U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy




2019 PROJECT PEER REVIEW

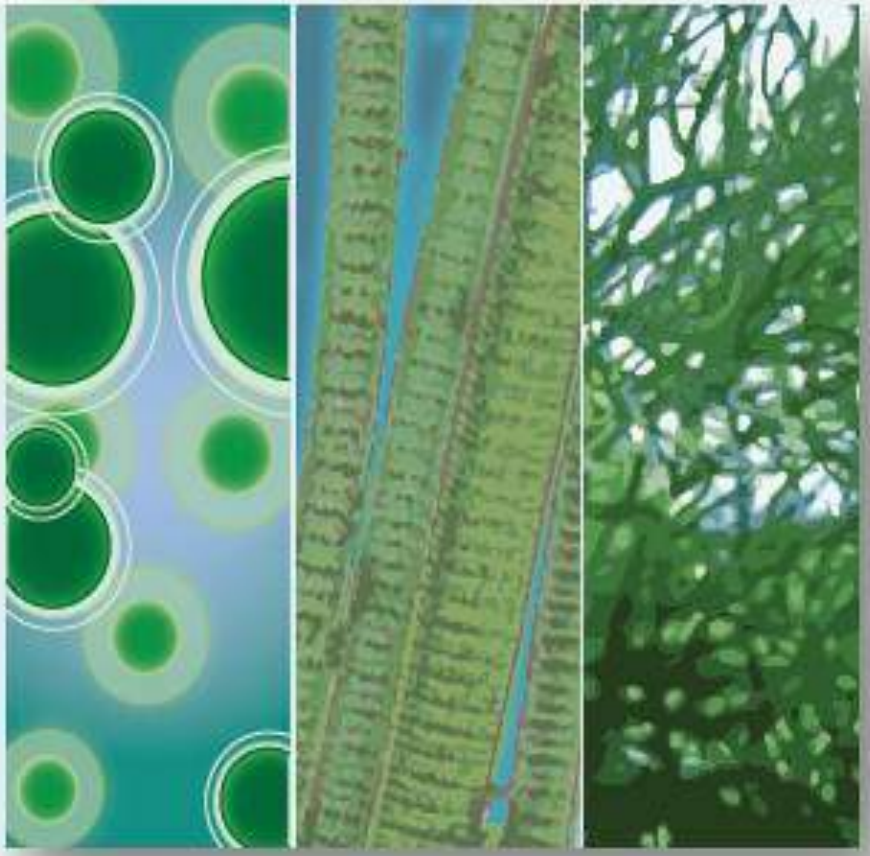
U.S. DEPARTMENT OF ENERGY
BIOENERGY TECHNOLOGIES OFFICE

Advanced Algal Systems

March 4, 2019

Alison Goss Eng
Program Manager

Advanced Algal Systems Program Overview



- The Team
- Goals
- Focus Areas
- R&D Strategy
- Funding History
- Key Accomplishments
- Addressing 2017 Peer Review Feedback

The Advanced Algal Systems (AAS) Team

Alison Goss Eng, Program Manager

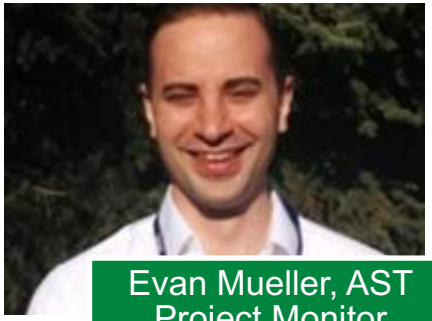
Daniel Fishman, Technology Manager

Christy Sterner, Technology Manager

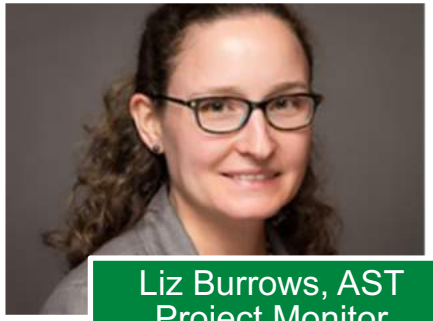
Devinn Lambert, Technology Manager

Colleen Tomaino, BCS Project Monitor

Ali Hewett, BCS Project Monitor



Evan Mueller, AST Project Monitor



Liz Burrows, AST Project Monitor

Ben Walsh, The Building People

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Advanced Algal Systems (AAS)

Strategic Goal: *Develop technologies that enable production of sustainable algal feedstocks that perform reliably in conversion processes to yield renewable fuel blendstocks, as well as bioproducts and chemical intermediates.*

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.
- Develop higher-value bioproducts that can be produced and recovered along with biofuel intermediates.

Verify laboratory improvements outdoors at increasing scales

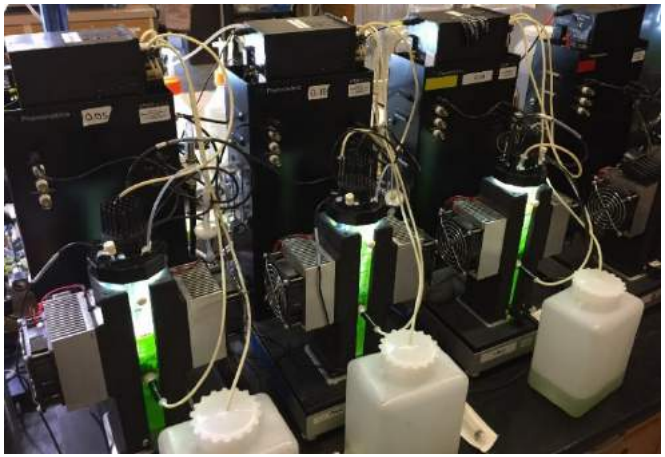
AAS Major Goals: FY 2019–FY 2030

By 2019, develop strain cultivation technologies that enable the production of valuable co-products to increase the value of cultivated algal biomass by 30% over the 2015 SOT baseline.

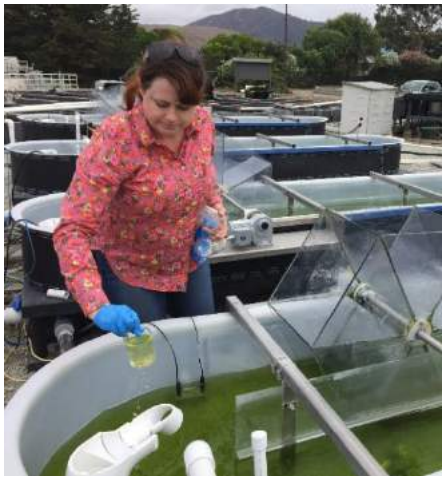
By 2020, develop technologies that enable mature modeled annual average algae yields of 3,700 gallons of biofuel intermediate per acre per year.

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 2030, deliver technologies that enable the verification of integrated systems research at engineering scale for hydrocarbon biofuel technologies at mature modeled MFSP of $2.5/GGE.



