NREL
NATIONAL RENEWABLE ENERGY LABORATORY





Bioenergy Technologies Office (BETO)
2017 Project Peer Review

Algae Technology Educational Consortium (ATEC)

March 8, 2017
Advanced Algal Systems

Ira “Ike” Levine, Principal Investigator (Algae Foundation, University of Southern Maine [USM])
Cindy Gerk, Principal Investigator (National Renewable Energy Laboratory [NREL])

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Goal Statement: Fill Jobs with Skilled Techs

Goal: Educate the next generation of skilled algal technicians to fill the ~12,000 U.S. job openings by 2021 (ATEC phase I jobs survey) to support algal commercialization by creating the Algae Technology Educational Consortium (ATEC) degree program.

Outcomes: Develop, implement, and democratize the *first-of-a-kind,* community college, algal-based degree program.

Relevance: Support algal industry growth (supplemental slides) through the ATEC Community College Degree Programs, which will provide trained graduates who "will support the development of a more robust bioeconomy, which can create green jobs, spur innovation, improve the environment, and achieve national energy security." (DOE 2015 Bioenergy Technologies Incubator 2 award statement).

Quad Chart Overview

Timeline

- Start date: 10/1/15
- Merit review date: 5/10/16
- End date: 9/30/19
- Percent complete: 38%

Budget

	FY 16 Costs	FY 17 Costs	Total Planned Funding (FY 18–19)
DOE-Funded	**$281K**	**$600K**	**$1,200K**

Barriers

- Aft-B Sustainable Algae Production
  - Need skilled workers
- Aft-H Overall Integration and Scale-Up
  - Need interdisciplinary expertise
- Im-F Uncertain Pace of Biofuel Availability
  - Domestic production
- Im-H Lack of Acceptance and Awareness of Biofuels as a Viable Alternative
  - Stakeholder involvement

Partners

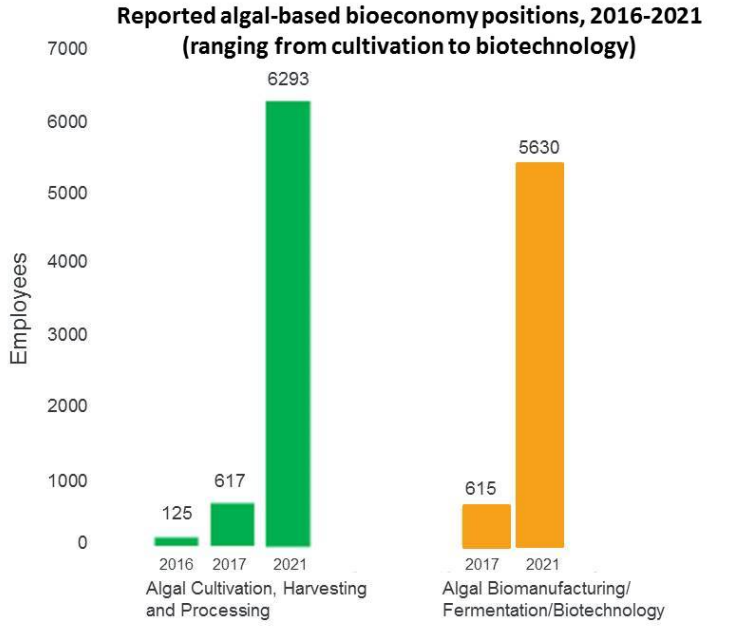
Other interactions/collaborations:

- Algae Foundation
- NREL
- Algae Biomass Organization
- Arizona State University
- Austin Community College (ACC)
- Rutgers University
- Santa Fe Community College (SFCC)
- Solano Community College
- University of California, San Diego
- University of Connecticut
- University of Maine
- University of New England
- USM
- University of Texas, Austin

1 – Project Overview

Current Situation:

- Anticipated shortage of high-quality technicians. Fill ~12,000 jobs by 2021
- Costly and time-consuming post-hire training
- No existing formal college degree training programs



Long-term Job Potential: Estimated jobs growth based on existing companies. Anticipated commodification of the algal industry, may result in bioeconomy jobs exceeding 100,000 positions with a 3x-5x jobs multiplier.

Challenges:

- Industry reluctance to share job descriptions and hiring requirements
- Adoption of ATEC curriculum by community colleges
- Incorporation of regional diversity
- Democratization of course and degree access
- Identification and recruitment of educational professionals and existing curriculums
- Managing diverse pedagogies and experiences

1 – Project Overview

Solutions:

Create Stakeholder Team

- Formation of Algae Technology Educational Consortium (ATEC) team and Industrial Advisory Board

Train Technicians to Meet Required Industrial Skill Sets

- 30+ industrial skills and experiences identified
- Learning outcomes customized to commercial skill requirements

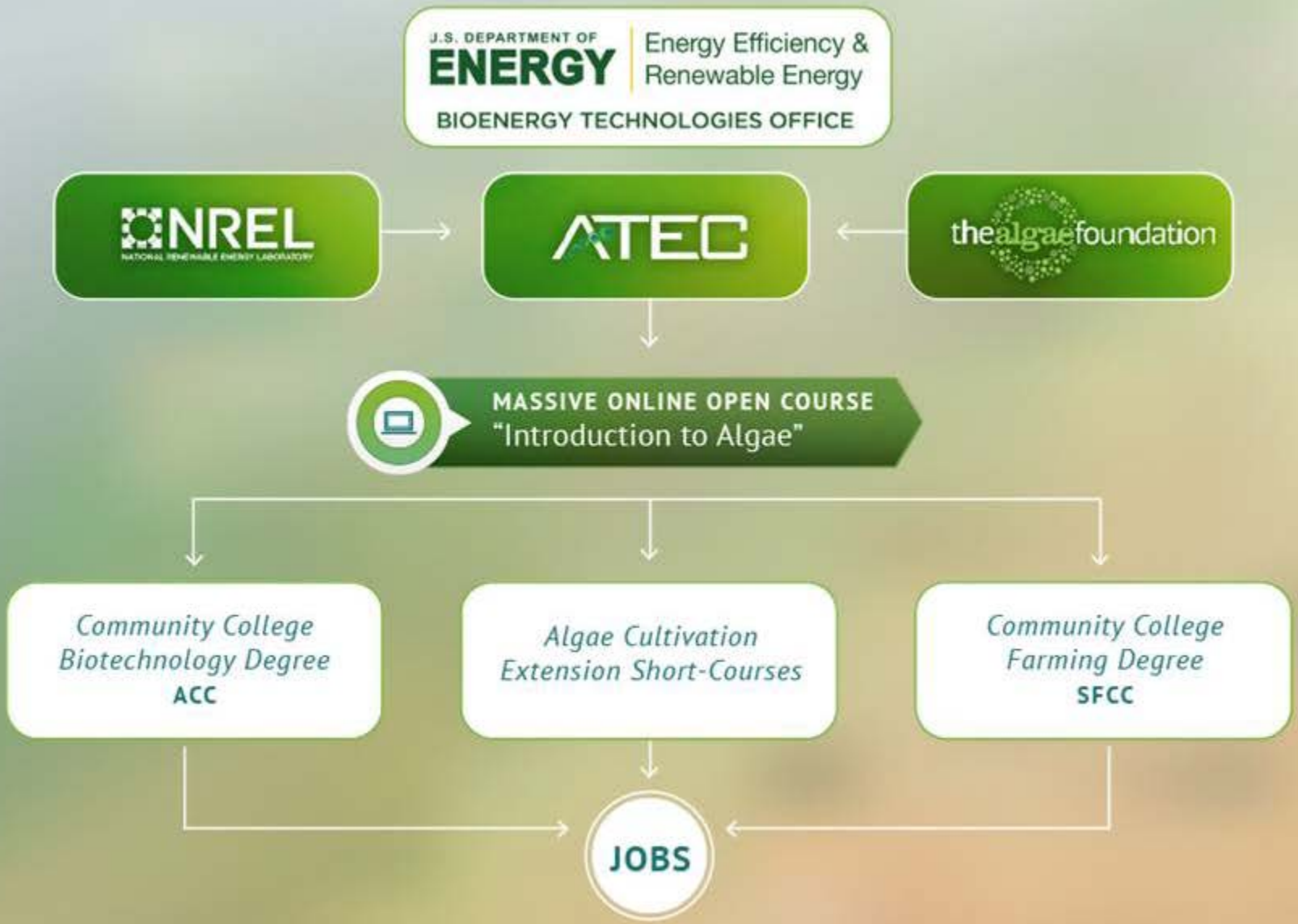
Design Specialized Training Programs

- Identification and incorporation of industry skill sets
- Development of two community college degrees (Farming and Biotechnology)
- Construct Algae Cultivation Extension Short-courses (ACES)

Recruit Community College ATEC Partner Institutions

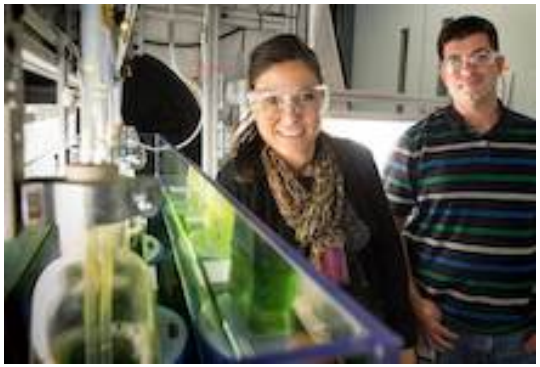
- Collaborate with two lead institutions (SFCC - Farming, ACC - Biotechnology)
- Assemble collaborative partners for subsequent adoption

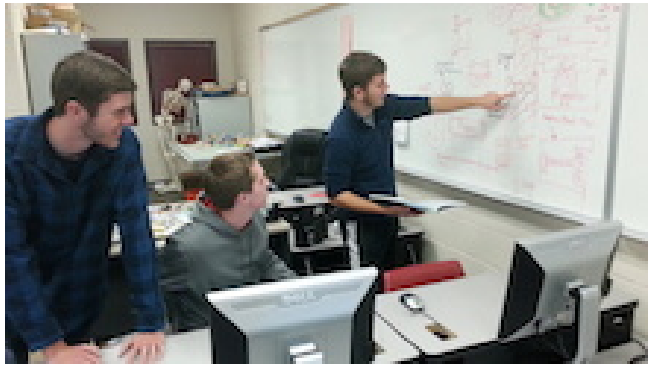
2 – Approach (Management)



2 – Approach (Technical)

- Democratize degree for national adoption by community colleges
  - Initiate introductory Algal Massive Online Open Course (Algal MOOC)
    - Algal interest generator
    - Gateway to Farming or Biotechnology degree programs, Algal Extension learning modules, and/or ATP^3 short courses
  - Originate in-person/blended/online courses
    - Learning outcomes based on commercial skill set requirements
  - Develop intensive, in-person laboratory courses
    - Reinforcement of commercial skill set requirements and blended course learning outcomes
  - Update commercial input and review of degree curriculums
  - Scope and scale material to target audience (community college students)
  - External assessment of degree programs by algal companies and educational assessment teams





