

DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

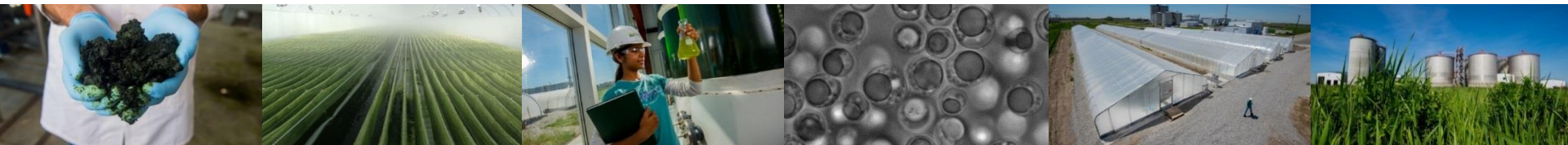
Pilot-Scale Mixotrophic Algae Integrated Biorefinery (IBR)

March 23-27, 2015

Technology Area: Demonstration and Market Transformation

Principal Investigator: Toby Ahrens

Organization: BioProcess Algae



This presentation does not contain any proprietary, confidential, or otherwise restricted information

- Project Overview
- Project Approach
- Technical Progress and Accomplishments
- Project Relevance
- Future Work

BIOPROCESS ALGAE BACKGROUND



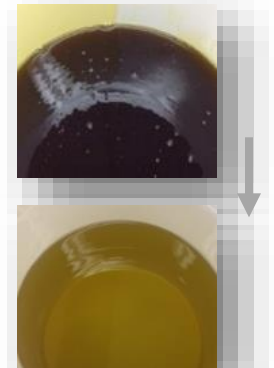
Integrated production since 2009



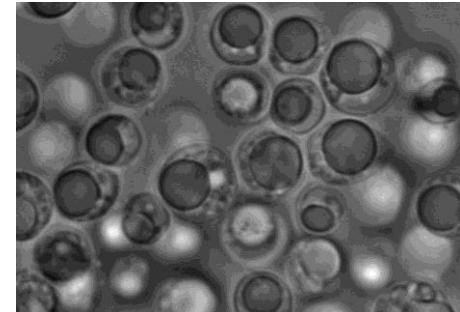
Option to stress with sugars



On-site production of powders



Crude and refined oils for fuels/chemicals



GOAL STATEMENT

- **Goal of this project:** The primary goal is to integrate unit operations and validate techno-economics in a pilot-scale Mixotrophic Algal Integrated BioRefinery (Mixo-IBR) facility to produce sustainable, cost-competitive fuels meeting military specifications (F-76, JP-5 and JP-8), using a combination of renewable CO₂, lignocellulosic sugars and waste heat at a site adjacent to a corn ethanol facility in Iowa.
- **How the project fits with the goals/objectives of the... :**
 - **Technology Area:** The mission of the IBR Technology Area is to bridge the gap between R&D and a need for commercial-scale production of advanced biofuels. Investment in our project will help integrate unit operations and validate techno-economics to reduce the investment risk for future expansion to demonstration- and commercial-scale facilities while accelerating expansion timelines.
 - **DOE Bioenergy Technologies Office:** The DOE Biomass Program mission is to convert renewable, non-food biomass into sustainable, cost-competitive biofuels, which is identical to the value proposition of the proposed Mixo-IBR. The Mixo-IBR converts renewable CO₂ and cellulosic sugars into advanced biofuels with a modeled production cost of <\$3.00 GGE.
 - **Overall bioenergy industry:** The Mixo-IBR technology has many synergies with the existing and future bioenergy industry, including co-location and rapid deployment within the ethanol sector (first- or next-gen), products that can utilize existing infrastructure, and deployment plans in locations that understand the target markets.
- **Relevance and tangible outcomes for the United States:** If commercialized, the Mixo-IBR could produce low-carbon biofuels at competitive costs that could help reduce American dependence on foreign oil. In addition, the Mixo-IBR approach would allow for rapid deployment in rural regions, providing short- and long-term job creation for construction, operators, biologists, chemists, engineers, and others.