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



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

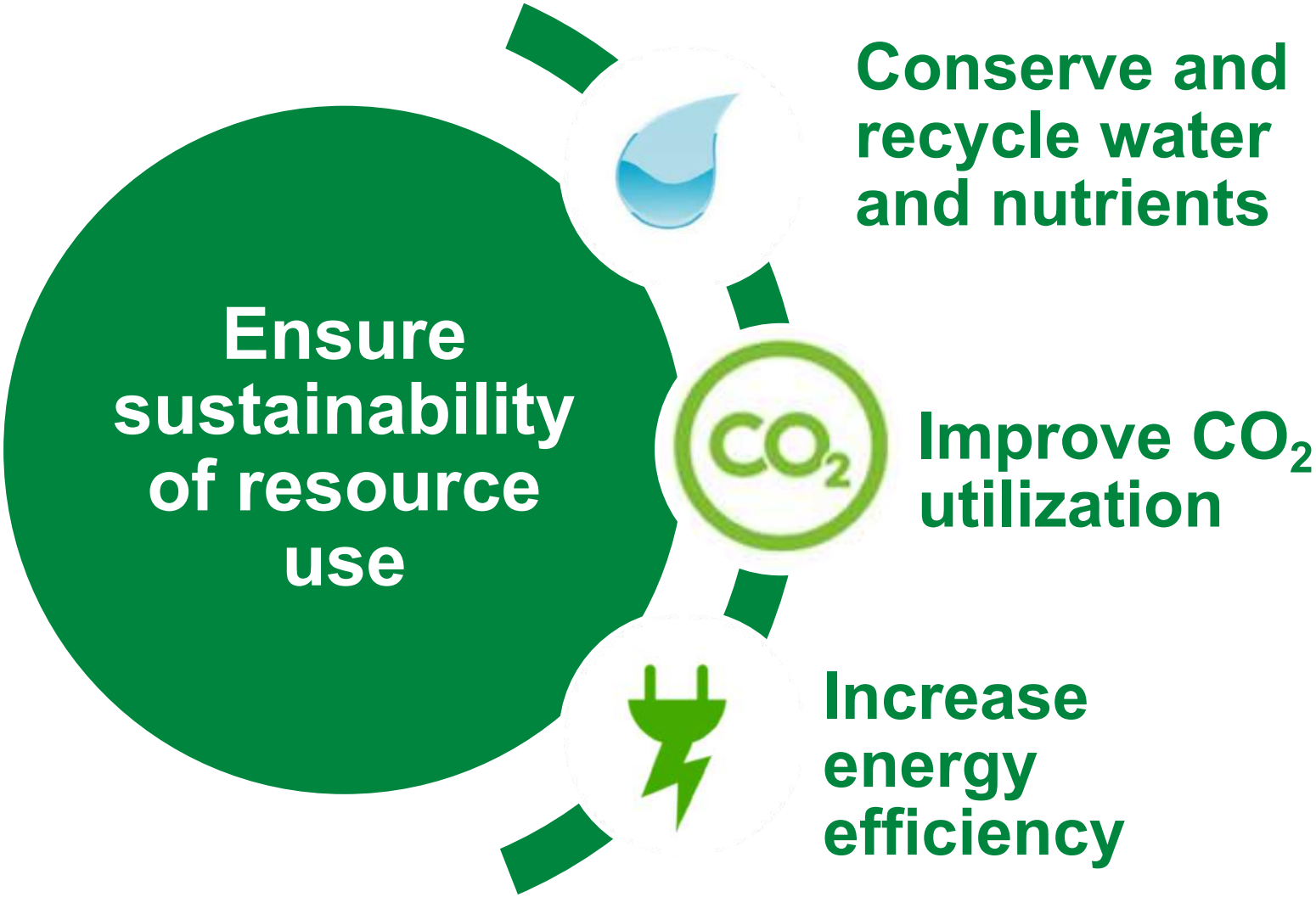
Algae Focus Areas

Increase Value of Biomass

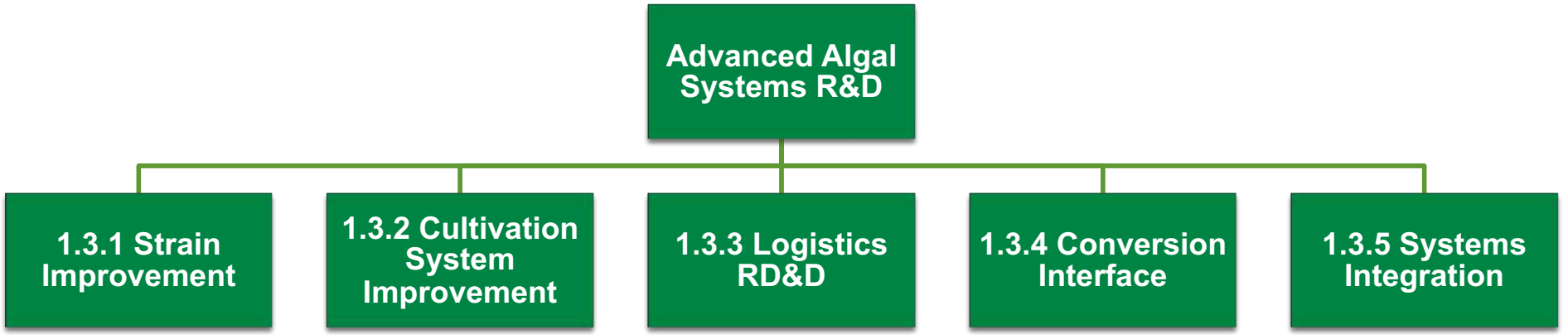
Reduce Costs of Production

Strategies focus on **enhancing productivity**, **feedstock quality**, and **robust yields**, while developing higher-value bioproducts.

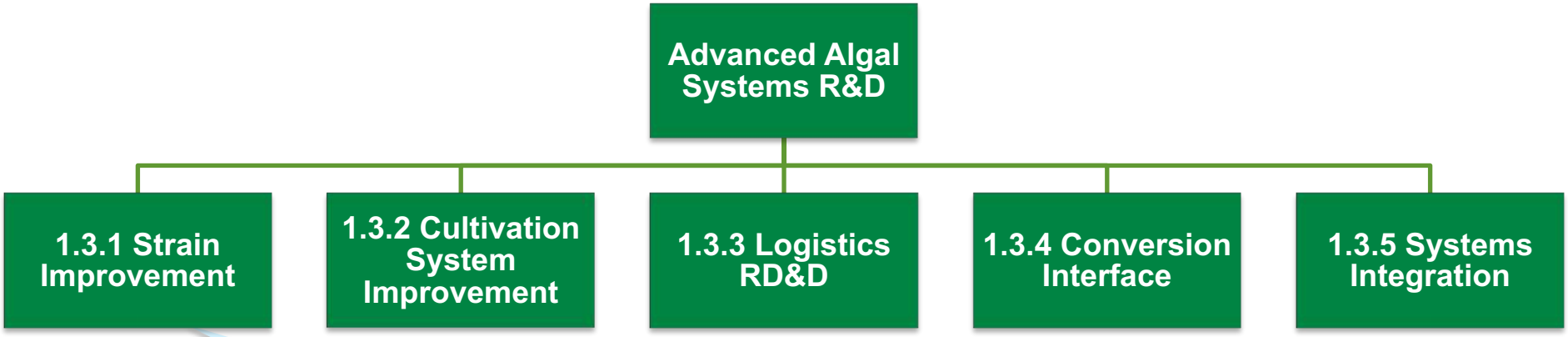
Algae Focus Areas



Algae R&D Strategy New Work Breakdown Structure

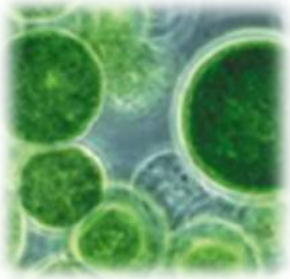


Algae R&D Strategy: Work Breakdown Structure



Develop stable algal strains that:

