U.S. DEPARTMENT OF ENERGY

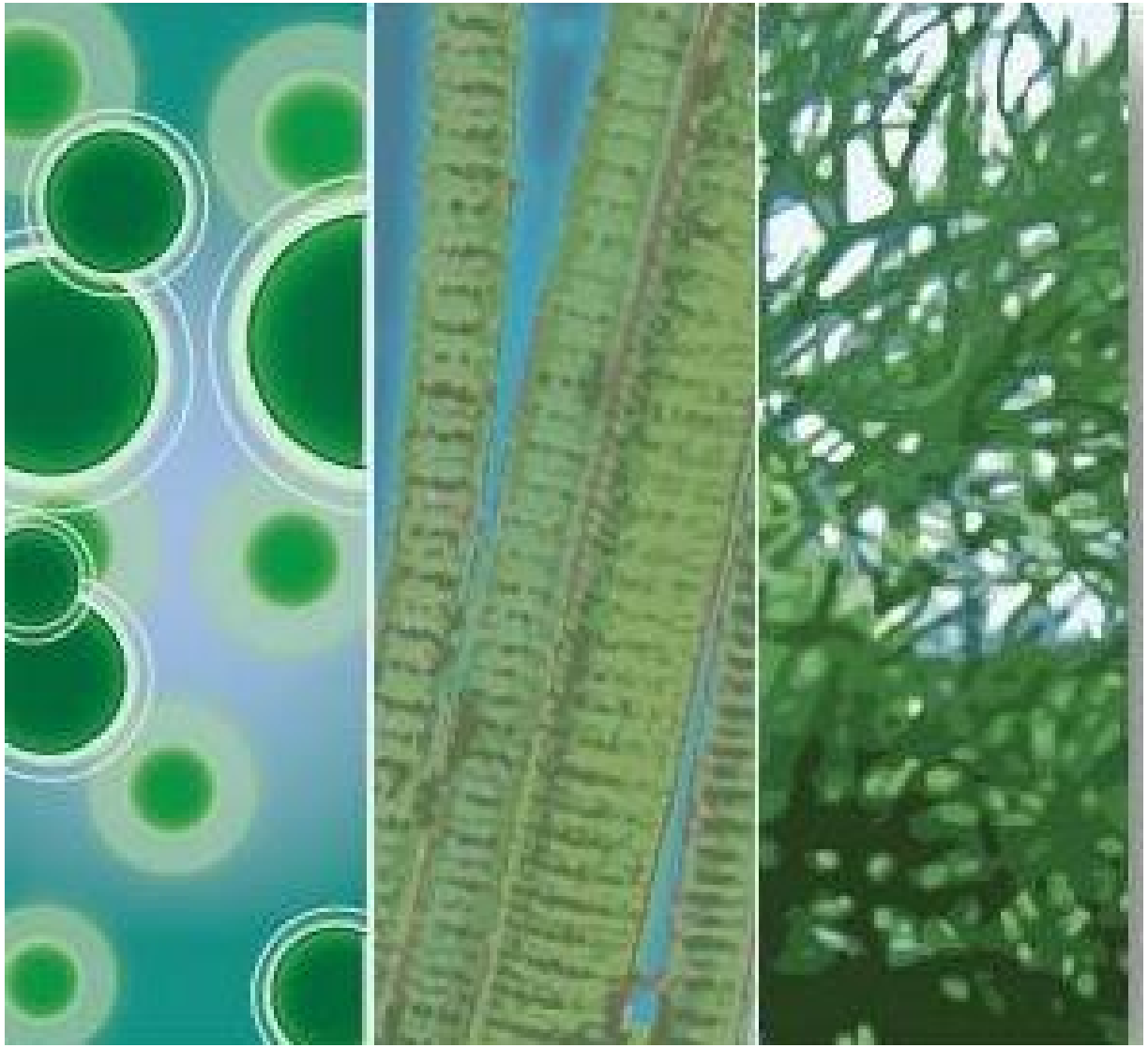
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Algal Systems

Christy Sterner, Technology Manager

March 8, 2021

Advanced Algal Systems Overview



- Agenda Overview
- The Team
- Reviewer Introductions
- Program Goals
- Approach
- Portfolio
- Engagement
- Active Management
- Progress
- Future Plans

Agenda-at-a-glance

Tues 3/9/21	Wed 3/10/21	Thurs 3/11/21
Strain Development	Strain Development	Systems Integration
	Systems Integration	

Mon 3/22/21	Tues 3/23/21	Wed 3/24/21
Cultivation System Improvement	Cultivation System Improvement	Cultivation System Improvement
		Logistics
		Conversion Interface

Note: There are some deviations to accommodate presenter schedule constraints

Detailed Agenda for Tuesday, March 9th

Day #1 **Strain Development (1.3.1)**

Time start (ET)	Time end (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:15 AM	0:15	Session introduction and Strain development overview	BETO	Christy Sterner		
11:15 AM	11:40 AM	0:25	Functional characterization of cellular metabolism	LANL	Scott Twary	1.3.1.100	AOP
11:40 AM	12:05 PM	0:25	REAL HYPE: Respiration Engineering of Algal Losses for High Yields and Productivity Enhancement	SNL	Anne Ruffing	1.3.1.105	AOP
12:05 PM	12:30 PM	0:25	IGET: Informatics-based genetic tools for rapid enhancement of production strains	LANL	Blake Hovde	1.3.1.001	AOP
12:30 PM	12:55 PM	0:25	Multi-scale Characterization of Improved Algae Strains	LANL	Taraka Dale	1.3.1.120	AOP
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	2:15 PM	1:00	Algae DISCOVR	PNNL, NREL, SNL, LANL, AzCATI	Michael Huesemann, Taraka Dale, Todd Lane, Lieve Laurens, John McGowen	1.3.1.501, 502, 503, 505	AOP
2:15 PM	2:30 PM	0:15	DISCOVR Q&A	PNNL, NREL, SNL, LANL, AzCATI	All	NA	AOP
2:30 PM	2:35 PM	0:05	Closing	BETO	Christy Sterner		
2:35 PM	3:05 PM	0:30	Comment Review Session				

Detailed Agenda for Wednesday, March 10th

Day #2 Strain Development (1.3.1) and Systems Integration (1.3.5)

Time start (ET)	Time end (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Algae Biotechnology Partnership	NREL	Mike Guarnieri	1.3.1.130	AOP
11:30 AM	11:55 AM	0:25	Genetic blueprint of microalgae carbon productivity	LBNL	Igor Grigoriev Shawn Starkenburg	1.3.1.110 1.3.1.111	AOP
11:55 AM	12:20 PM	0:25	Algal Translational Genomics	LANL	Shawn Starkenburg	1.3.1.600	AOP
12:20 PM	12:25 PM	0:05	Systems integration overview	BETO	Christy Sterner		
12:25 PM	12:50 PM	0:25	Life Cycle Analysis	ANL	Troy Hawkins	1.3.5.204	AOP
12:50 PM	1:10 PM	0:20	Break				
1:10 PM	1:35 PM	0:25	Marine Algae Industrialization Consortium (MAGIC): Combining Biofuels and High-value Bioproducts to Meet RFS	Duke University	Zackary Johnson	1.3.5.310	FY15 - TABB
1:35 PM	2:00 PM	0:25	Rewiring Algal Carbon Energetics for Renewables	NREL	Lieve Laurens	1.3.5.270	FY16 - ABY2
2:00 PM	2:25 PM	0:25	Integrated Low Cost and High Yield Microalgal Biofuel Intermediates Production	MicroBio Engineering	John Benemann	1.3.5.243	FY16 - ABY2
2:25 PM	2:50 PM	0:25	Algae Cultivation from Flue Gas with High CO2 Utilization Efficiency	Global Algae Innovations	Dave Hazlebeck	1.3.5.610	FY18 - ECUAS
2:50 PM	2:55 PM	0:05	Closing	BETO	Christy Sterner		
2:55 PM	3:25 PM	0:30	Comment Review Session				

Detailed Agenda for Thursday, March 11th

Day #3 Systems Integration (1.3.5)

Time start (ET)	Time end (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction		TBD		
11:05 AM	11:30 AM	0:25	Innovations in Algae Cultivations	Global Algae Innovations	Dave Hazlebeck	1.3.5.284	FY19 - CIPA
11:30 AM	11:55 AM	0:25	Optimizing Selection Pressures and Pest Management to Maximize Algal Biomass Yield	The New Mexico Consortium	Alina Corcoran	1.3.5.280	FY19 - CIPA
11:55 AM	12:20 PM	0:25	Improving the Productivity and Performance of Large-Scale Integrated Algal Systems for Wastewater Treatment and Biofuel Production	University of Illinois	Lance Schideman	1.3.5.286	FY19 - CIPA
12:20 PM	12:45 PM	0:25	Algal Productivity Enhancements by Rapid Screening and Selection of Improved Biomass and Lipid Producing Phototrophs (APEX)	Colorado School of Mines	Matt Posewitz	1.3.5.282	FY19 - CIPA
12:45 PM	1:05 PM	0:20	Break				
1:05 PM	1:30 PM	0:25	Decision-Model Supported Algal Cultivation Process Enhancement	Arizona State University	John A. McGowen	1.3.5.287	FY19 - CIPA
1:30 PM	1:55 PM	0:25	Algae Technology Educational Consortium	NREL	Cindy Gerk	1.3.5.201	AOP
1:55 PM	2:20 PM	0:25	Microalgae Analysis	PNNL	Mark Wigmosta	1.3.5.203	AOP
2:20 PM	2:25 PM	0:05	Closing		Christy Sterner		
2:25 PM	2:55 PM	0:30	Comment Review Session				

Detailed Agenda for Monday, March 22nd

Day 4 Cultivation System Improvement (1.3.2)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:15 AM	0:15	Session introduction and Cultivation System Improvement introduction	BETO	Christy Sterner		
11:15 AM	11:40 AM	0:25	Success Through Synergy: Increasing Cultivation Yield and Stability with Rationally Designed Consortia.	LANL	Shawn Starkenburg	1.3.2.610 1.3.2.641	FY17 - PEAK
11:40 AM	12:05 PM	0:25	High-Throughput Directed Evolution of Marine Microalgae and Phototrophic Consortia for Improved Biomass Yields	Colorado School of Mines	Matthew Posewitz	1.3.2.640	FY17 - PEAK
12:05 PM	12:30 PM	0:25	SOFAST: Streamlined Optimization of Filamentous Arthrospira / Spirulina Traits	Lumen Bioscience	Rachelle Lim	1.3.2.601	FY17 - PEAK
12:30 PM	12:55 PM	0:25	Developing Advanced Genetic and Synthetic Biology Tools for Improved Algae Productivity	University of California San Diego	Stephen Mayfield	1.3.2.650	FY17 - PEAK
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	1:40 PM	0:25	Microbiome engineering of Desmodesmus to alleviate carbon limitation	LLNL	Xavier Mayali	1.3.2.652	FY17 - PEAK
1:40 PM	2:05 PM	0:25	A comprehensive strategy for stable, high productivity cultivation of microalgae with controllable biomass composition	University of Toledo	Sridhar Viamajala	1.3.2.651	FY17 - PEAK
2:05 PM	2:30 PM	0:25	Prevention of low productivity periods in large-scale microalgae cultivation	Global Algae Innovations	Aga Pinowska	1.3.2.630	FY17 - PEAK
2:30 PM	2:55 PM	0:25	Protective bacteria in algal ponds: inducible protection to maximize response	LLNL	Rhona Stuart	1.3.2.002 1.3.2.003	AOP
2:55 PM	3:00 PM	0:05	Closing	BETO	Christy Sterner		
3:00 PM	3:30 PM	0:30	Comment Review Session				

Detailed Agenda for Tuesday, March 23rd

Day 5 Cultivation System Improvement (1.3.2)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session Introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Chytrid Control Advancing Algal Targets (ChytCAAT)	LLNL	Ty Samo	1.3.2.040	AOP
11:30 AM	11:55 AM	0:25	Membrane Carbonation for 100% Efficient Delivery of Industrial CO2 Gases	Arionza State University	Bruce Rittmann	1.3.2.430	FY18 - ECUAS
11:55 AM	12:20 PM	0:25	Enhanced Algal Production of CA for Improved Atmospheric Deliver of CO2 to Ponds	J. Craig Venter Institute	Andrew E. Allen	1.3.2.402	FY18 - ECUAS
12:20 PM	12:45 PM	0:25	Carbon Utilization Efficiency in Marine Algae Biofuel Production Systems Through Loss Minimization and Carbonate Chemistry Modification	Duke University	Zackary Johnson	1.3.2.440	FY18 - ECUAS
12:45 PM	1:05 PM	0:20	Break				
1:05 PM	1:30 PM	0:25	Integrating an Industrial Source and Commercial Algae Farm with Innovative CO2 Transfer Membrane and Improved Strain Technologies	Colorado State University	Ken Reardon	1.3.2.400	FY18 - ECUAS
1:30 PM	1:55 PM	0:25	Multi-pronged Approach of Improved Biological and Physicochemical Systems to Improving Carbon Utilization by Cyanobacterial Cultures	Arionza State University	Wim Vermaas	1.3.2.410	FY18 - ECUAS
1:55 PM	2:20 PM	0:25	Air Carbon for Algae Production - AirCAP	MicroBio Engineering	John Benemann	1.3.2.600	FY18 - ECUAS
2:20 PM	2:45 PM	0:25	Direct Air Capture of CO2 and Delivery to Photobioreactors for Algal Biofuel Production	Georgia Institute of Technology	Christopher W. Jones	1.3.2.620	FY18 - ECUAS
2:45 PM	3:10 PM	0:25	Attached Periphytic Algae Production and Analysis	SNL	Ryan W. Davis	1.3.2.130	AOP
3:10 PM	3:15 PM	0:05	Closing	BETO	Christy Sterner		
3:15 PM	3:45 PM	0:30	Comment Review Session				

Detailed Agenda for Wednesday, March 24th

Day 6 Cultivation System Improvement (1.3.2), Logistics (1.3.3), and Conversion Interface (1.3.4)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Algal Biomass Composition	NREL	Lieve Laurens	1.3.2.001	AOP
11:30 AM	11:55 AM	0:25	LEAF: Leveraging Algae Traits for Fuels	SNL	Amanda Barry	1.3.2.043	AOP
11:55 AM	12:00 PM	0:05	Logistics R&D overview	BETO	Christy Sterner		
12:00 PM	12:25 PM	0:25	Algal Feedstocks Logistics and Handling	INL	Brad Wahlen	1.3.3.100	AOP
12:25 PM	12:30 PM	0:05	Conversion interface overview	BETO	Christy Sterner		
12:30 PM	12:55 PM	0:25	Cyanobacteria Photosynthetic Energy Platform	NREL	Jianping Yu	1.3.4.301	AOP
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	1:40 PM	0:25	Thermochemical Interface	PNNL	Dan Anderson	1.3.4.101	AOP
1:40 PM	2:05 PM	0:25	HTL Model Development	PNNL	Lesley Snowden-Swan	1.3.5.202	AOP
2:05 PM	2:30 PM	0:25	Algal biofuels techno-economic analysis	NREL	Ryan Davis	1.3.5.200	AOP
2:30 PM	2:55 PM	0:25	Bioconversion of Algal Carbohydrates and Proteins to Fuels	SNL	Ryan W. Davis	1.3.4.200	AOP
2:55 PM	3:20 PM	0:25	CAP Process Research	NREL	Jacob Kruger	1.3.4.201	AOP
3:20 PM	3:25 PM	0:05	Closing	BETO	Christy Sterner		
3:25 PM	3:55 PM	0:30	Comment Review Session				

Advanced Algal Systems Team

Nichole Fitzgerald
Program Manager

Dan Fishman
Technology Manager

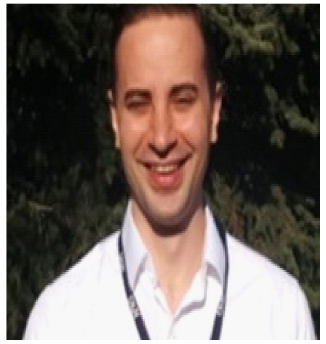
Devinn Lambert
Technology Manager

Christy Sterner
Technology Manager

Jamie Meadows
AAAS Fellow

Ty Robinson
Business Support

Phil Lee
Verification Lead
Project Monitor



Evan Mueller
Project Monitor

Jesse Glover
Project Monitor

Colleen Tomaino
Project Monitor

The Advanced Algal Systems Peer Reviewers

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Project Manager
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Scientific Team Leader
CMC Connect

Linda Rauch
Process Engineering Consultant
Next Rung Technology

Why Algae?

Productivity 4 times as dense as corn. Biofuel yield 8-13 times larger. Can grow on brackish and saline water.