QUAD CHART OVERVIEW

Timeline

- Project start date: 9/30/2013
- Project end date: 4/6/2017
- Percent complete: 6%

Budget

	Total Costs FY 10 – FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date)
DOE Funded	\$0.00	\$0.00	\$384,929	\$5,974,428
Project Cost Share (Comp.)*	\$0.00	\$0.00	\$384,929	\$5,974,429

Barriers

- Barriers addressed
 - It-A (End-to-end Process Integration)
 - Additional barriers
 - Im-F (Cost of Production)
 - Ft-N (Algal Feedstock Processing)

Partners

- Other interactions/collaborations



➤ Lipid Conversion



➤ Lipid Extraction & Conversion
➤ Hydroprocessing

1 – PROJECT OVERVIEW



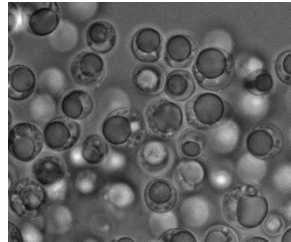
Step 1

Autotrophic algae production



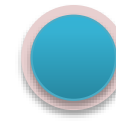
Step 2

Heterotrophic stressing



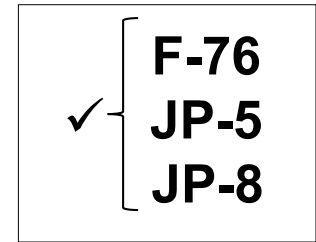
Step 3

Downstream processing



Step 4

Conversion to one or more qualified fuels



- **History:** BioProcess Algae was formed in 2008 to commercialize a unique biofilm-based approach to algae production. BPA has been operating an algae production facility integrated with a corn ethanol plant in Shenandoah, IA since 2009.
- **Context:** Integration with a corn ethanol facility has presented many synergies for BPA's platform. For example, CO₂ emissions and waste heat from the adjacent facility are used to lower the cost of algae production. BPA may also be able to take advantage of existing infrastructure at the ethanol facility to get fuel and animal feed co-products to market.
- **The primary objective** is to integrate unit operations and validate techno-economics in a pilot-scale Mixotrophic Algal Integrated BioRefinery (Mixo-IBR) to produce sustainable, cost-competitive fuels meeting military specifications (F-76, JP-5 and JP-8), using a combination of renewable CO₂, lignocellulosic sugars and waste heat at a site adjacent to a corn ethanol facility in Iowa.
- **Important interim objectives** include meeting autotrophic production targets, successfully increasing lipid concentrations with lignocellulosic sugars, meeting lipid conversion & extraction efficiency targets, and successfully converting those lipids to military fuels.

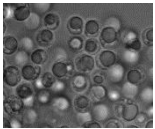
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2 – APPROACH (TECHNICAL)

- **Critical success factors** (technical) that will define technical and commercial viability:



Meeting autotrophic production goals using CO₂ and waste heat from adjacent plant

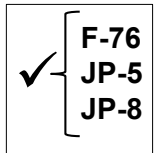


Use non-food sugars to increase algal densities and lipid content in fermentation tanks



Minimize evaporative drying during downstream processing prior to lipid extraction

Low cost oil conversion process meeting military fuel specifications



Integrated operations support assumptions for commercial-scale economic feasibility, life cycle analysis and petroleum displacement projection



Go/No-Go Decisions: Approval of baseline claims; Validation of scope/schedule/budget for construction and operation; Approval of post-construction shake-down; Validation of integrated unit operations

- **Top 2-3 potential challenges** (technical) to overcome for successful project results
 - Sugar purity, concentration, speciation requirements during heterotrophy
 - Mitigation of contamination during heterotrophic stressing

2 – APPROACH (MANAGEMENT)