- Produce high yields,
- Resist predators
- Are suitable for cultivation in farming operations



Los Alamos NATIONAL LABORATORY EST. 1943

BERKELEY LAB

Sandia National Laboratories

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

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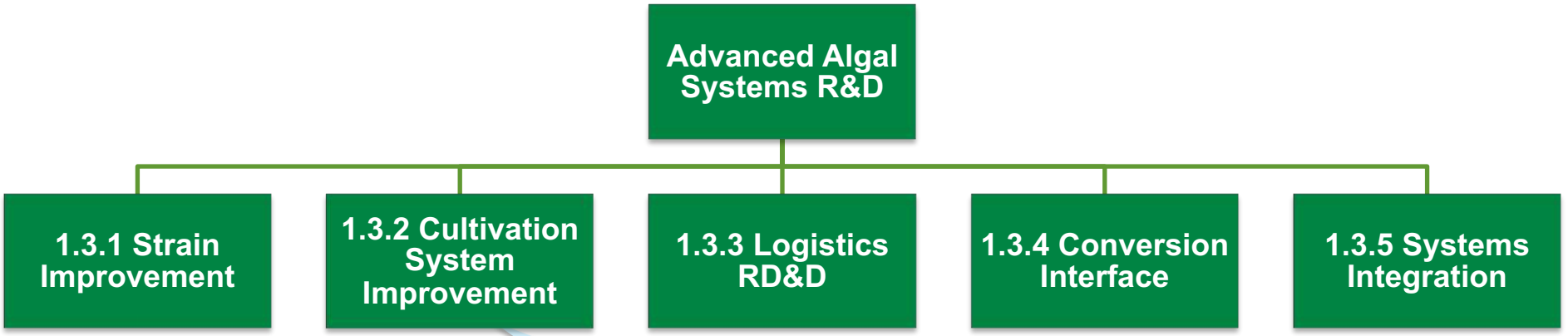
Algae R&D Strategy: Work Breakdown Structure



Improve cultivation systems through:

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

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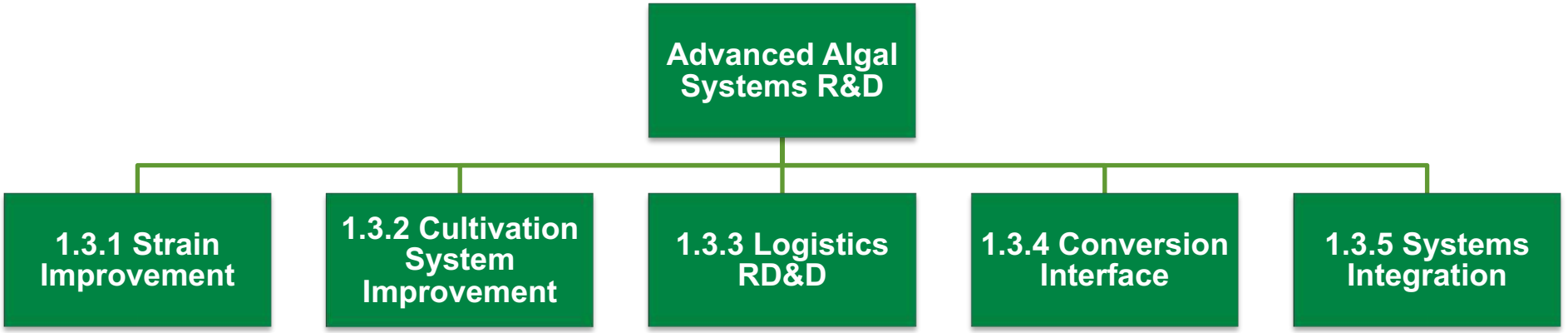
Algae R&D Strategy: Work Breakdown Structure



Reduce costs and improve efficiencies of:

- Algae harvesting
- Processing
- Stabilization and transport

ASU Arizona State University

INL Idaho National Laboratory

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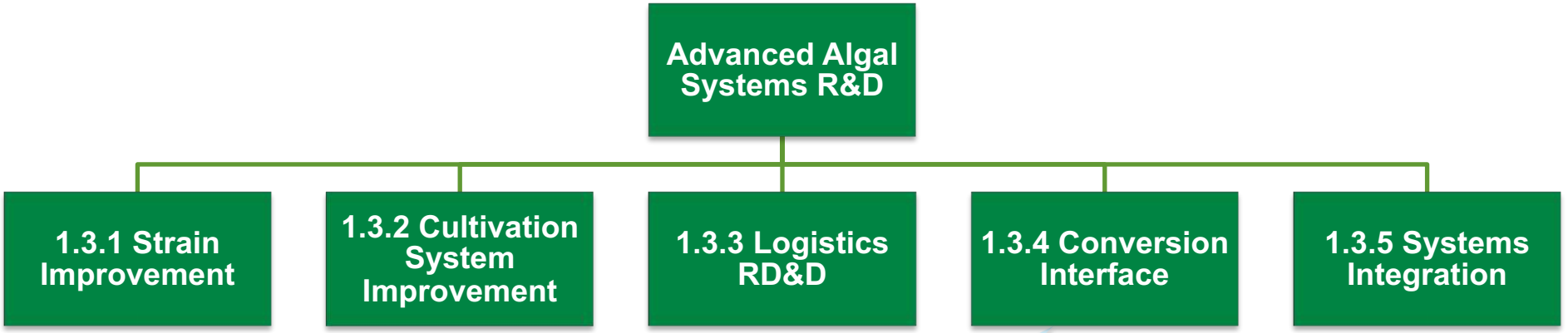
Algae R&D Strategy: Work Breakdown Structure



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

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

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Sandia National Laboratories

Photo courtesy of PNNL

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Algae R&D Strategy: Work Breakdown Structure

