

Overview of the Algae Program

Renewable Carbon Resources Overview

Daniel Fishman, Technology Manager

April 3, 2023



Feedstock



Algae



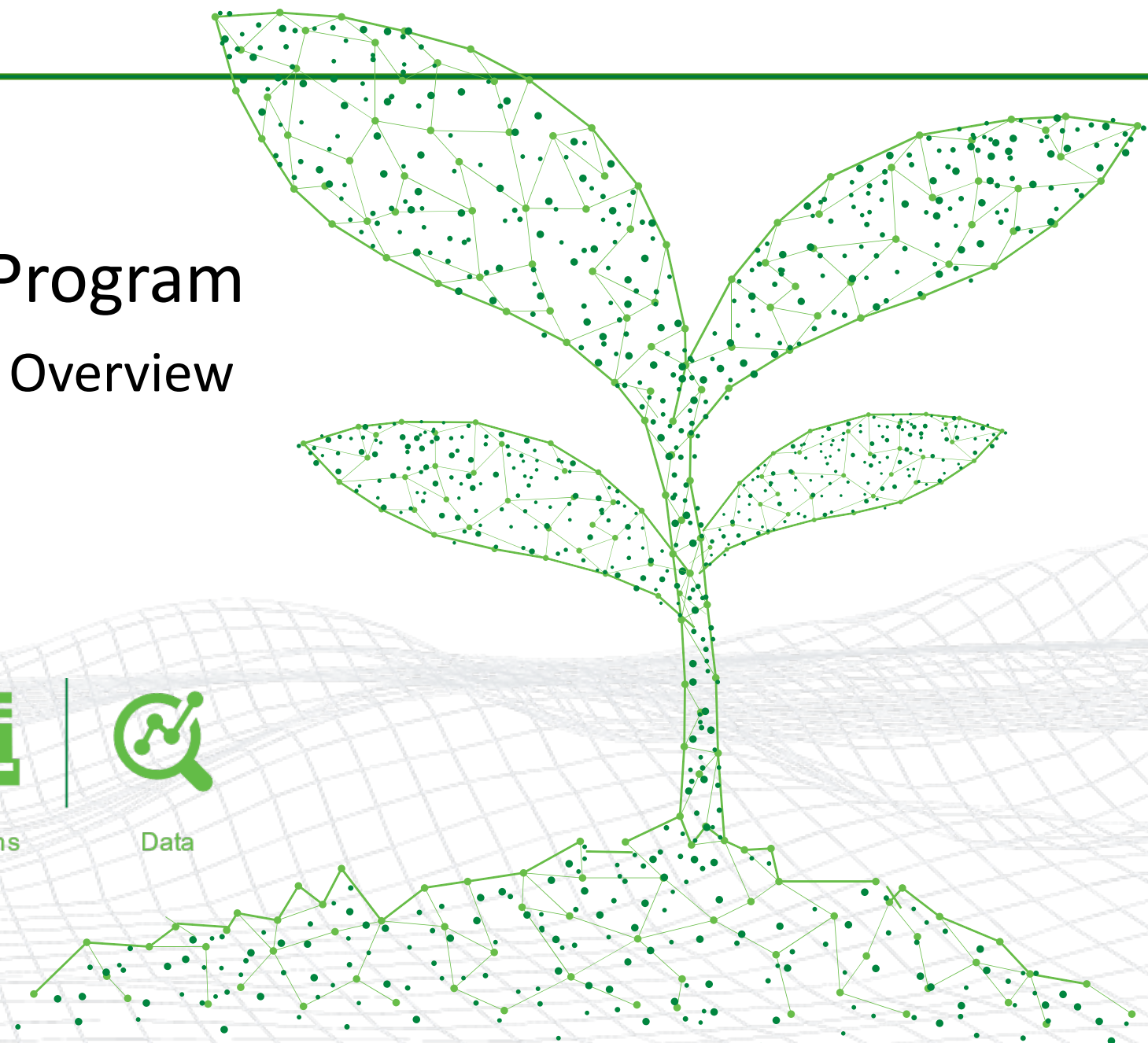
Conversion



Systems

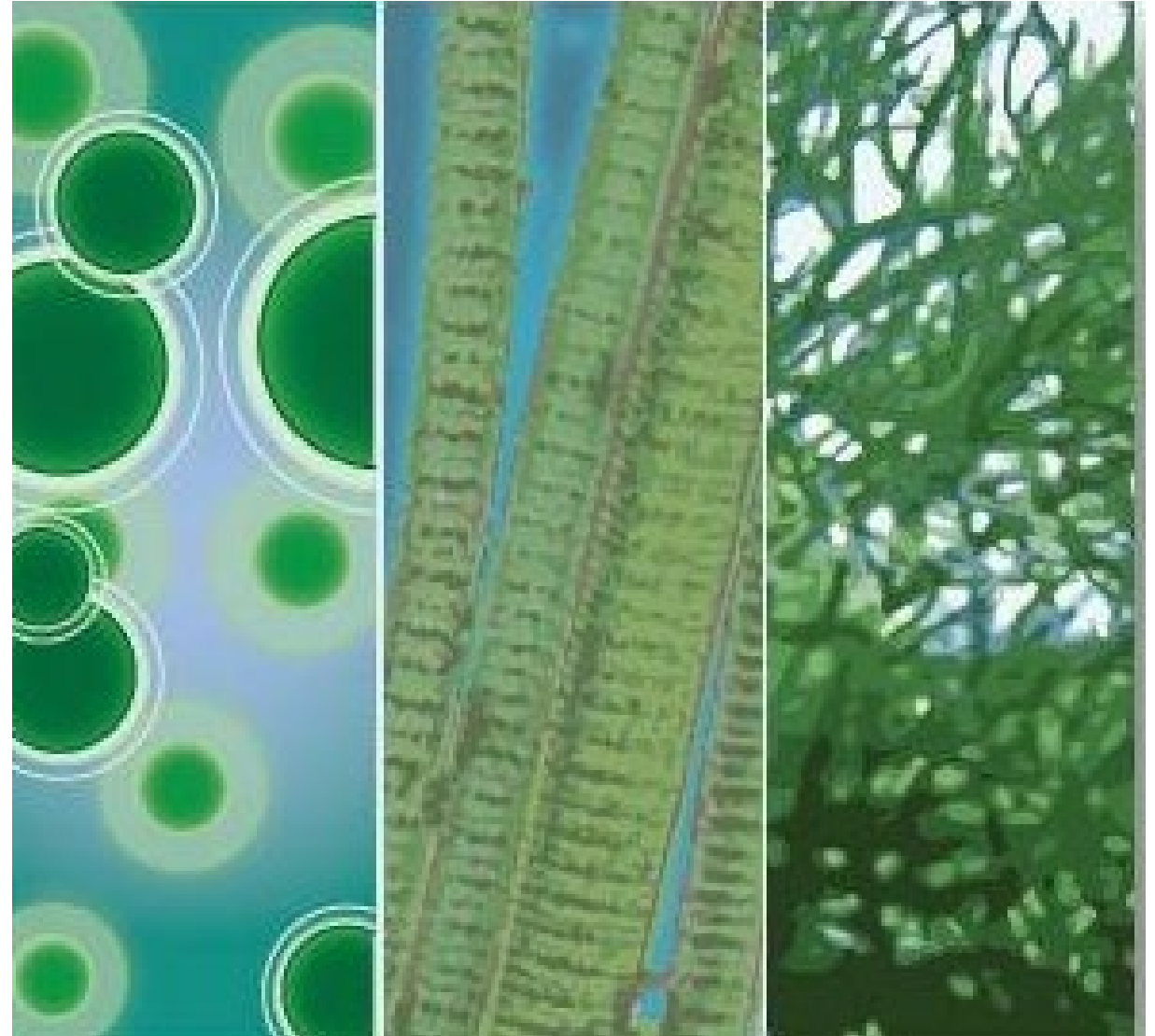


Data



Agenda

- **BETO Team**
- **Reviewers**
- **Technology Area Strategy**
 - Goals
 - Approach
 - Portfolio
 - Engagement
- **Technology Area Progress**
 - Active Management
 - Recent Successes
 - Future Plans



Renewable Carbon Resources (RCR) – Algae Team



Nichole Fitzgerald
Program Manager



Dan Fishman
Technology Manager



Christy Sterner
Technology Manager



Liz Burrows
Technology Manager



Annie Otwell
AAAS Fellow



Jamie Meadows
Project Monitor



Phil Lee
Project Monitor



Frank Fields
Project Monitor



Ty Robinson
Business Support

Reviewer Introductions: Cultivation and Strains

- Lead reviewer: Dr. Tyler Johannes, Professor at University of Tulsa
- Dr. Ify Iwuchukwu, Director, Pilot Plant at Oxford Biomedica Solutions, LLC
- Dr. Kalyani Maitra, Associate Professor at Fresno State University
- Dr. Laura Carney, Former Director of Ag Sciencee at Heliae



THANK YOU, REVIEWERS!

Reviewer Introductions: Integration

- Lead reviewer: Dr. Lora Cameron-Landis, Associate Director of Upstream Process Development and Manufacturing at Eli Lilly
- Valerie Harmon, President and CEO at Harmon Consulting, Inc
- Dr. Mark Jones, Dow (retired)
- Dr. Paul Roessler, Algenol (retired)



THANK YOU, REVIEWERS!

