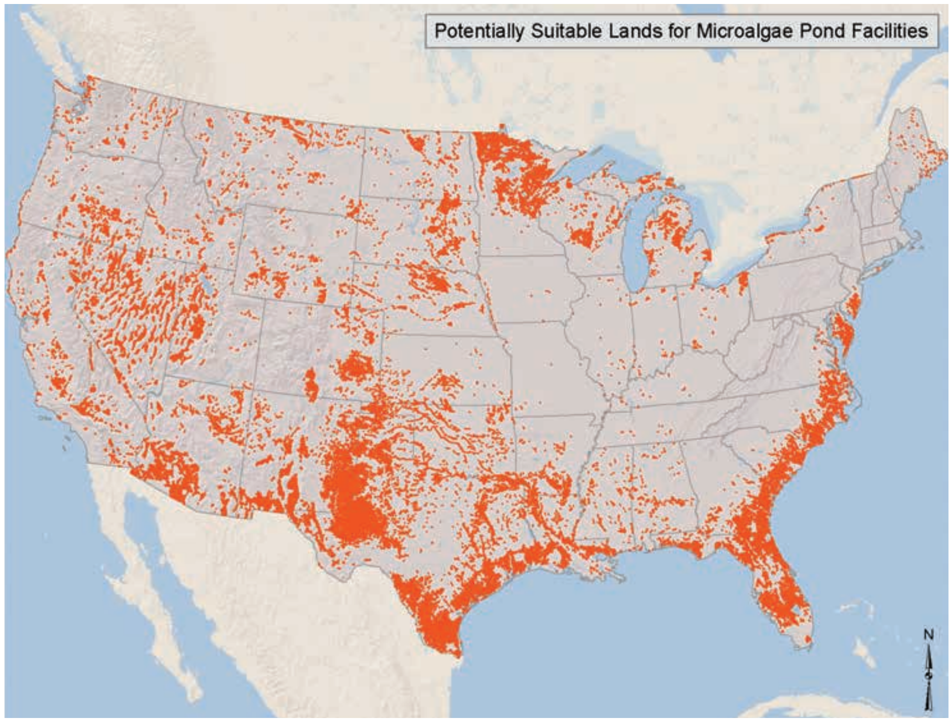
Algae Resources

Algae are highly efficient at producing biomass, and they can be found all over the planet. Many use sunlight and nutrients to create biomass, which contain key components—including lipids, proteins, and carbohydrates—that can be converted and upgraded to a variety of biofuels and products. A functional algal biofuels production system requires resources such as suitable land and climate, sustainable management of water resources, a supplemental carbon dioxide (CO_2) supply, and other nutrients (e.g., nitrogen and phosphorus).

Algae can be an attractive feedstock for many locations in the United States because their diversity allows for high-potential biomass yields in a variety of climates and environments. Depending on the strain, algae can grow by using fresh, saline, or brackish water from surface water sources, groundwater, or seawater. Additionally, they can grow in water from second-use sources such as treated industrial wastewater; municipal, agricultural, or aquaculture wastewater; or produced water generated from oil and gas drilling operations.

Summary

The *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy* summarizes the most recent estimates of potential biomass that could be available for biorefining in the future. This report is the first in the *Billion-Ton* series to include algae in the biomass resource potential assessment. As is the case for terrestrial feedstocks, important resource analysis questions for algae include not only how much of the crop may be available, but also what price might be needed to procure that supply.



The results of the BAT land characterization and suitability model resulted in 74,606 suitable "unit farms" (1,200 acres) totaling approximately 139,886 mi^2 (362,304 km^2).

Identifying opportunities for co-location of algal biofuel facilities with existing resources has the potential to reduce costs, reduce waste, and focus attention on appropriate technologies and locations for commercialization. While it does not project actual measured biomass or a simulation of commercial projects, the *2016 Billion-Ton* algae resource assessment estimates the site-specific and national economic availability of algal biomass under co-location scenarios that use waste CO_2 from existing point-sources for cultivation.