2 – Approach (Technical)

- Train ~12,000 new algal professionals by 2021
  - Initiate Algae Technology Educational Consortium
  - Organize unique community college degree program
  - Develop Algae Cultivation Extension Short Courses (ACES)

- Support BETO's history of funding algal-based initiatives and the bioeconomy
  - Identify customers:
    - NEEDS – Collaboration with leading companies to identify commercial skill sets
    - WANTS – Student training and skills resulting in applicants attractive to potential employers

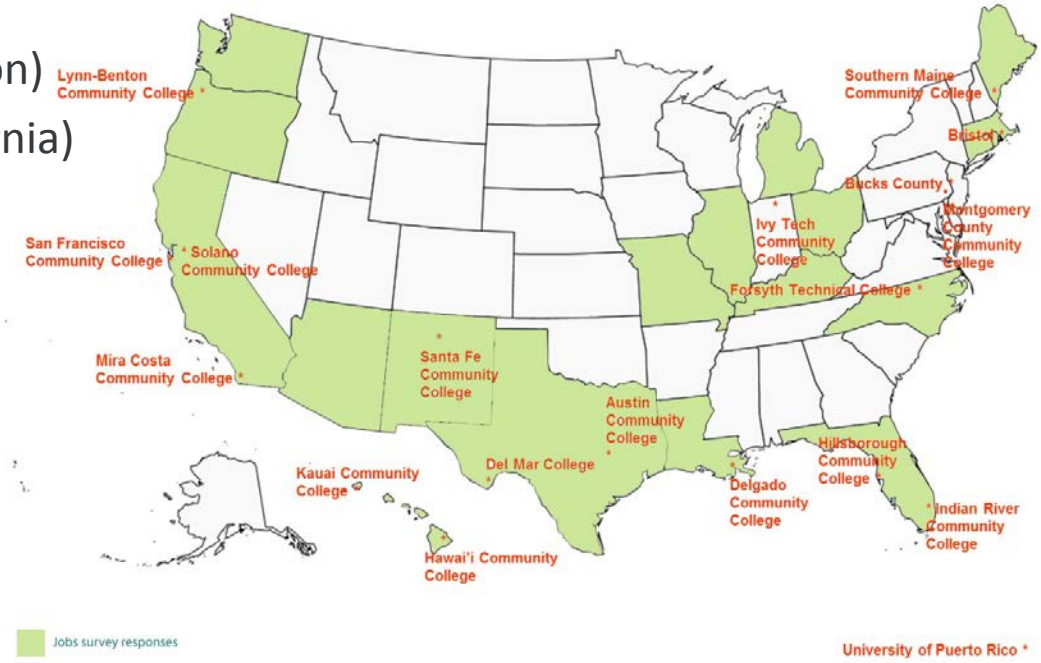
3 – Technical Accomplishments/Progress/Results

Completed:

- Formed industrial advisory board
- Phase I ATEC jobs survey: 66% response rate (50 of 76 algal companies responded)
- Corporate job requirement transition from four-year college degree to two-year ATEC Algal Biotechnology Community College degree
- Adoption of ATEC Algal Farming Degree Program by SFCC (fall 2016)
- Initiated three new SFCC courses in fall 2016, two in spring 2017, and one planned for summer 2017
- Formalized ATEC relationships with

  Linn-Benton Community College (Oregon)

  and Solano Community College (California)



3 – Technical Accomplishments/Progress/Results

Ongoing and Near Completion:

- Recruiting > 12 additional community colleges to adopt ATEC degree programs
- Completing MOU with Austin Community College of Texas
- Acquiring complete commercial algal job descriptions and requirements
- Expanding ATEC each year, reflecting increased interest and participation
- Acquisition and modification of existing educational curriculums, assets, labs, workbooks, manuals, and lectures
- Conversion of educational materials to the appropriate scale and scope of our community college student by community college and university-based educators

ATEC 18-month progress and challenge reflections

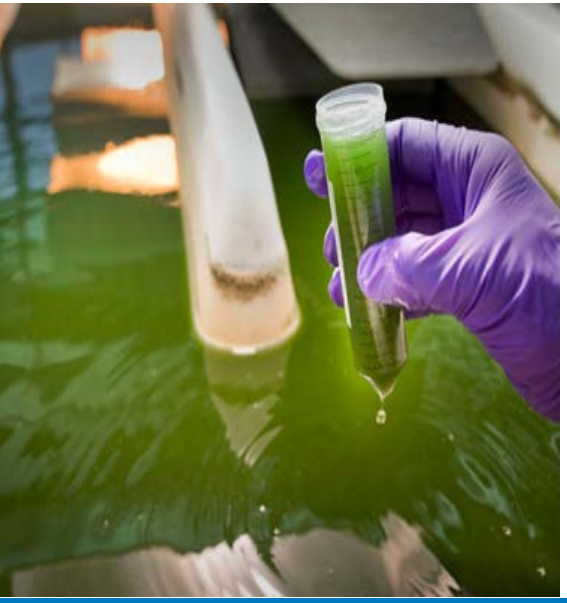
- Curriculum transfer and pedagogy adjustments
- Scaling of materials to community college student level of understanding
- Building course learning outcomes to deliver commercial skill-set requirements

4 – Relevance

- Generate skilled workforce to fill U.S. jobs supporting sustainable algal production (~12,000 jobs by 2021, a ten fold increase in five years) and other related bioeconomy jobs (wastewater treatment, biotechnology, multitrophic aquaculture, greenhouse horticulture, plant nurseries) [Barrier Aft-B]
- Create near-term job potential: Upon completion of the ATEC curriculum, graduates can immediately apply for technician positions in both the algal and waste water industries. New owner of 100 acre algal farm in NM indicated a preference for ATEC graduates (25 immediate positions and 75 within 3 years with salaries > $ 40,000 per year) [Barrier Aft-H]
- Create long-term job potential: Estimated jobs growth based on existing companies. Anticipated commodification of the algal industry may result in bioeconomy jobs exceeding 100,000 positions with a 3x-5x jobs multiplier [Barrier Im-F]

4 – Relevance

- Retrain aquaculturists to participate in the seaweed cultivation renaissance in coastal and offshore waters
- Algae Farming Nutrient Bioextraction: Kelp production of up to 116 wet metric tons per hectare per six month season (December - May) removing 180 Kg Nitrogen
- Expand crossover applications in biotechnology and wastewater industries [Barrier Im-H]
- Develop education and workforce development programs (BETO Strategic Plan, page 34)
- Support algal industry growth and commercial development (2009–2016, 24 grant awards)



The ATEC collaboration team with support from DOE and NREL has created the first algae educational program with comprehensive input from industry, government, and academia. This program provides community colleges, dual credit high school programs, and industry participants with access to a network of established campus facilities and online training to earn a degree with the ability to transfer to the leading university algal programs. The ATEC program closes the existing gap in algal education efforts and creates a clear pathway for establishing a knowledgeable and skillful job sector to face the challenges of the industry.

—Luke Spangenburg, *Director, SFCC Biofuels Center of Excellence*

5 – Future Work

- Perform phase II job assessment survey (FY17). Plan to integrate next job survey into BETO's Jobs and Economic Development Impact (JEDI) model. *Direct* technical jobs, *indirect* and *induced* secondary job growth will be examined.
- Assist with internship coordination involving national labs and corporate concerns
- Expand ATEC community college program nationally (FY17–FY19)
- Complete (FY17) and distribute (FY18) ACES training modules
- Complete algal farming and biotechnology courses (FY18)
- Implement algal biotechnology degree and one online algae biotechnology credit course (FY18)
- Offer a no-cost, introductory, noncredit algal MOOC (FY18)
- Implement intensive, in-person, regionally located laboratory courses (FY19)

Summary

Overview: ATEC supports the growing industry for algal-based bioproducts and biofuels through the design and implementation of a first-in-the-nation, two-year community college degree in algal cultivation and algal biotechnology and an extension retraining program to support the future employment requirements of an emerging algal-based industry

Approach: ATEC supports development of novel in-person, blended, and online courses to offer national, sustainable educational opportunities to a new generation of algal professionals

Technical Accomplishments/Progress/Results:

- Formation of ATEC team and industrial advisory board
- Initiation of first degree program in Algaculture at SFCC (fall 2016)
- Initiation of the second ATEC degree program, Algal Biotechnology, by Austin Community College (fall 2017)

Relevance: Bioeconomy workforce development; creating skilled workforce to fill ~12,000 positions customized to industry's job skill requirements, breaking through algal production and scale-up barriers

Future work:

- Initiate and offer Introduction to Algae MOOC, (spring 2018)
- Complete individual degree courses, both blended/online, (summer 2018)
- Offer complete ACES (spring 2018)
- Develop and initiate intensive, regional laboratory courses (fall 2018)

Acknowledgments

ATEC Team Members

Name	Organization
Ira Levine	Algae Foundation/USM
Deb Charest	Algae Foundation/USM
Peter Lammers	Arizona State University
William Brandt	Arizona State University
Tom Dempster	Arizona State University
Milton Sommerfeld	Arizona State University
John McGowan	ATP^3
Patricia "Trish" Phelps	Austin Community College
Linnea Fletcher	Austin Community College
Thomas Mumford	Friday Harbor Laboratories
Valerie Harmon	Harmon Consulting
Philip Pienkos	NREL
Cindy Gerk	NREL
James T. Dawson	Pittsburg State University
Gef Flimlin	Rutgers University
Stephen Gomez	SFCC
Ondine Frauenglass	SFCC
Luke Spangenburg	SFCC Biofuels Center of Excellence
Wendy Groves	University of California, San Diego
Steve Mayfield	University of California, San Diego
Greg Mitchell	University of California, San Diego
Charlie Yarish	University of Connecticut
Joe Fox	University of Texas, A&M
Schonna Manning	University of Texas, Austin

ATEC Advisory Board

Name	Organization
Dr. Amha Belay (Chair)	Earthrise Nutritionals, Inc.
Dr. John Benemann	MicroBio Engineering, Inc.
Mr. Joel Murdock	FedEx, Inc.
Mr. Martin Sabarsky	Cellana, Inc.
Dr. Dave Hazlebeck	Global Algae Innovations, Inc.
Mr. Jacques Beaudry-Losique	Algenol Biotech, LLC

