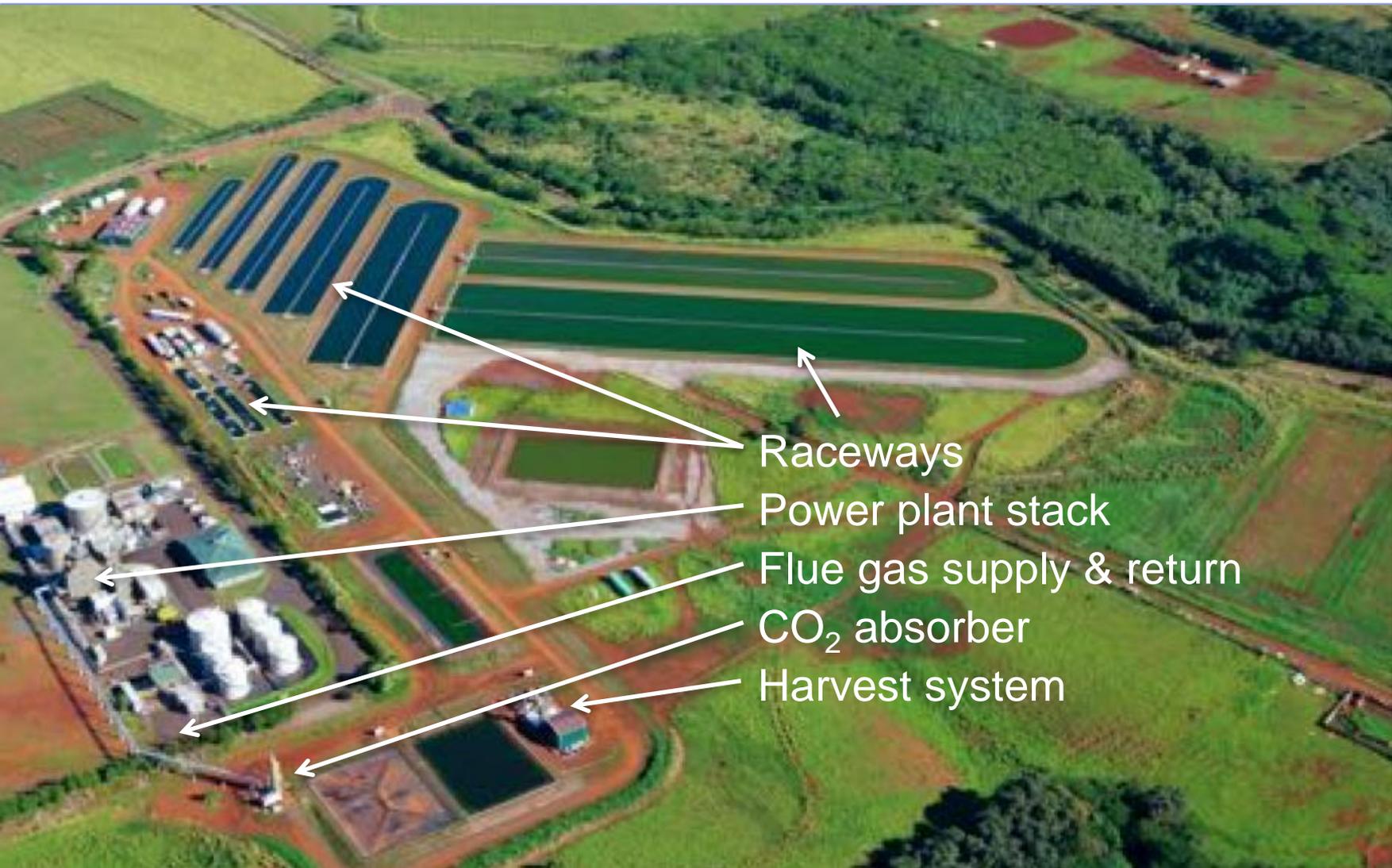
Project Overview - Global Algae Innovations

Algae Solutions to Global Dilemmas

- Founded Dec 2013
- Algae for commodities
- Initial technology development complete
- Radical advances throughout the entire process



Project Overview - Prior Facility



Project Overview - Changes

Original	Changes
Scale to 150 acres	Scale to 90 -150 acres
Profitable with 50% DOE, 25% State of CA	Profitable with other non-dilutive capital options
ABY1 & TABB advances	Options to include ABY2+ advances without adding risk
315,000 gal algal oil per year	200,000 to 350,000 gal of algal oil per year
10 tons of algae per day	6 to 10 tons of algae per day
Imperial or Riverside County	Imperial, Riverside, or San Diego County
32-acre largest raceway side	13-acre largest raceway side

2 – Approach (Technical)

Approach

- Design criteria, business assessment, site selection, and permitting plan
- Conceptual design & start trade-off studies
- Revise design criteria, business plan and permitting plan
- Finish trade-off studies
- Preliminary design & planning including civil engineering