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

Global Algae Innovations

μBIO MicroBio Engineering

Algenol Biofuels

Duke University

School of Mines 1874 Colorado

ATP³ Algae Testbed Public-Private Partnership

ASU Arizona State University

Pacific Northwest National Laboratory

cellana

NREL National Renewable Energy Laboratory

The University of Arizona

RAFT Regional Algal Feedstock Testbed

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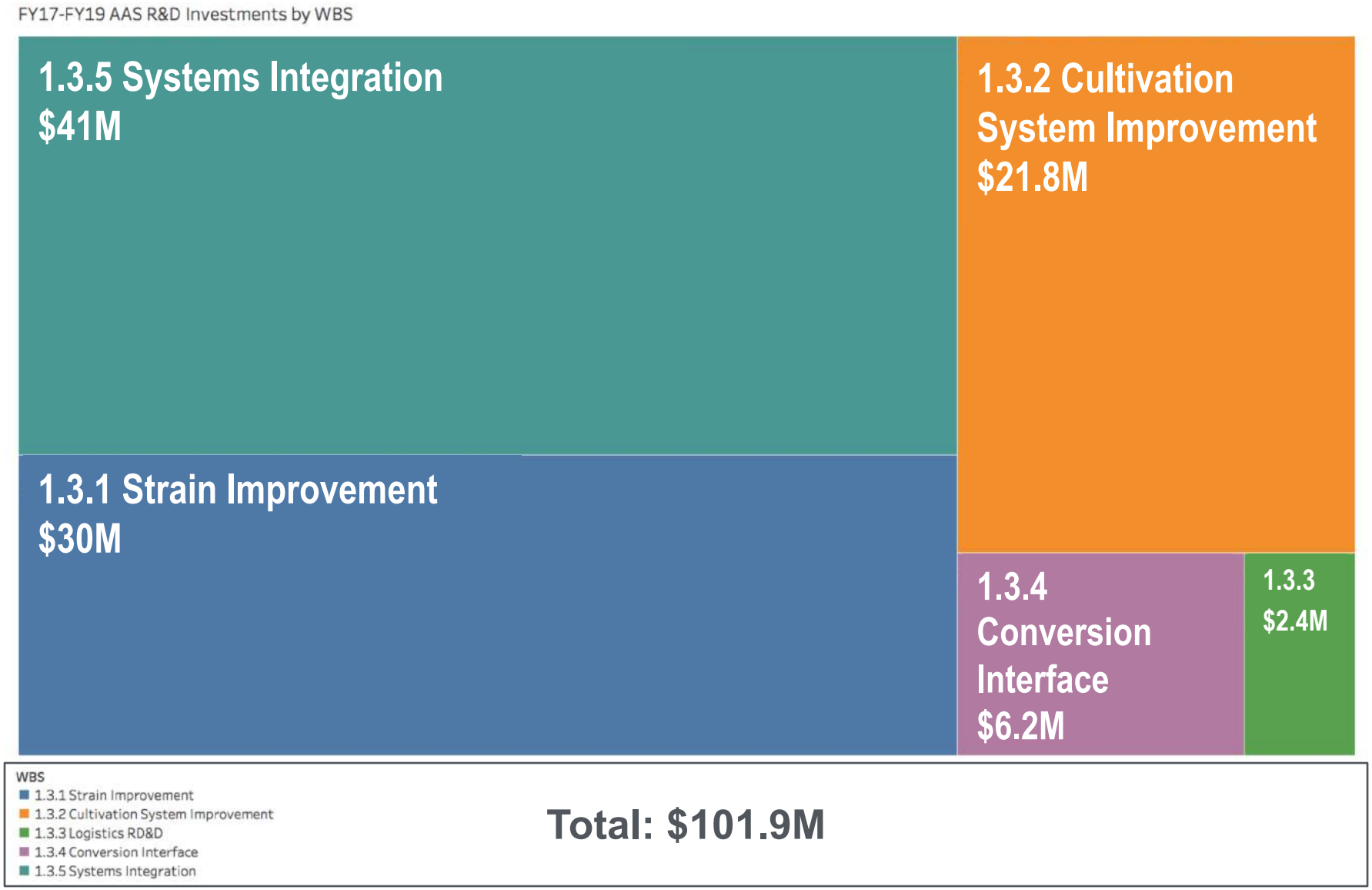
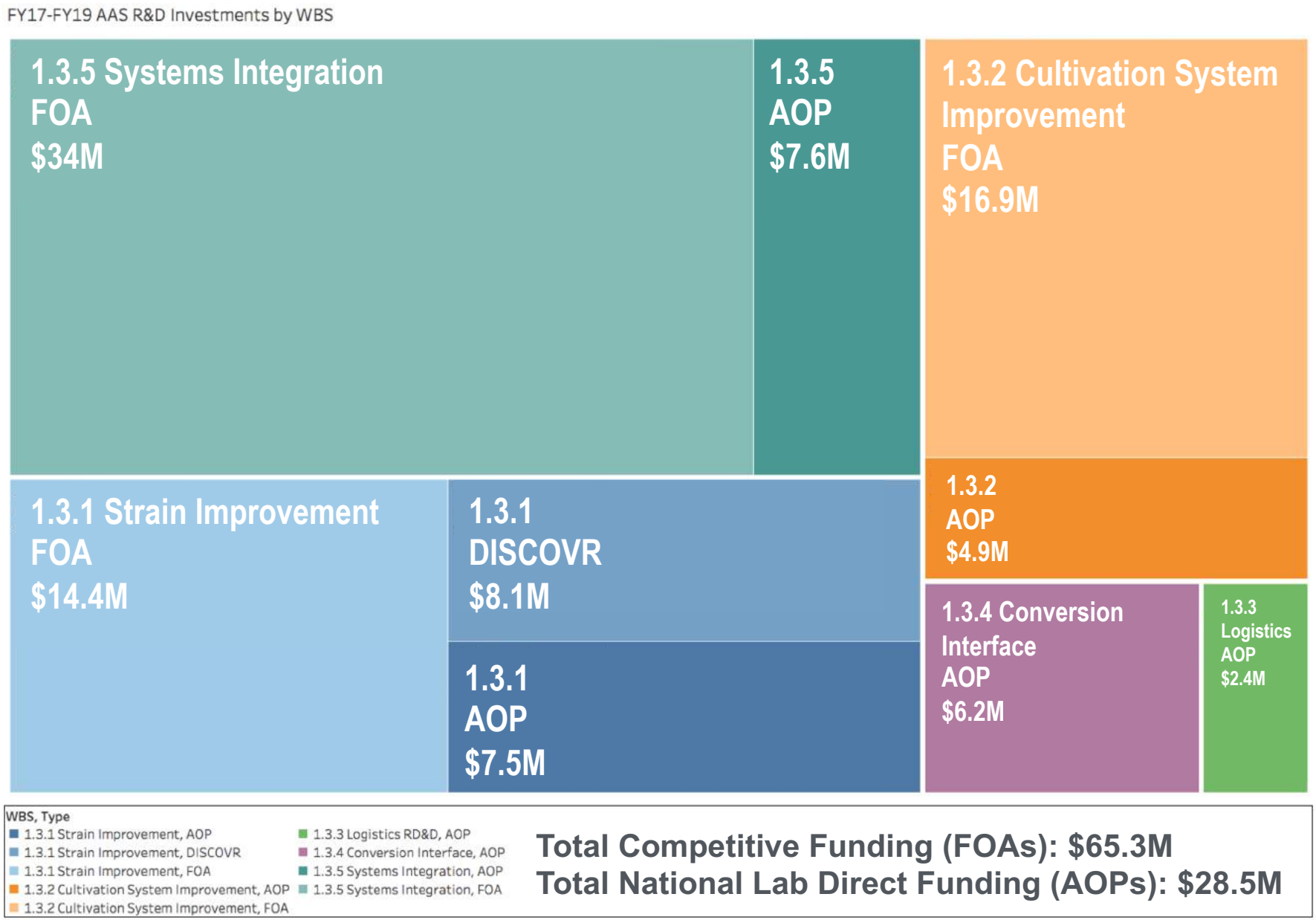
FY17 – FY19 Algae R&D Funding by WBS