- **Structure of approach:**
 - BPA follows a stage-gate management approach and uses an Earned Value management system to plan, track, and report on progress toward milestones.
 - A comprehensive Project Management Plan is used to identify and mitigate risk, coordinate communications, identify procedures for change control, outline quality assurance and analysis approaches, and outline approaches for environmental health and safety.
 - **BPA accomplished all milestones in the initial Budget Period while successfully using Earned Value management to track and report progress. The initial Budget Period was completed on time and under budget.**
- **Critical success factors** (market, business) that will define technical and commercial viability:
 - Demonstrate requirements for cellulosic sugar stream (purity, concentration, speciation)
 - Justify minimum co-product value of defatted meals
 - Utilize established commercial entities/technologies for non-critical steps in process integration
 - Complete the project within budget and on or ahead of schedule
- **Top 2-3 potential challenges** (non-technical) to overcome for successful project results:
 - Timely execution of contracts and disbursement of funds from DOE
 - Timely decision-making during Go/No Go stage gates

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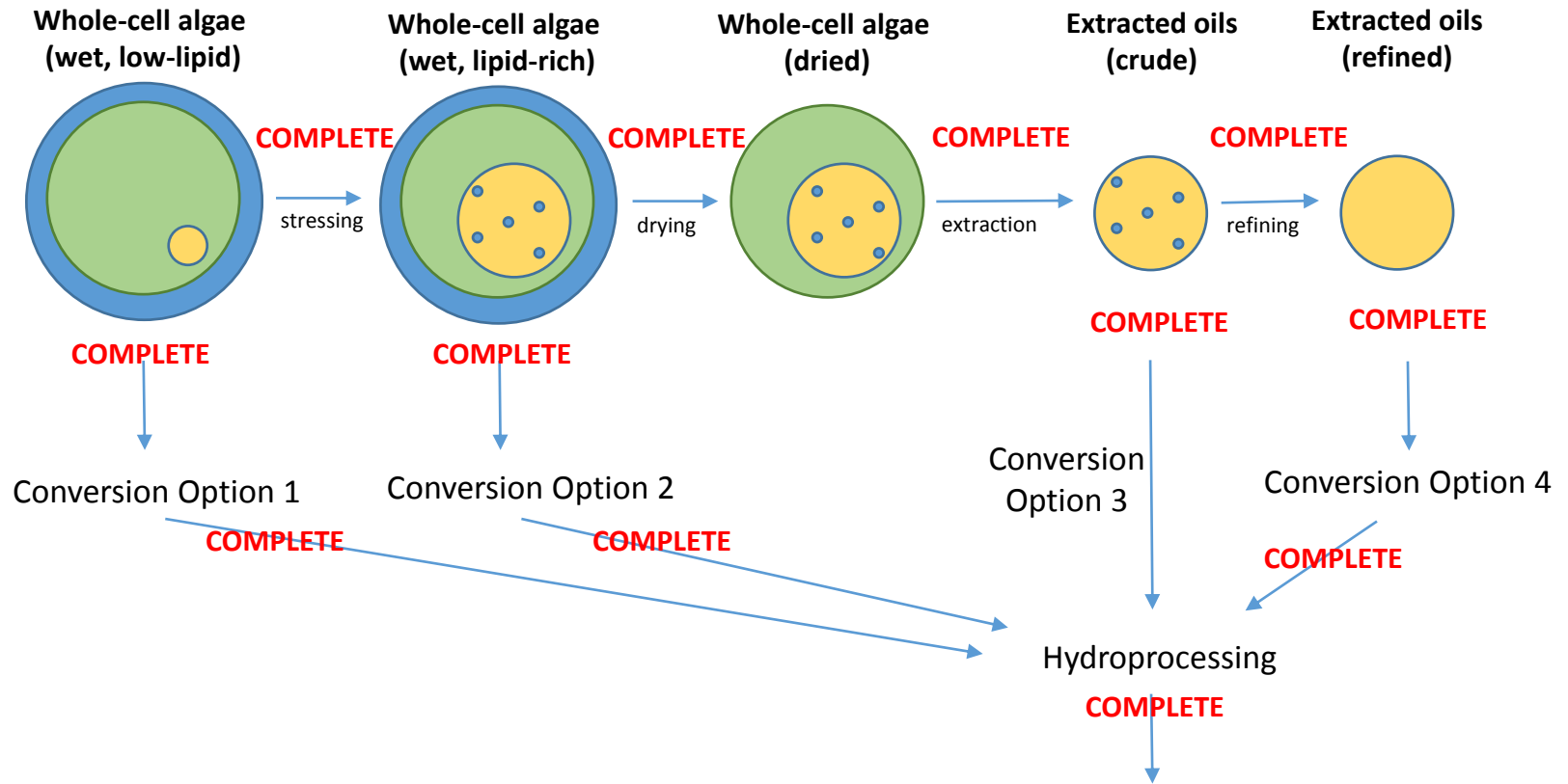
3 – TECHNICAL ACCOMPLISHMENTS/PROGRESS/RESULTS