Corn

Productivity: 4.22 tons/acre;

Conversion quality: 77 GGE/ton

Fuel yield: 326 GGE/ton

Algae

Productivity: 20 (current)- 33 (potential) tons/acre;

Conversion Quality: 85-120 GGE/ton,;

Fuel yield potential: 2,837- 4,000 GGE/acre

45 acres of cultivation on marginal land in Imperial, Texas, with water drawn from a hyper-saline aquifer. Photo: Qualitas

Convert carbon emissions into market opportunities

Demonstration testing of direct flue gas injection into a filamentous algae open system operated by the Orlando Utilities Commission at the Stanton Energy Center and MicroBio Engineering Inc. Photo by MicroBio Engineering Inc. Funding by Office of Fossil Energy.

Improve nitrogen and phosphorous recovery from point and dilute sources

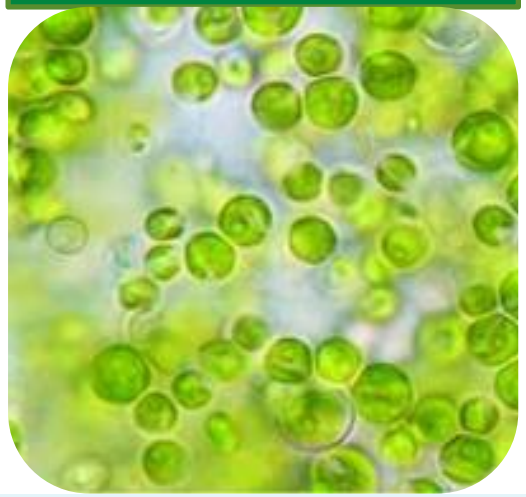
Near term ecosystem services
Credit: Clearas Water Recovery

900 foot algae turf scrubber cleaning impaired water in California
Credits SNL

Societal Challenges Algae Can Help Solve

Today

Better manage carbon, nitrogen, and other resources.



Algae coupled with DAC can capture 1 gigaton of CO_2 a year using marginal lands equivalent to 15% the area of corn.

15 years

Fly a total of 6.9 billion passengers. 3.1 billion more than today.

Algae can produce 16% of U.S. jet fuel needs using marginal lands equivalent to 3% of the area of corn.

30 years

Feed a world population that is estimated to reach more than 9 billion people.

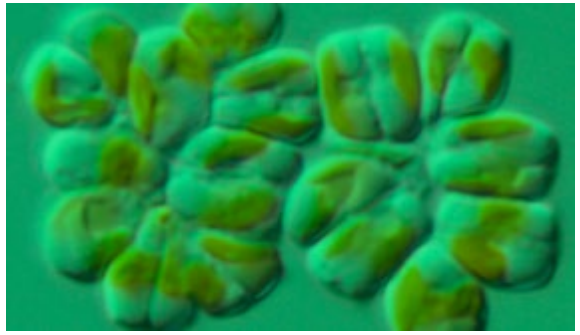
Algae grown on marginal lands equivalent to 2% of the area of soy can yield 17 million more tons of protein.

Advanced Algal Systems Program

Strategic Goal: *Develop technologies that enable production of environmentally sustainable algal feedstocks that perform reliably in conversion processes to yield renewable fuel blendstocks, as well as bioproducts and chemical intermediates. Developing algal feedstocks and processes to achieve BETO's goals requires technology breakthroughs along the entire algal supply chain.*

Priorities:

- Develop biology and culture management approaches to increase algal productivity.
- Develop low-cost, scalable cultivation and harvesting systems *that reduce costs and impacts* by minimizing the use of energy, water, land, and nutrients.
- Perform integrative analysis to evaluate impacts on overall yield and identify critical barriers to developments in biology, cultivation, and processing.
- Investigate high-value co-products that can be produced along with biofuels.




Verify laboratory improvements outdoors at increasing scales

Major Goals: FY2021 - FY2030

By 2021, develop strain improvement toolkits and technologies that enable algae biomass compositions in environmental simulation cultivation conditions that represent an energy content and convertibility of 80 GGE of biofuel per AFDW ton of algae biomass.

By 2023, develop technologies that enable mature modeled algae yields of 30 tons ash-free dry weight algae biomass per acre per year with conversion yields of 80 GGE per ton of biomass.

By 2025, increase the summer seasonal areal productivity to 25 grams per square meter per day ($g/m^2/d$) from the 2018 benchmark of 13.3 $g/m^2/d$.

By 2030, deliver technologies that enable the verification of integrated systems research at engineering scale for hydrocarbon biofuel technologies at mature modeled MFSP of $2.50/GGE.

Ruth Spierling from MicroBio Engineering taking samples from outdoor test raceway ponds at a wastewater treatment plant in San Luis Obispo.

Phenometrics ePBRs which allow researchers to simulate outdoor conditions in the laboratory.

National Potential for Affordable & Sustainable Algae Biofuels

BETO uses modeling to provide **process design and economic analysis support** for the algae platform to **guide R&D priorities** to commercialization and to **track progress** toward goals through state of technology (SOT) updates

Modeling annual future productivities of 25g/m²/day

Over 7 million acres of land with suitable CO_2 access that satisfy land and water sustainability criteria

100-270 MM tons per year biomass;
Over 5 billion gallons of fuel

Biomass cost averages
$472/ton (freshwater) to $655/ton (saline)

National fuel targets can be delivered at <$2.50/gge when co-produced with high-value commodities like polyurethanes

Pathways achieve 50% GHG reduction

Qualitas Health Inc.; Imperial, TX, Farm

Harvested biomass; Harmon Consulting

ANL, NREL, and PNNL. *2017 Algae Harmonization Study: Evaluating the Potential for Future Algal Biofuel Costs, Sustainability, and Resource Assessment from Harmonized Modeling*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5100-70715. https://www.nrel.gov/docs/fy18osti/70715.pdf.

State of Technology Studies Track R&D Progress

State of technology updates rely on BETO funded **standard, rigorous, and objective long term cultivation trials** to provide a realistic assessment of the state of technology for algal based biofuels.

Current annual avg productivity: >18g/m²/day

Summer productivity: 31 g/m²/day

57% improvement in annual average productivity over past 2 years

27% decrease in MBSP over past two years

2021 projection at $560/ton on way to 2030 target ($488/ton)

DISCOVR

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

AzCATI Arizona Center for Algae Technology and Innovation

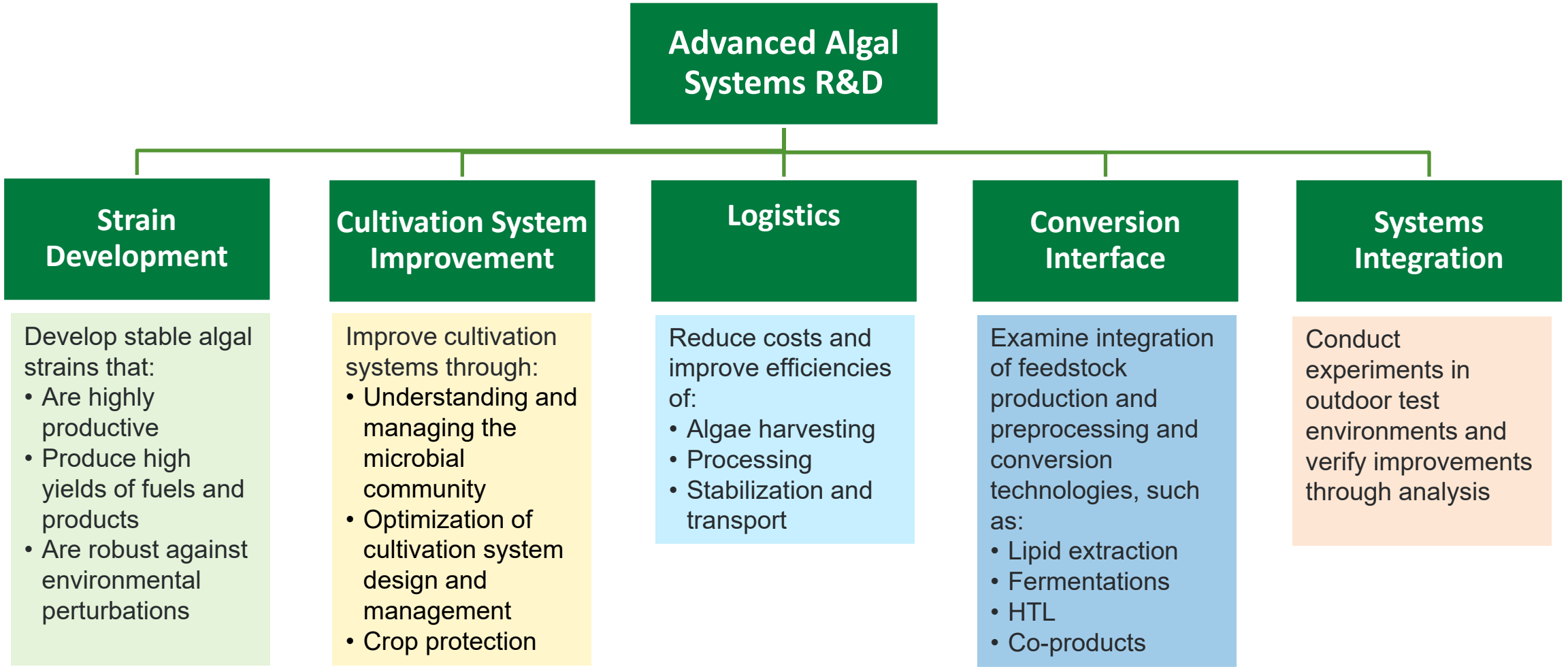
Los Alamos NATIONAL LABORATORY EST. 1943

Sandia National Laboratories

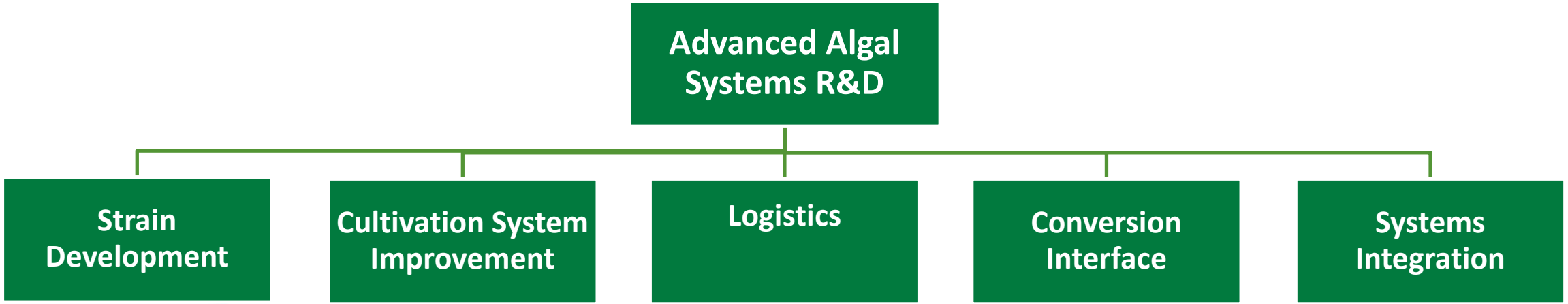
Algae cultivation; Arizona Center for Algae Technology and Innovation

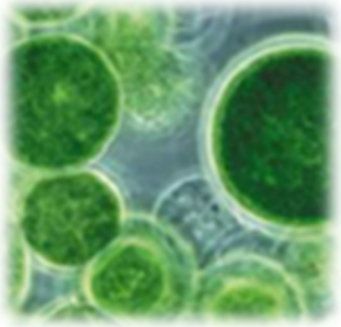
Data from DISCOVR Presentation – 1.3.501_Huesemann_DISCOVR_Organized-by-Tasks-for-Presenting_Final.pdf; 3.9.21

AAS – Strategy, Approach: Program Structure



Program Structure: Strain Development 1.3.1





Develop stable algal strains that:

- Produce high yields of fuels and products
- Highly productive
- Robust against environmental perturbations

Program Structure: Cultivation System Improvements 1.3.2

Advanced Algal Systems R&D

- Strain Development
- **Cultivation System Improvement**
- Logistics
- Conversion Interface
- Systems Integration

Los Alamos National Laboratory EST. 1943

The University of Toledo

μBIO MicroBio Engineering

Global Algae Innovations

Lawrence Livermore National Laboratory

ASU Arizona State University

NREL National Renewable Energy Laboratory

Colorado State University

School of Mines 1874 Colorado

Sandia National Laboratories

Duke University

LUMEN BIOSCIENCE

JCVI J. Craig Venter Institute

Georgia Tech

UC San Diego

New Mexico Consortium

Improve cultivation systems through:

- Understanding and managing the microbial community
- Optimization of cultivation systems and design management
- Crop protection

Program Structure: Logistics 1.3.3

Advanced Algal Systems R&D

- Strain Development
- Cultivation System Improvement
- **Logistics**
- Conversion Interface
- Systems Integration

Reduce costs and improve efficiencies of:

- Algae harvesting
- Processing
- Stabilization and transport

Utah State University

ASU Arizona State University

INL Idaho National Laboratory

Program Structure: Conversion Interface 1.3.4

Advanced Algal Systems R&D

- Strain Development
- Cultivation System Improvement
- Logistics
- Conversion Interface
- Systems Integration

Examine the integration of feedstock production and preprocessing and conversion technologies, such as:

- Lipid extraction
- Fermentations
- Hydrothermal liquefaction
- Co-products development

μBIO MicroBio Engineering

UC San Diego

Sandia National Laboratories

Duke University

Pacific Northwest National Laboratory

NREL National Renewable Energy Laboratory

LUMEN BIOSCIENCE

Global Algae Innovations

ASU Arizona State University

Montana State University

Photo courtesy of PNNL

Program Structure: Systems Integration 1.3.5

Advanced Algal Systems R&D

- Strain Development
- Cultivation System Improvement
- Logistics
- Conversion Interface
- Systems Integration

New Mexico Consortium

Colorado School of Mines 1874

ASU Arizona State University

Argonne National Laboratory

NREL National Renewable Energy Laboratory

Pacific Northwest National Laboratory

μBIO MicroBio Engineering

Duke University

The University of Arizona

University of Illinois Urbana-Champaign

Global Algae Innovations

Conduct experiments in outdoor test environments, as part of an iterative development process, and verify improvements through analysis projects

National Laboratory Core R&D

- The Program funds **foundational research & development** through its national laboratory partners.
- This funding aligns with national laboratory **core competencies.**
- Labs **collaborate** heavily within this core portfolio, as well as with competitive funding recipients.
- **Novel concepts** can be initiated easily within the “seed” program for minimal initial investment.

