U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Appendix D. Appendix to Chapter 7.1: Microalgae

March 2024

Disclaimer

Availability

This report and supporting documentation, data, and analysis tools are available online:

Report landing page: https://www.energy.gov/eere/bioenergy/2023-billion-ton-report-assessment-us-renewable-carbon-resources

Data portal: https://bioenergykdf.ornl.gov/bt23-data-portal

Suggested Citation

Davis, R., A. Coleman, T. R. Hawkins, B. Klein, J. Zhang, Y. Zhu, S. Gao, et al. 2024. "Appendix D. Appendix to Chapter 7.1: Microalgae." In *2023 Billion-Ton Report*. M. H. Langholtz (Lead). Oak Ridge, TN: Oak Ridge National Laboratory. doi: 10.23720/BT2023/2316183.

Appendix D. Appendix to Chapter 7.1: Microalgae

Appendix D.1: Multi-Criteria Land Screening

Further details of the Biomass Assessment Tool multi-criteria land screening data inputs and criteria are included in Table D-1.

Table D-1. Dataset Descriptions for the Multi-Criteria Land Screening for Determining Potential Algal Cultivation Farms at a Minimum Area of 1,000 Acres

Dataset	Year	Resolution (m)	Description and Processing	Source
Digital Elevation Model (DEM) from the National Elevation Dataset	2021	10	Elevation data used to derive weighted slope data set, where ≤1% slope is suitable (1), 1%–3% slope is weighted linearly, and ≥3% slope is not suitable (0). DEMs were downloaded from the national map.	U.S. Geological Survey
National Hydrography Dataset	2021	1:24,000 or better	Hydrography features, including rivers, streams, canals, lakes, ponds, and other open water. The database includes four datasets: areas, waterbodies, flowlines, and lines. The features are elevation-derived, and it is the most complete hydrological data set for the United States, according to the U.S. Geological Survey.	U.S. Geological Survey
National Land Cover Database	2019	30	Standardized land cover with 25 categories over the contiguous United States. Open water, perennial ice/snow, developed (open space; low, medium, and high intensity), deciduous, evergreen, and mixed forest, lichens, moss, and woody and emergent herbaceous wetlands are not suitable. Barren land, dwarf shrub, shrub/scrub, grassland/herbaceous, sedge/herbaceous, pasture/hay, and cultivated crops are suitable.	Multi-Resolution Land Characteristics Consortium
Coastal Change Analysis Program Land Cover	2009–2016	1–5	Standardized land cover with 24 categories over coastal regions of the United States, including islands and territories. Classification deviates slightly from the National Land Cover Database. Developed (open space; low, medium, and high intensity), deciduous, evergreen, and mixed forest, scrub/shrub, palustrine (forested, scrub/shrub, emergent) wetland, estuarine (forested, scrub/shrub, emergent), wetland, unconsolidated shore, water, palustrine and estuarine aquatic bed, tundra, and snow/ice are not suitable. Cultivated, pasture/hay, grassland, scrub/shrub, and bare land are suitable.	National Oceanic and Atmospheric Administration
Cropland Data Layer	2020, 2019, 2018	30	Standardized land cover data set including a wide variety of crops and general land cover classes over the contiguous United States. All crops, background, non-	U.S. Department of Agriculture

Dataset	Year	Resolution (m)	Description and Processing	Source
			agriculture/undefined, barren, shrubland, and grass/pasture are considered suitable. Forest, open water, wetlands, aquaculture, perennial ice/snow, developed (open space; low, medium, and high intensity), deciduous, evergreen, and mixed forest, and woody and herbaceous wetlands are suitable. A long-term (3-year) idle cropland data set was produced by isolating the fallow/idle class to a binary raster for each of the 2020, 2019, and 2018 data sets, then multiplying the rasters. The long-term idle cropland data are used to locate low-productivity croplands that may be ideal for siting an algal production facility, but are not included in the current screening.	
National Wetlands Inventory	2021	1:24,000 or better	Feature data set that covers all wetlands and surface water features on the landscape. Wetland areas are marked as unsuitable.	U.S. Fish & Wildlife Service
Urban Area Boundaries	2020	n/a	In accordance with new rules in the 2020 Census, any block group with a housing unit density of at least 385 people per square mile, where at least one-third of the census block has an impervious surface area of at least 20% and the area is compact in nature. Additionally, at least 40% of its boundary is contiguous with qualifying territory. These urban areas are marked as unsuitable.	U.S. Census
TIGER/Line Roads	2020	n/a	TIGER/Line all roads file containing all linear street features, such as primary, secondary, local, private, and rural roads; city streets; vehicular trails; ramps; service drives; walkways; stairways; and alleys. Roadways are an essential piece of infrastructure for an algal production farm, and existing roadways may reduce upfront cost for a new facility. Road features are considered following the land screening; however roads themselves are marked as unsuitable, as they are not appropriate for use, but from a modeling perspective, roads can link many small, otherwise non-contiguous areas together to meet a 1,000-acre minimum area.	U.S. Census
Aeroways	2021	n/a	An open crowdsourced data set containing polygon features for any infrastructure related to aviation and space flight. This includes runways, terminals, heliports, spaceports, parking lots, and more. Aeroways are not fully screened out as unsuitable, as there is potential to utilize part of the open areas typically associated with airports. A dataset was produced to indicate the presence of aeroway built infrastructure.	OpenStreetMap contributors