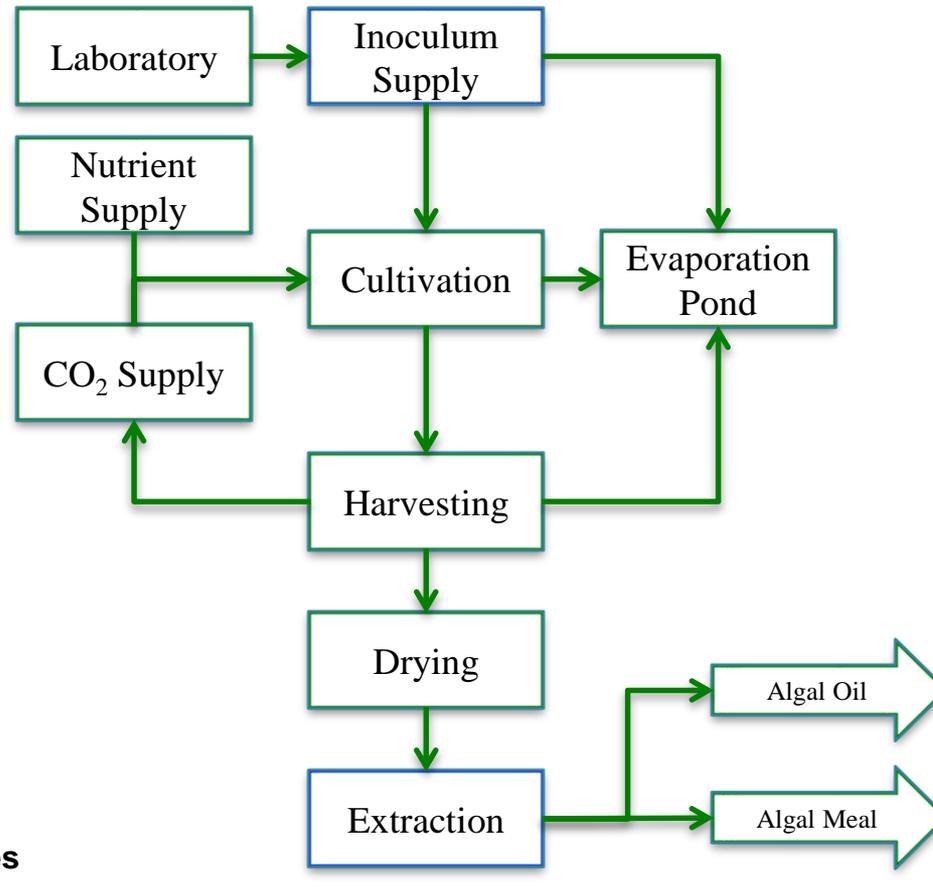
Critical success factors

- Full-scale projections < \$3/gge advanced biofuel
- Business plan for long-term operation
- Design with operating and capital costs that are in-line with a business plan for long-term operation

Top Challenges

- Siting and Permitting
- Variability in operating conditions – e.g. water management, thermal control
- Secure capital for construction and initial operation of the pilot plant

Process Operations Block Diagram



Technology

System	Technology	Scale-up	Issues/Opportunities
Laboratory	Robotic sample analyses Ecological measurements Cryogenic strain preservation Inoculum production	None	New analyses under development & testing would improve capabilities and reduce costs
Inoculum	Carboys, bags, or photobioreactor	TBD	May use current system or add a photobioreactor
Nutrients	Liquid or solid feed of fertilizers	8x	
CO ₂	Absorber & carbonate shuttle	3x	
Cultivation	Scalable, sloped, open raceways Contamination control Advanced cultivation methods Automated controls Thermal & water management	20x – prod 3x - mech	New engineering advances New strain New monitoring, New control algorithms
Harvesting	Zobi harvester®	2x	SBIR improvements in controls
Extraction	Extruder & solvent extraction	None	ABY2 extraction process Immersion vs. percolation
Drying	Ring Dryer using waste heat	None	ABY2 drying process

Conceptual Design

1. Business assessment & Design Basis (define trades)
2. Technology selection (additional trades) , process description
3. Site selection, risk assessment, permitting & compliance analysis
4. Block flow diagram, equipment list, preliminary plot plant
5. Cost estimate, life-cycle assessment, safety & hazards analysis

Preliminary Design

1. Trade-off studies, permitting & compliance plan
2. Design basis & process description update
3. PFD, M&EB, equipment list
4. Equipment scale-up analyses and equipment specifications
5. Single-line, plot plan, and equipment layout
6. P&ID, piping list, instrumentation list, operating procedures, safety & hazards analysis, and risk mitigation plan update
7. TEA, cost estimate, life-cycle assessment, business plan update
8. Project management plan – schedule, execution plan, risk mitigation plan, permitting and regulatory compliance