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Lawrence Livermore National Laboratory

BERKELEY LAB

Sandia National Laboratories

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

INL Idaho National Laboratory

Advanced Biology

Algae Cultivation

Conversion Interface

Resource Assessment

Techno-economics

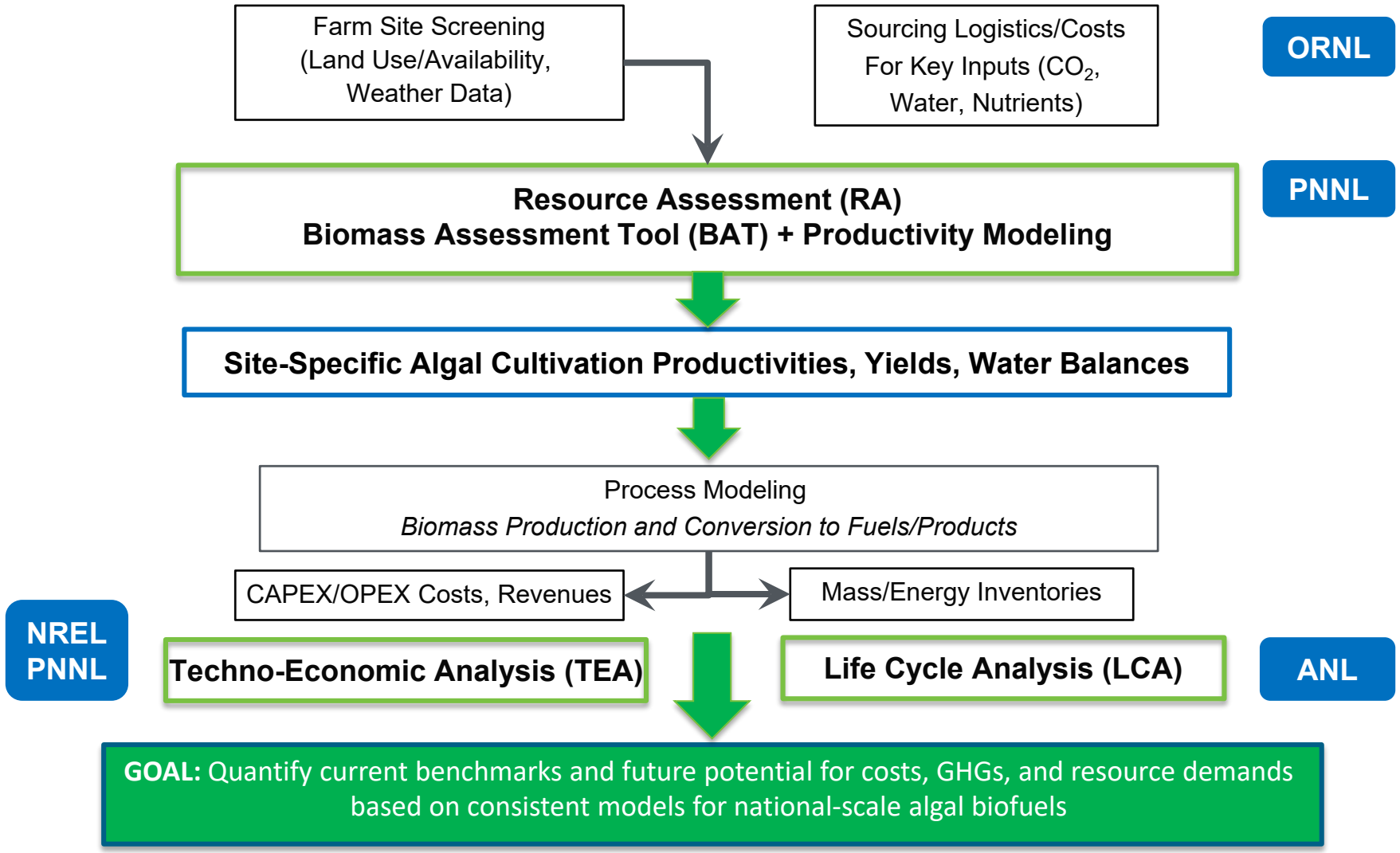
Logistics

National Laboratory Core R&D

Annual Operating Plans

- EERE is committed to funding multi-year project plans
- Plans include Go/No-go decisions in 12-18 month period
- Reviewed externally on a 3-year cycle project cycle
- Reviewed and approved by BETO annually

National Laboratory: Harmonization Collaboration

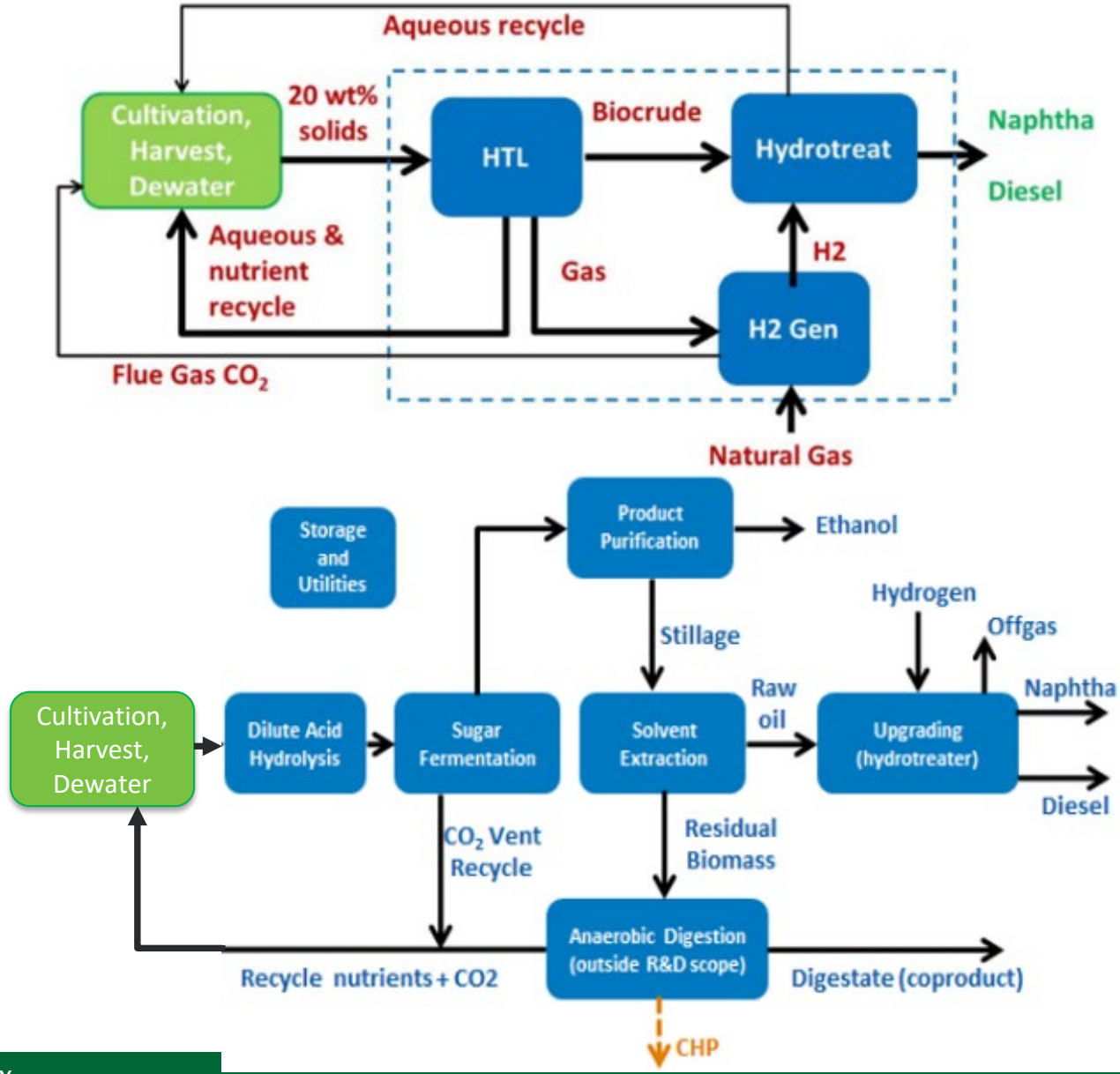


National Laboratory Conversion Analysis

Two representative pathways:

1. Hydrothermal Liquefaction

2. Combined Algae Processing



National Laboratory: Strain Characterization and Improvement

Characterization of Productivity and Robustness

DISCOVR

Genome Sequencing, Functional 'Omics, Metabolic Mapping

Algal Translational Genomics (Formerly Greenhouse)

Genetic Blueprint of Microalgae Carbon Productivity

Strain Improvement: Genetic Modification & Non-GM Strategies

Algae Biotechnology Partnership

Functional Characterization of Cellular Metabolism

Multi-scale Characterization of Improved Algae Strains

Robust Genome Engineering Tools for the Algal Research Community

GOAL: Deliver deeply characterized and improved strains, with accompanying data and tools, to stakeholders including industry, academics, and other BETO projects (e.g., BioFoundry)

Competitive Funding

- The Program annually supplements Core R&D with open and competitive funding through EERE Funding Opportunity Announcements (FOAs)
- Relatively large awards encourage partnership within the algal biofuels community
- Multi-year project work allows for research during multiple growing seasons
- This funding allows for robust outdoor validations at commercially-relevant scales

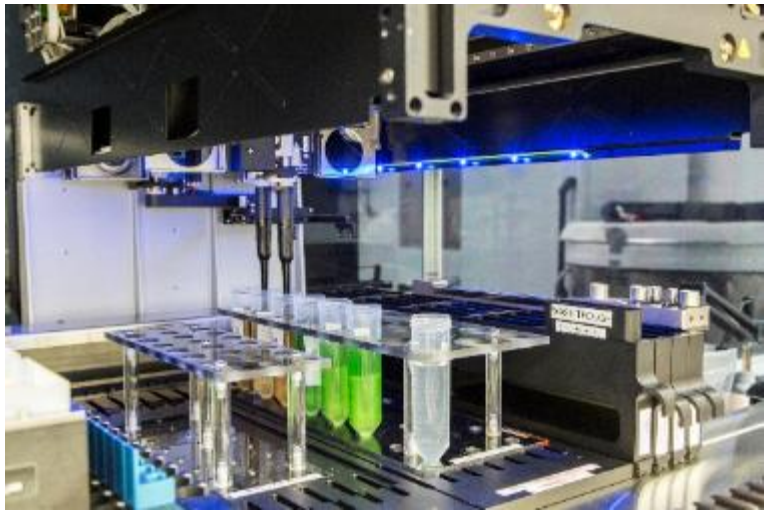
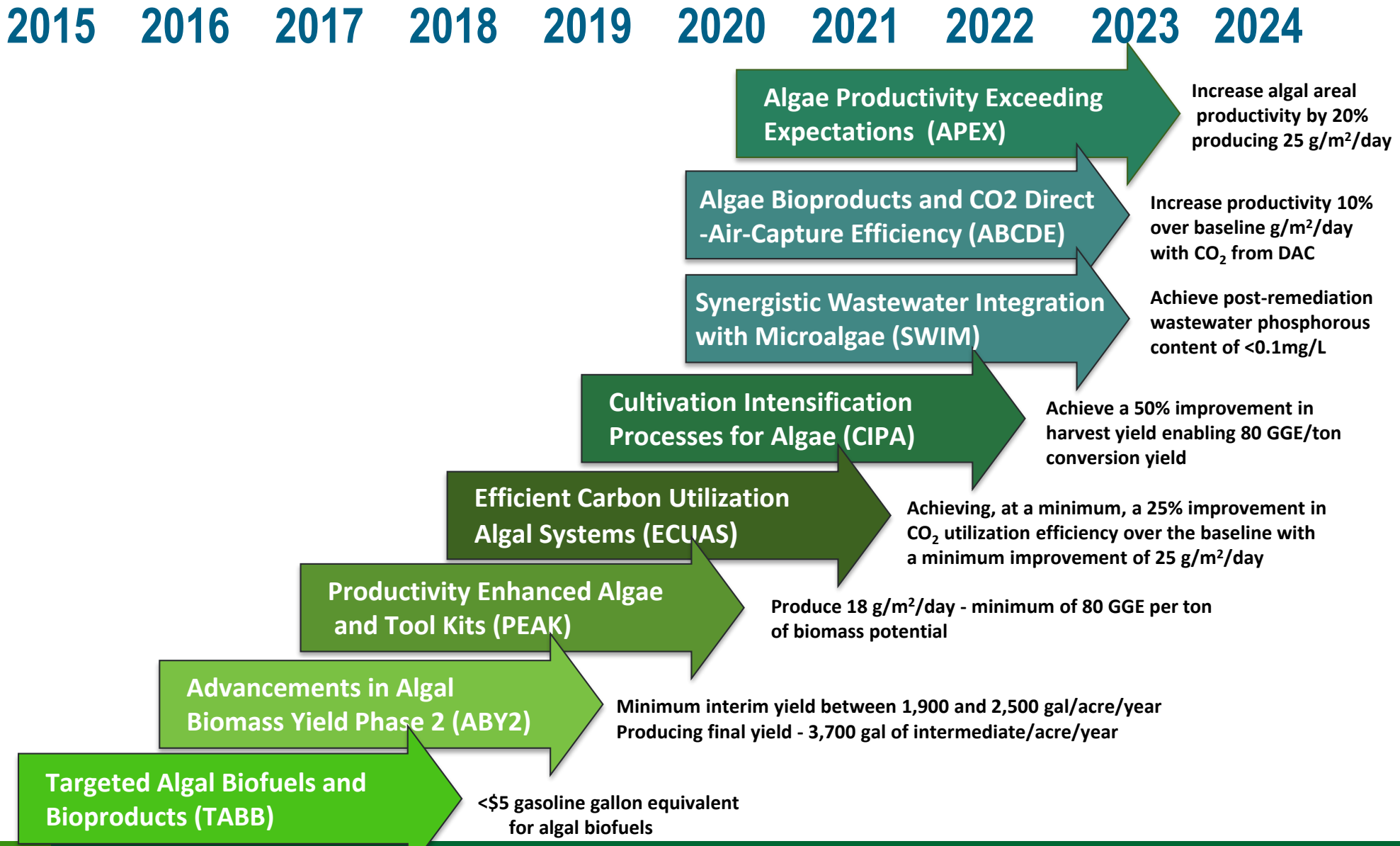


Photo courtesy Global Algae Innovations

University of Arizona's RAFT testbed in Tucson, AZ

Funding Opportunity Announcements



National Laboratory Targeted Algal Biofuels and Bioproducts (TABB)

Date: FY2015

- Selections announced July 2015

Goals:

- Enable a modeled minimum fuel selling price, assuming mature technologies, of less than $5 gasoline gallon equivalent for algal biofuels through creation of valuable products and higher feedstock yields by 2019.

Selections:

- Producing Algae and Co-Products for Energy (PACE), Colorado School of Mines led consortium
- Marine Algae Industrialization Consortium (MAGIC), Duke University led consortium
- Global Algae Innovations, Inc.
- Arizona State University
- University of California San Diego
- Lawrence Livermore National Laboratory

GAI's 33-acre algae facility in Kauai with CO_2 supplied from off-gas of adjacent power plant

Advancements in Algal Biomass Yield, Phase 2 (ABY 2)

Date: FY2016

- Selections announced July 2016, alternate announced 2017

Goals:

- Continue to advance yield improvements, building upon successes of ABY1, to a goal of 3,700 gallons of biofuel intermediate per acre per year by 2020.

Selections:

- Global Algae Innovations Inc.
- Algenol Biotech LLC,
- MicroBio Engineering, Inc.
- NREL

GAI's Zobi harvester (above) and effluent streams (below)

Productivity Enhanced Algae and Toolkits (PEAK)

Date: FY2017

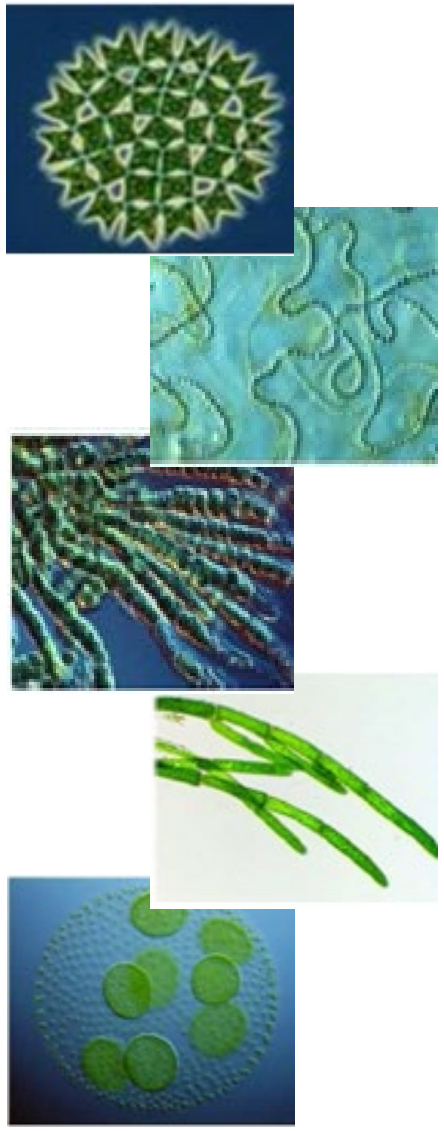
- Selections announced July 2017, alternates September 2017

Goals:

- Deliver high-impact tools and techniques for increasing algae productivity in order to reduce the costs of producing algal biofuels and bioproducts

Selections:

- Lumen Bioscience
- Global Algae Innovations
- Los Alamos National Laboratory
- Colorado School of Mines
- University of California San Diego
- University of Toledo
- Lawrence Livermore National Laboratory



Efficient Carbon Utilization in Algal Systems (ECUAS)

Date: FY2018

- Selections announced September 2018

Goals:

- Improve efficiency of carbon utilization and productivity of algal systems through improving uptake and conversion of waste CO2 emissions—such as from a power plant or industrial facilities—or through the development of new, affordable technologies to capture CO2 directly from ambient air to enhance algal growth

Selections:

- Colorado State University (TA1)
- Arizona State University (TA1)
- Global Algae Innovations (TA1)
- Arizona University (TA1)
- Duke University (TA1)
- MicroBio Engineering, Inc.
- Georgia Institute of Technology
- J. Craig Venter, Inc.

Cultivation Intensification Processes Algae (CIPA)

Date: FY2019

- Selections announced September 2019

Goals:

- Develop technologies for outdoor algae systems that increase the harvest yield, reliability and quality of algae

Selections:

- Global Algae Innovations
- New Mexico Consortium
- Colorado School of Mines
- University of Illinois
- Arizona State University

Algae Bioproducts and CO2 Direct-Air-Capture Efficiency (ABCDE)

Date: FY2020

- Selections announced July 2020

Goals:

- Improve algal feedstock quality for algae grown using CO_2 captured from the air (i.e., DAC). Successful projects will capture CO_2 from the air, grow high quality algal biomass suitable for conversion to fuels and products, and develop fuels and/or products made from the algae biomass.

