U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Algae: A Single Cell for Multiple Solutions

Open raceway ponds in the Field Test Laboratory Building (FTLB) greenhouse. Each pond is 100L at 20cm depth and is equipped with temperature, dissolved oxygen, and pH probes. *Photo by Dennis Schroeder, NREL 55150.*

To combat climate change, the United States is leading by example to build a 100% clean energy economy and reach net-zero emissions no later than 2050. In pursuit of that goal, the U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) supports public and private partners that work to improve and increase the use of algae for production of biofuels and bioproducts.

Algae are unique among the various bioenergy feedstocks being researched and developed by BETO-funded programs. Like traditional crops, algae need sunlight, nutrients, water, and carbon dioxide (CO_2) to grow, but algal production has numerous advantages over that of traditional crops that sprout from the dirt.

With a high areal productivity, algae's high rate of growth and its favorable biomass composition for recovery of valuable fuel and product precursors, algae can be up to 10 times more productive than some terrestrial biocrops being grown today. In fact, some algal strains are capable of doubling in yield overnight. Beyond that, there is potential to grow, harvest, and convert algal biomass—from microalgae, seaweeds, and cyanobacteria—in every state in the United States if the right growth system is paired with the regional environment. Every year, BETO researchers learn more about the composition and genetic makeup of algae and how to adapt it to different climates, improve productivity, and make it more resilient to pests and disease.

From Photosynthesis to Fuel Tanks

Algal-related activities funded by BETO strategically address technology challenges in the scale-up of algae-based production and utilization. For years, DOE and its partners have been researching algae growth on non-productive lands without using fresh water.

Algae cells accumulate lipids at a significant rate compared to other biomass crops. Using existing technology, these lipids can be extracted and converted into renewable fuels that are compatible with current engines and can be delivered to consumers through current infrastructure, as gasoline and diesel are today.

The increased efficiency of algae combined with its compatibility to current infrastructure means it has potential to be a key solution for expanding the production of sustainable fuels to help decarbonize the transportation sector. BETO's Advanced Algal Systems Program has set targets for productivity, quality, and availability that, if scaled-up and replicated, could lead to cost-competitive algae-based biofuels for airplanes, trucks, and cars by 2030.

From Ponds to Skies

In the nation's effort to realize a lower carbon future, aviation fuel poses one of the greatest challenges because, unlike ground transportation, airplanes will not have the technology to run on electricity in the foreseeable future. Aviation accounts for 2% of all human-caused CO_2 emissions globally and is expected to grow.[1] To have an impact on this growing source of carbon emissions will require the implementation of sustainable aviation fuels such as those derived from algae.

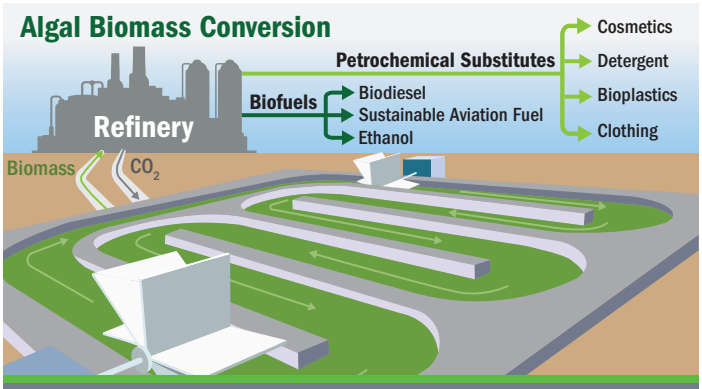
BETO projections for the future state-of-the-art algae industry indicate that by 2030, algal technologies will be capable of scaling up to provide more than five billion gallons of fuel annually in the United States. This would represent more than 40% of all jet fuel consumed for U.S. domestic flights in 2019.[2] The impact of such a shift would be equivalent to taking around five million cars off the road.

From Blooms to Bioproducts

Decarbonizing fuel alone will not be enough to achieve the nation's goal of net-zero GHG emissions no later than 2050. Plastics and other petroleum-based products are key contributors to carbon emissions, and must be replaced

[1] iata.org/contentassets/ed476ad1a80f4e-c7949204e0d9e34a7f/corsia-fact-sheet.pdf

[2] transtats.bts.gov/fuel.asp



Co-locating algae ponds near refineries and other carbon producers allows greenhouse gases and other waste to be fed directly to the algae as part of its growth cycle. Algae can then be converted to substitutes for petroleum-based chemicals that are used to make biofuels and a variety of sustainable bioproducts.

with sustainable, bio-based replacements. Algae is already doing that in a variety of commercial fields.

Algae Products for Sun and Snow

Flip-flops are the world's top-selling footwear, with around three-billion pairs produced every year from petroleum-based polyurethane. Because flip-flops are considered inexpensive and, therefore, disposable, many end up in landfills or the ocean, making polyurethane from shoes one of the ocean's top pollutants.[3] Using algal cultivation research funded by BETO, Algenesis has created biodegradable flip-flops derived from renewable algae.[4]

Algae products are also useful in the mountains. Checkerspot, a high-performance materials company, has partnered with BETO researchers to develop technologies to produce sustainable Algal Cast polyurethane that ski manufacturer WNDR Alpine has used to build its Vital 100 and Intention 110 backcountry ski models.[5, 6]

Skiers may also find themselves wearing another Checkerspot innovation on the slopes. The company developed a microalgae oil that replaces petroleum and other unsustainable chemicals used by the textile industry to create wicking fabrics.[7] Beyond Surface Technologies, a green chemistry company, applied the oil to its miDori bioWick material, which has been used in sportswear made by Patagonia[8] and others to reduce the carbon footprint of their clothing by up to 80% over traditional wicking fabrics.[9]

[3] ucsdnews.ucsd.edu/feature/a_flip_flop_revolution
[4] algenesismaterials.com/algenesis-products
[5] checkerspot.com/matt-sterbenz
[6] wndr-alpine.com
[7] checkerspot.com/matthias-foessel
[8] patagonia.com/our-footprint/wicking-additives.html
[9] beyondst.com/kopie-von-portfolio-1

From Now to the Future

An additional benefit of algae could be its role in cleaning current fossil fuel production. Ongoing research studies how algal ponds can be used to clean air and water around oil refineries and power producers, which helps capture carbon dioxide. Carbon dioxide and other waste streams from such operations can be piped to the algae, which feeds on them as it grows.

As our country and the world move away from fossil fuels and petroleum-based plastics, algae-based fuels and products are not only alternatives to aid in decarbonizing our energy and our economy, but algae itself can be an environmental asset. BETO's goals to lower the cost of production while raising the productivity of an energy source that already produces biomass at rates more than double other terrestrial biocrops make algae one of the most promising bioenergy options available. ■

About the Bioenergy Technologies Office

BETO supports research, development, and demonstration to enable the sustainable use of domestic biomass and waste resources for the production of biofuels and bioproducts. BETO's overall goals are designed to:

- Lower costs and reduce technology risks for production of biofuels and bioproducts
- Improve environmental benefits of bioenergy production
- Reduce greenhouse gas emissions from the transportation, industrial, and agricultural sectors to address the climate crisis
- Support the scale-up of sustainable, low-carbon biofuel production technologies
- Create economic opportunities and good-paying jobs in agriculture and manufacturing sectors.

Meeting these goals requires significant and rapid advances in technology development and innovation across the entire biomass-to-bioenergy supply chain.

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