Algal Biofuels: Long-Term Energy Benefits Drive U.S. Research

Algal biofuels can help build U.S. energy security as part of a broad national strategy to cultivate domestic energy sources. The Energy Department's Bioenergy Technologies Office (BETO) supports the development of technologies to sustainably grow and convert algae into advanced biofuels and bioproducts.

Biofuels produced from algae have attracted significant interest. Algae's unique attractiveness as a resource for transportation fuels is based on its diverse benefits, which include the following:

- High potential yield per acre
- Ability to grow on land not suited for agriculture
- Ability to grow in brackish or waste water
- Absorption of carbon dioxide during growth
- Relative ease of conversion into fuels and products that are fully compatible with today's vehicles, jets, and delivery systems.

A significant amount of research and development (R&D) must be completed before algal biofuels will be cost effective at a commercial scale. One of the biggest challenges is to develop economical and sustainable technologies to produce, harvest, extract, and convert the useful components into advanced biofuels. BETO conducts research on relevant technologies to scale up the production of algal biofuels in accordance with its Multi-Year Program Plan.

Sustainability

BETO and its partners have conducted rigorous techno-economic, resource, and life-cycle assessments to determine the potential for algal biofuels to help sustainably meet national transportation energy goals. The Office aims to validate an algal bioenergy production system that cuts emissions of greenhouse gases by 50% or more relative to petroleum, creates socioeconomic benefits, meets water conservation targets, and satisfies federal standards for wastewater and emissions.

Algal Biofuels Goal

Develop algae production and logistics technologies that, if scaled up and deployed, could support the annual production of 5 billion gallons of sustainable, reliable, and affordable, advanced biofuels from algae.

Algae are a diverse group of primarily aquatic organisms ranging in size from the microscopic to large seaweeds. Research on algae production for biofuels requires fundamental knowledge of biology as well as expertise in large-scale farming and water management. Shown in the left image above is a culture pond built by Pacific Northwest National Laboratory to simulate the temperature, water, and sunlight of any location. The right image shows photobioreactors at Algenol. *Photo credits: Pacific Northwest National Laboratory (left) and Algenol (right).*

BETO-supported studies tend to estimate the productivity of microalgae biofuels more conservatively than other studies. Even so, these analyses support a scenario in which the United States could meet the BETO goal of producing 5 billion gallons of renewable algae diesel per year by 2030.[1]

Many developers already target use of brackish or saltwater, nutrient-rich wastewater, or closed-loop systems to minimize fresh water demand. While unproven at commercial scale, these approaches could reduce water and nutrient needs, assist in wastewater remediation, and utilize nonproductive lands.

R&D Planning and Progress

After publishing the National Algal Biofuels Technology Roadmap in 2010, BETO selected four multidisciplinary research consortia to accelerate technology development in algal biofuels (see side bar). This investment has established a new generation of algae researchers and has catalyzed progress across the supply chain. Two of the four consortia continue to advance the science of algal biofuels, while the National Alliance for Advanced Biofuels and

[1] For detailed information on algal biofuel resource assessments, please refer to:

- ANL, NREL, PNNL (June 2012). "Renewable Diesel from Algal Lipids: Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model." ANL/ESD/12-4; NREL/TP-5100-55431; PNNL-21437
- Quinn Jason, et al. "Current Large-Scale US Biofuel Potential from Microalgae Cultivated in Photobioreactors." BioEnergy Res. 2012; 5(1):49—60.
- Davis, Ryan, et al. "Integrated Evaluation of Cost, Emissions, and Resource Potential for Algal Biofuels at the National Scale." Environmental Science & Technology (2014).

Bioproducts has completed its research and issued a final report. The diverse successes of this 39-member consortium range from basic advances in algal biology, such as the genetic sequencing of production strains, to the development of hydrothermal liquefaction—a breakthrough conversion pathway for algae.

New biological and engineering approaches are enabling 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 secreted compounds (without destroying the cells) or the whole algae biomass of some strains. Scientists are also working to improve the algal biofuels value chain by incorporating higher-value co-products into the revenue stream.

To establish consistent, quantitative metrics for evaluating algal biofuel production pathways, BETO integrated its resource assessment, techno-economic, and life-cycle analysis capabilities into an integrated modeling framework. To date, modeling efforts have identified two design pathways deemed capable of producing an algae-based biofuel that could sell for less than $5 per gallon (gasoline equivalent) by 2022:

- Whole algae hydrothermal liquefaction (http://bit.ly/1tVgR6P)
- Algal lipid upgrading (http://go.usa.gov/pSDe)

To assess progress since the publication of the 2010 Roadmap, BETO hosted two strategy workshops (in November 2013 and March 2014). Stakeholders from industry, government, and academia discussed barriers and the R&D needed to achieve affordable, scalable, and sustainable algae-based biofuels. Workshop results were summarized as valuable input for consideration during BETO planning exercises.

Project Funding

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. For example, BETO provides cost-shared funding to the following partners for the demonstration of various algae production and conversion technologies: Sapphire Energy Inc. (demonstration scale), Algenol Biofuels Inc. (pilot scale), Solazyme Inc. (pilot scale), and BioProcess Algae (pilot scale).

BETO also awarded funds for "Advancements in Sustainable Algal Production" to develop testbeds and integrate technologies for recycling the water and external nutrients during algae cultivation. In 2013, the Office announced a funding opportunity to foster "Advancements in Algal Biomass Yield" and lower costs, resulting in five awards (see below).

Most recently, BETO announced a funding opportunity, "Targeted Algal Biofuels and Bioproducts," to reduce the cost of algal biofuels to less than $5 per gallon of gasoline equivalent by 2019. The teams selected for this award will conduct R&D on co-products, carbon dioxide utilization, and crop protection strategies. ■

BETO Initiatives in Algal Biofuels

May 2010 – Algal Biofuels Consortia Initiative created collaborative partnerships to address issues across the algae biofuels supply chain:

- National Alliance for Advanced Biofuels and Bioproducts
- Sustainable Algal Biofuels Consortium
- Consortium for Algal Biofuels Commercialization
- Cornell Consortium

August 2012 – Advancements in Sustainable Algal Production awarded funding to five teams in two areas:

Water and Nutrient Recycling

- California Polytechnic State University
- Sandia National Laboratories
- University of Toledo

Testbeds

- Algae Testbed Public-Private Partnership
- Regional Algae Feedstock Testbed Partnership

November 2013 and March 2014 – Workshops on Algal Biofuels Strategy convened to gather stakeholder input.

Fiscal years 2013 and 2014 – Advancements in Algal Biomass Yield awarded cost-shared R&D funding to support the work of:

- Hawaii Bioenergy, LLC
- Sapphire Energy
- New Mexico State University
- California Polytechnic University
- Cellana, LLC

September 2014 – Targeted Algal Biofuels and Bioproducts funding opportunity announced.