BETO

Christy Sterner

Supplemental Slides

thealgaefoundation

OUR FOCUS

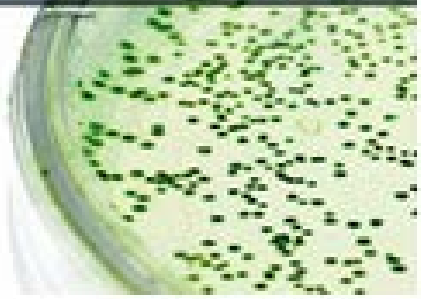
promote education

ATEC

ATEC
ALGAE TECHNOLOGY
EDUCATIONAL CONSORTIUM

K-12 STEM initative

technical standards



all about algae

ALL ABOUT
algae
.COM

student scholarships

Founded in early 2013 as a 501(c)(3) non-profit Educational Foundation

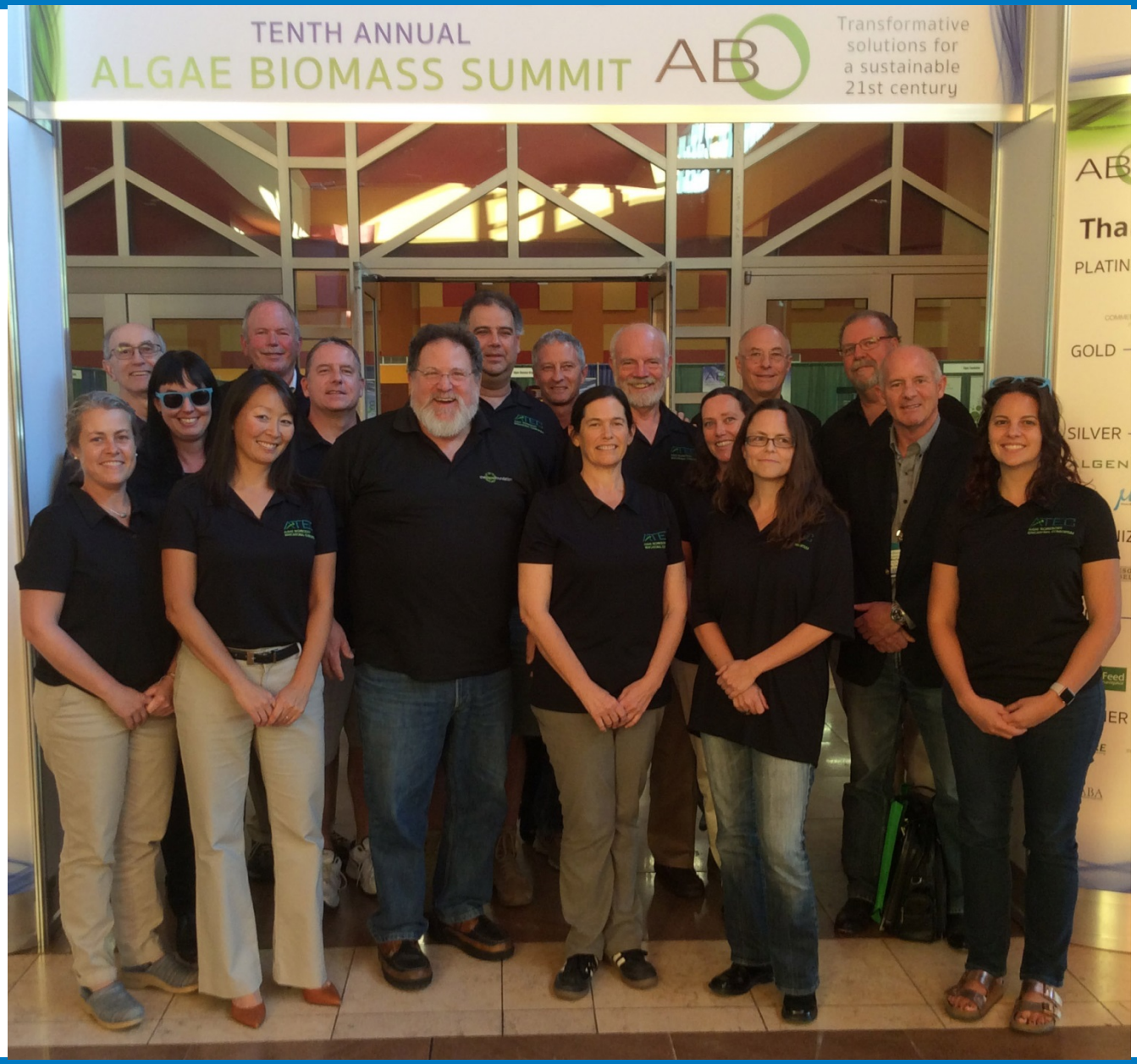
Objectives:

1. Develop an educational-based effort to support DOE-BETO's vision of algae's future.

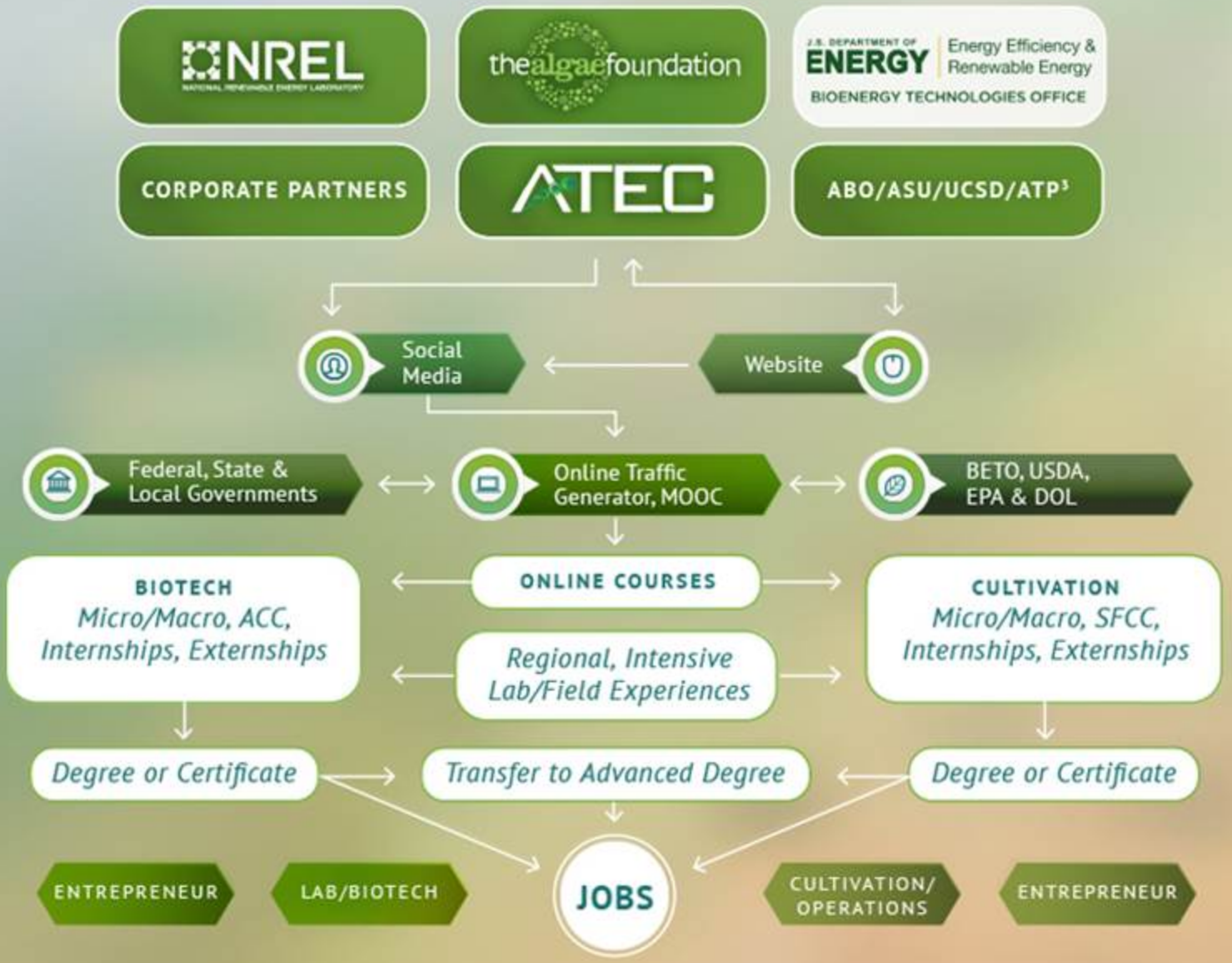
2. Implement two community college degrees in Algal Cultivation and Biotechnology.

3. Establishment of an Algae Cultivation Extension Short-courses (ACES) for both seaweeds and microalgae

ATEC Team


TENTH ANNUAL
ALGAE BIOMASS SUMMIT
AB
Transformative solutions for a sustainable 21st century
PLATIN
GOLD
SILVER

Detail Level



2 – Approach (Management)

- Algae Technology Educational Consortium (ATEC)
  - Ira Levine (Algae Foundation and University of Southern Maine)
  - Cindy Gerk (NREL)
- Massive Online Open Course (MOOC)
  - Steve Mayfield and Wendy Groves (UCSD)
- Farming Community College Degree
  - Luke Spangenburg, Steve Gomez, Ondine Frauenglass (SFCC)
  - Tom Dempster (ASU)
  - Charlie Yarish (UCONN)
  - Tom Mumford (Friday Harbor Marine Lab)
- Biotechnology Community College Degree
  - Linnea Fletcher, Erika Schwarz (ACC)
  - Schonna Manning (UTex)
  - James DeKloe (Solano CC)
- Algae Cultivation Extension Short-courses (ACES)
  - Gef Flimlin (Rutgers University)
  - Gary Wikfors (NOAA Northeast Fisheries Science Center)
  - Dana Morse (University Maine Extension)