Agenda overview for BETO

Panel A = Cultivation and Strains, Panel B = Integration

		Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Room 7	Room 8
Monday		Plenaries							
	Morning								
	Afternoon	Algae A	Algae B	FT	DMA	ABF	SDI A	SDI B	PABP
Tuesday									
	Morning	Algae A	Algae B	FT	DMA	ABF	SDI A	SDI B	PABP
	Afternoon	Algae A	Algae B	FT	DMA	ABF	SDI A	SDI B	PABP
Wednesday									
	Morning			FT	DMA	ABF	SDI A	SDI B	PABP
	Afternoon			FT	DMA	ABF	SDI A	SDI B	PABP
Thursday	Plenary	Plenaries							
	Morning								
	Afternoon	OW	FCIC			CO2	BC/Lignin	CatUp	PABP
	Afternoon	OW	FCIC			CO2	BC/Lignin	CatUp	PABP
Friday									
	Morning	OW				CO2	BC/Lignin	CatUp	
	Afternoon						BC/Lignin	CatUp	

Algae Session: 32 projects

Algae session themes at a glance

Monday 4/3/23

Plenary

Tuesday 4/4/23

Cultivation and
Strains

Integration

Lunch!

Cultivation and
Strains

Integration

Cultivation and
Strains

Integration

Algae is a key feedstock for BETO with potential to decarbonize multiple sectors

- Transportation: Algae is primed to contribute to Sustainable Aviation Fuel (SAF) goals
- Industry: Valuable co-product potential from algae including bioplastics, pharmaceuticals, nutraceuticals, hydrocolloids, alternative protein



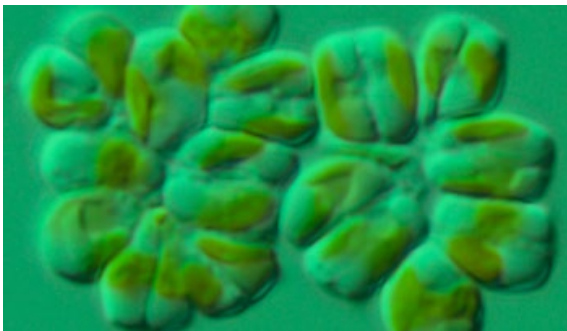
Algae jet fuel powered the first revenue passenger flight in the U.S. in 2011

Renewable Carbon Resources Algae R&D Focus

Strategic Objective: *Develop technologies to mobilize renewable carbon resources to enable the production of biofuels and bioproducts.*

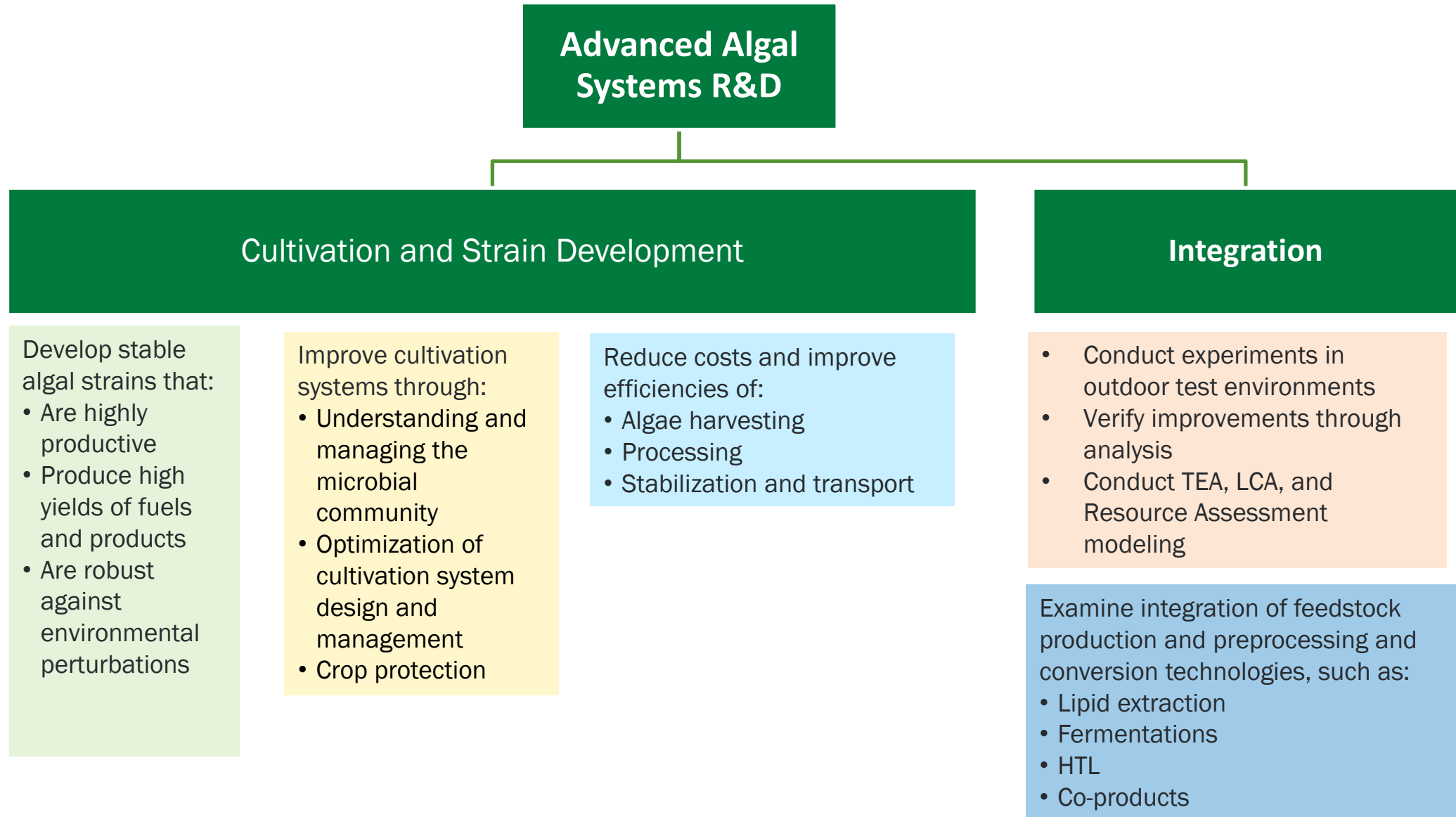
Strategic Approach:

- *Develop low-cost, reliable feedstock supply systems from the entire range of biomass and wastes*
- *Develop waste utilization and environmental remediation strategies*
- *Develop carbon management strategies including soil carbon storage and carbon drawdown*



BETO is funding a broad portfolio of algal research and development

Program Structure



National Laboratory Core R&D

Annual Operating Plans

- EERE is committed to funding multi-year project plans
- Release lab calls with research areas of interest
- Plans include Go/No-go decisions in 12-18 month period
- Reviewed externally

FY2022 Lab Call: LC000009

First year of forward funding

Objective - to develop science-based strategies and technologies to produce high quality algae to generate cost effective biofuels and bioproducts.

AOI1: Strain and Cultivation Development Tools: To build-out foundational knowledge, methods, and tools for algae strain and/or cultivation development.

AOI2: Alternative algae cultivation strategies (e.g. turf or attached growth): Development of periphytic algae cultivation technologies, such as turf scrubber technology, that leverage environmental services to grow or access algae without exogenous inputs.

AOI3: Carbon, nitrogen and phosphorus balances and the interface between cultivation and conversion: Develop new cost-effective, low GHG technologies for converting algae biomass to fuels and/or products and/or b) advance the SOT of resource recycling in advanced algal systems, thereby improving the economics of algae cultivation operations not explicitly related to biological productivity and yield improvements.

AOI4: Integrative analysis to quantify the technoeconomic and GHG effects of algae technology deployment: Interested in better integrating the annual reporting of SOT and Supply Chain Sustainability Analysis results and the delivery of additional TEA and LCA analyses from its current state as 2 separate pathways into a more unified framework.

Total FY21 AOP Funding	Continuing AOPs FY22	FY22 Lab Call for next phase/New projects	FY22 Project duration
\$12,400,000	\$7,410,000	\$5,000,000	1-3 years

FY2023 Lab Call: LC0000015

Objective - development of technologies for the cultivation and conversion microalgae, macroalgae, and cyanobacteria to biofuels (SAF and bioproducts); and educate and train the workforce, as well as provide training and collaboration within the existing workforce, particularly in underserved, disadvantaged, and rural communities.

AOI1: DISCOVER: strain development for improved carbon capture and utilization efficiency; harvesting and water/media recycle; improved translation between indoor and outdoor experimentation and results; improved biomass composition for production of SAF; and pest monitoring and crop protection strategies.

AOI2: Algae Technology Educational Consortium: develop novel educational programs to strengthen industry workforce capabilities while addressing the Program’s goals on workforce development and diversity, equity, and inclusion.

AOI3: Open topic, including macroalgae R&D and environmental services: advance fundamental algae research that supports the development of sustainable, cost-effective fuels and/or products.

Continuing AOP budget*	FY23 Lab Call for new projects	Total FY23 AOP budget	FY23 Project duration
\$1,000,000	\$15,000,000	\$16,000,000	1-3 years

*Estimated Funding on FY23 AOPs not being merit-reviewed as they were merit-reviewed in FY21-22.