- Progress made in meeting project objectives and following the project management plan
 - Accomplished all goals in initial budget period (BP1A Preliminary Validation and Negotiation) **on schedule and under budget using Project Management controls and Earned Value tracking**. Accomplishments included:
 - Selected strain and target operating conditions
 - Produced and extracted kilogram quantities of oils using mixotrophic platform
 - Produced kilogram quantities of fuels and/or fuel precursors
 - Successful support for Independent Engineer oversight of key activities
 - Effective Project Management and Reporting including timely reporting and establishment of routine monitoring of project progress and spending using Earned Value methodologies
- Summarize key milestones and status (**most important technical accomplishments in red**)
 - All three Budget Period 1A milestones met on-time and under budget:
 1. Agreements, scope, schedule, budget in place to perform proposed work
 2. **Data collected justifies the basis for selection of technology and scale-up factor**
 3. **'Go' decision by DOE Technical Project Officer and Contracting Officer on baseline claims in the application to FOA-0000739**
 - The current Budget Period 1B (Engineering and Design) milestones include:
 1. Design package, budget and agreements for Budget Period 2 (Construction & Operation)
 2. Data supports the engineering and design of the pilot-scale IBR
 3. Go/No Go decision by the DOE Technical Project Officer and Contracting Officer on the proposed scope, schedule and budget for Budget Period 2 (Construction & Operation)

3 – TECHNICAL ACCOMPLISHMENTS/PROGRESS/RESULTS

- **Tasks executed** leading to the technical accomplishments:
 1. Agreements, scope, schedule, budget in place to perform proposed work
 2. Data collected justifies the basis for selection of technology and scale-up factor
 - Selected strain and target operating conditions
 - Produced and extracted kilogram quantities of oils using mixotrophic platform
 - Installed additional tank capacity for stressing stage
 - Met or exceeded targets for biomass production, density, and lipid content
 - Produced kilogram quantities of fuels and/or fuel precursors
 3. 'Go' decision by DOE Technical Project Officer and Contracting Officer on baseline claims in the application to FOA-0000739
 - Successful support for Independent Engineer oversight of key activities
- **Progress compared to previously reported results**
 - Not applicable. This is first Peer Review of Mixo-IBR.
- **Accomplishments against the technical targets (if applicable):**
 - Accomplished all milestones in the initial Budget Period
 - Exceeded minimum production goals for biomass, extracted oils, and refined oils
 - Exceeded Pilot Plant target biomass concentrations in the reactor, solids densities during initial dewatering, and oil content of the cells.
 - Extraction efficiencies matched Pilot Plant targets

3 – TECHNICAL ACCOMPLISHMENTS/PROGRESS/RESULTS



Fuels (F-76, JP-5, JP-8) and/or fuel precursors

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4 – PROJECT RELEVANCE

- Describe how project accomplishments contribute to meeting the platform goals and objectives of the BETO Multi-Year Program Plan
 - **BETO’s overall Strategic Goal:** Develop commercially viable bioenergy and bioproducts technologies to enable the sustainable, nationwide production of biofuels that are compatible with today’s transportation infrastructure, can reduce GHG emissions relative to petroleum-derived fuels, and can displace a share of petroleum-derived fuels to reduce U.S. dependence on foreign oil and encourage the creation of a new domestic bioenergy industry. (MYPP BETO Nov 2014)
 - Commercialization of the Mixo-IBP approach could significantly contribute to the goal of producing sustainable, low-carbon biofuels through a technology that could be rapidly deployed throughout rural America.
 - **BETO MYPP objectives for Demonstration and Deployment milestones** include validating three pilot-scale processes by 2017, 1-2 demonstration scale by 2020, and one at appropriate scale by 2024. Pilot objectives include validating technical performance, operations, and supporting scale-up efforts to Demonstration Scale.
 - This project addresses those objectives by providing BETO an opportunity to fully validate a promising pilot-scale technology that, if successful, could be rapidly scaled up to demonstration and commercial scales.
 - **Supports concurrent activities** in Feedstock Supply and Logistics, Conversion R&D, and Sustainability.
 - For example, biomass produced in the initial Budget Period was used to evaluate several conversion and hydroprocessing pathways through collaboration with Pacific Northwest National Laboratories.