Selections:

Duke University

Global Algae Innovations

Montana State University

μBIO MicroBio Engineering

ASU

Lumen Bioscience

UC San Diego

Synergistic Wastewater Integration with Microalgae (SWIM)

Date: FY2020

- Selections announced July 2020

Goals:

- Develop technologies and operational strategies that, if commercialized, can reduce the energy intensity of removing pollutants in wastewater treatment operations while also producing algal biomass that can be converted into bioenergy, biofuels, and/or bioproducts

Selections:

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

UtahState University

Algae Productivity Exceeding Expectations (APEX)

Goals: to develop and test strain and cultivation technologies that advance the state-of-the-art for algal areal productivity, and biomass quality achievable in industrially relevant cultivation systems.

Topic Area 1

- Improvements in productivity with traditional carbon dioxide (CO_2) supply

Topic Area 2

- Improvements in productivity with Direct Air Capture (DAC) of CO_2 from ambient air

Concept papers were due on February 3, 2021

Full Applications are due on April 7, 2021

2021 Peer Review Projects

Total projects being reviewed: 52

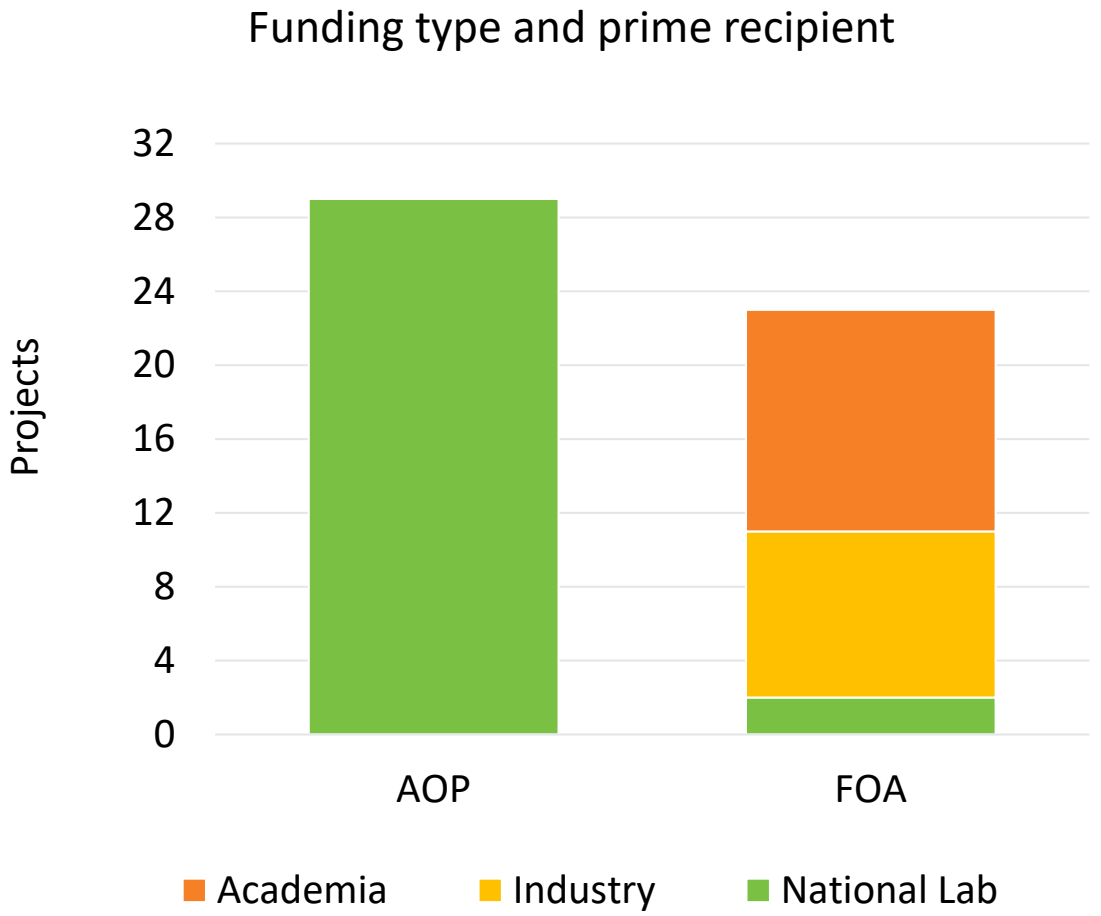
Strain development: 12

Cultivation system improvements: 20

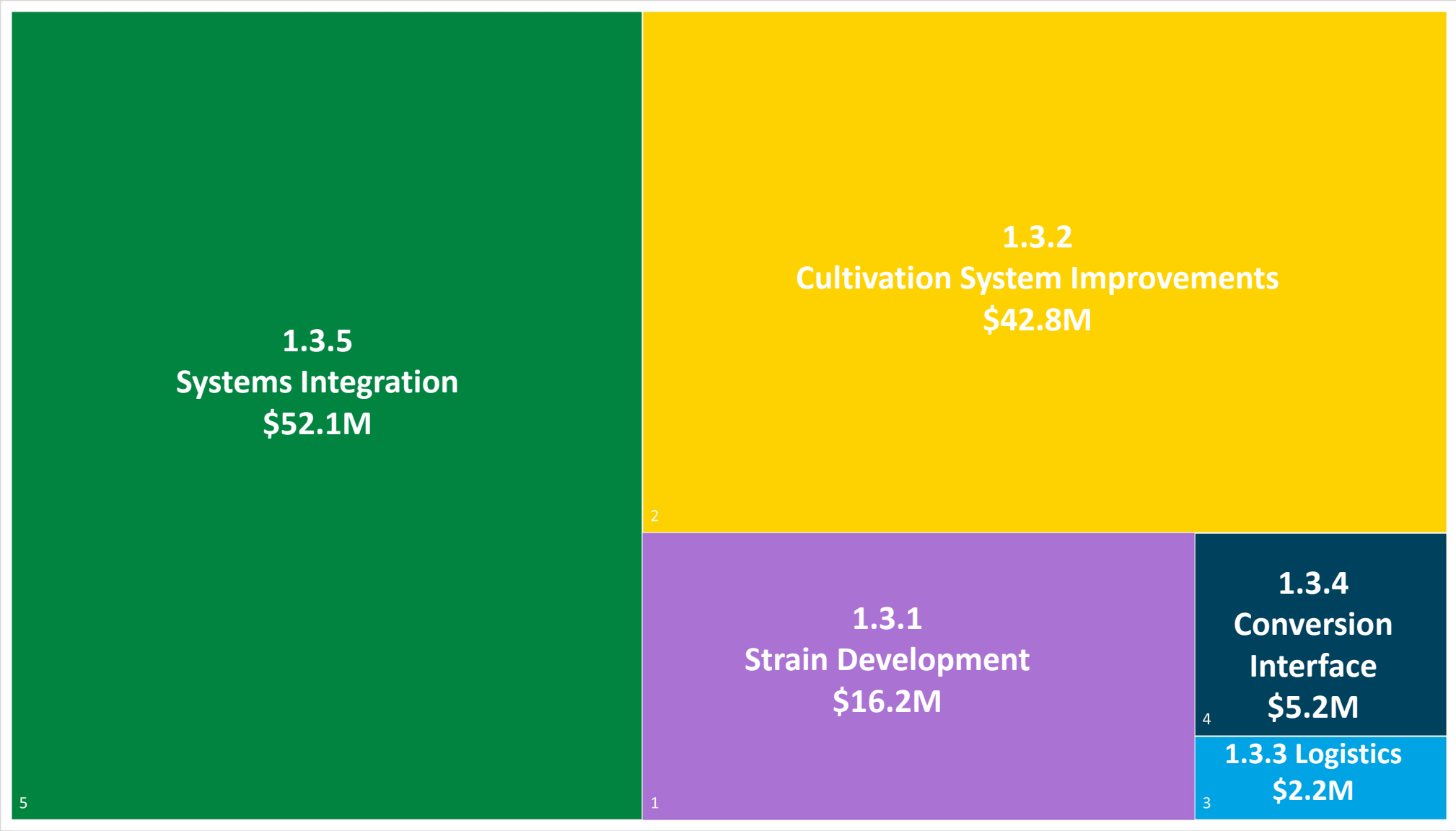
Logistics R&D: 1

Conversion interface: 4

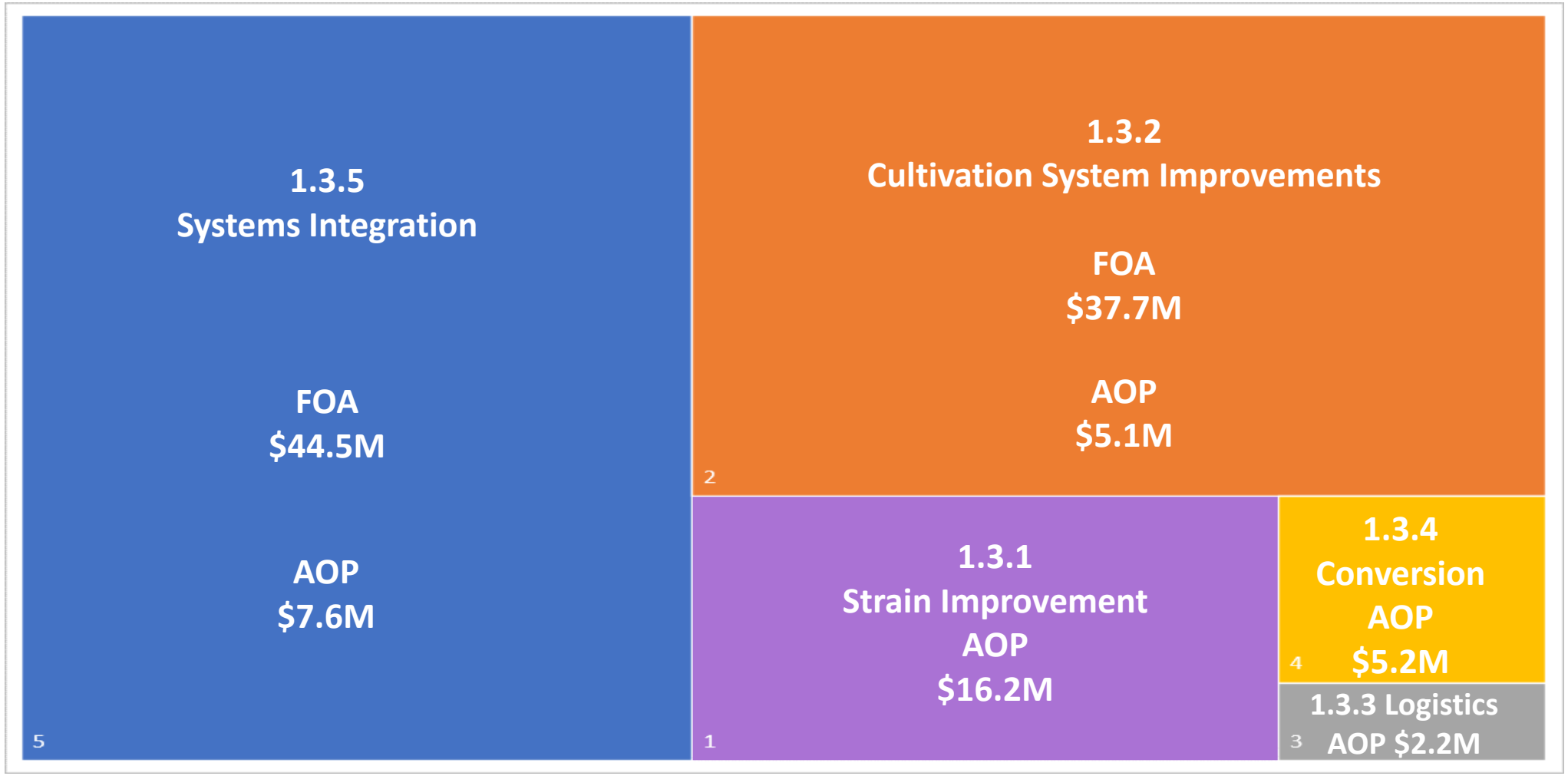
Systems integration : 15



FY18 – FY20 Algae R&D Funding by WBS



FY18 – FY20 Algae R&D Funding by Type



Total Competitive Funding: $82.3M

Total National Lab Direct Funding: $36.3 M

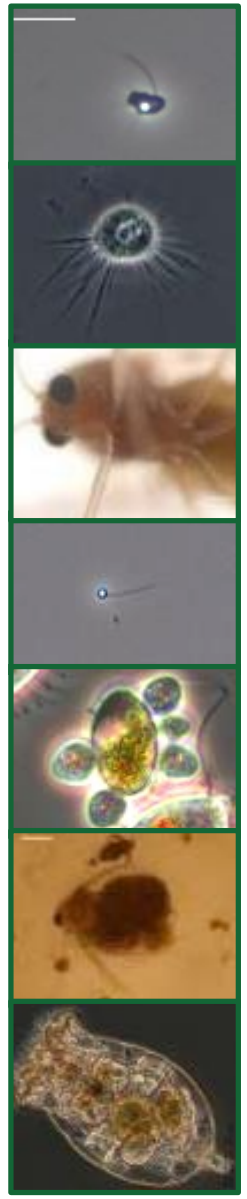
Examples of Stakeholder Engagement

Algae Inter/Intra- Agency Collaboration

- **Algae Interagency Working Group**
  - Membership: NOAA, EPA, NSF, FDA, USDA, and DOE's ARPA-E, FE, and SC
  - Published a federal framework on Algae Research and Regulatory Oversight
- **OSTP's *National Strategic Plan for Federal Aquaculture Research 2020-2024***
  - BETO leading development of the Emerging Areas section on Algae.
  - Focusing on intentionally cultivated cyanobacteria, microalgae, and macroalgae in terrestrial and marine systems; mitigation and reporting of unintentionally cultivated harmful algal blooms
- **Algae Genome Science Partnership**
  - Collaboration: BETO, BER, JGI, and LANL
  - Collecting and disseminating genomics data on a diverse collection of industrially-, environmentally-, evolutionarily-relevant algal strains

Barriers to Scale: Algae Crop Protection Workshop

- AAS is seeking stakeholder input on crop protection, a significant barrier to scaling the algae industry
- Register for free now! Event will be virtual, April 20-21, 2021
- Keynote, Panel Presentations + Q&A, Breakout Sessions, Networking
- Day 1, 11:00 – 4:30 (ET)
  - Keynote Presentation – Barry Goldman, Pluton Biosciences
  - Session #1 – Current State of Crop Protection
  - Session #2 – Alternative Crop Protection Approaches to Chemicals and Pesticides
- Day 2, 11:00 – 4:30 (ET)
  - Session #3 – Pest Models: Understanding Pest Life Cycles and Infection Mechanisms
  - Session #4 – Current and Future Pest Monitoring Practices
  - Session #5 – Developing Scalable, Economic, and Consumer- Accepted Pest Management Practices



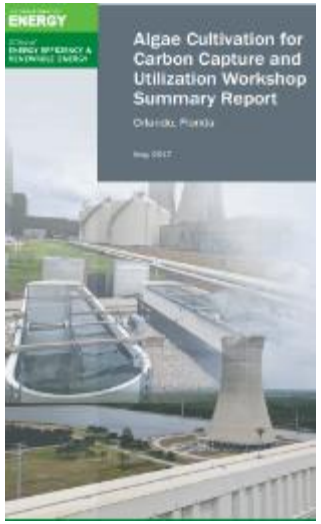
Advanced Algal Systems Investment in CCU and Partnership with FE

The **algae industry is an early DAC and flue gas capture adopter.**
BETO has **partnered with FE on carbon utilization** algae efforts to investigate both flue gas capture and direct air capture (DAC) to reduce delivered CO_2 costs and provide added value.

2015

Selection of FOA awards that include carbon utilization from a point source and direct air capture

2017

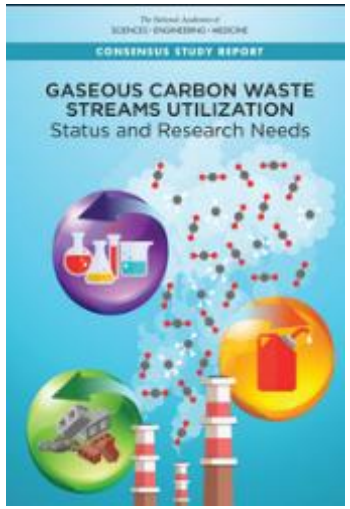


2018

ECUAS Topic language developed with input from FE

45Q includes algae as a CCU technology

2017-2019



2020

ABCDE
Scoping on FOA discussed with FE
FE reviewer
FE Federal Consensus Board

The IRS released a new set of regulations for the Section 45Q tax code that can award a federal investment tax credit of up to $35 per ton for carbon utilization with algae.