Competitive Funding

- The Program offers financial assistance 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
- BETO financial assistance requires at least 20% recipient cost share by law

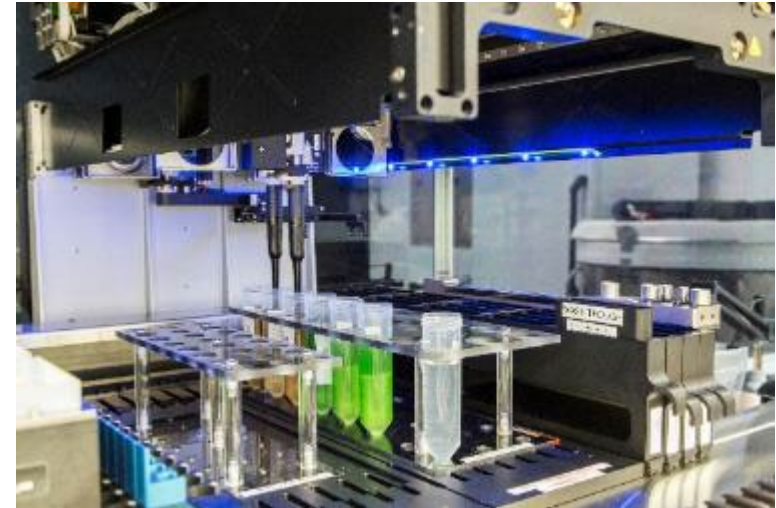
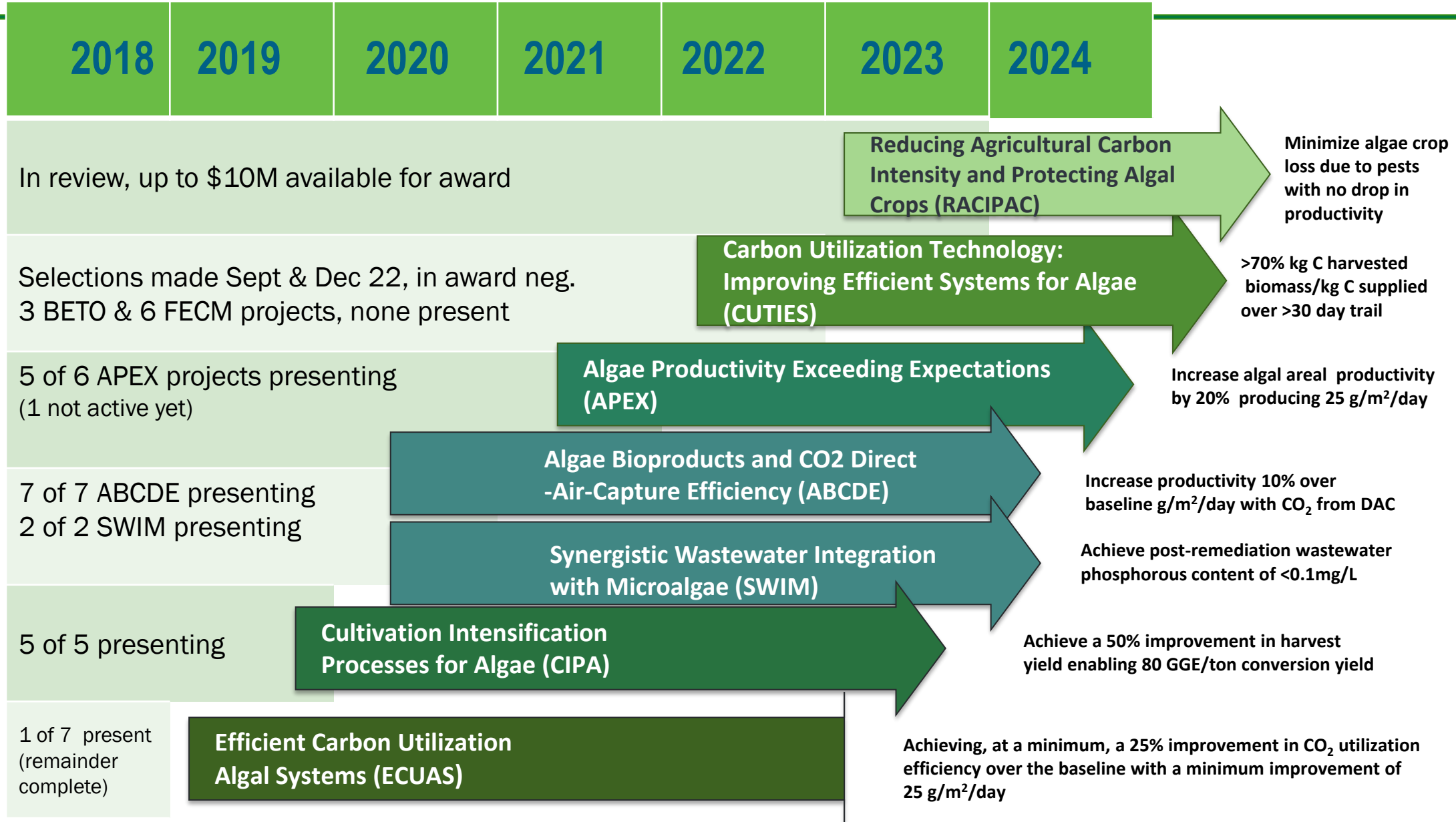


Photo courtesy Global Algae Innovations



University of Arizona's RAFT testbed in Tucson, AZ

Funding Opportunity Announcements



Efficient Carbon Utilization in Algal Systems (ECUAS)

FY2018: DE-FOA-0001908

Objective - 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.