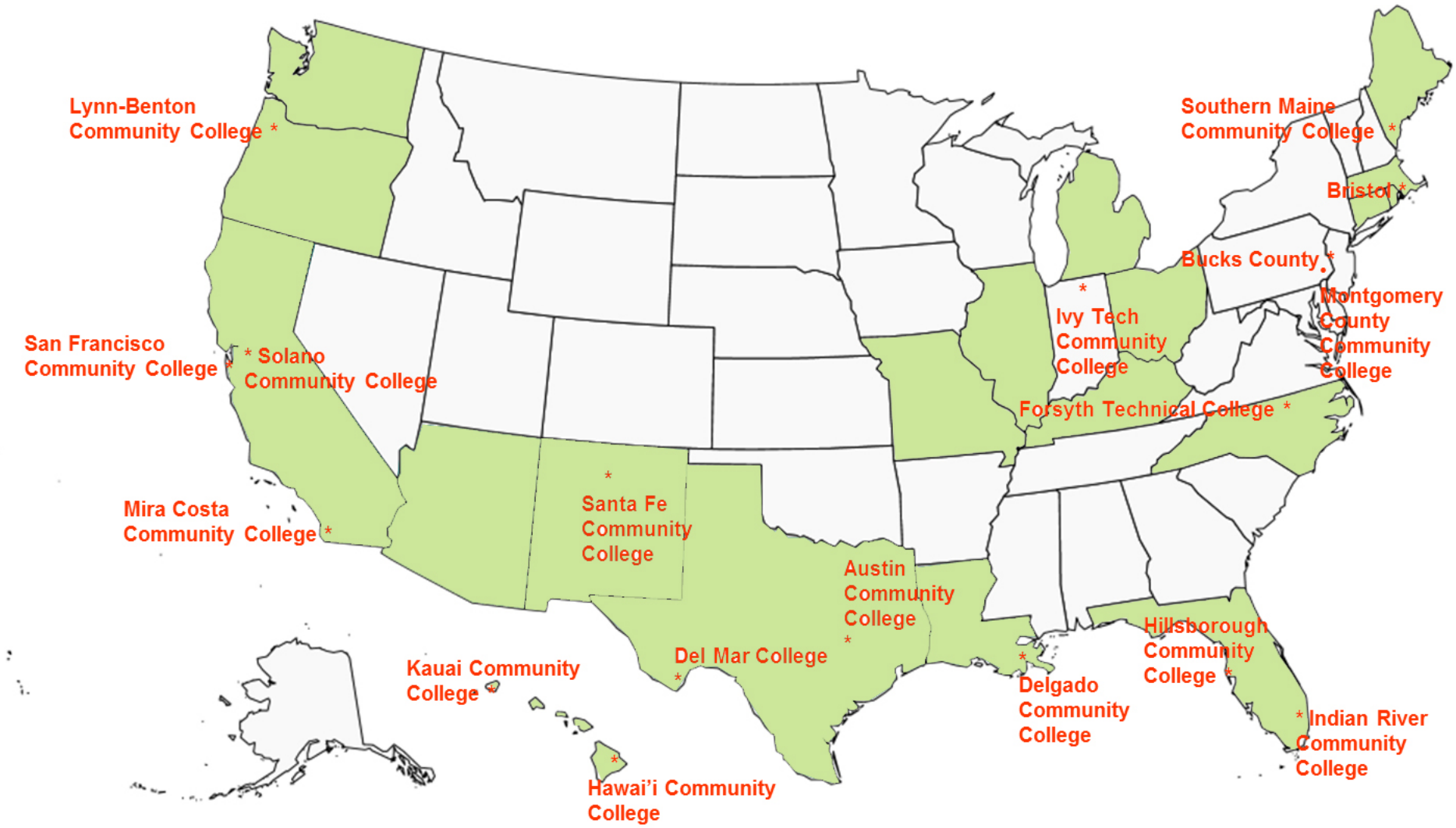
ATEC Milestones (FY 2016 and 2017)

Milestone Name/Description	End Date
Establish ATEC collaborative team	12/31/2015
Initiate the design of a curriculum and support materials for an algae aquaculture college degree	3/30/2016
Identify publisher or move forward with self-published support materials	6/30/2016
Design of a curriculum and support materials for an algae aquaculture extension certificate	9/30/2016
Initiation of ATEC curriculum in one community college (SFCC)	12/31/2016
Prepare and publish lab manuals and lecture support reading modules for Algaculture 1 (SFCC), Biotechnology (ACC)	3/31/2017
Production of Introduction to Algae: Massive Online Open Course (MOOC) University of California, San Diego	6/30/2017
Production of one, 3-credit online courses: Algaculture 1 by New Mexico Film Resource, Inc.	6/30/2017
Completion of algae extension training course videography and graphics	9/30/2017

ATEC Milestones (FY 2018 and 2019)

Milestone Name/Description	End Date
Incorporation of Algae Cultivation Extension Short-courses (ACES) into existing aquaculture extension programs in areas serving the algal industry	12/31/2017
Algal Biotechnology Degree Initiation	12/31/2017
Educational Assessment teams deployed to evaluate the program	3/31/2018
Industrial Advisory Board Assessment and feedback	6/30/2018
Five Community College ATEC Program adoption	9/30/2018
Initiation of Regional, Intensive, In-person, Laboratory Course	9/30/2018
Reconfigure courses as a function of assessment feedback	12/31/2018
Expand Regional, Intensive, In-person Laboratory Course to two centers	3/31/2019
Provide draft project report to BETO for feedback	6/30/2019
Provide final project report to BETO	9/30/2019

Community Colleges Expressing Interest in the ATEC Curriculum

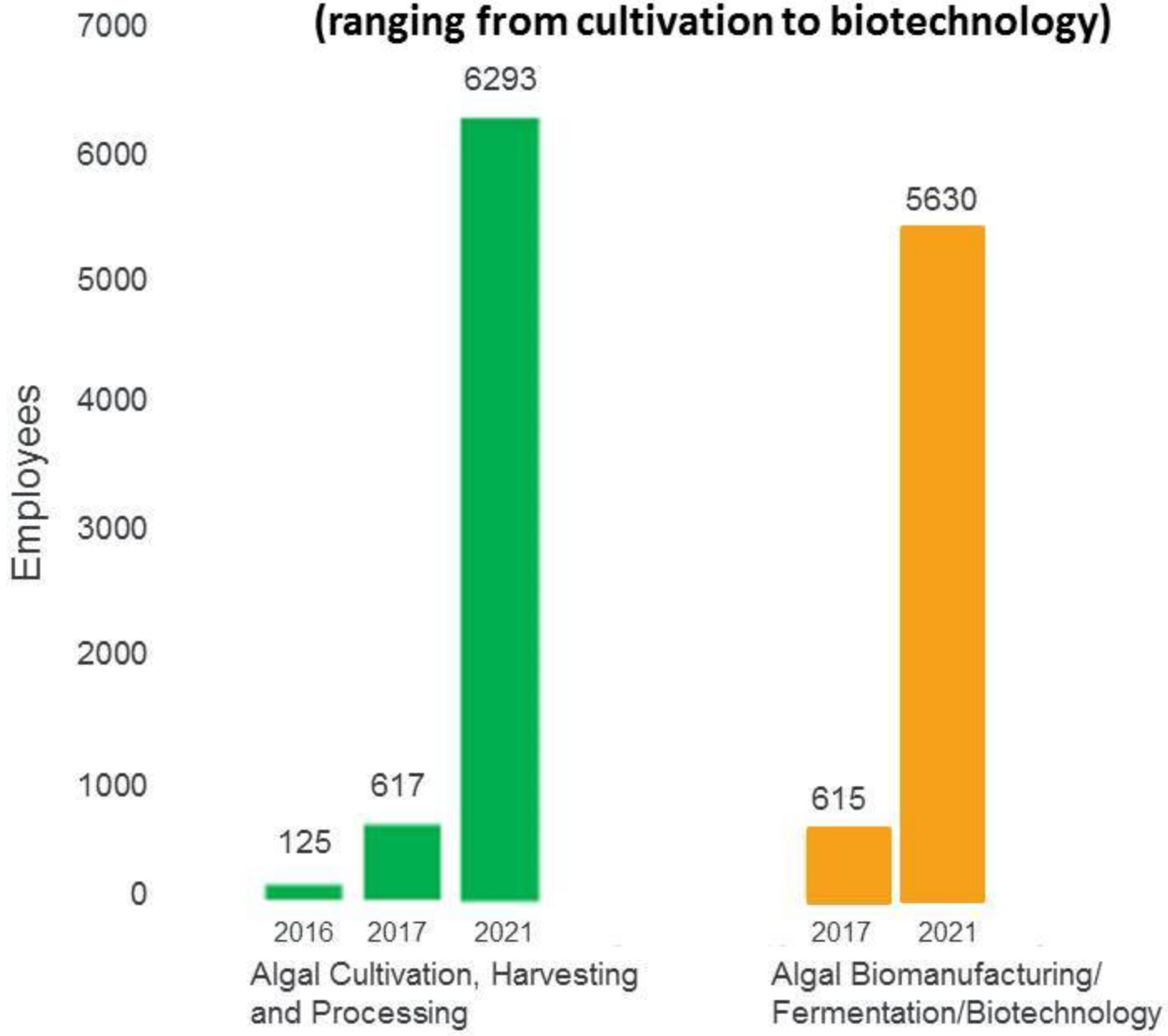


ATEC Community College Recruitment Efforts

Table 3.

Community College	City	State	Signed Commitment Letter	Developing Commitment Letter	ATEC Member	Expressed Interest in ATEC Degree	Expressed Interest in ATEC Certificate	Expressed Interest in ATEC Course	Algae Biology & Cultivation Degree	Algal Biotechnology Degree
Austin	Austin	TX		X	X	X	X			X
Bristol	Fall River	MA				X	X	X	X	
Bucks County	Newton	PA				X	X	X		X
Del Mar	Corpus Christi	TX				X	X	X		X
Delgado	New Orleans	LO				X	X			X
Forsyth Technical	Winston-Salem	NC				X	X			
Hillsborough	Tampa	FL						X		X
Hilo	Hilo	HI			X	X	X	X	X	
Indian River	Ft. Pierce	FL						X	X	
Ivy Tech	South Bend	IN				X	X			X
Kauai	Lihue	HI			X	X	X		X	
Lynn-Benton	Albany	OR	X		X	X	X		X	
Miracosta	Oceanside	CA			X					X
Montogomery County	Blue Bell	PA				X	X	X	X	
San Francisco	San Francisco	CA				X	X	X	X	
Santa Fe	Santa Fe	NM	X		X	X	X			
Solano	Fairfield	CA		X		X	X			X
Southern Maine	South Portland	ME						X	X	
University of Puerto Rico	San Juan	PR				X	X	X	X	

Reported algal-based bioeconomy positions, 2016-2021 (ranging from cultivation to biotechnology)



Long-term Job Potential: Estimated jobs growth based on existing companies. Anticipated commodification of the algal industry, may result in bioeconomy jobs exceeding 100,000 positions with a 3x-5x jobs multiplier.

Jobs Survey

Algal Employment Assessment Survey

The Algae Foundation launched the Algae Technology Educational Consortium (ATEC) project, recognizing algal commercialization will provide a sustainable source of biomass for bio-based products, feed, fuel and foods creating high quality jobs for an educated workforce. Through algal education students learn practical applications of farming and biotechnology, developing the skills for the next generation of algal-based jobs.

ATEC is presently comprised of seventeen members based throughout the United States who collectively have more than 100 years in algal-based education, research, and commercial experience. ATEC is currently supported by a U.S. Department of Energy/NREL grant to produce a novel two year degree in Algae Biology, Technology and Cultivation. The ATEC team members include professionals from the following organizations:

Algae Foundation	Algae Biomass Organization
Univ. of California, San Diego	National Renewable Energy Lab
University of Texas, Austin	Arizona State University
University of Southern Maine	Santa Fe Community College
Austin Community College	Rutgers University
Univ. of Maine Aquaculture Ext.	University of South Florida

The following request for information is critical for ATEC's effort to successfully determine the potential algal-based employment potentials locally, regionally, and nationally. The data will be used to support the adoption of the new degree program by community colleges throughout the United States. Community College administrators have all stated their requirement for employment potentials as a critical step in the adoption of a new degree program.