Preparatory R&D

- **Photobioreactor tests for inoculum production**
- **Local algae collection and screening to expand strain library**
- **Testing to support off-takes and specifications**

2 – Approach (Management)

All technologies and decisions filtered through business assessment and plan to accomplish overall objectives

- Secure capital for phase 2
- Economically viable & sustainable at pilot scale
- Commercially viable at full-scale

Management

- Cost & schedule, configuration control, risk management, reporting
- Team has worked together on other projects
- All documents on box.com
- Synergistic projects and opportunities
- Cost and technology status/potential transparent to team
- Utilize DOE, independent engineer, and CA technical advisory committee to help avoid pitfalls and identify opportunities

3- Technical Accomplishments, Progress and Results

Verification and Go/No-go Results

Unit Operation	Baseline	Issues	Anything Lacking?	Readiness to Proceed with Design
Inoculum System	Carboy system	May require different type	Data on PBR's	PBR testing needed
CO ₂ Supply	5' x 50' absorber on flue gas with carbonate shuttle	None	No	Yes
Cultivation	23 g/m ² d, 0.66 ac Mechanical, 3.2ac	Limit to 20x	Larger scale data	Yes at 13 acre
Harvesting	Zobi harvester®	None	No	Yes
Dryer	Dedert ring dryer	Testing not witnessed	No	Yes
Extruder	Anderson Int'l extruder	Testing not witnessed	No	Yes
Extraction	Crown Iron Works Immersion system	Testing not witnessed	No	Yes
Conversion	Refining to jet or diesel fuel	No	No	Not included in the pilot plant

Design Basis – Issued

Some of the Trade Studies Identified

- Water management study (rain/evaporation, water for rinsing raceways and harvester)
- Inoculation trade study – inoculation system volume, size of first stage
- Inoculum photobioreactor down-selection – cleaning, cost, reliability, maintenance
- Thermal management – modeling raceway temperature & thermal control options
- Harvest timing, duration, and location
- Incorporation of new cultivation advances without requiring use
- Raceway control and operational options
- Wet or dry fertilizer addition
- Hold-up time for CO₂ to smooth out seasonal and power plant variations
- Harvester internals optimization
- Dryer heat source
- Options for use of new drying methods
- Packaging and storage of dry algae
- Packaging and storage of algal oil
- Options of use of new extraction methods and off-site toll processing
- Inclusion of new laboratory technologies

4 – Relevance

Higher yield, lower energy use, lower cost algae biofuel intermediate production in an integrated outdoor facility

Directly Supports the BETO mission to “Develop and demonstrate transformative and revolutionary bioenergy technologies for a sustainable nation.”

Goal aligned with major Algal R&D targets:

- Higher biofuel intermediate yield
- Lower energy for processing algal biomass
- Lower cost of algal biofuel

Technology advance objectives

- Advanced cultivation and strain improvements for a very high productivity system
- Much lower energy and cost for harvesting, extraction, and drying
- Higher productivity, lower cost processing, and protein co-product to enable cost competitive algal biofuel

Tech Transfer/marketability

- Incorporating advances into integrated biorefinery project
- Zobi harvester® is commercially available
- Partnering with multiple teams on DOE FOAs
- Building IP portfolio that covers the entire process with dozens of innovations
- Building cultivation and processing database

5 – Future Work

Design

- Complete Business assessment, permitting assessment, site selection, and conceptual design
- Complete trade studies, permitting plan, and process documents
- Complete preliminary design
- Initiate permitting activities
- Project management plan, TEA, LCA

Funding to Build and Operate

- Business plan for profitable operation
- Investment and off-takes from customers
- Secure remaining funding

Summary

- 1. Overview:** First scale-up of economically viable, sustainable, advanced algae cultivation and processing systems
- 2. Approach:** Front-end loaded design
Operation at a profit for algal oil and algae meal
Business plan and project management plan to implement
- 3. Technical Accomplishments/Progress/Results:**
 - Verification that technology is ready for scale-up design
 - Design basis complete and analyses/site selection underway
- 4. Relevance:** Pilot-scale demonstration of BETO algal systems objectives
Economical production of algal oil and algal meal
- 5. Future Work**
 - Finish design and project plan
 - Raise funds to build and operate the pilot facility

Risk Registry Table

ID	Step	Description	Prob	Severity	Mitigation	Date	Status
1	Inoculum	PBR doesn't work well	Low	High	Prep R&D: test PBR; Use current system	5/19	Open
2	Cultivation	Lower productivity	Low	Med	Design for 16 g/m ² d; data supports 23 g/m ² d	1/19	Closed
3	Cultivation	Strains can't handle weather variations	Med	High	Prep R&D: Collect local strains to expand library	12/19	Open
4	Cultivation	Problems with thermal & water variations	High	High	Trade studies and analysis to accommodate	10/19	Open
5	Extraction	Pilot test data on high capital system and limited data on commercial-scale methods and	High	Med	Include low capital in design and line-up toll processor for original method	3/19	Open