4 – PROJECT RELEVANCE

- Demonstrate how the project considers applications of the expected outputs in the emerging bioenergy industry
 - **Builds on existing accomplishments** in corn ethanol sector with an approach that is fully compatible with cellulosic economy
 - Further reductions in CO₂ emissions of host facility and beneficial use of waste heat
 - Uses existing infrastructure with co-product opportunities
 - Clear modularity for rapid deployment throughout Midwest with existing and future partners
 - **Advances state of technology** by:
 - Monetizes waste streams from existing biomass-based technologies (CO₂ emissions and waste heat)
 - Combining benefits of autotrophic and heterotrophic approaches
 - Improves sugar utilization in non-sterile reactors
 - **Positively impacts the commercial viability of biomass and biofuels** by:
 - Novel approach lowers feedstock production costs through utilization of waste streams and products from ancillary bio-based industries
 - Commercial viability of biomass supported by feed value as well as renewable fuels
 - Commercial opportunities are in locations with existing infrastructure to get products to target markets

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- **Plans through the end of the project** with emphasis on the next 18 months (through September 30, 2016)
 - Budget Period 1B: Completion expected Spring 2016
 - Engineering and design package for Pilot Mixo-IBR
 - Engineering and design package with budget
 - Optimized individual unit operations
 - Report on process optimization as well as an updated life cycle analysis
 - DOE Project Officer and Independent Engineer Process Validation
 - Milestone: Go/No Go decision from DOE
 - Critical Decision 3: Approval to start construction
 - Budget Period 2: Construction and Operation
 - Expected to begin Spring 2016 and end Spring 2017
- **Approach to decision points** during that time (Go/No-Go Points) and any remaining issues with proposed abatement actions
 - BPA remains committed to the Earned Value management system in combination with a comprehensive Project Management Plan to plan, track, and report on progress, as well as monitoring risk and managing any unforeseen changes in project execution.

1. Project Overview

1. BPA accomplished all milestones in the initial Budget Period while successfully using Earned Value management to track and report progress.
2. The initial Budget Period was completed on time and under budget.
3. BPA received a 'Go' decision to proceed to the Engineering and Design Budget Period.

2. Project Approach

1. The unique Mixo-IBR approach builds on the existing bioeconomy by utilizing waste CO₂ emissions and waste heat from a co-located corn ethanol facility, and the approach is equally well-suited for future co-locations with cellulosic sugar fermentation facilities.
2. The initial budget period implemented an Earned Value management system to track progress against milestones.

3. Technical Accomplishments/Progress/Results

1. Accomplished all milestones in the initial Budget Period on schedule and under budget
2. Exceeded minimum production goals for biomass, extracted oils, and refined oils
3. Exceeded Pilot Mixo-IBR target biomass concentrations in the reactor, solids densities during initial dewatering, and oil content of the cells.
4. Evaluated multiple oil conversion pathways in addition to the baseline technology.

4. Project Relevance

1. Technical accomplishments continue to support modeled commercial economics of <\$3.00 GGE.
2. Results continue to support goals to commercialize the Mixo-IBR technology, which could be rapidly deployed throughout the first- and next-generation ethanol sectors for meaningful production of advanced renewables fuels that could contribute to reducing American dependence on foreign oil.
3. Deployment of commercial Mixo-IBR systems would generate short- and long term employment opportunities in distributed locations through the rural Midwest and beyond.

5. Future work

1. Current budget period (including engineering and design) expected to be complete in April 2016
2. Construction and Operation expected to start in April 2016 and run through April 2017

Thank you.

Questions?