Please take the time to complete this survey, using your best estimates as to the potential of algal-based expertise needed in future positions. Our degree program has two concentrations: algal-based biotechnology and algal-based cultivation/farming. If you have any additional thoughts please add them at the end of this form. If you have any questions concerning our program or this assessment don't hesitate to contact me.

Please email your response to ilevine@maine.edu . Thank you in advance.

Ira Levine, Ph.D.
ATEC P.I.

1. How many positions does your company presently have that a graduate with a two year degree in Algae Biology, Technology, and Cultivation would be considered qualified for? ____
2. How many algal cultivation, harvesting, & extraction positions will be needed next year? ____
3. How many algal cultivation, harvesting, & extraction positions will be needed next 5 years? ____
4. How many Biomanufacturing (Fermentation/Heterotrophic) positions will be needed next year? ____
5. How many Biomanufacturing (Fermentation/Heterotrophic) positions will be needed five years? ____
6. How many R&D and Biotechnology technicians will you need in the next year? ____
7. How many R&D and Biotechnology technicians will you need in the next five years? ____
8. Do you predict any new emerging trends in workforce needs (e.g., algal-based photosynthetic, heterotrophic cultivation, fermentation, bio-based products, biofuel seed stocks, wastewater remediation, commercial waste digestion, bioinformatics, stem cell production) in the next year? In the next 5 years?

9. Please add any additional thoughts you may have on the potential employment options for a graduate with a two year degree in Algae Biology, Technology, and Cultivation.

NOTES:

a) **Cultivation, harvesting, & extraction positions**: Cultivation - strain selection, basic lab analytics, micro/macro algae, monoculture, polyculture production in photosynthetic systems including indoor/outdoor, closed/open cultivation systems, including ocean, ponds and lakes. Water resources- fresh, salt water, municipal, industrial and agricultural effluent treatment. Harvesting systems - membrane, flocculation, centrifuge, DAF, & novel evolving systems. Extractions, feedstock conversion and postharvest processing (animal feed, biofuels, bioplastics, biochar, cosmeceuticals, nutraceuticals, soil conditioners and enhancers).
b) **Biomanufacturing (Fermentation/Heterotrophic systems) positions:** pilot to commercial scale fermentation systems; designer bio-based products, nutraceuticals, cosmeceuticals, soil conditioners and enhancers.
c) **R&D and Biotechnology positions**: Cultivar isolation, identification, culture and enhancement (molecular genetics, mutations, protoplast fusion), bioinformatics, laboratory analyses (GC-mass spec, AA, spectrophotometers, balances, cryopreservation, pH, dissolved oxygen, robotics)

Name _____

Company or Institution _____

Phone # _____

Email _____

Jobs Survey Respondents

50 of 76 Algal Companies Responded and listed here
66% response rate

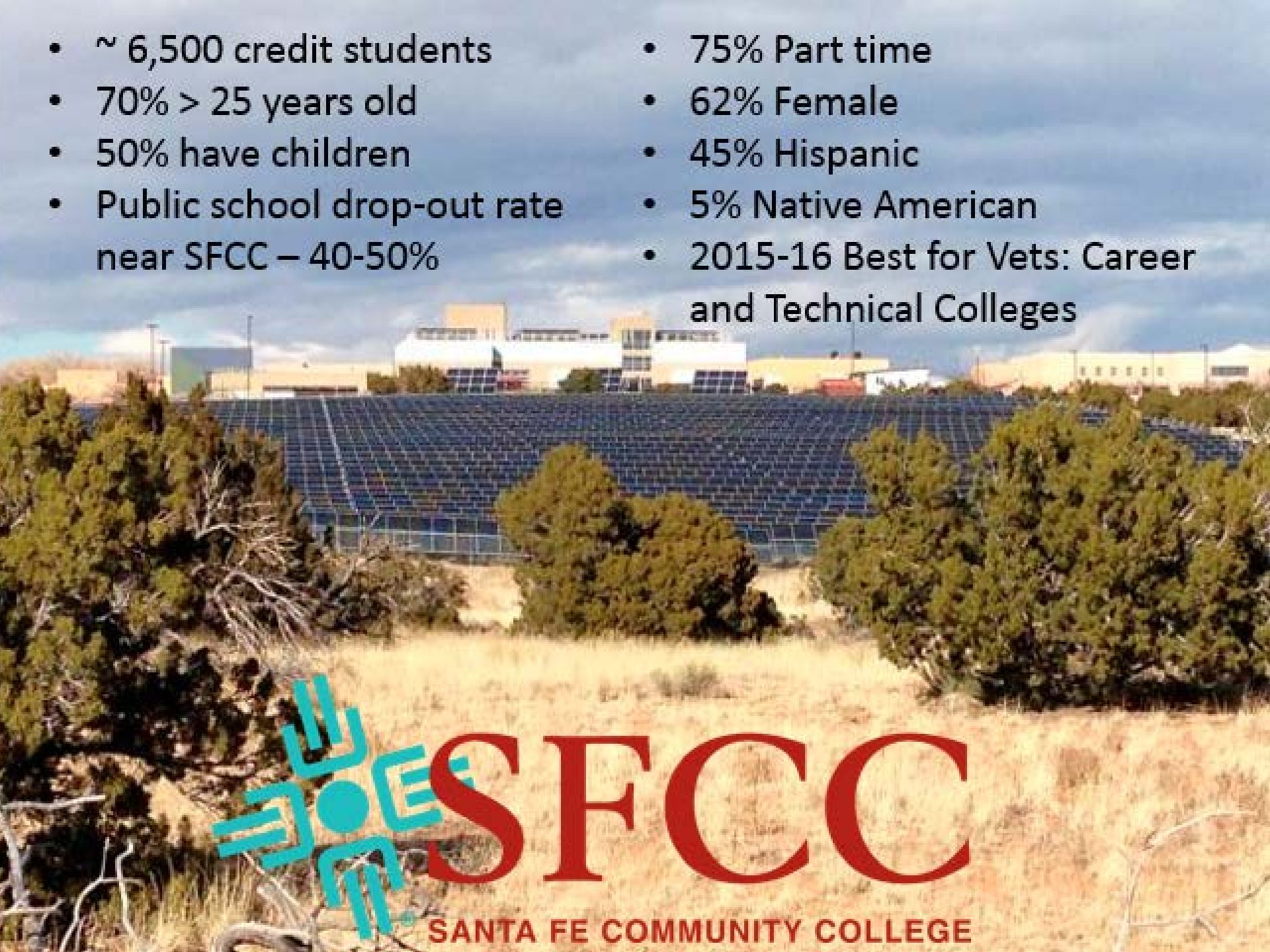
Earthrise
Duke Energy Corp
Arabian Shrimp Co.
Hiroaki Hara - Field Energy
Agcore Tech
Clearas Water
Algix LLC
Grupo Alimenta -
Algaeon, Inc.
NOLA Microfarm
Matrix Genetics
Ouroborous Biorefinery
Texas A&M
PHYCO2
MicroBio Engineering, Inc
Baylor University
Harmon Consulting
Wayne Brown
Cerule (formerly called Desert Lake Technology)
eePARC/ZONS
Triton Health and Nutrition
Algenisis
Agrifuels
Commercial Algae Mgmt.
Diversified Technologies

Qualitas Health, Ltd
Proteos Inc.
Bigelow Laboratory
Delaware Aquaculture Resource Center
Kuehnle AgroSystems, Inc.
Smart Microfarms
Accelergy
El Dorado Biofuels
New Solutions Energy
Santa Fe Community College
Ecoponex Systems International
ATP3
GE Water Processing and Technologies
Ocean Approved
Phyco Biosciences
Orlando Utilities Comm.
Susan Schoenung
AFS Bio oil
Searen LLC
Intelligent Biotechnologies
AFS Biooil
Algal Scientific Corporation
Global Algal Innovations
Cellana
Synthetic Genomics

Commercial Job Skills & Farming Degree Learning Outcomes

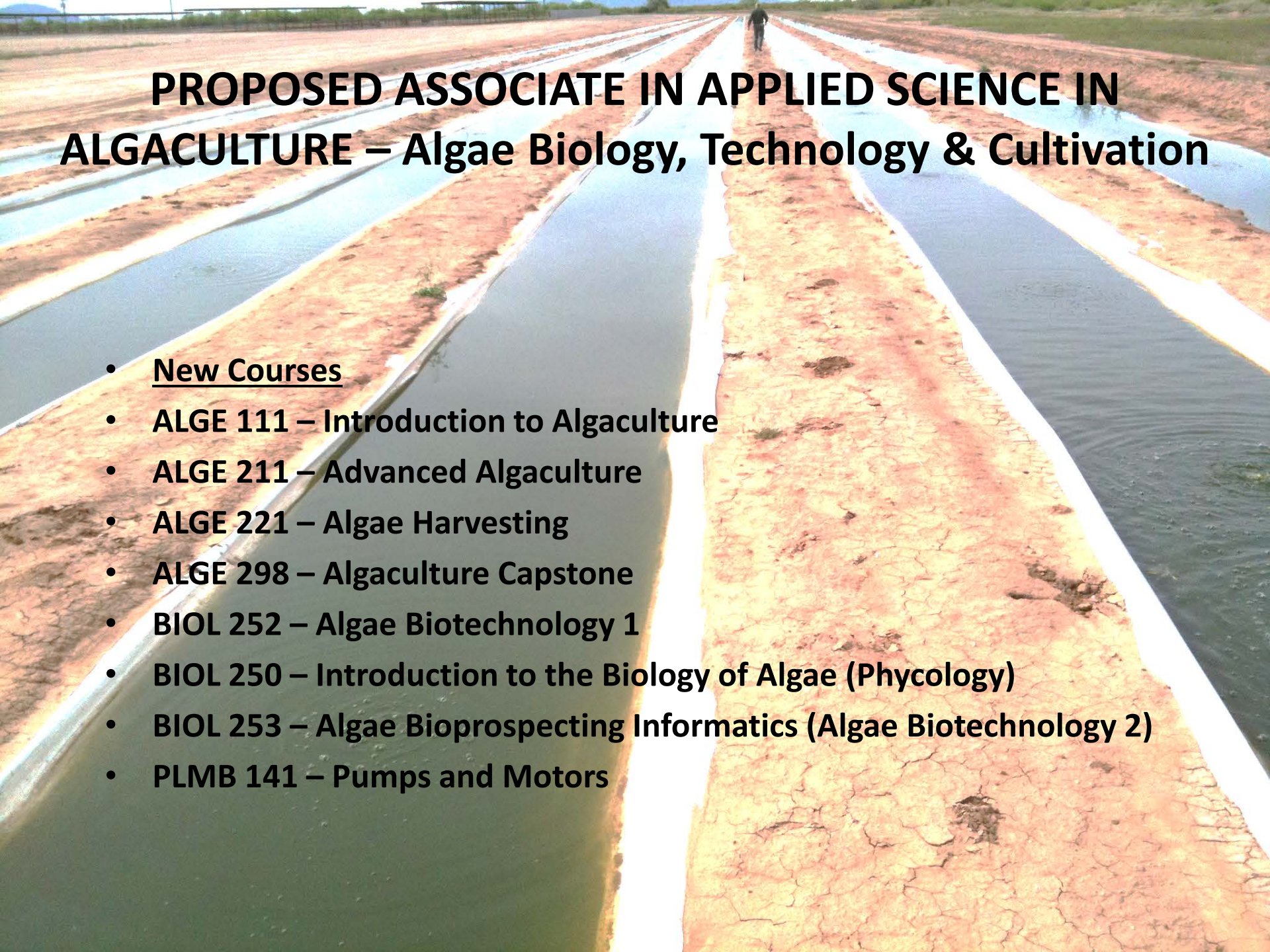
- Media preparation, sterile techniques, microscopy
- Culture inoculation,
- Scale-up - petri plate to 10 L
- Monitoring procedures for media and biomass analyses
- Lab and farm safety
- Operations and maintenance of algal cultivation systems.
- Scale-up - 10L to 1000 – 50,000L algae production systems.
- System maintenance
- Harvesting operations
- Biomass analysis and quality assessment
- Biomass storage techniques
- Heterotrophic and fermentation techniques
- Wastewater treatment utilization
- Quality control analysis
- Data collection and operational reports
- System troubleshooting and operational awareness
- Internship
- Pump and motor operations,
- Hydraulic sizing and electrical demand requirements
- Mechanical properties of water