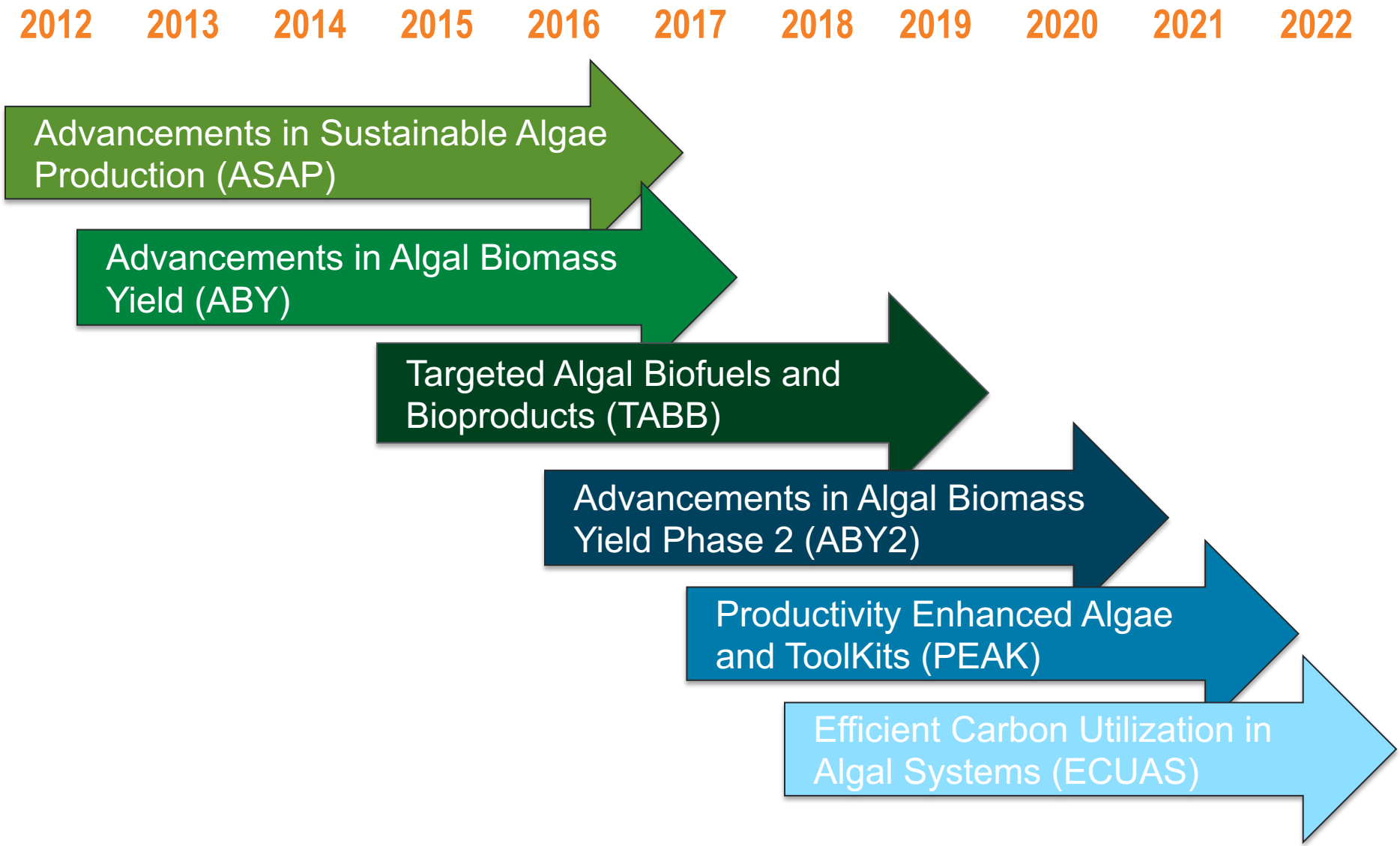


FY17 – FY19 Algae R&D Funding by Type



Total Competitive Funding (FOAs): $65.3M
Total National Lab Direct Funding (AOPs): $28.5M

Algae R&D Strategy: Competitive Funding



Efficient Carbon Utilization in Algal Systems (ECUAS) FOA

Up to $15 million to improve the efficiency of carbon utilization and productivity of algal systems through improving uptake and conversion of waste CO_2 emissions—such as from a power plant or industrial facilities—or through the development of new, affordable technologies to capture CO_2 directly from ambient air to enhance algal growth.

Topic Area 1 Carbon Dioxide Utilization Improvement

Colorado State University

ASU

Global Algae Innovations

Duke University

ASU

Topic Area 2 Direct Air Capture Systems

μBIO MicroBio Engineering

Georgia Tech

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Key Accomplishments

Advancing Strain Development Techniques

The Development of Integrated Screening, Cultivar Optimization, and Verification Research (DISCOVR) team released a rolling Call for Collaboration to solicit ideas, strains, tools, and techniques to help achieve BETO's aggressive technical and economic targets for algae bioenergy production.

Significant Biomass Yield Improvements

Projects in the FY16 Advancements in Algal Biomass Yield (ABY) 2 portfolio met a crucial milestone, demonstrating their ability to produce 3,700 gallons of biofuel intermediate per acre on average annually.

Workforce Development

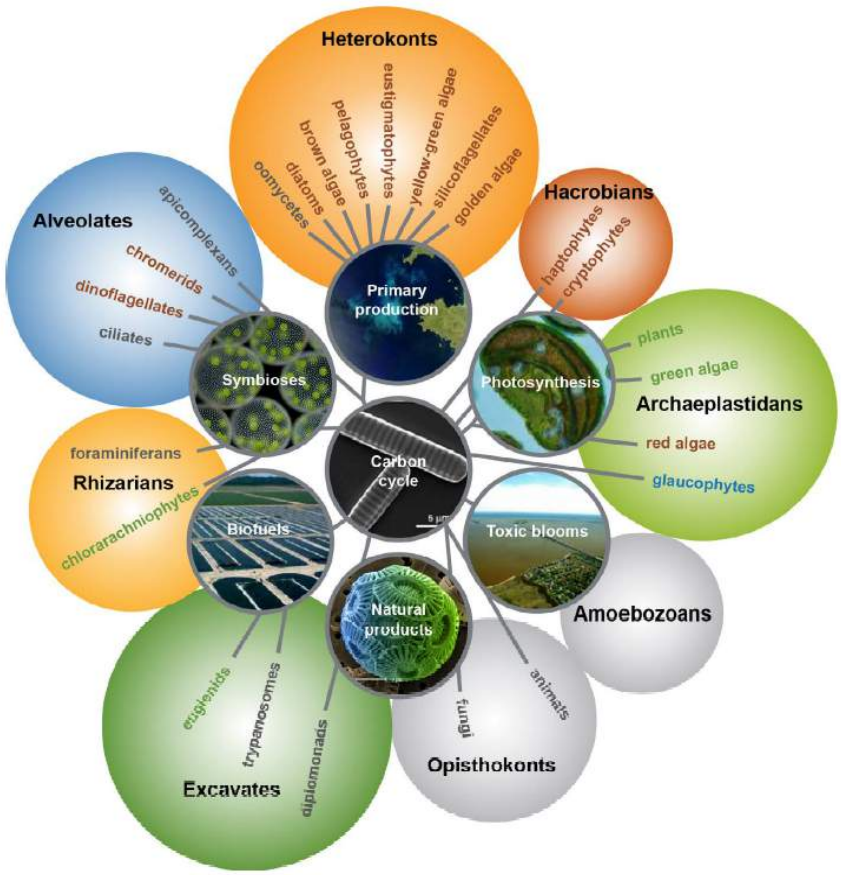
The Algae Technology Education Consortium (ATEC)'s first cohort graduated with an Algae Cultivation certificate in May 2018. Through algal education, students learn practical applications of farming and biotechnology, developing the skills for the next generation of algal-based jobs.