Federal \$\$ Per Award	Total Federal Funding	Award Duration	Cost Share (%)
\$1.5 - \$2.5M	\$15M	3 years	20%

Cultivation Intensification Processes Algae (CIPA)

FY2019: DE-FOA-0002029

Objective - Develop technologies for outdoor algae systems that increase the harvest yield, robustness, and quality of algae cultivation for biofuels and bioproducts.



Federal \$\$ Per Award	Total Federal Funding	Award Duration	Cost Share (%)
\$3M - \$5M	\$15.5M	5 years	20%

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

FY2020: DE-FOA-0002203

Objective - Improve algal feedstock quality for algae grown using CO₂ captured from the air (i.e., DAC). Successful projects will capture CO₂ 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.



Federal \$\$ Per Award	Total Federal Funding	Award Duration	Cost Share (%)
\$1M - \$2M	\$14M	3 years	20%

Synergistic Wastewater Integration with Microalgae (SWIM)

FY2020: DE-FOA-0002203

Topic 2C: Synergistic Wastewater Integration with Microalgae (SWIM)

Objective - 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.



Federal \$\$ Per Award	Total Federal Funding	Award Duration	Cost Share (%)
\$1M - \$2M	\$18.5M	3 years	20%

Algae Productivity Exceeding Expectations (APEX)

FY2021: DE-FOA-0002423

Objective - 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 (CO₂) supply
- Topic Area 2: Improvements in productivity with Direct Air Capture (DAC) of CO₂ from ambient air



Federal \$\$ Per Award	Total Federal Funding	Award Duration	Cost Share (%)
\$2.5M - \$3.2M	\$20M	3 years	20%

Carbon Utilization Technology: Improving Efficient Systems for Algae (CUTIES)

FY2022: DE-FOA-0002654

Objective - Develop technologies that increase carbon utilization efficiency of algal growth systems that use carbon dioxide sourced from fermentation (e.g., ethanol production), biogas purification (e.g., CO2 removed from anaerobic digestion or landfill gas collection), or directly from the atmosphere to lower costs and improve the GHG reduction potential of fuels.



Federal \$\$ Per Award	Total BETO Funding	Award Duration	Cost Share (%)
\$2M - \$3M	\$9M	3 years	20%

Algae program 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

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.

2022 11 month* avg productivity: >19g/m²/day

Summer productivity: 29 g/m²/day

2.2x improvement in annual average productivity over 2015 baseline

47% decrease in MBSP over baseline
2022 projection at \$602 ton on way to
2030 target (\$488/ton)

**Cultivation up time assumed at 330 days*



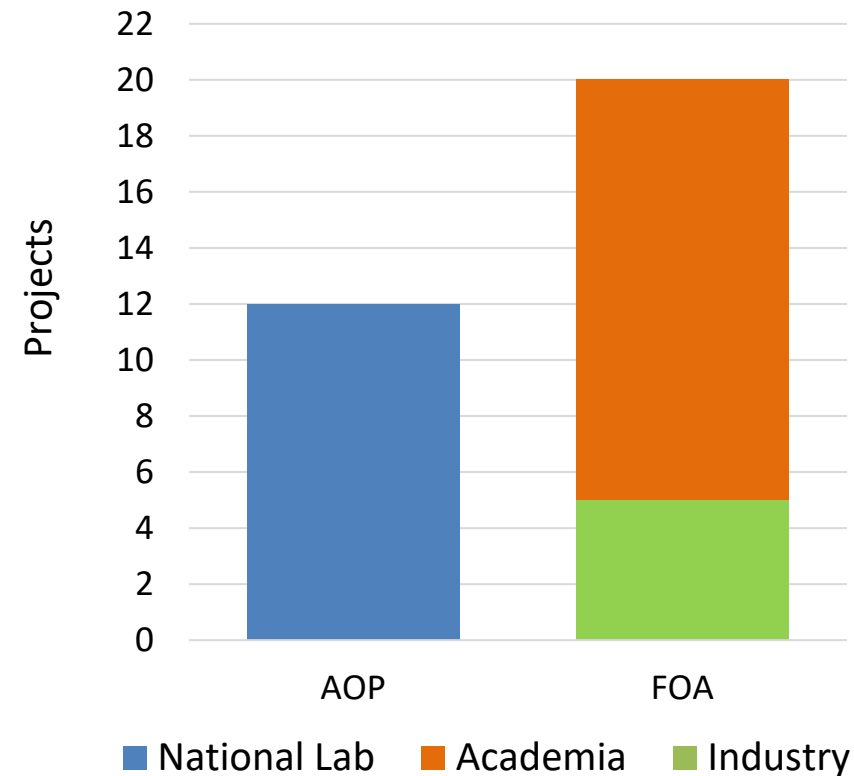
Algae cultivation; Arizona Center for Algae Technology and Innovation