AAS Progress – Active Management

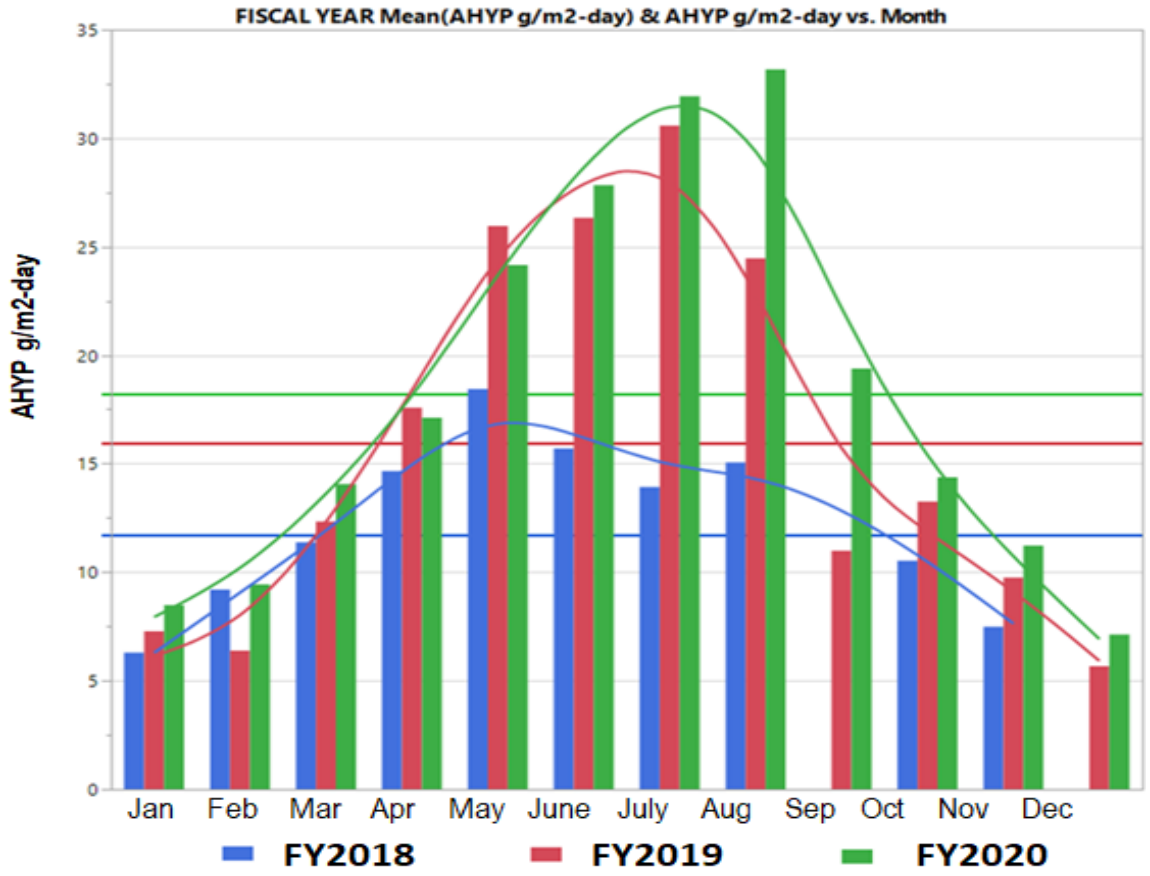
- Verification Process
  - Verify metrics (baseline, mid-, and end)
  - Alignment with FOA
- Go/No Go Decision Points
  - Established in ALL projects, every 12-18 months minimum
- Weekly to Monthly Project Calls
  - Project specific
  - Includes meeting with boards, etc.
- Site Visits
- Participation in Strategy/Planning Efforts
- Lab Calls
- Stakeholder Engagement

DISCOVR – Enhancing Productivity

- Developing **high-performance** algae strains
- Developing **high-throughput** environmental testing of strains
- Developing **biological and culture management approaches** to unlock algal biomass-productivity potential

ASU AZCATI mini ponds in Mesa, AZ used for DISCOVR Consortium SOT data

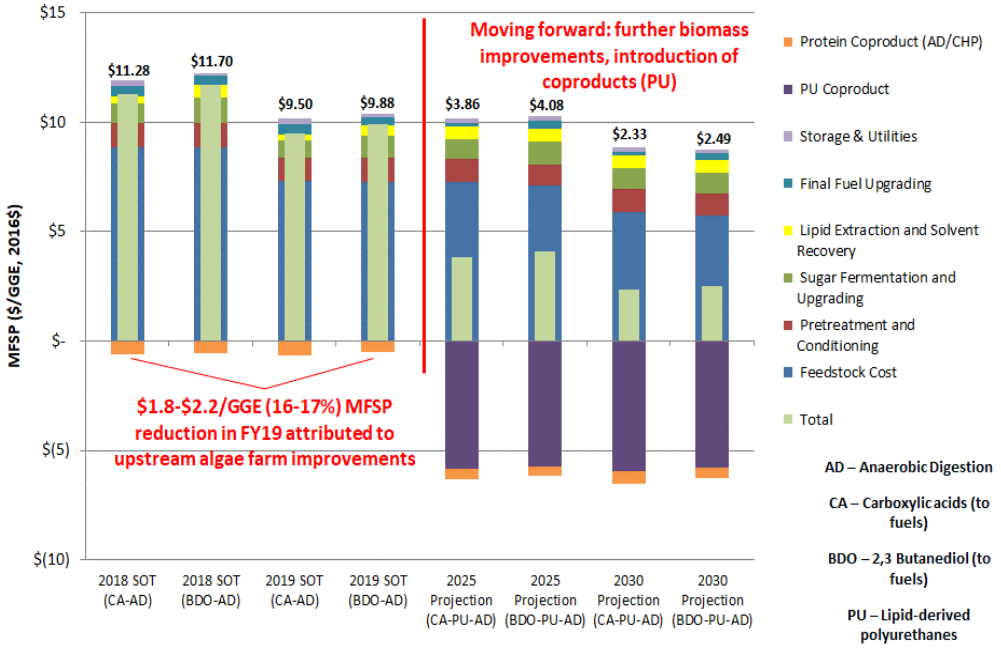
FY20 State of Technology



- 2020: ~353 days of continuous culture
- 2019: 328 days of continuous culture
- 2018: 265 days of continuous culture
- ~$2M in DOE investment

Products from Algae

NIPU foam samples made from algae.
Photo credit: NREL



A flip flop prototype made by Algenesis in their UCSD laboratory. Photo credit: Daniel Fishman

Key Accomplishments

Global Algae Innovations

- Direct air capture supports 20-30 $g/m^2/d$ for \$8/ton CO_2
- Open raceway contamination control with 99.95% reduction in area and cost for inoculum
- Zobi harvester produces up to 20% algae slurry and crystal clear permeate using 0.05 kWh/m^3

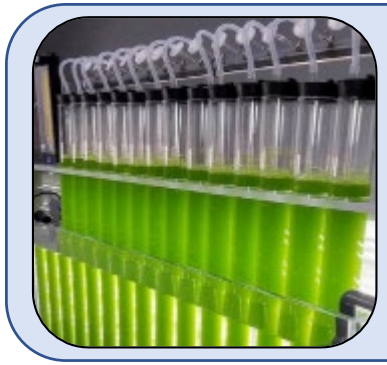
Zobi Harvester at Qualitas Facility; picture courtesy of Global Algae

DISCOVR

- Fall 2020 (FY21) formal SOT seasonal average was 19.3 $g/m^2/day$ compared to 15.0 $g/m^2/day$ for Fall 2019 (FY20), **an increase of 28.7%.**
- Demonstrated improvement of greater than 20% in simulated AZ summer season biomass productivity of *P. celeri*

Scenedesmus cultivation; Arizona Center for Algae Technology and Innovation

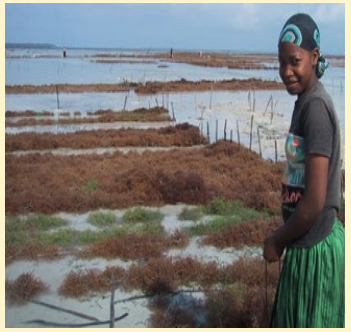
Key Accomplishments



31% higher outdoor productivity by an improved *Scenedesmus obliquus* vs. wild type.

- New isolate *Tribonema minus* monoculture had higher productivity than a native polyculture (prior leading producer). *T. minus* is filamentous; harvested by screens.
- In g/m^2/d annual average: **17.1** *Tribonema,* **13.3** polyculture, vs. **9.1** BETO 2016 SOT.

Covid-19 Pivet
Conversion of Algae Academy (K-12) to online; for 2020-2021 more than 250 schools and 35,000 students to be served; conversion of college face to face courses to online lectures and intensive face to face laboratories



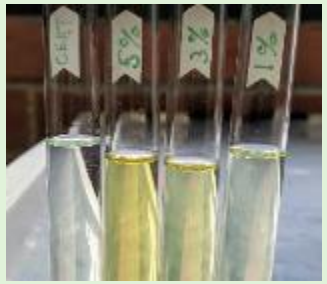
Massive Open Online Courses (MOOCs): MOOC #1 Introduction to Algae > 16,500 enrollees. MOOC #2 Introduction to Algae Biotechnology > 500 enrolled (3 weeks on Coursera.org platform)

Established partnership with the Future Farmers of America (FFA) and its 760,000 members to introduce algae as a crop and STEM curricula

Key Accomplishments

Producing Algae for Coproducts and Energy Algal Biofuel from Field to Engine

Reliance Industries Ltd. Algal Ponds – largest raceway ~1 km.
Average annual productivities during PACE project ~23 g/m^2/d



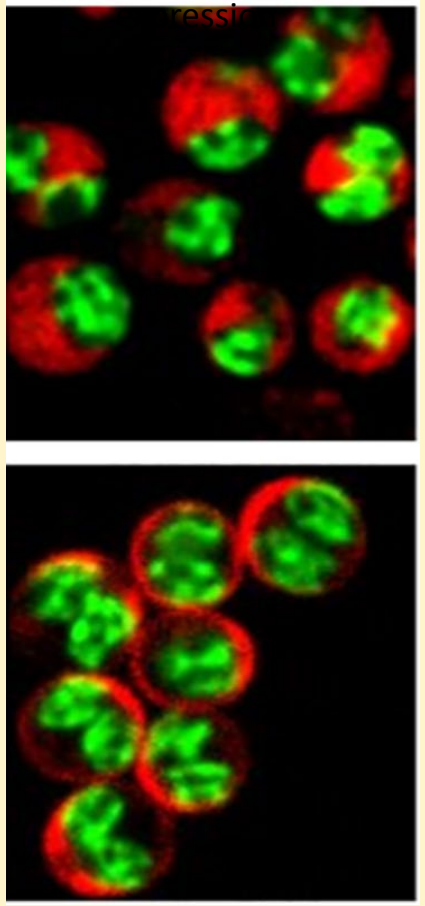
Biocrude produced by RIL was hydrotreated at Pacific Northwest National Laboratory (*Anderson Laboratory*) but NOT fractionated. Blended up to 5% with certification diesel.

Diesel Engine Testing at Colorado State University (Marchese Laboratory). Undistilled, hydrotreated HTP fuel produced from algal biomass can be blended to 5% without negatively affecting engine performance. Higher levels not yet tested.

Algae Biotechnology Partnership

- *Picochlorum renovo* is a robust algae strain with high growth rate, salinity, and temperature tolerance
- Strain isolation, genome sequencing, transformation tools developed through DOE funded projects
- Genome analysis identified native signal peptides
- Robust protein secretion tools are now being applied to other projects in the portfolio

Intracellular mCherry fluorescent protein



Secreted mCherry fluorescent protein

Future Direction

Strategic Goal

Develop technologies that enable production of environmentally sustainable algal feedstocks that perform reliably in conversion processes to yield renewable fuel blendstocks, as well as bioproducts and chemical intermediates. Developing algal feedstocks and processes to achieve BETO's goals requires technology breakthroughs along the entire algal supply chain.

Outyear Milestones

By 2021, develop strain improvement toolkits and technologies that enable algae biomass compositions in environmental simulation cultivation conditions that represent an energy content and convertibility of 80 GGE of biofuel per AFDW ton of algae biomass.
By 2023, develop technologies that enable mature modeled algae yields of 30 tons ash-free dry weight algae biomass per acre per year with conversion yields of 80 GGE per ton of biomass.
By 2025, increase the summer seasonal areal productivity to 25 grams per square meter per day ($g/m^2/d$) from the 2018 benchmark of 13.3 $g/m^2/d$.
By 2030, deliver technologies that enable the verification of integrated systems research at engineering scale for hydrocarbon biofuel technologies at mature modeled MFSP of $2.50/GGE.


Thank you!
279676

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Algal Systems

Tuesday, March 9, 2021

Session will start at 11am ET

Agenda-at-a-glance

Tues 3/9/21

- Strain development

Wed 3/10/21

- Strain development
- Systems integration

Thurs 3/11/21

- Systems integration

Mon 3/22/21

- Cultivation system improvement

Tues 3/23/21

- Cultivation system improvement

Wed 3/24/21

- Cultivation system improvement
- Logistics
- Conversion interface

Note: There are some deviations to accommodate presenter schedule constraints

Rule Keeping

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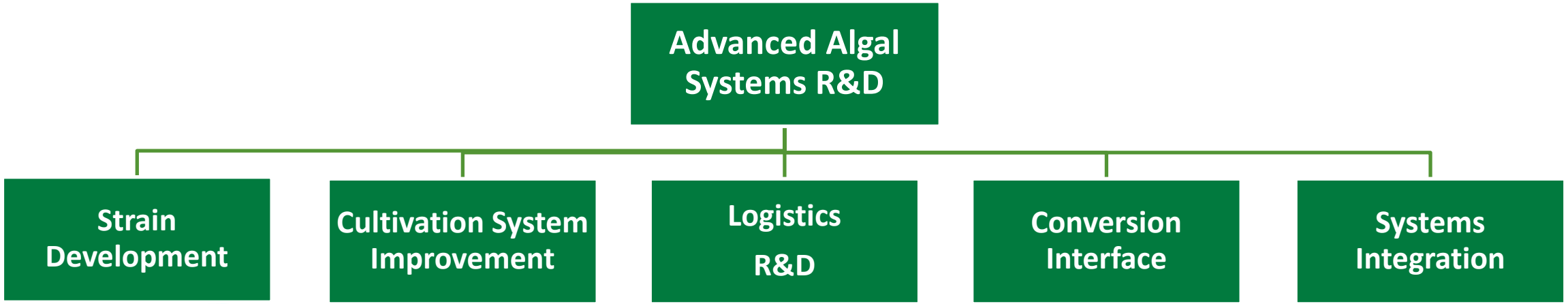
https://www.energy.gov/eere/bioenergy/2021-project-peer-review

Detailed agenda for Tuesday, March 9th

Day #1 **Strain Development (1.3.1)**

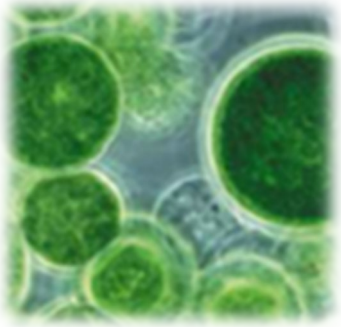
Time start (ET)	Time end (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:15 AM	0:15	Session introduction and Strain development overview	BETO	Christy Sterner		
11:15 AM	11:40 AM	0:25	Functional characterization of cellular metabolism	LANL	Scott Twary	1.3.1.100	AOP
11:40 AM	12:05 PM	0:25	REAL HYPE: Respiration Engineering of Algal Losses for High Yields and Productivity Enhancement	SNL	Anne Ruffing	1.3.1.105	AOP
12:05 PM	12:30 PM	0:25	IGET: Informatics-based genetic tools for rapid enhancement of production strains	LANL	Blake Hovde	1.3.1.001	AOP
12:30 PM	12:55 PM	0:25	Multi-scale Characterization of Improved Algae Strains	LANL	Taraka Dale	1.3.1.120	AOP
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	2:15 PM	1:00	Algae DISCOVR	PNNL, NREL, SNL, LANL, AzCATI	Michael Huesemann, Taraka Dale, Todd Lane, Lieve Laurens, John McGowen	1.3.1.501, 502, 503, 505	AOP
2:15 PM	2:30 PM	0:15	DISCOVR Q&A	PNNL, NREL, SNL, LANL, AzCATI	All	NA	AOP
2:30 PM	2:35 PM	0:05	Closing	BETO	Christy Sterner		
2:35 PM	3:05 PM	0:30	Comment Review Session				

Program Structure: Strain Development WBS 1.3.1



Develop stable algal strains that:

- Produce high yields of fuels and products
- Highly productive
- Robust against environmental perturbations



Advanced Algal Systems Scheduled Break

Break time! 1:00 – 1:20 ET

Feel free to unmute yourself and catch up with colleagues.

We will start at 1:20 ET SHARP! So don't be late ☺

The Advanced Algal Systems Peer Review meeting has concluded for today. It will continue tomorrow, March 10th at 11am ET.

Break out room is for reviewers and BETO staff.