Dataset	Year	Resolution (m)	Description and Processing	Source
World Database on Protected Areas	2021	n/a	A worldwide database containing protected areas, with emphasis on conservation. In an effort to preserve valuable habitat, all protected areas are marked unsuitable.	Protected Planet Initiative
Protected Areas Database of the United States	2021	n/a	All areas in the United States that are held in public trust. The data set is considered functionally complete, though the estimated completion varies by state. These lands are marked as unsuitable.	U.S. Geological Survey
Military Installations, Ranges, and Training Areas	2021	n/a	Feature data set containing major installations, ranges, and training areas in the United States and its territories. Similar to aeroways, there is potential to utilize part of the land on military installations, thus not all areas are screened as unsuitable.	U.S. Department of Defense
Brownfields	2021	n/a	Point feature data set containing the location of brownfield sites in the United States. Brownfields are ideal for algal production facilities, as they are typically idle land that have potential for redevelopment. The sites included back in after the land screening analysis.	U.S. Environmental Protection Agency
Net Primary Productivity	2018	960	Net primary productivity derived from the Integrated Biosphere Simulator model in kg C/m^2. Data span 1971–2015, and the period of 1985–2015 was averaged for this analysis. Net primary productivity is considered especially in grassland areas to avoid removing or disturbing grasslands that are effective in capturing and storing carbon.	U.S. Geological Survey

Appendix D.2: Algae Farm TEA Modeling: Cost Breakouts for Selected Cases

Figure D-1 shows additional techno-economic analysis (TEA) details for minimum biomass selling price (MBSP) results for selected individual farm cases representing the minimum, maximum, and a representative point within the middle of the full MBSP curve. The plot breaks down the individual contributions to MBSP, with costs for inoculum and production ponds universally representing the most significant expenses (in turn driven by high capital costs for production ponds); however, water handling costs also become significant for many of the higher-MBSP locations, reflecting higher blowdown handling and associated forward osmosis/brine injection costs due to higher evaporation and/or higher makeup water salinities. Annual average cultivation productivities are also included for each case, reiterating typical trends for MBSP being inversely proportional to productivity.

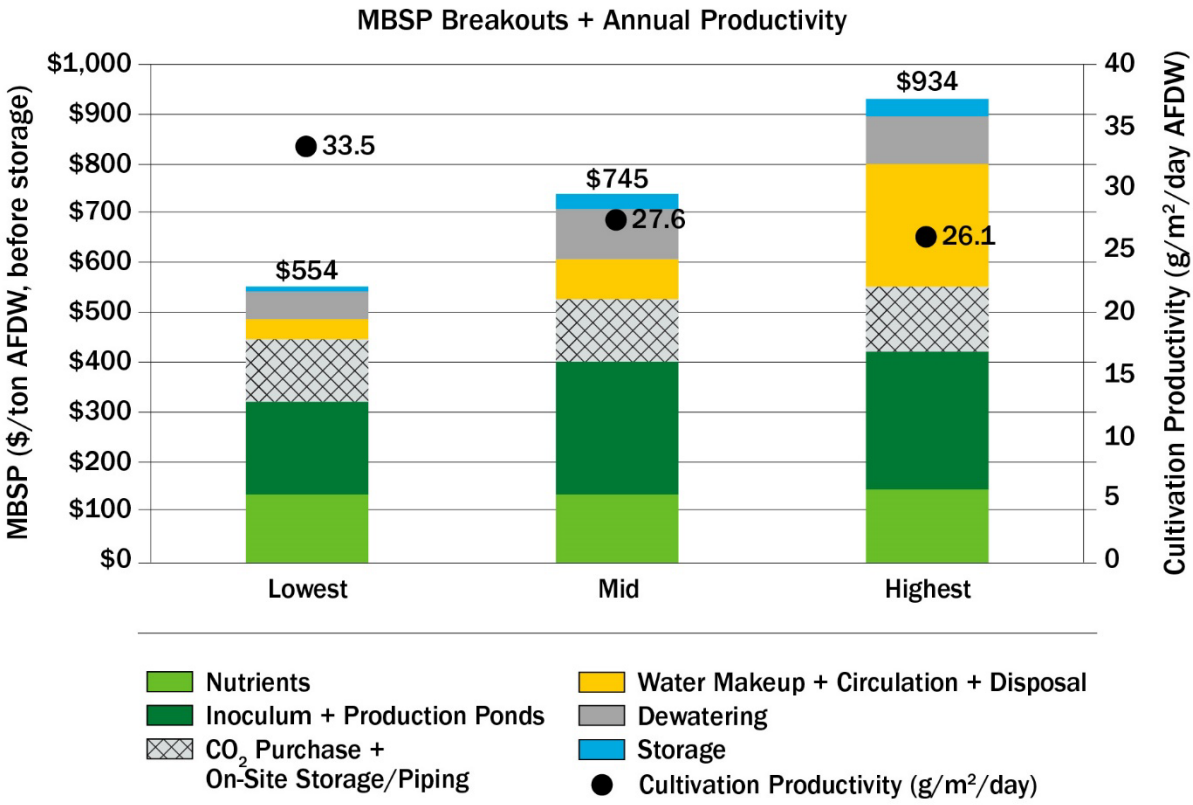

Figure D-1. TEA breakouts showing cost contributions to MBSP for selected individual algae farm cases representing minimum, maximum, and mid-range MBSPs, alongside annual average cultivation productivity