Communicating Results

The Regional Algal Feedstock Testbed (RAFT) published results on long-term algal cultivation trials that were conducted across a wide range of conditions. The Harmonization Report details a multi-lab effort to evaluate the potential for algal biofuels though combined models for TEA, LCA, and resource assessments.

Algae Inter/Intra-agency Collaboration

- **Algae Interagency Working Group**
  - Membership: NOAA, EPA, NSF, FDA, USDA, and DOE's ARPA-E, FE, and SC
  - Developing an internal draft 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.



FY19–FY20 Federal Support for Algae

- BETO's SBIR Phase I topic—Algae Engineering Incubator—provides $200k for a 1-year, Phase I award (applications due February 25). Potential for selection as a 2-year Phase II award for $1.1 million.

- Algal Production Systems is a FY19 research priority under USDA-NIFA's SBIR Phase I topic on aquaculture. Phase II applications due March 14.

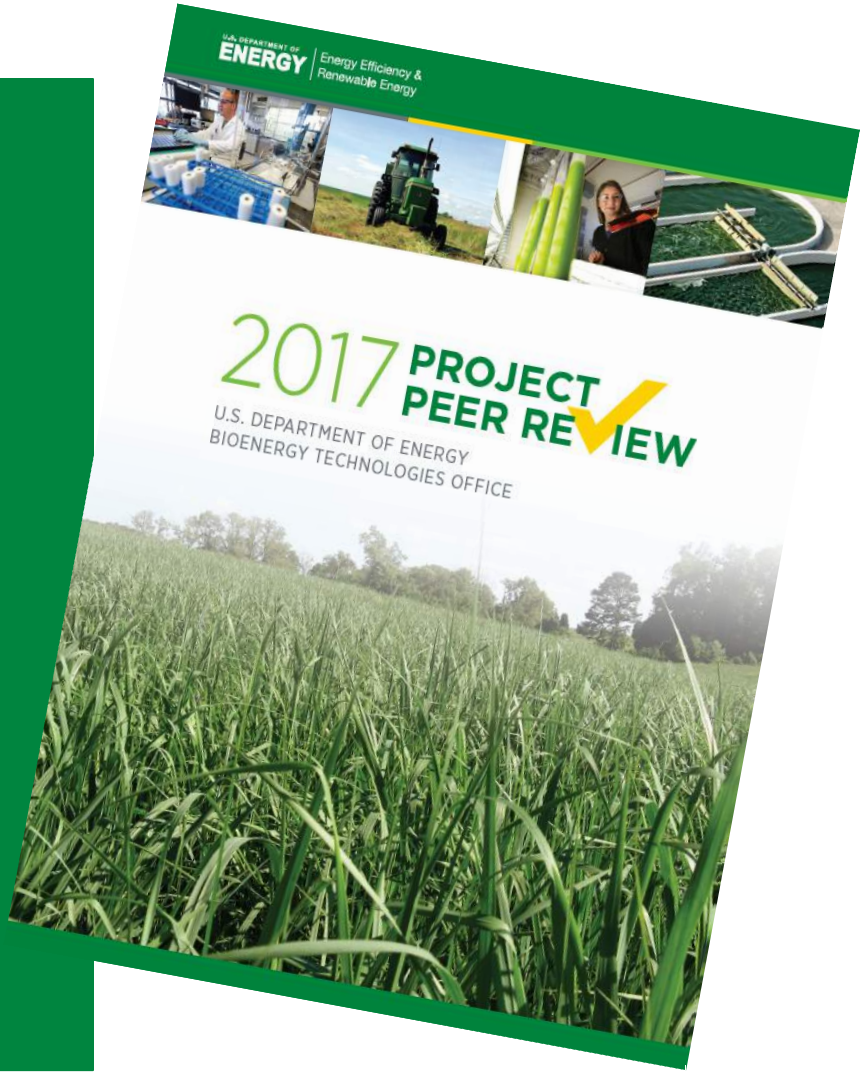
- The JGI Community Science Program Annual Call, supported by the Office of Science, includes Algal Genomics as an emphasis for sequencing. Letter of Intent (LOI) due April 11.

- The "Facilities Integrating Collaborations for User Science" (FICUS) Annual Call includes biofuels and bioproducts as a topic area, specifically including algae. LOI due March 20.

2017 AAS Peer Review

Key Recommendations:

- ✓ Increase connections with industry,
- ✓ Incorporate agronomy approaches, and
- ✓ Continue to focus on productivity.



Increasing Connections with Industry

2018 Advanced Algal Systems Listening Session Summary

Key takeaways include:

- Translating bench-scale research to outdoor cultivation practices is a challenge
- Improving productivity requires efficiency and integration of operations, not just biological strategies
- Incorporating practices from agriculture and aquaculture is an opportunity

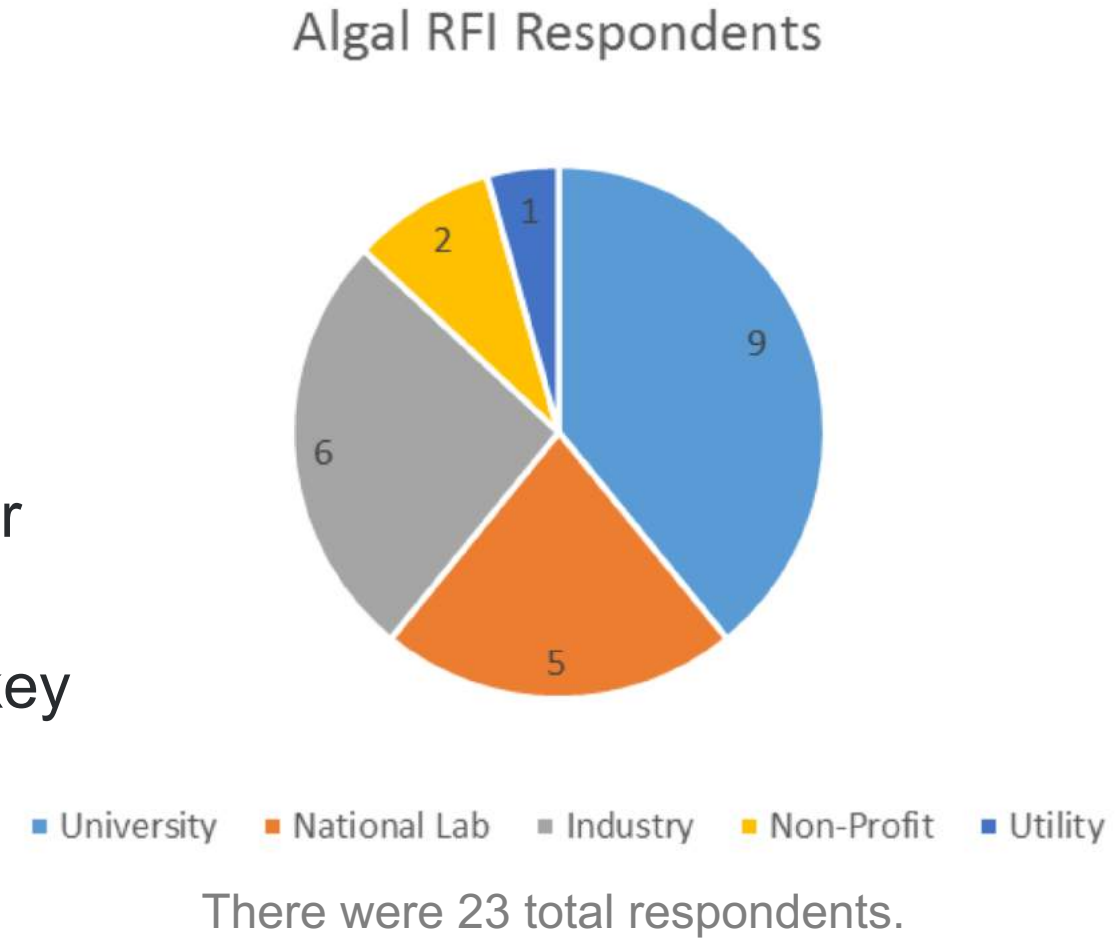
Arizona Center for Algae Technology and Innovation testbed facility at Arizona State University