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Algal Systems

Wednesday, March 10, 2021

Session will start at 11am ET

Agenda-at-a-glance

Tues 3/9/21	Wed 3/10/21	Thurs 3/11/21
Strain development	Strain development	Systems integration
	Systems integration	

Mon 3/22/21	Tues 3/23/21	Wed 3/24/21
Cultivation system improvement	Cultivation system improvement	Cultivation system improvement
		Logistics
		Conversion interface

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https://www.energy.gov/eere/bioenergy/2021-project-peer-review

Detailed agenda for Wednesday, March 10th

Day #2 Strain Development (1.3.1) and Systems Integration (1.3.5)

Time start (ET)	Time end (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Algae Biotechnology Partnership	NREL	Mike Guarnieri	1.3.1.130	AOP
11:30 AM	11:55 AM	0:25	Genetic blueprint of microalgae carbon productivity	LBNL	Igor Grigoriev Shawn Starkenburg	1.3.1.110 1.3.1.111	AOP
11:55 AM	12:20 PM	0:25	Algal Translational Genomics	LANL	Shawn Starkenburg	1.3.1.600	AOP
12:20 PM	12:25 PM	0:05	Systems integration overview	BETO	Christy Sterner		
12:25 PM	12:50 PM	0:25	Life Cycle Analysis	ANL	Troy Hawkins	1.3.5.204	AOP
12:50 PM	1:10 PM	0:20	Break				
1:10 PM	1:35 PM	0:25	Marine Algae Industrialization Consortium (MAGIC): Combining Biofuels and High-value Bioproducts to Meet RFS	Duke University	Zackary Johnson	1.3.5.310	FY15 - TABB
1:35 PM	2:00 PM	0:25	Rewiring Algal Carbon Energetics for Renewables	NREL	Lieve Laurens	1.3.5.270	FY16 - ABY2
2:00 PM	2:25 PM	0:25	Integrated Low Cost and High Yield Microalgal Biofuel Intermediates Production	MicroBio Engineering	John Benemann	1.3.5.243	FY16 - ABY2
2:25 PM	2:50 PM	0:25	Algae Cultivation from Flue Gas with High CO2 Utilization Efficiency	Global Algae Innovations	Dave Hazlebeck	1.3.5.610	FY18 - ECUAS
2:50 PM	2:55 PM	0:05	Closing	BETO	Christy Sterner		
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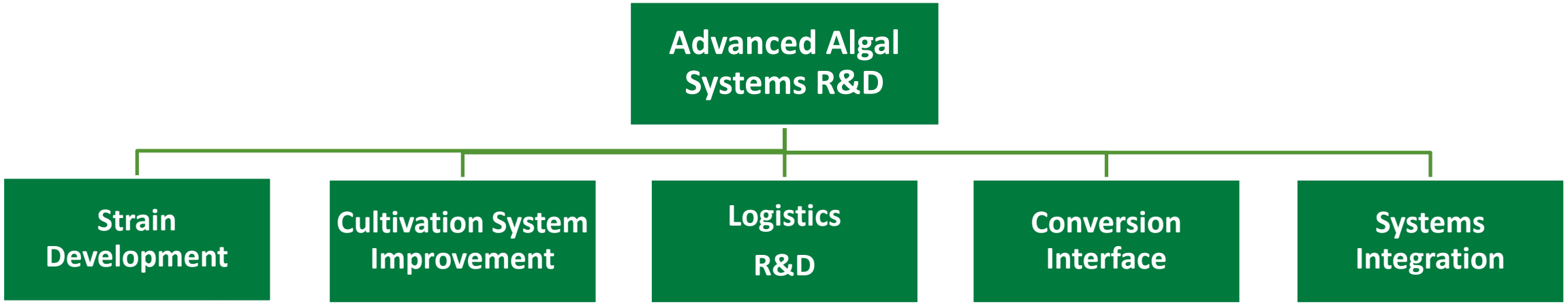
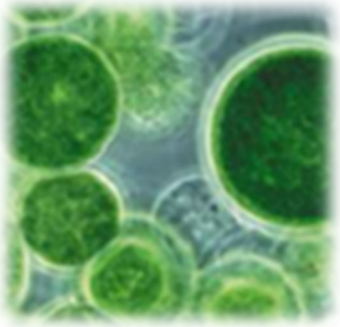
Program Structure: Strain Improvements WBS 1.3.1





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12:50 PM	1:10 PM	0:20	Break				
1:10 PM	1:35 PM	0:25	Marine Algae Industrialization Consortium (MAGIC): Combining Biofuels and High-value Bioproducts to Meet RFS	Duke University	Zackary Johnson	1.3.5.310	FY15 - TABB
1:35 PM	2:00 PM	0:25	Rewiring Algal Carbon Energetics for Renewables	NREL	Lieve Laurens	1.3.5.270	FY16 - ABY2
2:00 PM	2:25 PM	0:25	Integrated Low Cost and High Yield Microalgal Biofuel Intermediates Production	MicroBio Engineering	John Benemann	1.3.5.243	FY16 - ABY2
2:25 PM	2:50 PM	0:25	Algae Cultivation from Flue Gas with High CO2 Utilization Efficiency	Global Algae Innovations	Dave Hazlebeck	1.3.5.610	FY18 - ECUAS
2:50 PM	2:55 PM	0:05	Closing	BETO	Christy Sterner		
2:55 PM	3:25 PM	0:30	Comment Review Session				

Program Structure: Systems Integration WBS 1.3.5

Advanced Algal Systems R&D

- Strain Development
- Cultivation System Improvement
- Logistics
- Conversion Interface
- Systems Integration

New Mexico Consortium

Colorado School of Mines 1874

ASU Arizona State University

Argonne National Laboratory

NREL National Renewable Energy Laboratory

Pacific Northwest National Laboratory

μBIO MicroBio Engineering

Duke University

The University of Arizona

University of Illinois Urbana-Champaign

Global Algae Innovations

Conduct experiments in outdoor test environments, as part of an iterative development process, and verify improvements through analysis projects

Targeted Algal Biofuels and Bioproducts (TABB)

Date: FY2015

- Selections announced July 2015

Goals:

- Enable a modeled minimum fuel selling price, assuming mature technologies, of less than $5 gasoline gallon equivalent for algal biofuels through creation of valuable products and higher feedstock yields by 2019.

Selections:

- Producing Algae and Co-Products for Energy (PACE), Colorado School of Mines led consortium
- Marine Algae Industrialization Consortium (MAGIC), Duke University led consortium
- Global Algae Innovations, Inc.
- Arizona State University
- University of California San Diego
- Lawrence Livermore National Laboratory

GAI's 33-acre algae facility in Kauai with CO_2 supplied from off-gas of adjacent power plant

Advancements in Algal Biomass Yield Phase 2 (ABY2)

Date: FY2016

- Selections announced July 2016, alternate announced 2017

Goals:

- Continue to advance yield improvements, building upon successes of ABY1, to a goal of 3,700 gallons of biofuel intermediate per acre per year by 2020.

Selections:

- Global Algae Innovations Inc.
- Algenol Biotech LLC,
- MicroBio Engineering, Inc.
- NREL

GAI's Zobi harvester (above) and effluent streams (below)

Efficient Carbon Utilization in Algal Systems (ECUAS)

Date: FY2018

- Selections announced September 2018

Goals:

- Improve efficiency of carbon utilization and productivity of algal systems through improving uptake and conversion of waste CO2 emissions—such as from a power plant or industrial facilities—or through the development of new, affordable technologies to capture CO2 directly from ambient air to enhance algal growth

Selections:

- Colorado State University (TA1)
- Arizona State University (TA1)
- Global Algae Innovations (TA1)
- Arizona University (TA1)
- Duke University (TA1)
- MicroBio Engineering, Inc.
- Georgia Institute of Technology
- J. Craig Venter, Inc.

Advanced Algal Systems Scheduled Break

20-minute break time! 12:50 – 1:10 ET
Feel free to unmute yourself and catch up with colleagues.

We will start at 1:10 ET SHARP! So don't be late ☺

The Advanced Algal Systems Peer Review meeting has concluded for today. It will continue Thursday, March 11th at 11am ET.

Break out room is for reviewers and BETO staff.

U.S. DEPARTMENT OF ENERGY

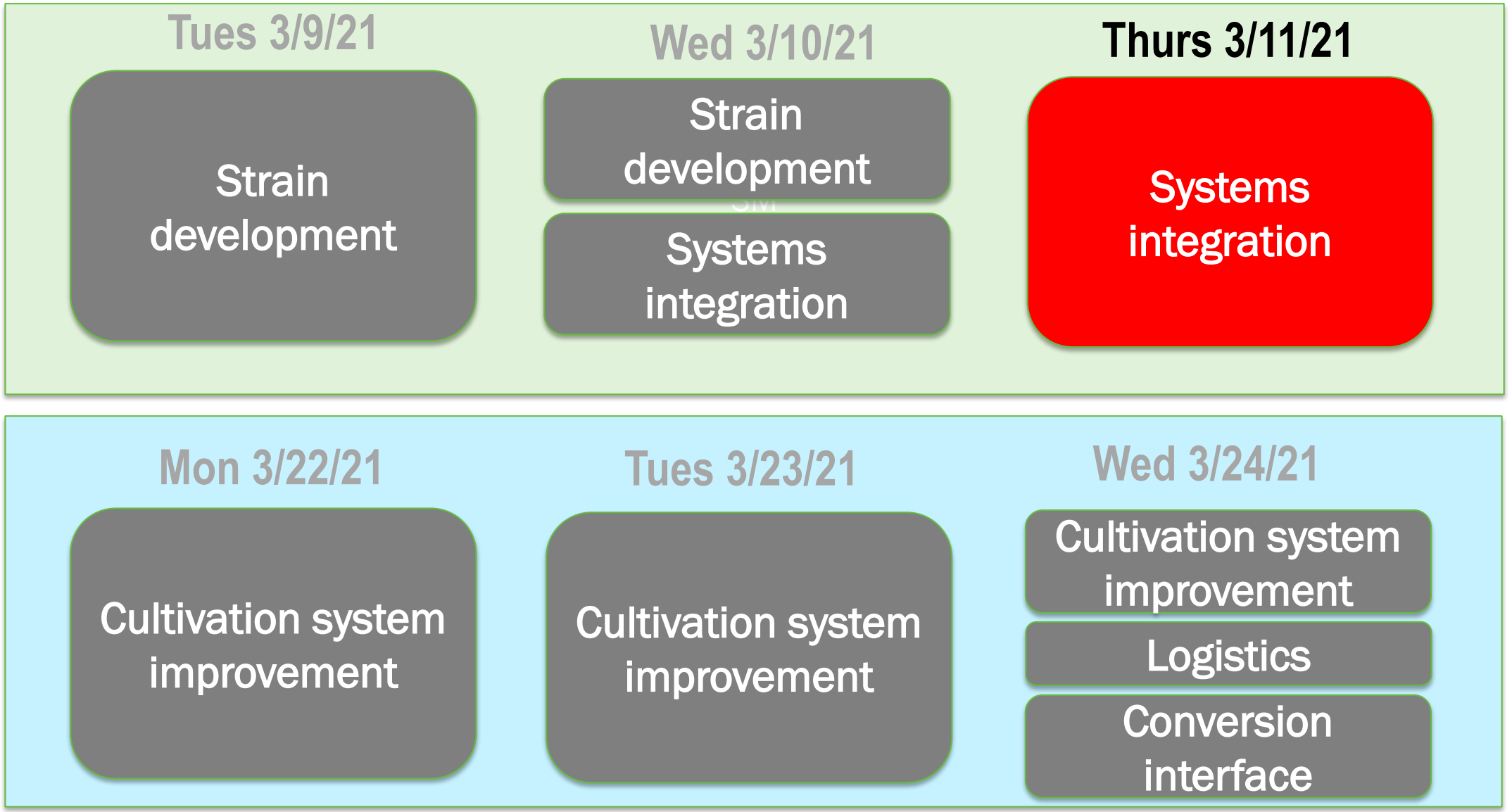
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Algal Systems

Thursday, March 11, 2021

Session will start at 11am ET

Agenda-at-a-glance



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https://www.energy.gov/eere/bioenergy/2021-project-peer-review

Detailed agenda for Thursday, March 11th

Day #3 Systems Integration (1.3.5)

Time start (ET)	Time end (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction		TBD		
11:05 AM	11:30 AM	0:25	Innovations in Algae Cultivations	Global Algae Innovations	Dave Hazlebeck	1.3.5.284	FY19 - CIPA
11:30 AM	11:55 AM	0:25	Optimizing Selection Pressures and Pest Management to Maximize Algal Biomass Yield	The New Mexico Consortium	Alina Corcoran	1.3.5.280	FY19 - CIPA
11:55 AM	12:20 PM	0:25	Improving the Productivity and Performance of Large-Scale Integrated Algal Systems for Wastewater Treatment and Biofuel Production	University of Illinois	Lance Schideman	1.3.5.286	FY19 - CIPA
12:20 PM	12:45 PM	0:25	Algal Productivity Enhancements by Rapid Screening and Selection of Improved Biomass and Lipid Producing Phototrophs (APEX)	Colorado School of Mines	Matt Posewitz	1.3.5.282	FY19 - CIPA
12:45 PM	1:05 PM	0:20	Break				
1:05 PM	1:30 PM	0:25	Decision-Model Supported Algal Cultivation Process Enhancement	Arizona State University	John A. McGowen	1.3.5.287	FY19 - CIPA
1:30 PM	1:55 PM	0:25	Algae Technology Educational Consortium	NREL	Cindy Gerk	1.3.5.201	AOP
1:55 PM	2:20 PM	0:25	Microalgae Analysis	PNNL	Mark Wigmosta	1.3.5.203	AOP
2:20 PM	2:25 PM	0:05	Closing		Christy Sterner		
2:25 PM	2:55 PM	0:30	Comment Review Session				

Program Structure: Systems Integration WBS 1.3.5

Advanced Algal Systems R&D

- Strain Development
- Cultivation System Improvement
- Logistics
- Conversion Interface
- Systems Integration

New Mexico Consortium

Colorado School of Mines 1874

ASU Arizona State University

Argonne National Laboratory

NREL National Renewable Energy Laboratory

Pacific Northwest National Laboratory

μBIO MicroBio Engineering

Duke University

The University of Arizona

University of Illinois Urbana-Champaign

Global Algae Innovations

Conduct experiments in outdoor test environments, as part of an iterative development process, and verify improvements through analysis projects

Cultivation Intensification Processes Algae (CIPA)

Date: FY2019

- Selections announced September 2019

Goals:

- Develop technologies for outdoor algae systems that increase the harvest yield, reliability and quality of algae

Selections:

- Global Algae Innovations
- New Mexico Consortium
- Colorado School of Mines
- University of Illinois
- Arizona State University

Advanced Algal Systems Scheduled Break

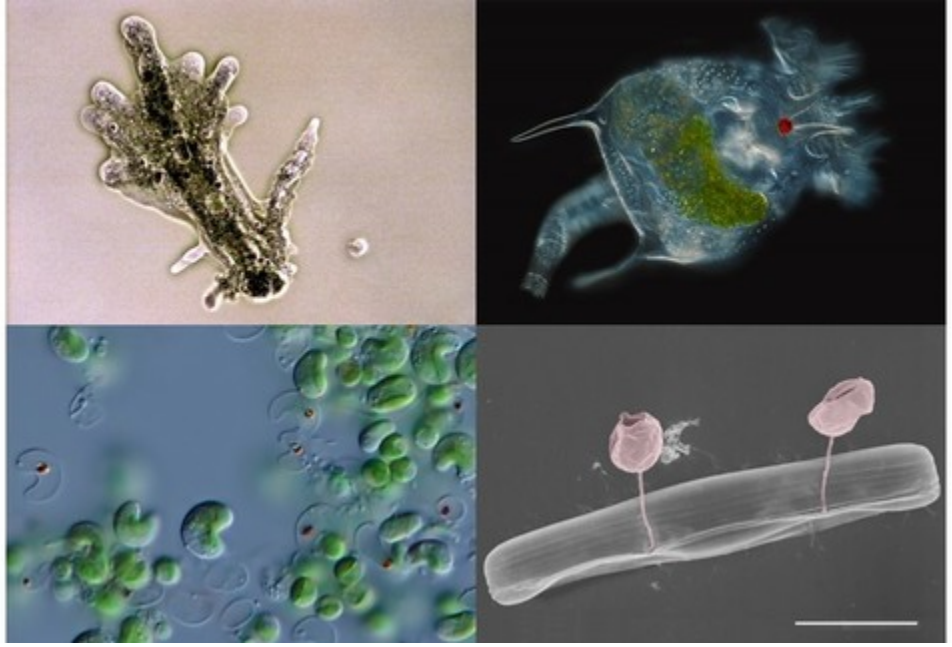
20-minute break time! 12:45 – 1:05 ET

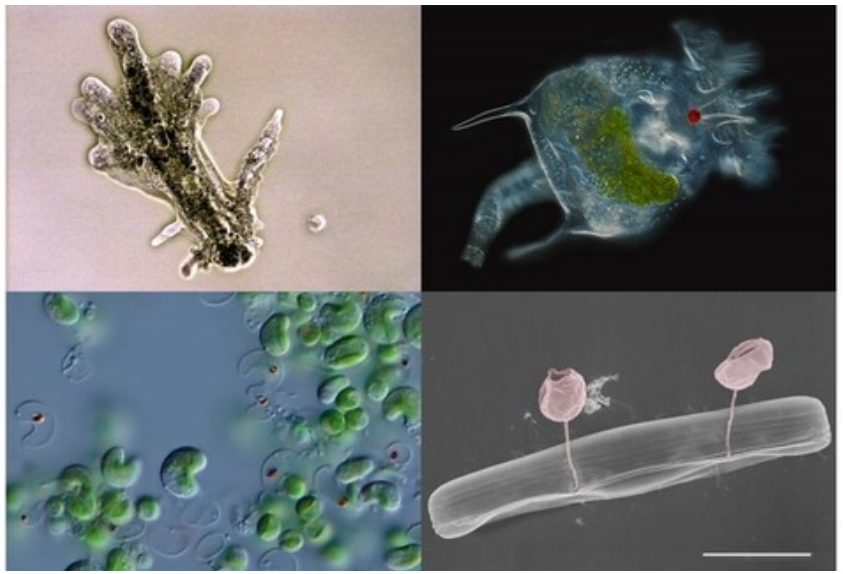
Check out our BETO-AAS Crop protection workshop!

https://www.energy.gov/eere/bioenergy/events/barriers-scale-algae-crop-protection-workshop

Register: https://cvent.me/ov70Mv

We will start at 1:05 ET SHARP! So don't be late ☺





Microscopic images of pests that harm algal cultivation. Images courtesy of Cymothoa exigua, Frank Fox, AzCATI at Arizona State University, and Estelle S. Kilias, Leandro Junges, Luka Šupraha, Guy Leonard, Katja Metfies & Thomas A. Richards

When : April 20-21
Where : Virtual

Keynote presentations:

- Barry Goldman, Pluton Biosciences (formerly Monsanto and Indigo Ag)
- Claire Gachon, Scottish Association for Marine Science

Panel presentations and discussions:

- Current State of Crop Protection
- Alternative Crop Protection Approaches to Chemicals and Pesticides
- Pest Models: Understanding Pest Life Cycles and Infection Mechanisms
- Current and Future Pest Monitoring Practices

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Register: https://cvent.me/ov7OMv

The Advanced Algal Systems Peer Review meeting has concluded for today. It will continue Monday, March 22nd at 11am ET.

