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 Bioenergy Technologies Office is exploring ways to sustainably develop algae into advanced biofuels such as renewable diesel and jet fuel.

Biofuels produced from algae are attracting significant interest and investment. Algae's unique attractiveness as a resource for transportation fuels is based on its diverse benefits:

- 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, airplanes, and delivery systems.

A significant amount of research and development (R&D) work must be completed before algal biofuels will be cost-effective at a commercial scale. Some of the biggest challenges are to find economical and sustainable ways to produce, harvest, extract, and convert the useful components into advanced biofuels. The Energy Department's Bioenergy Technologies Office (BETO) pursues research in all of these areas to integrate and scale up these technologies in accordance with its *Multi-Year Program Plan*.

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 at left above are climate-simulated culture ponds built by Pacific Northwest National Laboratory to simulate the temperature, water, and sunlight of any location. At right is Sapphire Energy's array of one- and two-acre ponds.

Focus on Sustainability

Sustainability is a guiding principle for all R&D conducted under BETO. The Office and its research partners work to mitigate any adverse health, environmental, or socio-economic impacts of bioenergy development.

Two analyses have underscored the importance of minimizing land and water requirements for algal biofuels. The first, a study by the Pacific Northwest National Laboratory published in *Water Resources Research*,[1] recommends strategically locating algae production facilities to limit water usage to 25% or less of current irrigation demand. Using such safeguards, the analysis suggests the United States can sustainably produce enough algal biofuels to displace about 17% of oil imports by 2022 (about 20 billion gallons).

The second analysis, by the National Academy of Sciences,[2] explores the sustainability of cultivating and converting into biofuels enough algae to meet 5% of all U.S. transportation fuel needs (about 10 billion gallons). The report identifies areas of potential concern as well as opportunities for mitigation through research and technology innovation.

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

Bioenergy Technologies Office: 2022 Algae Goals

- Identify adequate U.S. resources to sustainably produce the equivalent of more than one billion gallons of non-cellulosic advanced biofuels.
- Develop, demonstrate, and integrate algal biofuels technologies that are cost-competitive with conventional fuels, focusing on scalability, productivity, and sustainability.

1 M. Wigmosta et al., "National microalgae biofuel production potential and resource demand," *Water Resources Research*, Vol. 47 W00H04, 13 pp., 2011

2 *Sustainable Development of Algal Biofuels*, National Academies Press, October 2012.

Targeted Research

BETO began scoping activities on affordable algal biofuels by holding a national workshop to clarify the critical technical barriers. The results of the workshop were published as the *National Algal Biofuels Technology Roadmap* in 2010.

To address priorities established in the roadmap, BETO launched four multi-disciplinary research consortia to conduct applied research (see side bar). These efforts have helped to advance the science and have generated valuable genetic tools.

BETO is integrating resource assessment, techno-economic, and life-cycle analysis capabilities into an integrated model framework. The purpose is to establish consistent, quantitative metrics for evaluating algal biofuel production pathways.

The initial outcome from this process was a June 2012 report on *Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model*. By establishing a framework for quantifying costs, emissions, and resource needs, the report enables data validation and technology improvements based on shared assumptions and metrics. Researchers and developers can use this conservative baseline to measure their successes and benchmark progress toward commercial viability. Two promising pathways identified so far include whole algae hydrothermal liquefaction and algal lipid upgrading.

Driving Down Costs

Researchers are working to improve the algal biofuels value chain by developing high-value co-products. In addition, significant advancements in algal feedstock cultivation, processing, and logistics are expected to reduce capital and operating expenses.

New biological and engineering approaches are enabling productive use of an increasing share of the 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.

Project Funding

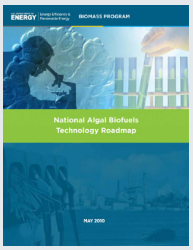
Although the conversion and upgrading of algae into biofuels entail major challenges, results of the Office's techno-economic models suggest that the biggest challenge is to lower the cost of producing algae feedstocks. BETO addresses the affordability and sustainability of algal biofuels production by providing cost-shared funding for R&D and technology demonstrations at various scales. For example, BETO provides cost-shared funding to the following biorefinery projects for algal biofuels:

- Sapphire Energy Inc. (demonstration-scale)
- Algenol Biofuels Inc. (pilot-scale)
- Solazyme Inc. (pilot-scale)

The Office also supports Advancements in Sustainable Algal Production (see projects in sidebar) to develop and integrate technologies for recycling the water and external nutrients during algae cultivation. In early 2013, the Office announced a funding opportunity to increase algal biomass yields and lower costs. The aim is to demonstrate annual yields sufficient to produce 2,500 gallons of algal biofuels (per acre equivalent) by 2018. The longer-term goal is to obtain yields that enable 5,000 gallons by 2022.

To learn more, please visit our website at biomass.energy.gov

Bioenergy Technologies Office Initiatives in Algal Biofuels



May 2010: *National Algal Biofuels Technology Roadmap* published

May 2010-2013: Algal Biofuels Consortia Initiative created four collaborative partnerships among universities, national laboratories, and industry to address issue throughout the algae biofuels supply chain. All awards require at least a 20% cost share from the private sector.

- National Alliance for Advanced Biofuels and Bioproducts
- Sustainable Algal Biofuels Consortium
- Consortium for Algal Biofuels Commercialization
- Cellana, LLC Consortium

June 2012: *Renewable Diesel from Algal Lipids: An Integrated Baseline for Cost, Emissions, and Resource Potential from a Harmonized Model* published

August 2012: Advancements in Sustainable Algal Production award provides funding for four key projects.

- California Polytechnic State University (to recycle 75% or more of water and nutrients)
- University of Toledo (to use wastewater and return key nutrients for algal cultivation)
- Sandia National Laboratory (to develop cost-effective nutrient recycling process)
- Arizona State University (to develop network of testbeds and generate regional data)

2013: Algal Biomass Yield funding opportunity announced

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