U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ALGAL BIOFUELS

Photo courtesy of Qualitas Health, Inc.

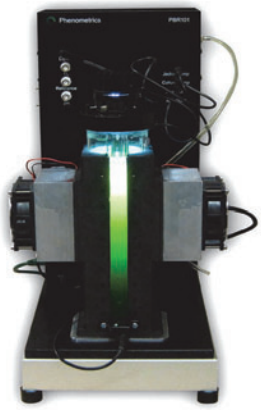
2016 National Algal Biofuels Technology Review

Algae-based biofuels and bioproducts offer great promise in contributing to the U.S. Department of Energy (DOE) Bioenergy Technologies Office's (BETO's) vision of a thriving and sustainable bioeconomy fueled by innovative technologies. The state of technology for producing algal biofuels continues to mature with ongoing investment by DOE and the private sector, but additional research, development, and demonstration (RD&D) is needed to achieve widespread deployment of affordable, scalable, and sustainable algal biofuels.

The 2010 *National Algal Biofuels Technology Roadmap* sought to comprehensively summarize the state of technology for fuels and bioproducts from algal feedstocks and to document the feasibility and techno-economic challenges associated with commercial scaling. Since that initial review, there have been significant advancements in the field, as well as the articulation of new challenges, lessons learned, and critical next steps, which have been detailed in the *2016 National Algal Biofuels Technology Review*.

The 2016 *National Algal Biofuels Technology Review* covers the following subject areas:

- Algal Biomass, Genetics, and Development
- Resources for Algal Research
- Algal Cultivation
- Harvesting and Downstream Processing
- Extraction of Products from Algae
- Algal Biofuel Conversion Technologies
- Commercial Products
- Distribution and Utilization
- Resources and Sustainability
- Systems and Techno-Economic Analyses.



An environmental photobioreactor (Photo courtesy of Phenometrics)

Summary of Advancements in the Field

In recent years, the algal biofuels RD&D has achieved technological advancements that can bring about transformational changes, including the ability to predict, breed, and select the best-performing strains; the ability to monitor and control system inputs in a dynamic and integrated fashion; the ability to harvest algae at high throughputs; and the ability to extract and convert more algal biomass components into fuels. BETO is dedicated to ensuring that these advancements are aligned with sustainability principles—such as the best management of resources, including water and nutrients—and that they are economically viable in a competitive global marketplace.

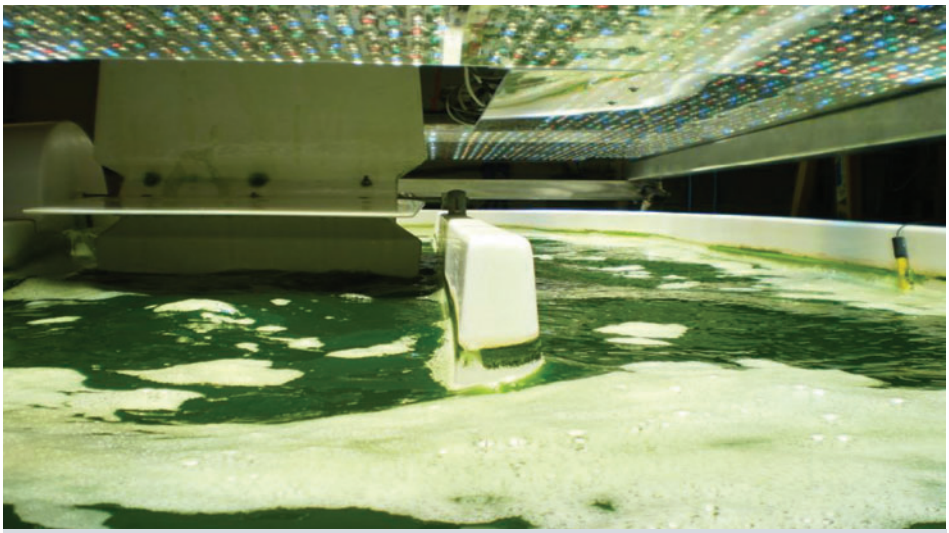
For more information and to access the report, please visit http://energy.gov/eere/bioenergy/downloads/2016-national-algal-biofuels-technology-review

Algal Biomass Production

One of the most critical areas of focus, algal biology, has benefited from dedicated researchers advancing the understanding of the true requirements of outdoor algae cultivation. The field has recognized that strain robustness, not just lipid content, is critical for large-scale cultivation. Molecular technologies have been developed to make the necessary improvements in robustness and productivity, including molecular toolboxes for strain improvement. Work in directed evolution and high-throughput selection systems have led to the development of advanced algal strains. In addition, multiple libraries of catalogued species from marine, freshwater, and brackish water environments have been collected. Some research has also discovered that "superior strain" development may not hold the whole answer, and beneficial symbioses and ecosystem responses exist within certain bacteria, microbes, and algal strain communities. Development of standardized protocols for the quantification and characterization of biomass has allowed for the establishment of a common language and consistent metrics for success among researchers.

Moving many of these biological advances to outdoor cultivation environments has been a major success, and it is still an area of continued research effort. The development of laboratory tools and methods that mimic outdoor conditions has allowed for the ability to predict pond performance. Pond crashes are being addressed by species-specific pathogen- and predator-prevention methods, as well as approaches to create a stable, diversified culture that is less sensitive to predation.

Novel cultivation designs have demonstrated productivity improvements at increasing scales, including systems capable of using industrial-waste carbon dioxide, nutrient-rich impaired water, or wastewater streams. Nutrient- and water-recycle strategies have proven necessary for both economic and environmental sustainability, and advances in these strategies are consistently improving system viability. Much of this cultivation data has been made publicly available.



PNNL's indoor, LED-lighted, and temperature-controlled climate-simulation raceway pond (Photo courtesy of Michael Huesemann, Pacific Northwest National Laboratory)

Processing and Conversion

Major advances have also been made in feedstock processing and conversion to biofuel intermediates and finished fuels. Innovations in hydrothermal liquefaction have demonstrated the conversion of wet biomass into crude oil at high yield, with low energy costs, in a continuous process. Wet solvent extraction processes have also improved total fuel yields. Researchers have demonstrated the effectiveness of an integrated technology based on moderate temperatures and low pH to convert the carbohydrates in wet algal biomass to soluble sugars for fermentation, while making lipids more accessible for downstream extraction and leaving a protein-enriched fraction behind.

Algal oil has been successfully converted to jet and biodiesel, meeting the American Society for Testing and Materials standards. Algae companies are beginning to see off-take agreements with fuel producers such as Tesoro, Phillips 66, and others. Test runs in aviation and cross-country road trips have demonstrated high fuel performance.

There's Work Left to Do!

Even with all these advancements, there is still work left to do to achieve cost-competitive algal biofuels. In general, a dedicated research and development focus on cost-effective solutions for simple, low-energy inoculum and culture production, product extraction, and conversion systems is required.

BETO's Advanced Algal Systems Program is focused on demonstrating progress toward achieving high-yield, low-cost, environmentally sustainable algal biofuel-production systems, and it is actively working with the research and development community to make algal biofuel a part of a diversified energy future.

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

For more information, visit:
bioenergy.energy.gov

DOE/EE-1425 • June 2016