- ~ 6,500 credit students
- 70% > 25 years old
- 50% have children
- Public school drop-out rate near SFCC – 40-50%
- 75% Part time
- 62% Female
- 45% Hispanic
- 5% Native American
- 2015-16 Best for Vets: Career and Technical Colleges



SFCC

SANTA FE COMMUNITY COLLEGE



PROPOSED ASSOCIATE IN APPLIED SCIENCE IN ALGACULTURE – Algae Biology, Technology & Cultivation

- <u>New Courses</u>
- ALGE 111 – Introduction to Algaculture
- ALGE 211 – Advanced Algaculture
- ALGE 221 – Algae Harvesting
- ALGE 298 – Algaculture Capstone
- BIOL 252 – Algae Biotechnology 1
- BIOL 250 – Introduction to the Biology of Algae (Phycology)
- BIOL 253 – Algae Bioprospecting Informatics (Algae Biotechnology 2)
- PLMB 141 – Pumps and Motors

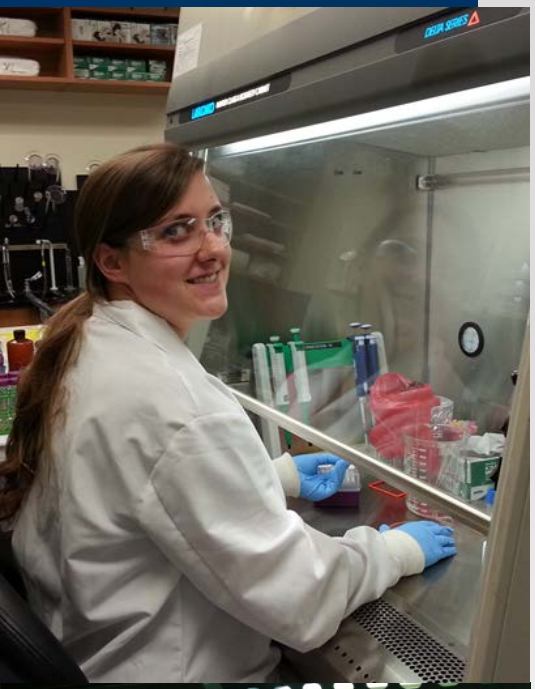
Certificate in Algaculture (32 hrs min)

Associate in Applied Science - Algaculture Technologies (61 hrs min)

Fall 1	Spring 1	Summer 1
ALGE 111 Introduction to Algaculture (3–proposed)	ALGE 211 Advanced Algaculture (3 – proposed)	ALGE 221 Algae Harvesting (3 – proposed)
STEM 111 Introduction to Science, Technology, Engineering and Mathematics (3)	PLMB 141 – Pumps and Motors (2 – proposed)	ENGL 111 Composition and Rhetoric (3)
BLDG 111 Construction Safety (3)	BSAD 119 Entrepreneurial – Planning and Introduction (3)	HPER – any (1)
ALTF 111 Introduction to Alternative Fuels and Vehicle Technologies (3) [or] ENVR 111 Introduction to Sustainability (3)	CHEM 111 Introduction to Chemistry [and] (3) CHEM 111L Introduction to Chemistry Lab (1)	
BIOL 111P Introduction to Biology [and] (3) BIOL 111PL Introduction to Biology Lab (1)	ELEC 111 Electronic Fundamentals (4)	
TOTAL (16) TOTAL (16)	TOTAL (16) TOTAL (16)	TOTAL (3) TOTAL (7)

Fall 2	Spring 2	Summer 2
BIOL 250 – Introduction to the Biology of Algae (3 – proposed)	ALGE 298 – Algaculture Capstone (3 – proposed)	
ENVR 113 Instrumentation and Control Labs (3)	HIST 260 History of New Mexico *** (3)	
PHIL 258 Environmental Ethics and Sustainability (3)	Approved Social/Behavioral Sciences [or] Humanities and Fine Arts (3)	
BLDG 115 Trades Math [or] (3) WATR 112 Applied math for Water Operators (4) [or] MATH 111 *or higher* (3)	ENGL 119 Professional Communication [or] (3) ENGL 216 Technical Writing (3)	
Approved elective (1-4)	Approved elective (1-4)	
TOTAL (13-17)	TOTAL (13-16)	

Proposed ACC Degree Algae Biotechnology



Semester I

- BIOL 1414 Intro to Biotechnology 4 (light & algae lab)
- BIOL 1406 Cellular and Molecular Biology 4
- ENGL 1301 English Composition I 3
- MATH 1314 College Algebra 3

Semester II

- BIOL 1415 Introduction to Biotechnology II 4 (purification of phycobiliproteins from cultured microalgae lab)
- ENGL 2311 Technical & Business Writing 3
- CHEM 1311 General Chemistry I - Lecture 3
- CHEM 1111 General Chemistry I - Lab 1
- BITC 1340 Quality Assurance for the Biosciences 3

Semester III

- BITC 1491 Special Topics - Algal Biotechnology 1 course (online)
- CHEM 1312 General Chemistry II -- Lecture 3
- CHEM 1112 General Chemistry II - Lab 1
- SPCH 1321 Business and Professional Communication 3
- BITC 2350 Bioinformatics 3 (algal gene sequencing lab)

Semester IV

- BITC 2411 Biotechnology Laboratory Instrumentation 4 (isolation of astaxanthans and purification by HPLC lab)
- BITC 2441 Molecular Biology Techniques 4 (algae as Test Organism)
- ECON 2301 Principles of Macroeconomics 3
- Languages, Philosophy, & Culture/Creative Arts 3

Semester V

- BITC 2487 Internship-Biology Technician/Biotechnology Laboratory Technician II 4

Integrating algae training

First-year

Introduction to Biotechnology I. Including a lab module on culturing algae, framed by a research question, such as the effect of light intensity, color of phycobiliprotein production in cultured microalgae.

Introduction to Biotechnology II. Including a lab module on purification of phycobiliproteins from cultured microalgae.

Integrating algae training

Second-year

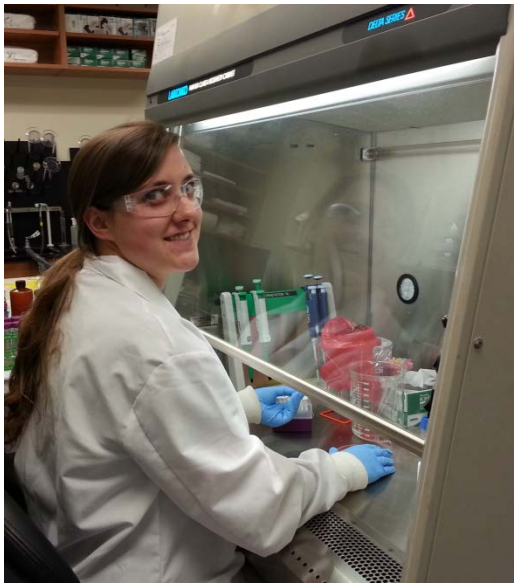
Bioinformatics. Including a comparison of phycobiliprotien gene sequences and identification of binding sites of phycobilins in proteins.

Biotechnology Instrumentation. Including a lab module on the isolation of astaxanthans and purification by HPLC.

Cell Culture Techniques. Comparison of photobioreactor performance in scale-up. (for the biomanufacture-focused course, when offered) Isolation, culturing, and cryopreservation of environmental isolates (for the lab technician- focused course)

Molecular Biology Techniques. Include a DNA barcoding module for identification of microalgae in environmental isolates.

Making it happen



Small changes in the lab module selections of existing courses can easily adjust the biotechnician training program to serve the algae technician workforce.

Support from the online algae biotechnology 1 courses can assist in the flexibility of the biotechnology program in rapidly meeting the changing needs of industry.

ATEC Publications and Presentations

Levine, I.A. 2013. Algae Foundation. Plenary Lecture. 7th Algae Biomass Summit. Orlando, Fl. September 30 – October 3, 2013.

Levine, I.A., J. Murdock, L. Laurens. 2014. Technical Standards 6.0. Plenary Lecture. 8th Algae Biomass Summit. San Diego, CA. September 29 – October 2, 2014.

Levine, I.A. 2015. The Algae Foundation and formation of Algae Technology Educational Consortium (ATEC). Plenary Lecture. 9th Algae Biomass Summit. Washington, D.C. September 30 – October 2, 2015.

Levine, I.A. 2016. Algae Technology Educational Consortium, Training the Next Generation of Algal-based Professionals. Community College Program at BIO 2016. San Francisco, CA. June 6, 2016.

Levine, I.A. 2016. ATEC. International Seaweed Symposium 2016. Book of Abstracts. Page 27: OR-01-06. Copenhagen, Denmark. June 19-24, 2016.

Levine, I.A. 2016. Algae Foundation – Algae Technology Educational Consortium (ATEC). 6th International Conference on Algal Biomass, Biofuels and Bioproducts. San Diego, CA. June 27-29, 2016.