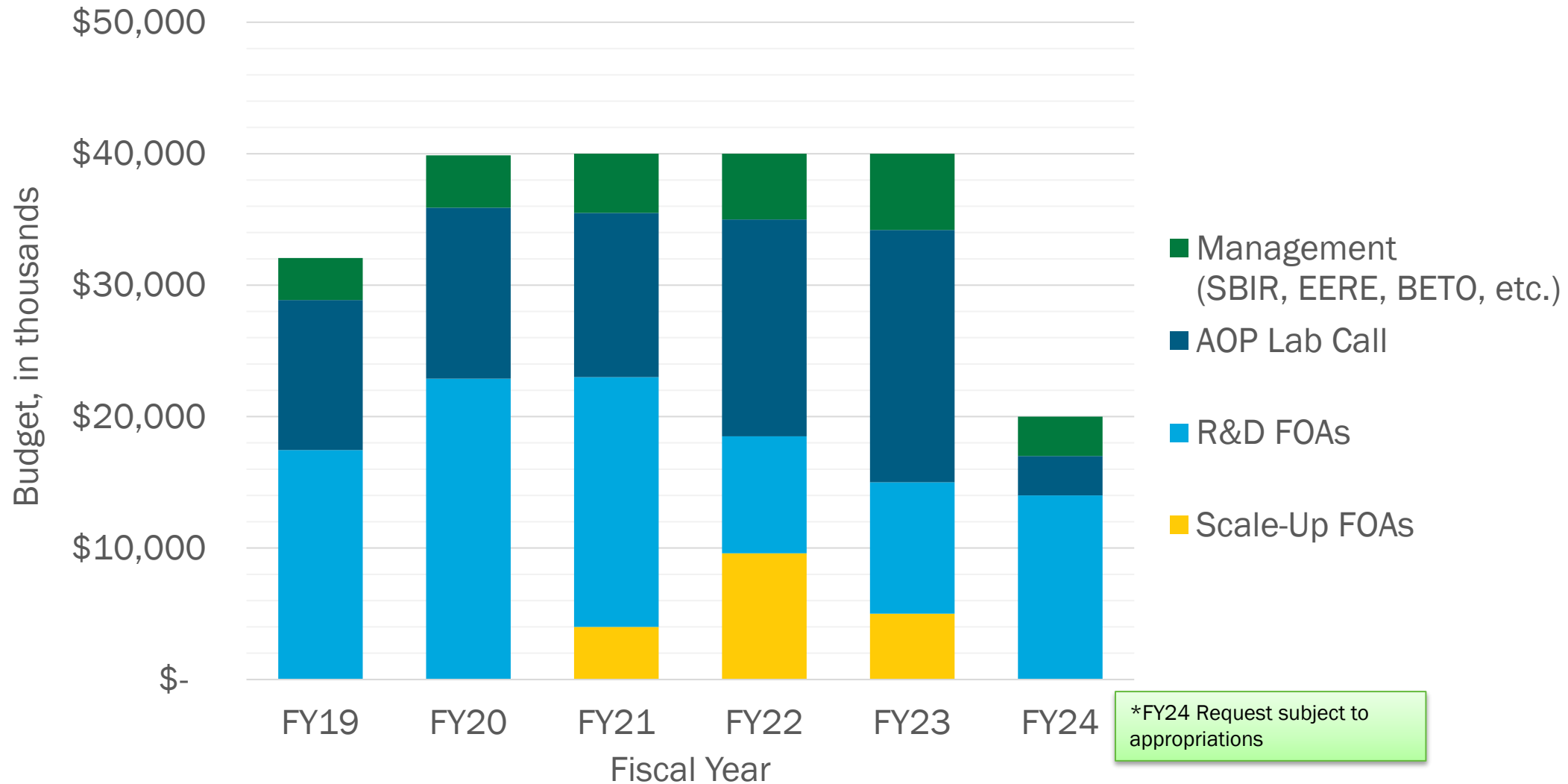
Algae portfolio: 2023 project breakdown

- 32 Projects will be reviewed
 - Cultivation and strains 14
 - Integration 18
- 2 types of projects
 - National Laboratories
 - Competitive awards