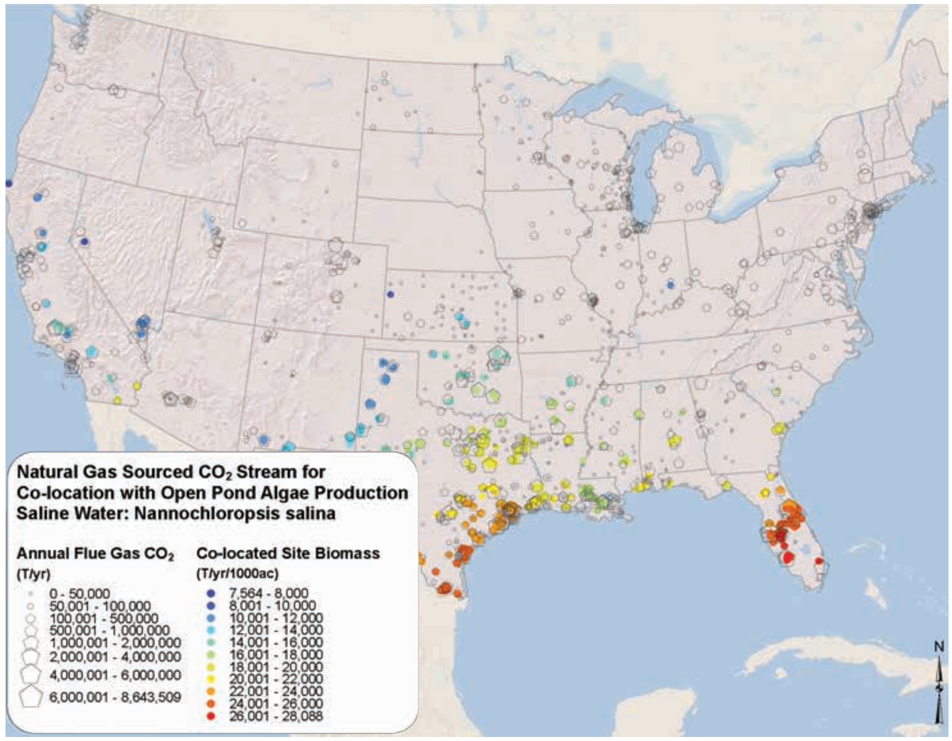
Three significant sources of waste CO_2 were selected, representing a range of purities and geographic distributions: natural gas electric generating units (EGU), coal EGU, and ethanol production facilities. These three classes of point-source CO_2 represent approximately 86.6% of CO_2 emissions in the continental United States—the major portion of the U.S. waste CO_2 supply.

Algal biomass yield potential is estimated based on 30 years of hourly local climate and strain-specific biophysical characteristics using the Biomass Assessment Tool (BAT) and assuming sufficient available nutrients (including CO_2). This analysis identified 74,606 unit farms—based on a nominal farm size of 1,000 acres—throughout the continental United States, totaling approximately 139,886 mi^2 (362,304 km^2) that are potentially suitable for large-scale, open-pond algae production.

Approach

The economic availability of biomass resources is influenced by variables including, but not limited to, biomass market development, land values, rate of adoption, and the profitability of alternative land uses. The *2016 Billion-Ton Report's* overall approach to quantifying algae biomass supply is to (1) develop engineering and cost estimates for CO_2 co-location scenarios; (2) select priority land areas for co-location; (3) generate national, site-specific, biophysically based production estimates; (4) develop spatially explicit transport pathways and incorporate available CO_2 supply, demand, and costs; and (5) generate estimates of minimum selling price as a function of supply. The *2016 Billion-Ton Report* also estimates the cost differential between co-location with CO_2 sources and a base case. The base-case costs are primarily based on a 2016 process design case report for the production of algal biomass in open ponds.[1]

The BAT is an integrated model, analysis, and data management architecture that couples advanced spatial and numerical models to capture site-specific environmental conditions, production potential, resource requirements, and sustainability metrics for bioenergy feedstocks. To determine land suitability for algae production, each modeled open-pond algae cultivation facility (unit farm, 1,200 acres) consists of 100 30-cm deep, 10-acre raceway style ponds requiring 1,000 acres of land for ponds and another 200 acres for operational infrastructure. Additionally, the potential facilities and associated infrastructure are constrained by several topographic and land use/land cover criteria to determine potentially suitable lands.



CO_2 co-location opportunity for coal-fired EGU and algae cultivation using freshwater strain *Chlorella sorokiniana*; colored dots represent co-located biomass potential.

The *2016 Billion-Ton Report* also evaluates the potential economic benefit of three CO_2 co-location scenarios, with a defined cost limit of $40 per ton of CO_2 to avoid exceeding projected commercial supply costs. In combination with the CO_2 co-location sources, a current cultivation productivity rate scenario and a future higher-productivity scenario are presented for both freshwater and saline water algae strains. For saline scenarios, both fully lined ponds and minimally lined ponds are considered because of the substantial costs of pond liners and uncertainty as to where they are needed.

The Path Forward

The Advanced Algal Systems program within the Bioenergy Technologies Office is implementing a focused strategy to achieve the vision of a thriving and sustainable bioeconomy fueled by innovative technologies. Central to its strategic research and development investment approach, the program works to ensure the sustainable use of key resources, such as land and water, by selecting projects that incorporate nutrient and water recycle, waste sources of CO_2, and add value to marginal or otherwise unproductive lands. The Bioenergy Technologies Office supports the annual domestic production goal of 5 billion gallons of algae-based biofuels by the year 2030.

[1] Davis, et al. 2016. NREL/DOE. *Process Design and Economics for the Production of Algal Biomass: Algal Biomass Production in Open Pond Systems and Processing Through Dewatering for Downstream Conversion*. http://www.nrel.gov/docs/fy16osti/64772.pdf.

This fact sheet refers to the following documents

U.S. Department of Energy. 2016. *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy*. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p.

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