Levine, I. A. 2016. Growing a Bioeconomy Workforce, Panel Discussion. Bioenergy 2016: Mobilizing the Bioeconomy through Innovation. Washington, D.C. July 12-14, 2016.

Levine, I.A. 2016. The Algae Foundation Report & Update. Plenary Lecture. 10th Algae Biomass Summit. Phoenix, AZ. October 24-26, 2016.

Levine, I.A. 2016. Land Based, Marine Gracilaria Farming in New Mexico. 10th Algae Biomass Summit. Phoenix, AZ. October 24-26, 2016.

ATEC Publications and Presentations

Levine, I.A. 2016. Algae's Role in Mitigating Global Climate Change. Global Sustainable Development Summit: Towards United Nations Sustainable Development Goals. Guwahati, Assam, India. December 5-6, 2016. Book of Abstracts: 58

Levine, I.A. 2016. Algal-based STEM Education Initiatives for a Sustainable Future. International Conference on Green Trends in Environmental Sustainability: Creating Innovative Solutions for a Sustainable Future. Hyderabad, Andrah Pradesh. December 16-17, 2016. Book of Abstracts: 19.

Levine, I.A. 2016. Sustainable Microalgae Cultivation for Biofuels and Biotechnology. Advances in Life Sciences Symposium. Indian Institute of Science Education and Research Kolkata. Mohanpur, West Bengal. January 13-15, 2017. Book of Abstracts: 6.

Nalley, J.O., T. Cannis, and I. A. Levine. 2016. Promoting the Power of Algae in K-12 Classrooms: An Algae Foundation Initiative. International Society for Applied Phycology Newsletter. 2-2016: 4-8.
http://www.appliedphycologysoc.org/newsletter/ISAP_Newsletter_October_2016.pdf

Levine, I.A. 2017. The Algae Foundation® and Algal-based Education Initiatives. J. Applied Phycology: submitted.

ATEC Algae Cultivation Extension Short-courses (ACES)

The extension learning modules will be available throughout the country via online and blended platforms.

Short Course duration 1-2 weeks

Initial offering will be seaweed-based to reflect new DOE support for macroalgal technology and commercialization.

Led by Dr. Gef Flimlin, Emeritus Professor, Rutgers University, President U.S. Aquaculture Society

BETO Algal-based Funding History

2009: INTEGRATED BIOREFINERIES
- Algenol Biofuels, Inc. (Freeport, Texas)

2010: ALGAL BIOFUELS RESEARCH GRANTS
- **Sustainable Algal Biofuels Consortium** (Mesa, Arizona), led by Arizona State University, will test the acceptability of algal biofuels as substitutes for petroleum
- **Consortium for Algal Biofuels Commercialization** (San Diego, California), led by the University of California, San Diego, will concentrate on developing algae as a biofuels feedstock
- **Consortium of Kailua-Kona, Hawaii, led by Cellana, LLC,** will examine large-scale production of fuels and feed from seawater microalgae

2011: USDA-DOE JOINT GRANTS ON BIOMASS RESEARCH AND DEVELOPMENT FOR ENERGY INDEPENDENCE
- **Cellana, LLC** (Kailua-Kona, Hawaii)

2011: DROP-IN BIOFUELS AND BIOPRODUCTS
- **General Atomics** (San Diego, California)

2012: BIO-OIL STABILIZATION AND COMMODITIZATION
- **Sapphire Energy** (San Diego, California)

2012: INNOVATIVE PILOT- AND DEMONSTRATION-SCALE PRODUCTION OF ADVANCED BIOFUELS
- **BioProcess Algae** (Shenandoah, Iowa)

2013: ADVANCEMENT OF ALGAL BIOMASS YIELD
- **Hawai'i BioEnergy, LLC** (Honolulu, Hawaii)
- **Sapphire Energy** (San Diego, California)
- **New Mexico State University** (Las Cruces, New Mexico)
- **California Polytechnic State University** (Delhi, California).

The alternate awardee was announced in 2014:
- **Cellana, LLC** (Kailua-Kona, Hawaii)

2015: TARGETED ALGAL BIOFUELS AND BIOPRODUCTS (TABB)
- **Producing Algae and Co-Products for Energy (PACE), Colorado School of Mines** (Golden, Colorado)
- **Marine Algae Industrialization Consortium (MAGIC), Duke University** (Durham, North Carolina)
- **Global Algae Innovations, Inc.** (El Cajon, California)
- **Arizona State University** (Mesa, Arizona
- **University of California, San Diego** (San Diego, California)
- **Lawrence Livermore National Laboratory** (Livermore, California

2015: BIOENERGY TECHNOLOGIES INCUBATOR 2
- **Arizona State University** (Tempe, Arizona)

2015: ADVANCEMENTS IN ALGAL BIOMASS YIELD, PHASE 2 (ABY2)
- **Global Algae Innovations** (San Diego, California)
- **Algenol Biotech LLC** (Ft. Myers, Florida)
- **MicroBio Engineering, Inc.** (San Luis Obispo, California)

2016: PROJECT DEFINITION FOR PILOT- AND DEMONSTRATION-SCALE MANUFACTURING OF BIOFUELS, BIOPRODUCTS, AND BIOPOWER
- **Global Algae Innovations** (San Diego, California)

BETO Closed Funding Opportunities

2009

AMERICAN RECOVERY AND REINVESTMENT ACT INVESTS IN INTEGRATED BIOREFINERIES
On December 4, 2009, the U.S. Department of Agriculture and U.S. Department of Energy announced selection of 19 integrated biorefinery (IBR) projects to receive up to $564 million in American Recovery and Reinvestment Act of 2009 funds.

- Algenol Biofuels, Inc. (Freeport, Texas).

2010

ALGAL BIOFUELS RESEARCH GRANTS
On June 28, 2010, the U.S. Department of Energy announced investment of $24 million to support three research groups in investigating obstacles to commercialization of algae-based biofuels.

- **Sustainable Algal Biofuels Consortium** (Mesa, Arizona), led by Arizona State University, will test the acceptability of algal biofuels as substitutes for petroleum. For more information, visit the **Sustainable Algal Biofuels Consortium website**.
- **Consortium for Algal Biofuels Commercialization** (San Diego, California), led by the University of California, San Diego, will concentrate on developing algae as a biofuels feedstock. For more information, visit the **San Diego Center for Algae Biotechnology website**.
- **Consortium of Kailua-Kona, Hawaii, led by Cellana, LLC,** will examine large-scale production of fuels and feed from seawater microalgae. For more information, visit the **Cellana, LLC website**.

2011

USDA-DOE JOINT GRANTS ON BIOMASS RESEARCH AND DEVELOPMENT FOR ENERGY INDEPENDENCE
On May 5, 2011, the U.S. Department of Agriculture and U.S. Department of Energy announced $47 million in grants to support research and development projects that will reduce the United States' reliance on imported oil. Funded through the Biomass Research and Development Initiative, the advanced biofuels produced through these projects are expected to reduce greenhouse gas emissions by at least 50% compared to fossil fuels and increase the availability of alternative renewable fuels and biobased products.

- **Cellana, LLC** (Kailua-Kona, Hawaii) will work to develop a protein supplement from algae as a by-product of algal biofuels production.

DROP-IN BIOFUELS AND BIOPRODUCTS
On June 10, 2011, the U.S. Department of Energy announced $36 million in grants to support six small-scale projects in California, Michigan, North Carolina, Texas, and Wisconsin that will advance the technology improvements and process integration needed to produce drop-in, advanced biofuels and other biobased chemicals.

- **General Atomics** (San Diego, California) aims to improve the production of algal oils as drop-in fuels.

BETO Closed Funding Opportunities

2012

BIO-OIL STABILIZATION AND COMMODITIZATION

On August 15, 2012, the U.S. Department of Energy (DOE) announced award of $11 million to support projects that produce stable bio-oils from lignocellulosic and algal biomass sources. The target goal is to create bio-oils capable of blending within existing petroleum refineries to produce drop-in fuel with a renewable edge.

- **Sapphire Energy** (San Diego, California) will validate and expand previous tests of algal bio-crude quality to a pilot scale.

INNOVATIVE PILOT- AND DEMONSTRATION-SCALE PRODUCTION OF ADVANCED BIOFUELS

On April 22, 2013, the Energy Department announced nearly $18 million in four innovative pilot-scale biorefineries in California, Iowa and Washington that will test renewable biofuels as a domestic alternative to power our cars, trucks, and planes that meet military specifications for jet fuel and shipboard diesel.

- **BioProcess Algae** (Shenandoah, Iowa) will receive up to $6.4 million to evaluate an innovative algal growth platform that will produce hydrocarbon fuels meeting military specifications using renewable carbon dioxide, lignocellulosic sugars, and waste heat. The proposed biorefinery will integrate low-cost autotrophic algal production, accelerated lipid production, and lipid conversion. While the primary product from the proposed biorefinery will be military fuels, the facility will also co-produce additional products, including other hydrocarbons, glycerine, and animal feed.

2013

ADVANCEMENT OF ALGAL BIOMASS YIELD

On August 1, 2013, the U.S. Department of Energy announced the selection of four projects for negotiation for the Advancement of Algal Biofuel Yield FOA:

- **Hawai'i BioEnergy, LLC** (Honolulu, Hawaii) was selected to receive up to $5 million to develop a cost-effective photosynthetic open pond system to produce algal oil and demonstrate preprocessing technologies that reduce energy use and the cost of extracting lipids and producing intermediates.
- **Sapphire Energy** (San Diego, California) was selected to receive up to $5 million to develop a new process to produce algae-based fuel that is compatible with existing refineries. The project will also work on improving algae strains and increasing yield through cultivation improvements.
- **New Mexico State University** (Las Cruces, New Mexico) was selected to receive up to $5 million to increase the yield of a microalgae, while developing harvesting and cultivation processes that lower costs and support year-round production.
- **California Polytechnic State University** (Delhi, California) was selected to receive up to $1.5 million to conduct research and development work to increase the productivity of algae strains and compare two separate processing technologies.

The alternate awardee was announced in 2014:

- **Cellana, LLC** (Kailua-Kona, Hawaii) was selected to receive $3.5 million to develop a fully integrated, high-yield algae feedstock production system by integrating the most advanced strain improvement, cultivation, and processing technologies into their operations at their Kona Demonstration Facility.

BETO Closed Funding Opportunities

2015

TARGETED ALGAL BIOFUELS AND BIOPRODUCTS (TABB)

On July 9, 2015, the Energy Department announced six projects that will receive **up to $18 million in funding** to reduce the modeled price of algae-based biofuels to less than $5 per gasoline gallon equivalent (gge) by 2019. This funding supports the development of a bioeconomy that can help create green jobs, spur innovation, improve the environment, and achieve national energy security.