Break out room is for reviewers and BETO staff.

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Algal Systems

Monday, March 22, 2021

Session will start at 11am ET

Agenda-at-a-glance

Tues 3/9/21	Wed 3/10/21	Thurs 3/11/21
Strain development	Strain development	Systems integration
	Systems integration	

Mon 3/22/21	Tues 3/23/21	Wed 3/24/21
Cultivation system improvement	Cultivation system improvement	Cultivation system improvement
		Logistics
		Conversion interface

Note: There are some deviations to accommodate presenter schedule constraints

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https://www.energy.gov/eere/bioenergy/2021-project-peer-review

Detailed agenda for Monday, March 22nd

Day 4 Cultivation System Improvement (1.3.2)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:15 AM	0:15	Session introduction and Cultivation System Improvement introduction	BETO	Christy Sterner		
11:15 AM	11:40 AM	0:25	Success Through Synergy: Increasing Cultivation Yield and Stability with Rationally Designed Consortia.	LANL	Shawn Starkenburg	1.3.2.610 1.3.2.641	FY17 - PEAK
11:40 AM	12:05 PM	0:25	High-Throughput Directed Evolution of Marine Microalgae and Phototrophic Consortia for Improved Biomass Yields	Colorado School of Mines	Matthew Posewitz	1.3.2.640	FY17 - PEAK
12:05 PM	12:30 PM	0:25	SOFAST: Streamlined Optimization of Filamentous Arthrospira / Spirulina Traits	Lumen Bioscience	Rachelle Lim	1.3.2.601	FY17 - PEAK
12:30 PM	12:55 PM	0:25	Developing Advanced Genetic and Synthetic Biology Tools for Improved Algae Productivity	University of California San Diego	Stephen Mayfield	1.3.2.650	FY17 - PEAK
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	1:40 PM	0:25	Microbiome engineering of Desmodesmus to alleviate carbon limitation	LLNL	Xavier Mayali	1.3.2.652	FY17 - PEAK
1:40 PM	2:05 PM	0:25	A comprehensive strategy for stable, high productivity cultivation of microalgae with controllable biomass composition	University of Toledo	Sridhar Viamajala	1.3.2.651	FY17 - PEAK
2:05 PM	2:30 PM	0:25	Prevention of low productivity periods in large-scale microalgae cultivation	Global Algae Innovations	Aga Pinowska	1.3.2.630	FY17 - PEAK
2:30 PM	2:55 PM	0:25	Protective bacteria in algal ponds: inducible protection to maximize response	LLNL	Rhona Stuart	1.3.2.002 1.3.2.003	AOP
2:55 PM	3:00 PM	0:05	Closing	BETO	Christy Sterner		
3:00 PM	3:30 PM	0:30	Comment Review Session				

Program Structure: Cultivation System Improvements WBS 1.3.2

Advanced Algal Systems R&D

- Strain Development
- **Cultivation System Improvement**
- Logistics
- Conversion Interface
- Systems Integration

Los Alamos National Laboratory – Est. 1943
The University of Toledo
ASU Arizona State University
Global Algae Innovations
MBIO MicroBio Engineering
Duke University
Lawrence Livermore National Laboratory
NREL National Renewable Energy Laboratory
Colorado State University
School of Mines 1874 Colorado
Sandia National Laboratories
LUMEN BIOSCIENCE
Georgia Tech
JCVI J. Craig Venter Institute
New Mexico Consortium
UC San Diego

Improve cultivation systems through:

- Understanding and managing the microbial community
- Optimization of cultivation systems
- Cultivation strategies, including crop protection and polycultures

Productivity Enhanced Algae and ToolKits (PEAK)

Date: FY2017

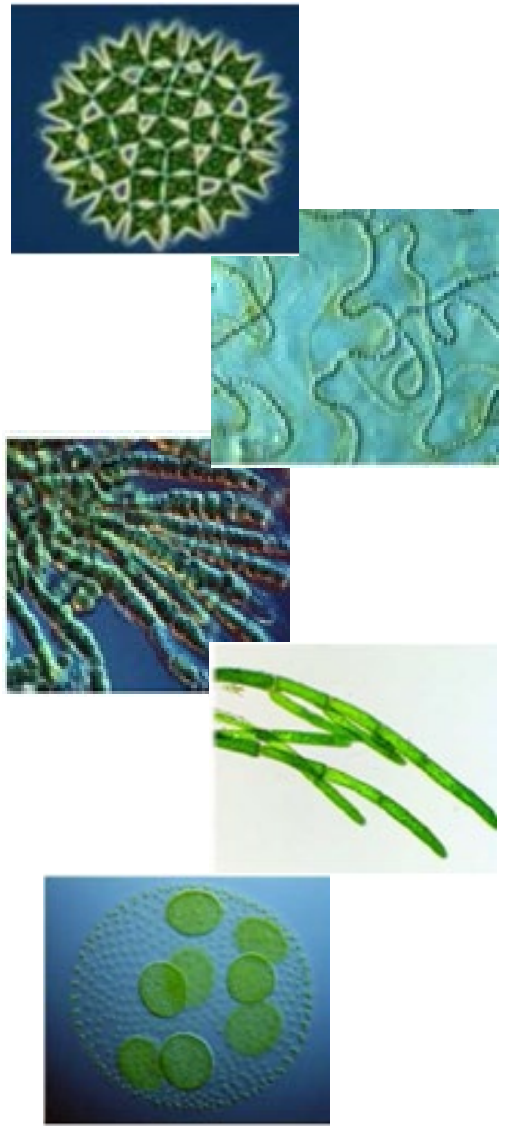
- Selections announced July 2017, alternates September 2017

Goals:

- Deliver high-impact tools and techniques for increasing algae productivity in order to reduce the costs of producing algal biofuels and bioproducts

Selections:

- Lumen Bioscience
- Global Algae Innovations
- Los Alamos National Laboratory
- Colorado School of Mines
- University of California San Diego
- University of Toledo
- Lawrence Livermore National Laboratory



Advanced Algal Systems Scheduled Break

20-minute break time! 12:55 – 1:15 ET

Check out our BETO-AAS Crop protection workshop!

https://www.energy.gov/eere/bioenergy/events/barriers-scale-algae-crop-protection-workshop

Register: https://cvent.me/ov7OMv

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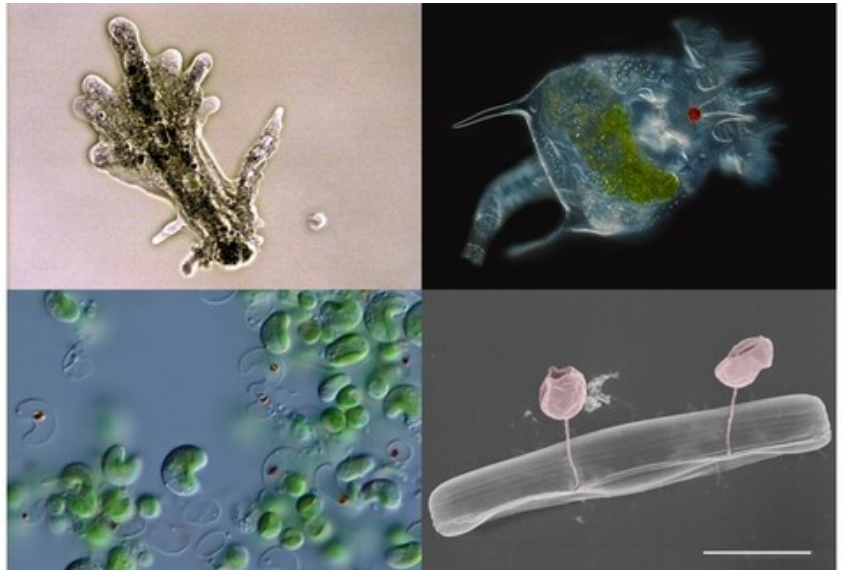
Bioenergy Technologies Office

March 11, 2021

Register Now! Barriers to Scale: Algae Crop Protection Workshop



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When : April 20-21
Where : Virtual

Keynote presentations:

- Barry Goldman, Pluton Biosciences (formerly Monsanto and Indigo Ag)
- Claire Gachon, Scottish Association for Marine Science

Panel presentations and discussions:

- Current State of Crop Protection
- Alternative Crop Protection Approaches to Chemicals and Pesticides
- Pest Models: Understanding Pest Life Cycles and Infection Mechanisms
- Current and Future Pest Monitoring Practices

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Break out room is for reviewers and BETO staff.

U.S. DEPARTMENT OF ENERGY

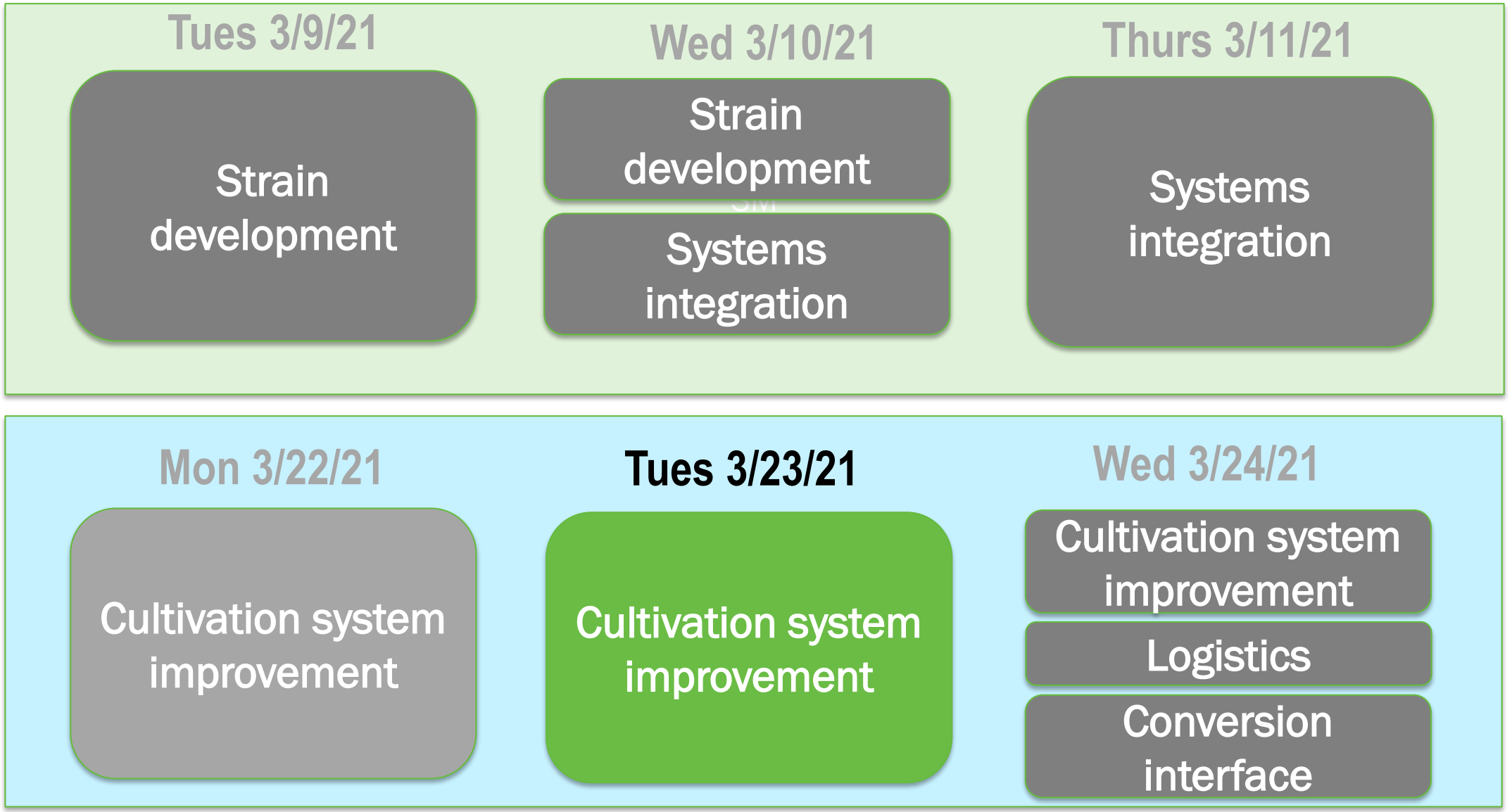
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Algal Systems

Tuesday, March 23, 2021

Session will start at 11am ET

Agenda-at-a-glance



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https://www.energy.gov/eere/bioenergy/2021-project-peer-review

Detailed agenda for Tuesday, March 23rd

Day 5 Cultivation System Improvement (1.3.2)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session Introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Chytrid Control Advancing Algal Targets (ChytCAAT)	LLNL	Ty Samo	1.3.2.040	AOP
11:30 AM	11:55 AM	0:25	Membrane Carbonation for 100% Efficient Delivery of Industrial CO2 Gases	Arionza State University	Bruce Rittmann	1.3.2.430	FY18 - ECUAS
11:55 AM	12:20 PM	0:25	Enhanced Algal Production of CA for Improved Atmospheric Deliver of CO2 to Ponds	J. Craig Venter Institute	Andrew E. Allen	1.3.2.402	FY18 - ECUAS
12:20 PM	12:45 PM	0:25	Carbon Utilization Efficiency in Marine Algae Biofuel Production Systems Through Loss Minimization and Carbonate Chemistry Modification	Duke University	Zackary Johnson	1.3.2.440	FY18 - ECUAS
12:45 PM	1:05 PM	0:20	Break				
1:05 PM	1:30 PM	0:25	Integrating an Industrial Source and Commercial Algae Farm with Innovative CO2 Transfer Membrane and Improved Strain Technologies	Colorado State University	Ken Reardon	1.3.2.400	FY18 - ECUAS
1:30 PM	1:55 PM	0:25	Multi-pronged Approach of Improved Biological and Physicochemical Systems to Improving Carbon Utilization by Cyanobacterial Cultures	Arionza State University	Wim Vermaas	1.3.2.410	FY18 - ECUAS
1:55 PM	2:20 PM	0:25	Air Carbon for Algae Production - AirCAP	MicroBio Engineering	John Benemann	1.3.2.600	FY18 - ECUAS
2:20 PM	2:45 PM	0:25	Direct Air Capture of CO2 and Delivery to Photobioreactors for Algal Biofuel Production	Georgia Institute of Technology	Christopher W. Jones	1.3.2.620	FY18 - ECUAS
2:45 PM	3:10 PM	0:25	Attached Periphytic Algae Production and Analysis	SNL	Ryan W. Davis	1.3.2.130	AOP
3:10 PM	3:15 PM	0:05	Closing	BETO	Christy Sterner		
3:15 PM	3:45 PM	0:30	Comment Review Session				

Program Structure: Cultivation System Improvements WBS 1.3.2

Advanced Algal Systems R&D

- Strain Development
- **Cultivation System Improvement**
- Logistics
- Conversion Interface
- Systems Integration

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The University of Toledo
ASU Arizona State University
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Efficient Carbon Utilization in Algal Systems (ECUAS)

Date: FY2018

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Selections:

- Colorado State University (TA1)
- Arizona State University (TA1)
- Global Algae Innovations (TA1)
- Arizona University (TA1)
- Duke University (TA1)
- MicroBio Engineering, Inc.
- Georgia Institute of Technology
- J. Craig Venter, Inc.