Increasing Connections with Industry (cont.)

Request for Information (RFI)

Key takeaways include:

- Predators are a major threat to outdoor cultivation
- Outdoor condition variability needs greater control and monitoring
- Information sharing is key to developmental advances.



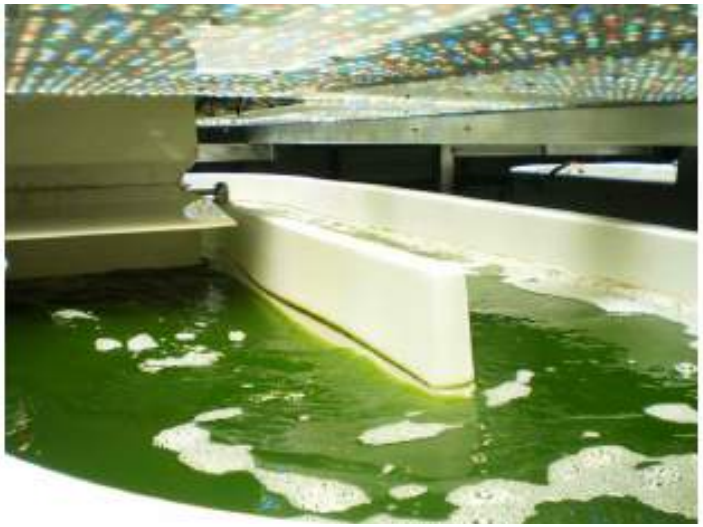
There were 23 total respondents.

Incorporating Agronomy Approaches

- Carbon Capture and Use
- Algae Agriculture Research Program
- Biomass Crop Assistance Program
- Biobased Markets Program (BioPreferred)
- Biorefinery Assistance (9003 Loan Guarantee) Program
- Crop Insurance

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



PNNL Pond Environmental Simulators, RAFT Final Technical Report

ARID Cultivation System, RAFT Final Technical Report

Peer Review Panel

- **Toby Ahrens**, Larta Institute (Lead Reviewer)
- **Louis Brown**, Synthetic Genomics
- **Michelle Legatt**, Patagonia
- **Jose Olivares**, Elsevier & Biologic Energy Partners
- **Becky Ryan**, Indigo Agriculture

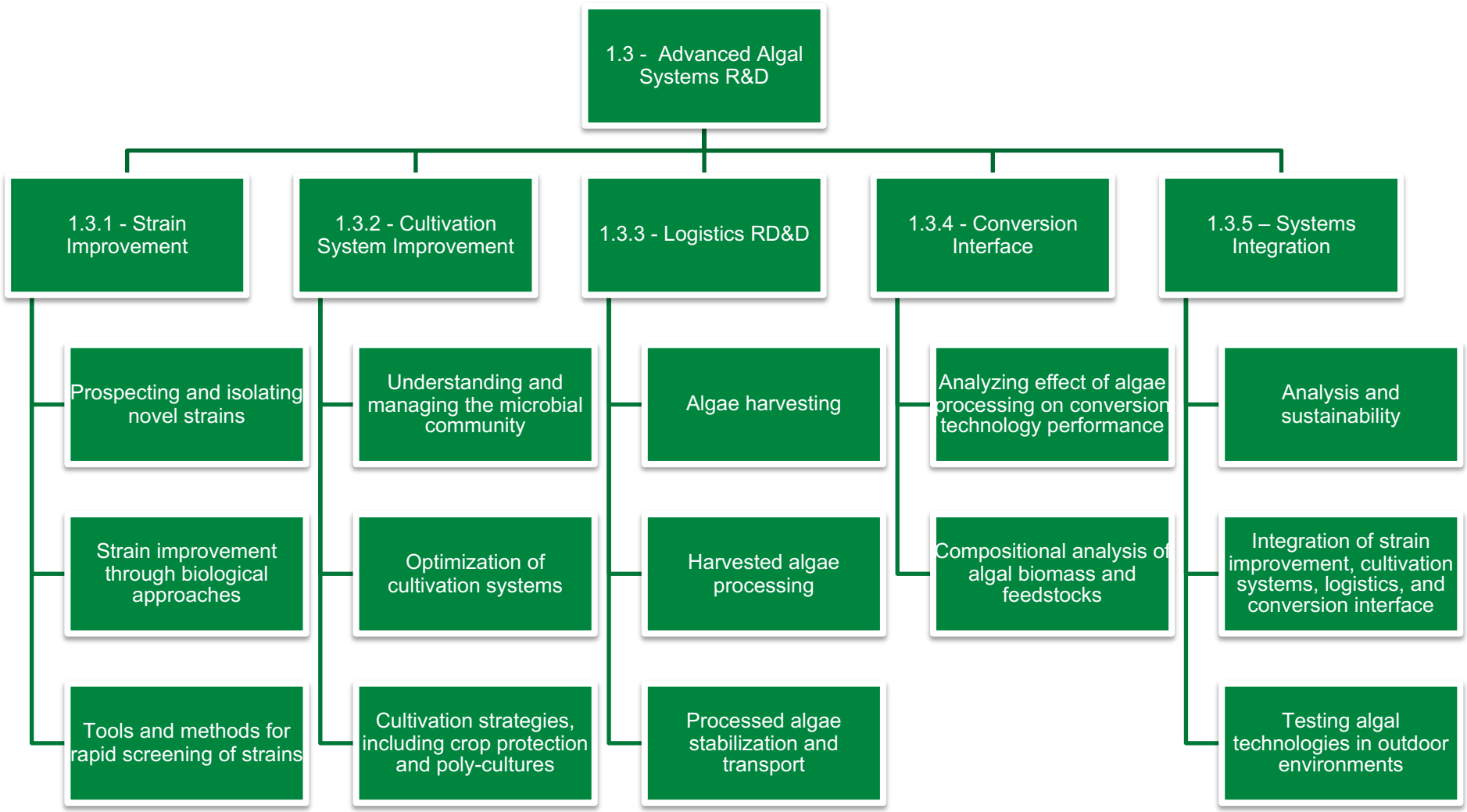




THANK YOU, REVIEWERS!

