U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Advanced Algal Systems

Research and development (R&D) on advanced algal biofuels and bioproducts presents an opportunity to sustainably expand biomass resource potential in the United States. The Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office (BETO) Advanced Algal Systems Program employs a long-term, applied R&D strategy to lower the costs of algal biofuel production by working with partners to develop innovative technologies.

The term "algae" refers to a great diversity of organisms—from microscopic cyanobacteria to giant kelp. Most algae convert sunlight into energy in a similar manner to plants; however, the genetic diversity of algae means there are an incredible number of unique properties that can be harnessed to develop promising algal biofuels and bioproducts. Algal biomass development focuses on identifying or improving those properties, such as a fast growth rate and high oil content, which make algae attractive to convert into biofuels.

Some of algae's unique properties include:

- High potential yield per acre
- Ability to grow on land not suited for agriculture
- Ability to grow in saline, brackish, or wastewater

Algenol Biotech, LLC cultivates spirulina in photobioreactors at a facility in southwest Florida. *Photo from Algenol Biotech LLC.*

- Potential for recycling of water and nutrients during production
- Relative ease of conversion into fuels and products that are fully compatible with today's vehicles, jets, and delivery systems.

Sustainability and Analysis

BETO and its partners conduct rigorous techno-economic, resource, and life cycle assessments to determine the potential for algal biofuels to help sustainably meet BETO strategic goals and to better understand the potential and challenges of growing the algae industry. BETO aims to validate an algal biofuel production system that cuts greenhouse gas emissions relative to petroleum baselines, meets water conservation targets, satisfies federal standards for wastewater and emissions, and is capable of converting algal feedstocks to biofuels and bioproducts in support of BETO's goals for mature modeled minimum fuel selling prices of $2.50/gasoline gallon equivalent.

Recent algae R&D efforts include studying the use of carbon dioxide (CO_2) emissions from stationary point sources in algae cultivation. Recovering these waste streams could support CO_2 reduction targets while simultaneously serving as an added value for algae producers.

Many developers are also targeting nutrient-rich wastewater to minimize freshwater demand while supplying necessary cultivation inputs. These approaches could reduce water and nutrient needs, assist in wastewater remediation, and add value to otherwise marginal lands.

New biological and engineering approaches are enabling the productive use of an increasing share of algal biomass—boosting process efficiency. In addition to using the stored fats (lipids) in microalgae, researchers are exploring ways to use algal proteins and starches, secreted compounds, or the whole algae biomass of some strains to produce biofuels and bioproducts.

Strategic R&D Planning and Implementation

A significant amount of R&D is needed for algal biofuels to be cost-competitive at a commercial scale. BETO funds R&D to strategically address challenges along the supply chain—from the application of advanced biological tools to the extraction and conversion of algal components

A scientist at Los Alamos National Laboratory (LANL) holds a flask of *Auxenochlorella protothecoides*, a green algae that can use raw plants as a carbon source. *Photo from LANL.*

into biofuels and bioproducts. Working with partners at National Laboratories and with competitively selected organizations through cooperative agreements, BETO addresses technical barriers. These barriers are prioritized through stakeholder outreach and engagement, strategic planning, out-year goal setting, and techno-economic, resource assessment, and life cycle analyses. BETO continually engages with stakeholders through workshops, webinars, meetings, peer reviews, conference participation, and formal requests for information.

While algae production remains a key challenge in the development of affordable algal biofuels, BETO is demonstrating promising cultivation techniques in open ponds, photobioreactors, and hybrid systems. BETO provided funding to study the potential of production systems through pilot and demonstration-scale integrated biorefineries, as well as large R&D consortia to catalyze a new generation of algae scientists and a foundation for R&D programs across the country. Results from this work clearly showed resource demands are a major consideration in scaling efforts; therefore, the Advanced Algal Systems Program supported semi-integrated technologies for recycling water and external nutrients during algae cultivation. BETO also focused competitive funding on the development of user-facility testbeds for the R&D community. Collaborative open testbeds formed a network of facilities for the algal research community and increased stakeholder access to real-world conditions for algal biomass production. Through hands-on learning opportunities, workshops, and seminars held at partner sites and selected public events, the testbeds offer formal and informal education and training in the use of microalgae as feedstock for biofuels and coproducts. These facilities also designed a unified experimental program across different regional, seasonal, environmental, and operational conditions to compare promising production strains at meaningful scales. In 2017 and 2018, BETO announced cost-shared funding aimed at advancing biomass productivity and fuel yield via advanced biology strategies and improving efficiency of CO_2 utilization. BETO acknowledges the important role bioproducts have to play in enabling the biofuels industry, and the Advanced Algal Systems Program has incorporated product development into its R&D portfolio and techno-economic modeling.

Algal biofuels R&D has achieved technological advancements that can bring about transformational changes, including the ability to predict, breed, and select the best-performing algal strains; monitor and control system inputs in a dynamic and integrated fashion; harvest algae at high throughputs; and extract and convert more algal biomass components into fuels. The *2016 National Algal Biofuels Technology Review*[1] summarizes successes and breakthroughs in this field and documents the feasibility and techno-economic challenges associated with commercial scaling. The recently released *Bioeconomy Initiative: Implementation Framework*[2] identifies federal programs working to achieve low-cost advanced algal systems and the knowledge and technology gaps that need to be overcome. These federal programs are working toward the following objectives:

- Increase algal biomass productivity and yield
- Develop strategies for co-production of value-added chemicals, energy, and materials to meet market needs
- Sustainably leverage resources for a national algal industry.

Visit energy.gov/bioenergy to find out how to become involved with upcoming program activities and to learn more about the program.

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For more information, visit:
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[1] https://www.energy.gov/sites/prod/files/2016/06/f33/national_algal_biofuels_technology_review.pdf
[2] https://biomassboard.gov/pdfs/Bioeconomy_Initiative_Implementation_Framework_FINAL.pdf