Funding type and prime recipient



Budget



Barriers to Scale: Algae Crop Protection Workshop

- 2 day workshop in April 2021
- Keynotes from Agriculture and Macroalgae experts
- 4 panel discussions on algal crop protection topics
- Presentations and summary online:
<https://www.energy.gov/eere/bioenergy/events/barriers-scale-algae-crop-protection-workshop>
- Report published:
<https://www.energy.gov/eere/bioenergy/articles/barriers-scale-algae-crop-protection-workshop-summary-report>
- FY23 DE-FOA-0002910 Topic Area 2



Reducing Agricultural Carbon Intensity and Protecting Algal Crops (RACIPAC)

DE-FOA-0002910

- **Topic Area 1: Climate-Smart Agricultural Practices for Low Carbon Intensity Feedstocks**

Assess the efficacy of climate-smart agricultural practices that reduce the carbon intensity (CI) of biomass feedstocks for biofuels.

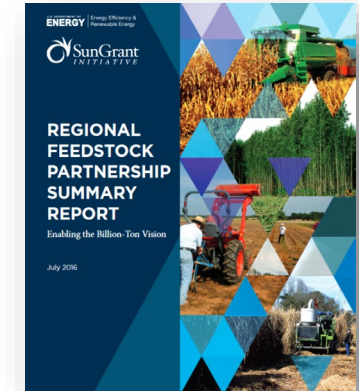
- Subtopic Area 1a: Climate-Smart Agricultural Practices to Produce Low CI Feedstocks Derived from Agricultural Residues
- Subtopic Area 1b: Biochar Strategies to Increase Soil Carbon Levels and Agronomic Benefits of Crops for Energy Production

- **Topic Area 2: Algae Crop Protection**

Develop crop protection methods and strategies for algae cultivation systems to maintain robust productivity. Protecting algal biomass production is essential to meeting BETO's long-term goals of decarbonizing the transportation and industrial sectors via cost competitive algal-derived biofuels and bioproducts.

Concept papers were due on March 20th, final applications are due May 16th, and selections are expected to be made in August 2023

Advancing the Regional Feedstock Partnership



Save the date!
June 6-7, 2023
Kansas City, MO

Purpose-grown energy crops will play an important role in meeting the 2050 SAF volumetric goals

Workshop to develop the vision for a next iteration of the RFP
Share ideas, find collaborators, shape the vision of this important initiative!

Thank you!



Additional slides for reviewers

Project Review Criteria

The reviewers will be asked to provide a score for each of the four equally weighted criteria listed below:

1. Management
2. Approach
3. Impact
4. Progress and Outcomes

The average scores from the review panel will be featured in the Final Peer Review Report.

Note the scores are from 1: Unsatisfactory to 5: Outstanding

Overall Impressions

The reviewers will also then be asked to provide a written assessment of the project based on the above criteria. These comments should provide adequate rationale for each score.

Please note that these comments will be featured in the Final Peer Review Report.

Project Review Criteria

1. Management

Please evaluate the degree to which:

- The project performers have clear management plan and successful implementation strategy which includes risk identification and mitigation strategies; and
- The project provides routes for communication and collaboration with related projects and/or advisory boards, if appropriate.

2. Approach

Please evaluate the degree to which:

- The project performers have developed an approach with substantial merit to advance the state of the art, as relevant to the defined BETO Program and Technology Area goals; and
- The project performers have developed an approach with significant potential for innovation in its application.

Project Review Criteria

3. Impact

Please evaluate the degree to which:

- The project demonstrated a clear connection of project approach to the potential for significant impact and outcomes; and
- The project has clear commercialization potential or has used or plans to use industry engagement to guide project deliverables, as relevant.

4. Progress and Outcomes

Please evaluate the degree to which:

- The project has made appropriate progress towards addressing the project goal(s); and
- The accomplishments have been achieved on schedule with the planned approach, and if relevant, the risk mitigation strategies have been employed to maintain project progress.

Project Scoring Rubric

Outstanding	Good	Satisfactory	Marginal	Unsatisfactory
5	4	3	2	1
All aspects of the criterion are comprehensively addressed. There are significant strengths and no more than a few—easily correctable—weaknesses.	All aspects of the criterion are adequately addressed. There are significant strengths and some weaknesses. The significance of the strengths outweighs most aspects of the weaknesses.	Most aspects of the criterion are adequately addressed. There are strengths and weaknesses. The significance of the strengths slightly outweighs aspects of the weaknesses.	Some aspects of the criterion are not adequately addressed. There are strengths and significant weaknesses. The significance of the weaknesses outweighs most aspects of the strengths.	Most aspects of the criterion are not adequately addressed. There may be strengths, but there are significant weaknesses. The significance of the weaknesses outweighs the strengths.