Appendix

Algae R&D Strategy: New Work Breakdown Structure

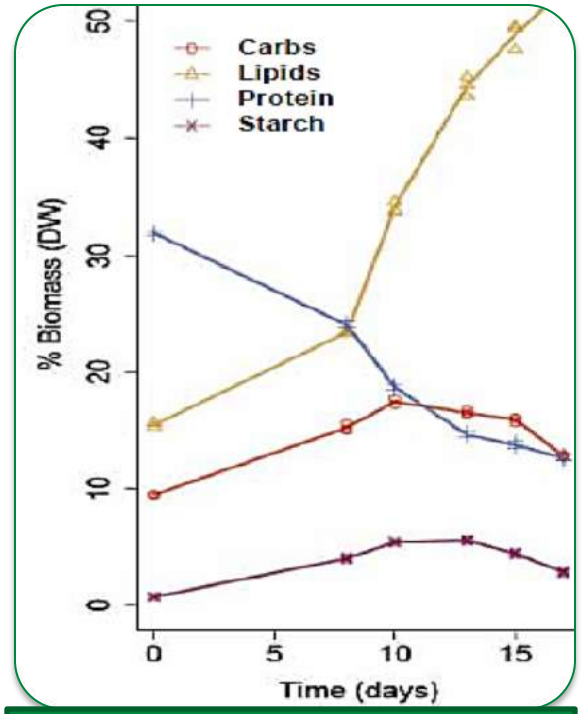


AAS R&D Priorities

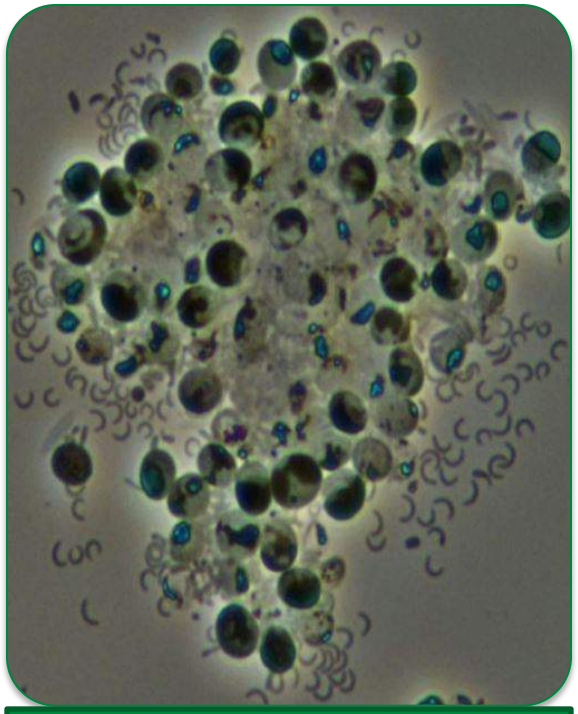
Addressing key barriers to the development of algal feedstocks: cost, quality, and volume of available, sustainably-grown biomass.

Enhanced Productivity

ARID with paddle wheel,
RAFT final report



Feedstock Quality



Robust Yields

Bacterial infected N. salina
Lee et al., 2018

Feedstock Quality

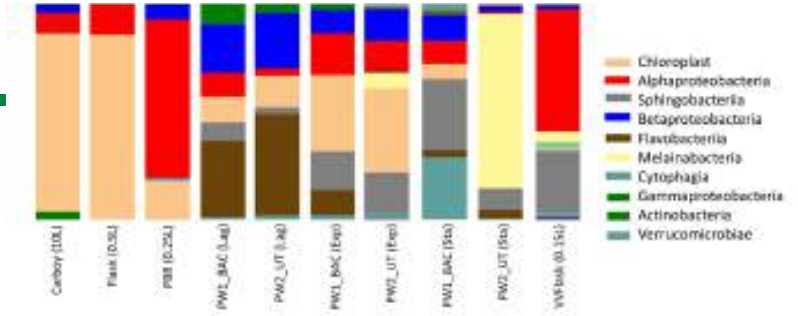
- Developing low-cost, scalable **cultivation systems** and approaches that maximize reliable annual biomass yield and quality and minimize energy use, water consumption, land use, and nutrient additions
- Developing **higher-value coproducts** that can be produced and recovered along with biofuel intermediates
- Developing **integrative approaches** to strain improvement, cultivation, harvesting, and conversion interfaces that produces biomass with a biochemical composition and materials properties that increases biofuel yields and conversion efficiency at the biorefinery

Zobi harvester and effluent streams, GAI

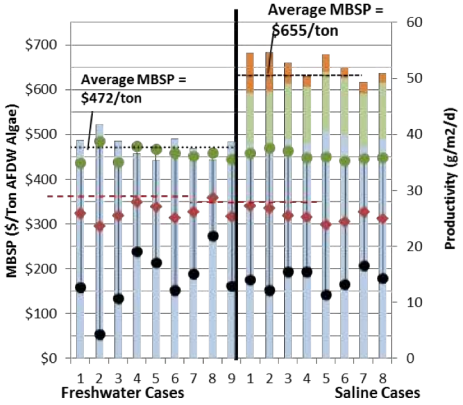
Undergraduate students at UCSD determined how to chemically change the oil from laboratory algae into different kinds of “polyols” to produce the core of the algae surfboard. Credit: Erik Jepsen, UC San Diego

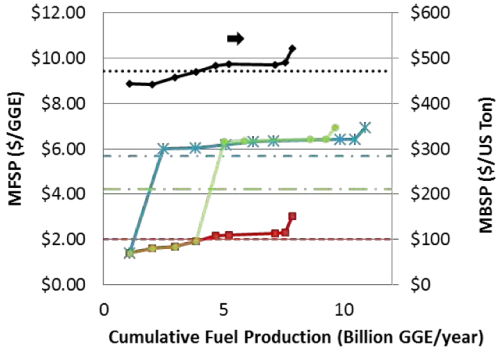
Robust Yields

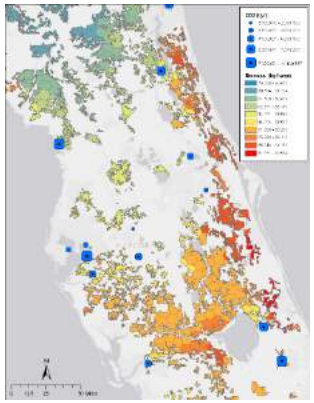
- Developing biology and culture management approaches to **stabilize cultivation and reduce yield losses**
- Performing integrative analysis to evaluate impacts on overall yield and **identify critical barriers** to developments in biology, cultivation, and processing
- Verifying feasible routes and developing rigorous models to **understand the economic and environmental parameters** for algal biomass and biofuel intermediate production

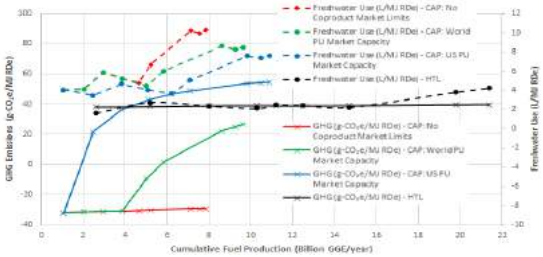


Taxonomic Distribution of Bacteria Phycosphere members, RAFT Final Technical Report









Modeling of minimum biomass and fuel selling prices, resource assessment, and life cycle assessment, 2017 Harmonization Report