Algal biomass can be converted to advanced biofuels that offer promising alternatives to petroleum-based diesel and jet fuels. Additionally, algae can be used to make a range of other valuable bioproducts, such as industrial chemicals, bio-based polymers, and proteins. However, barriers related to algae cultivation, harvesting, and conversion to fuels and products need to be overcome to achieve the Department's target of $3 per gge for advanced algal biofuels by 2030.

- **Producing Algae and Co-Products for Energy (PACE), Colorado School of Mines** (Golden, Colorado) – Colorado School of Mines, in collaboration with Los Alamos National Laboratory, Reliance Industries Ltd., and others, will receive up to $9 million to enhance overall algal biofuels sustainability by maximizing carbon dioxide, nutrient, and water recovery and recycling, as well as bio-power co-generation.
- **Marine Algae Industrialization Consortium (MAGIC), Duke University** (Durham, North Carolina) – Duke University will receive up to $5.2 million to lead a consortium including University of Hawaii, Cornell University, Cellana and others to produce protein-based human and poultry nutritional products along with hydrotreated algal oil extract.
- **Global Algae Innovations, Inc.** (El Cajon, California) – Global Algae Innovations will receive up to $1 million to increase algal biomass yield by deploying an innovative system to absorb carbon dioxide from the flue gas of a nearby power plant.
- **Arizona State University** (Mesa, Arizona) – Arizona State University will receive up to $1 million for atmospheric carbon dioxide capture, enrichment, and delivery to increase biomass productivity.
- **University of California, San Diego** (San Diego, California) – The University of California, San Diego will receive up to $760,000 to develop an automated early detection system that can identify and characterize infestation or infection of an algae production pond in order to ensure crop health.
- **Lawrence Livermore National Laboratory** (Livermore, California) – Lawrence Livermore National Laboratory will receive up to $1 million to protect algal crops by developing "probiotic" bacteria to combat pond infestation and increase ecosystem functioning and resilience.

BETO Closed Funding Opportunities

2015

BIOENERGY TECHNOLOGIES INCUBATOR 2

On May 16, 2016, the U.S. Department of Energy **announced up to $10 million in funding** for six projects representing innovative technologies and solutions to advance bioenergy development. This funding will also support the development of a more robust bioeconomy, which can create green jobs, spur innovation, improve the environment, and achieve national energy security.

The following projects were selected:

- **Arizona State University, Tempe, Arizona—**This project will engineer cyanobacteria for the production of ethyl laurate, which is easily converted to "drop-in" ready (i.e., compatible with existing infrastructure) biofuels or bioproducts. This uses carbon dioxide (CO2), water, and light as the main inputs, and does not waste carbon and energy by limiting the amount of biomass produced.
- **Arizona State University, Tempe, Arizona—**This project will develop mixotrophic algae which can consume both CO2 *and* cellulosic sugars, and significantly improve algal biomass growth. These heat-tolerant strains will be grown in in photobioreactors, potentially reducing evaporation and eliminating the need for cooling.

ADVANCEMENTS IN ALGAL BIOMASS YIELD, PHASE 2 (ABY2)

On July 14, 2016, the Energy Department **announced up to $15 million** for three projects aimed at reducing the production costs of algae-based biofuels and bioproducts through improvements in algal biomass yields. These projects will develop highly productive algal cultivation systems and couple those systems with effective, energy-efficient, and low-cost harvest and processing technologies. This funding will advance the research and development of advanced biofuel technologies to speed the commercialization of renewable, domestically produced, and affordable fossil-fuel replacements.

The following projects were selected:

- **Global Algae Innovations** (San Diego, California)—Global Algae Innovations Inc., in collaboration with the University of California-San Diego, TSD Management Associates, Texas A&M University, General Electric, Pacific Northwest National Laboratory, and the National Renewable Energy Laboratory, will accelerate the commercialization of algal biofuels through development of an integrated, photosynthetic, open raceway pond system to produce algal oil. Their approach is to combine best-in-class cultivation and pre-processing technologies with some of the world's leading strain development laboratories.
- **Algenol Biotech LLC** (Ft. Myers, Florida)—Algenol Biotech LLC, the National Renewable Energy Laboratory, Georgia Institute of Technology, and Reliance Industries Limited have formed a team to advance the state-of-the-art in algal production and biofuel processing with the end goal of a sustainable, economically viable biofuel intermediate through enhanced productivity of cyanobacteria, the conversion of the biomass to a biofuel intermediate, and the cost-sensitive operation of a photo-bioreactor system.
- **MicroBio Engineering, Inc.** (San Luis Obispo, California)—MicroBio Engineering, Inc., in partnership with Cal Poly University, Pacific Northwest National Laboratory, Sandia National Laboratories, and Heliae will deliver integrated technologies that achieve high yields of biofuels, combined with treatment of wastewater, higher value co-products, and carbon-dioxide mitigation.

BETO Closed Funding Opportunities

2016

PROJECT DEFINITION FOR PILOT- AND DEMONSTRATION-SCALE MANUFACTURING OF BIOFUELS, BIOPRODUCTS, AND BIOPOWER
On December 28, 2016, the Energy Department (DOE) **announced the selection of six projects** for up to $12.9 million in federal funding, entitled, “Project Definition for Pilot- and Demonstration-Scale Manufacturing of Biofuels, Bioproducts, and Biopower.”

- **Global Algae Innovations (San Diego, California)**: Global Algae Innovations ($1.2 million) has developed novel technologies that improve several stages of the algae production process. This project seeks to design a pilot-scale algae biofuel facility with improved productivity of open pond cultivation and more energy-efficient algae harvest.

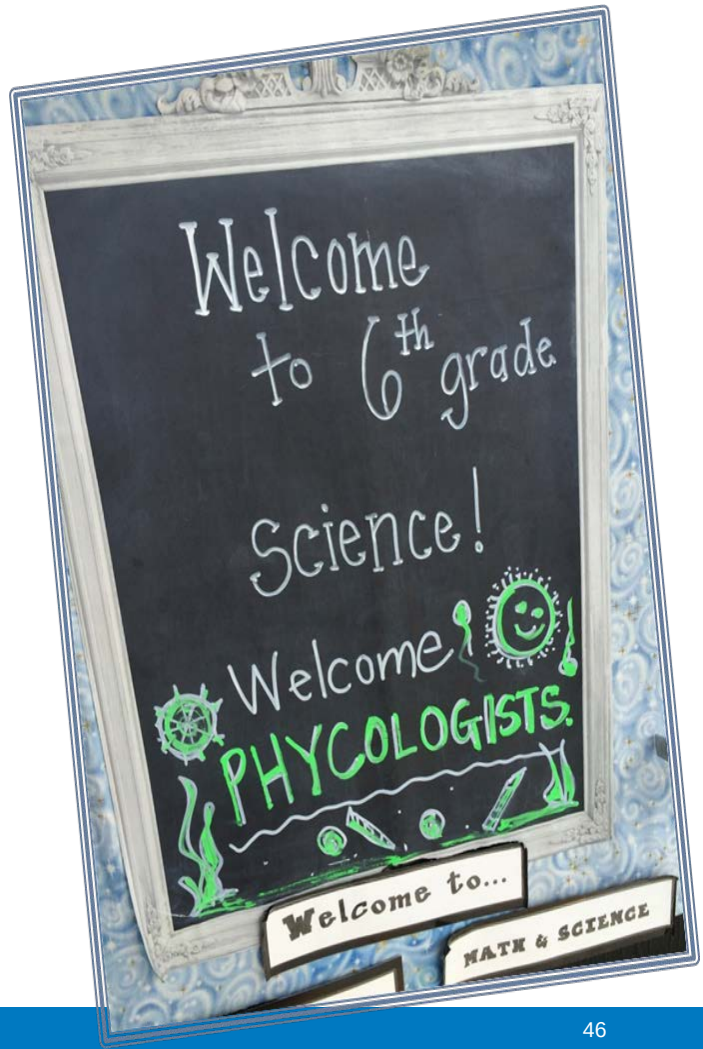
K-12 Initiative

thealgaefoundation

PURPOSE: To educate & excite students on the power of ALGAE to:

1. **Significantly reduce Greenhouse Gases**
2. **Provide a sustainable source of biomass for Food & Bioproducts**
3. **Lead the path to Commercial Biofuels**

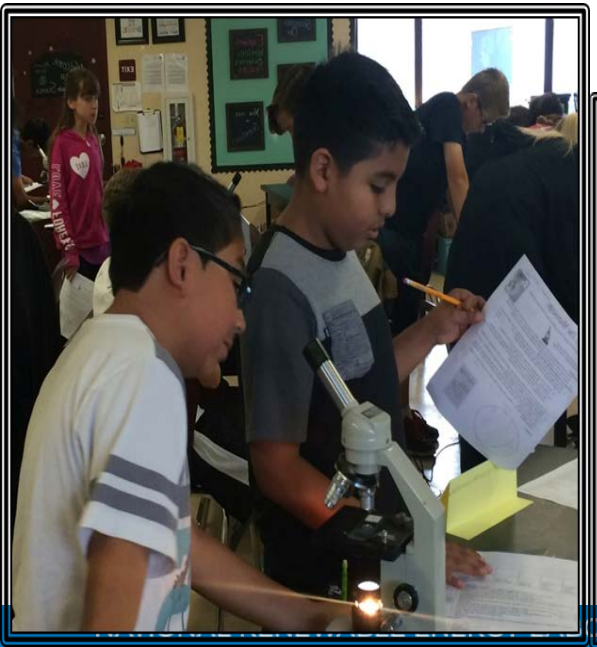
K-12 Initiative pilot completed
April 2016
300 *6th/7th grade students*
in San Diego, California



thealgaefoundation

1. Developing Algae STEM Kits to distribute free of charge to schools across the nation.
2. Fundraising through private funds & grants to fund kits for 50 schools in the 2016/2017 academic year.
3. Partnering with educators to develop curricula & training tools for teachers.
4. Networking with school districts and social media to spread the word!
5. Educating and inspiring students on how algae will meet global needs in our lifetime.

Students will join The Algae Nation!



Abbreviations and Acronyms

ABO – Algae Biomass Organization
ACC – Austin Community College
ACES – Algae Cultivation Extension Short-courses
ASU – Arizona State University
ATEC – Algae Technology Educational Consortium
BETO – Bioenergy Technologies Office
CC – Community College
DOE – Department of Energy
FY – Fiscal Year
MOOC – Massive Online Open Course
NOAA – National Oceanographic Atmospheric Administration
NREL – National Renewable Energy Laboratory
SFCC – Santa Fe Community College
STEM – Science Technology Engineering, and Mathematics
UCONN – University of Connecticut
UCSD – University of California, San Diego
US – United States
USM – University of Southern Maine
UTEX – University of Texas, Austin