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March 11, 2021

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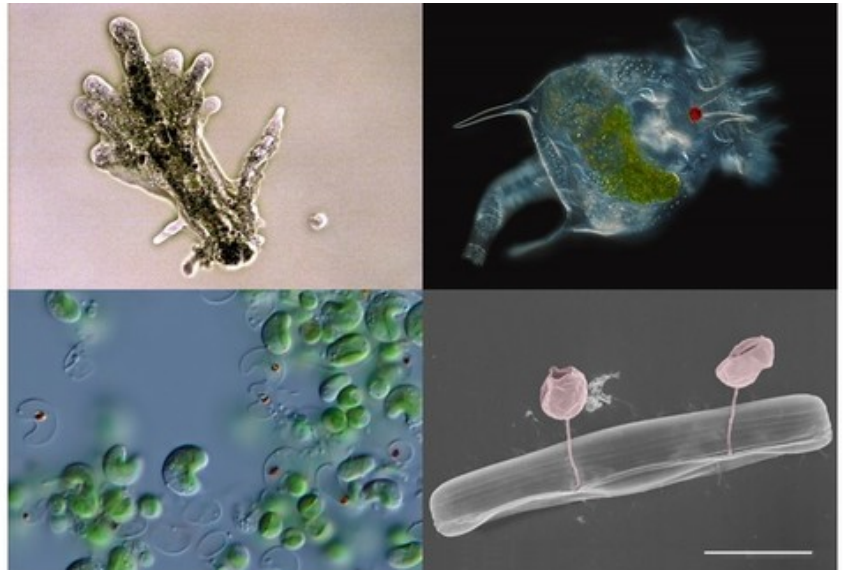

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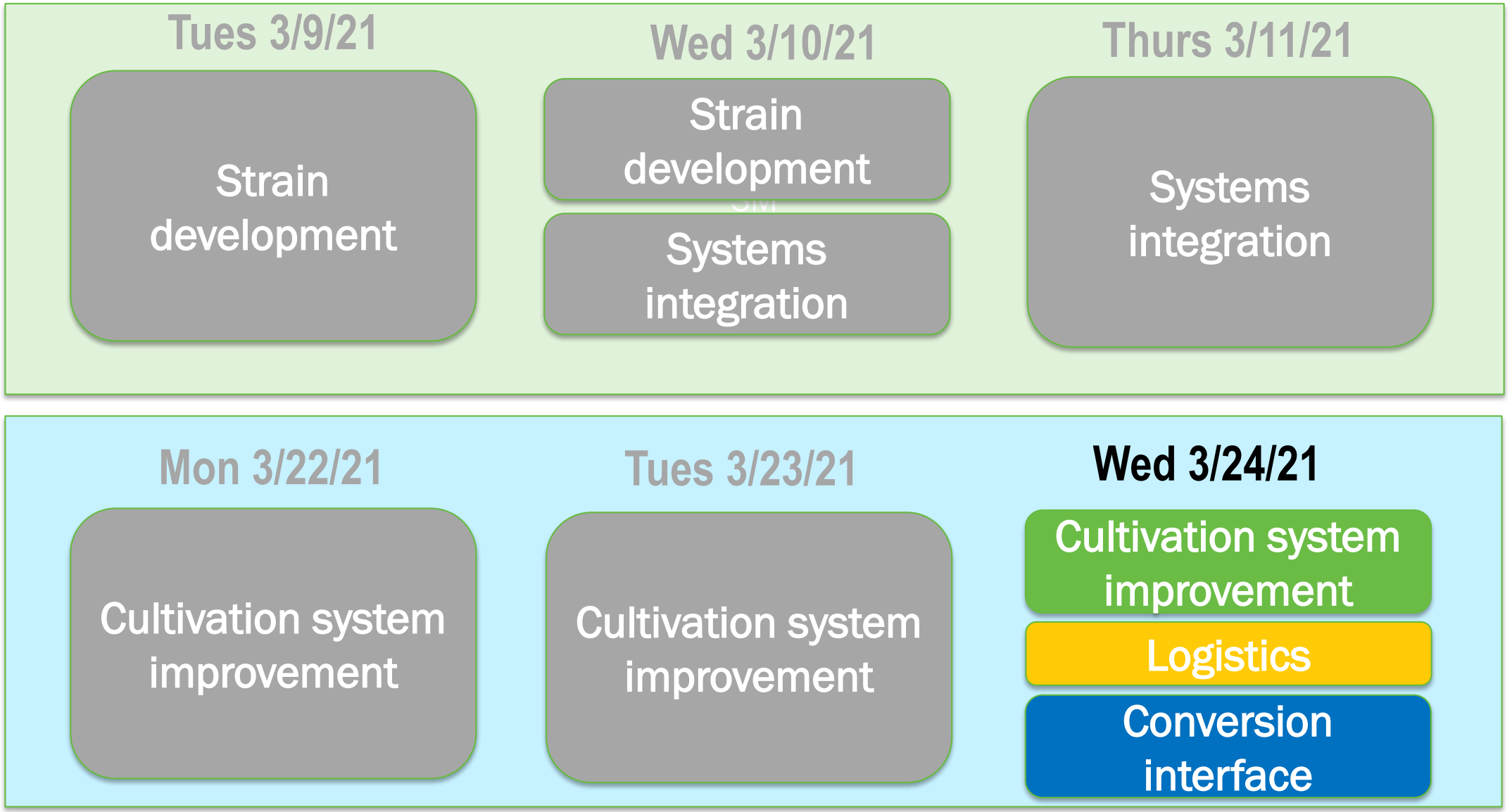
Advanced Algal Systems

Wednesday, March 24, 2021

Session will start at 11am ET

Agenda-at-a-glance



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https://www.energy.gov/eere/bioenergy/2021-project-peer-review

Detailed agenda for Wednesday, March 24th

Day 6 Cultivation System Improvement (1.3.2), Logistics (1.3.3), and Conversion Interface (1.3.4)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Algal Biomass Composition	NREL	Lieve Laurens	1.3.2.001	AOP
11:30 AM	11:55 AM	0:25	LEAF: Leveraging Algae Traits for Fuels	SNL	Amanda Barry	1.3.2.043	AOP
11:55 AM	12:00 PM	0:05	Logistics R&D overview	BETO	Christy Sterner		
12:00 PM	12:25 PM	0:25	Algal Feedstocks Logistics and Handling	INL	Brad Wahlen	1.3.3.100	AOP
12:25 PM	12:30 PM	0:05	Conversion interface overview	BETO	Christy Sterner		
12:30 PM	12:55 PM	0:25	Cyanobacteria Photosynthetic Energy Platform	NREL	Jianping Yu	1.3.4.301	AOP
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	1:40 PM	0:25	Thermochemical Interface	PNNL	Dan Anderson	1.3.4.101	AOP
1:40 PM	2:05 PM	0:25	HTL Model Development	PNNL	Lesley Snowden-Swan	1.3.5.202	AOP
2:05 PM	2:30 PM	0:25	Algal biofuels techno-economic analysis	NREL	Ryan Davis	1.3.5.200	AOP
2:30 PM	2:55 PM	0:25	Bioconversion of Algal Carbohydrates and Proteins to Fuels	SNL	Ryan W. Davis	1.3.4.200	AOP
2:55 PM	3:20 PM	0:25	CAP Process Research	NREL	Jacob Kruger	1.3.4.201	AOP
3:20 PM	3:25 PM	0:05	Closing	BETO	Christy Sterner		
3:25 PM	3:55 PM	0:30	Comment Review Session				

Program Structure: Cultivation System Improvements WBS 1.3.2

Advanced Algal Systems R&D

- Strain Development
- **Cultivation System Improvement**
- Logistics
- Conversion Interface
- Systems Integration

Los Alamos National Laboratory – Est. 1943
The University of Toledo
ASU Arizona State University
Global Algae Innovations
MBIO MicroBio Engineering
Duke University
Lawrence Livermore National Laboratory
NREL National Renewable Energy Laboratory
Colorado State University
School of Mines 1874 Colorado
Sandia National Laboratories
LUMEN BIOSCIENCE
Georgia Tech
JCVI J. Craig Venter Institute
New Mexico Consortium
UC San Diego

Improve cultivation systems through:

- Understanding and managing the microbial community
- Optimization of cultivation systems
- Cultivation strategies, including crop protection and polycultures

Detailed agenda for Wednesday, March 24th

Day 6 Cultivation System Improvement (1.3.2), Logistics (1.3.3), and Conversion Interface (1.3.4)

Start (ET)	End (ET)	Duration (min)	Project/Task	Organization	Presenter	WBS	AOP/ FOA
11:00 AM	11:05 AM	0:05	Session introduction	BETO	Christy Sterner		
11:05 AM	11:30 AM	0:25	Algal Biomass Composition	NREL	Lieve Laurens	1.3.2.001	AOP
11:30 AM	11:55 AM	0:25	LEAF: Leveraging Algae Traits for Fuels	SNL	Amanda Barry	1.3.2.043	AOP
11:55 AM	12:00 PM	0:05	Logistics R&D overview	BETO	Christy Sterner		
12:00 PM	12:25 PM	0:25	Algal Feedstocks Logistics and Handling	INL	Brad Wahlen	1.3.3.100	AOP
12:25 PM	12:30 PM	0:05	Conversion interface overview	BETO	Christy Sterner		
12:30 PM	12:55 PM	0:25	Cyanobacteria Photosynthetic Energy Platform	NREL	Jianping Yu	1.3.4.301	AOP
12:55 PM	1:15 PM	0:20	Break				
1:15 PM	1:40 PM	0:25	Thermochemical Interface	PNNL	Dan Anderson	1.3.4.101	AOP
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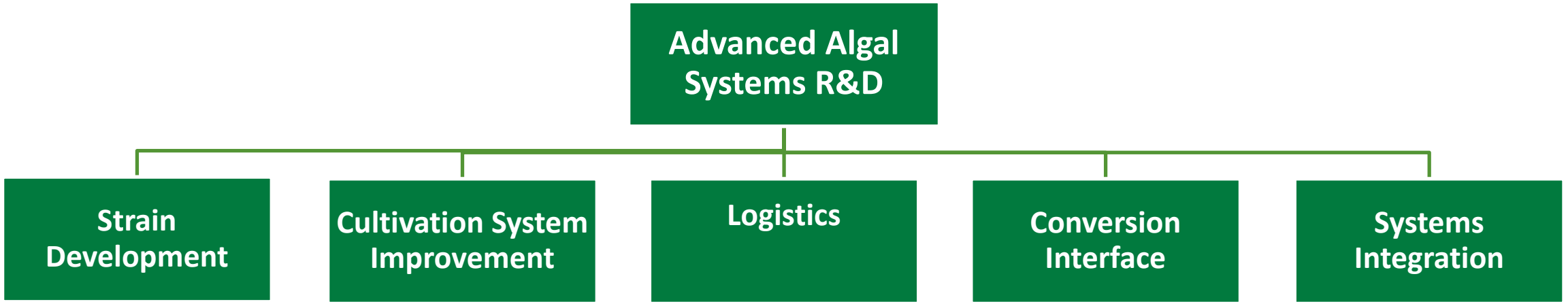
3:20 PM	3:25 PM	0:05	Closing	BETO	Christy Sterner		
3:25 PM	3:55 PM	0:30	Comment Review Session				

Program Structure: Logistics RD&D WBS 1.3.3



Reduce costs and improve efficiencies of:

- Algae harvesting
- Processing
- Stabilization and transport

Utah State University

ASU Arizona State University

INL Idaho National Laboratory

Detailed agenda for Wednesday, March 24th

Day 6 Cultivation System Improvement (1.3.2), Logistics (1.3.3), and Conversion Interface (1.3.4)

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3:20 PM	3:25 PM	0:05	Closing	BETO	Christy Sterner		
3:25 PM	3:55 PM	0:30	Comment Review Session				

Program Structure: Conversion Interface WBS 1.3.4

Advanced Algal Systems R&D

- Strain Development
- Cultivation System Improvement
- Logistics
- Conversion Interface
- Systems Integration

Examine the integration of feedstock production and preprocessing and conversion technologies, such as:

- Lipid extraction
- Fermentations
- Hydrothermal liquefaction
- Co-products development

ASU Arizona State University

Global Algae Innovations

μBIO MicroBio Engineering

Duke University

NREL National Renewable Energy Laboratory

Sandia National Laboratories

LUMEN BIOSCIENCE

UC San Diego

Montana State University

Pacific Northwest National Laboratory

Photo courtesy of PNNL

Advanced Algal Systems Scheduled Break

20-minute break time! 12:55 – 1:15 ET

Check out our BETO-AAS Crop protection workshop!

https://www.energy.gov/eere/bioenergy/events/barriers-scale-algae-crop-protection-workshop

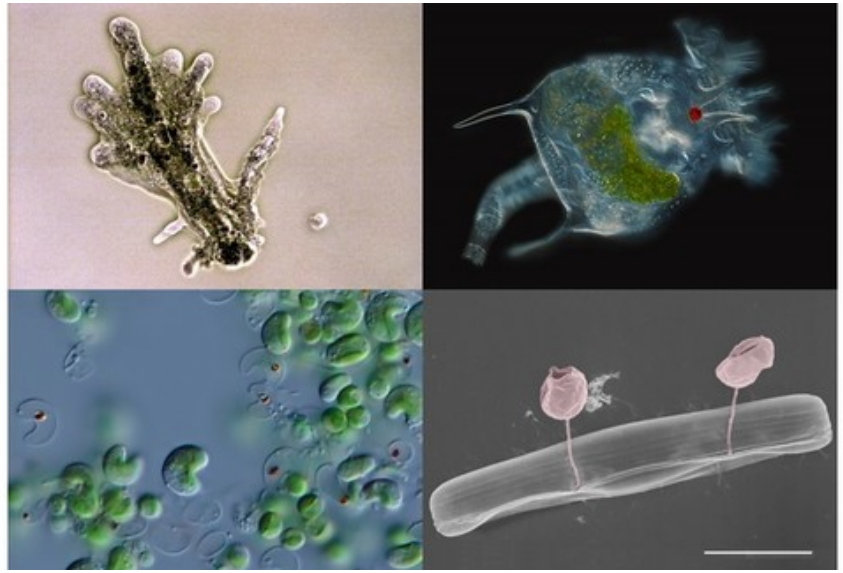
Register: https://cvent.me/ov7OMv

We will start at 1:15 ET SHARP! So don't be late ☺

Bioenergy Technologies Office

March 11, 2021

Register Now! Barriers to Scale: Algae Crop Protection Workshop



Microscopic images of pests that harm algal cultivation. Images courtesy of Cymothoa exigua, Frank Fox, AzCATI at Arizona State University, and Estelle S. Kilias, Leandro Junges, Luka Šupraha, Guy Leonard, Katja Metfies & Thomas A. Richards

When : April 20-21
Where : Virtual

Keynote presentations:

- Barry Goldman, Pluton Biosciences (formerly Monsanto and Indigo Ag)
- Claire Gachon, Scottish Association for Marine Science

Panel presentations and discussions:

- Current State of Crop Protection
- Alternative Crop Protection Approaches to Chemicals and Pesticides
- Pest Models: Understanding Pest Life Cycles and Infection Mechanisms
- Current and Future Pest Monitoring Practices

https://www.energy.gov/eere/bioenergy/events/barriers-scale-algae-crop-protection-workshop

Register: https://cvent.me/ov7OMv

The Advanced Algal Systems Peer Reviewers – Thank You!

Jaime E. Moreno, PE
Managing Principal
The GWP Group

Jose Olivarez
Editor in Chief
Algal Research

Brendan Scott
Project Manager
Pebbles Lab

Tyler Johannes, Chair &
Rumley Assoc. Prof.
Chemical Eng U. of Tulsa

Linda Rauch, Process
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Jennifer Stewart
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Oranugo
Associate Director
Homology Medicines, Inc

Lora Cameron-Landis
Sr Technical Lead Strategic Growth
Initiatives, Lonza Biologics

The Advanced Algal Systems Peer Review meeting has concluded.

Thank you for participating!

Break out room is for reviewers and BETO staff.