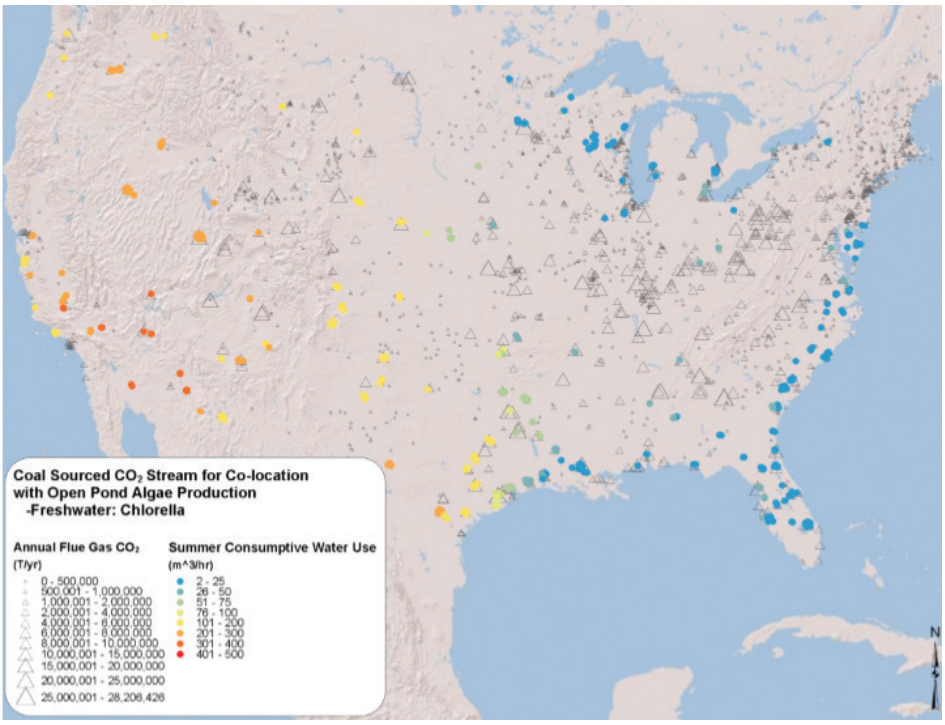
Qualitative Analysis of Environmental Effects of Algae Production

The *2016 Billion-Ton Report (BT16) Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1* is a pioneering effort to analyze a range of potential environmental effects associated with illustrative near-term and long-term biomass-production scenarios. The report includes a qualitative analysis of the environmental effects of algae production with considerations of water quantity, quality greenhouse gas (GHG) emissions, and other environmental factors.[1]



Consumptive freshwater use for 405-hectare freshwater open ponds co-located with coal-based power plants as average hourly summertime rate.

Summary

Few examples of commercial algae production exist, and few environmental indicators have been measured for systems resembling those that were modeled. However, some qualitative results are clear: (1) increasing productivity has benefits for water consumption on a per-mass basis; (2) GHG emissions are generated from plastic liner production and energy requirements to transport waste carbon dioxide (CO_2) in co-located flue gas for beneficial use by microalgae; and (3) water consumption can be reduced through the use of photobioreactors and/or recycling, but the broader significance of doing so depends on the regional context, including meteorology and light availability, competing water uses, type of water used, and requirements of regional biota, such as fish. Enclosed photobioreactors would have different environmental effects, such as lower water consumption because of very low evaporation, but these were not examined in *BT16* volume 1.

The majority of the analysis focuses on GHG emissions and water consumption, including freshwater and saline sources. The infrastructure modeled to deliver flue gas at low pressure across short distances to minimally lined ponds can potentially reduce CO_2 emissions compared to CO_2 stripping processes and fully lined ponds. GHG emissions are very dependent on latter stages of the biofuel supply chain, as well as biomass production.

BT16 volume 1 included a supply constraint that limits freshwater consumption for algae production to 5% of mean annual basin flow, an assumption intended to limit negative impacts on water availability. However, regional water requirements and related water stress indices should be investigated further.

Maintaining water quality of groundwater and surface water is an important regional goal. Co-locating algae production facilities with wastewater treatment plants offers the potential to utilize excess nutrients to mitigate eutrophication.

Effects of flue gas-related contaminants on algae in cultivation systems are not yet well understood, but the issue is being investigated and could offer a new metric for environmental sustainability.

Insights and Implications

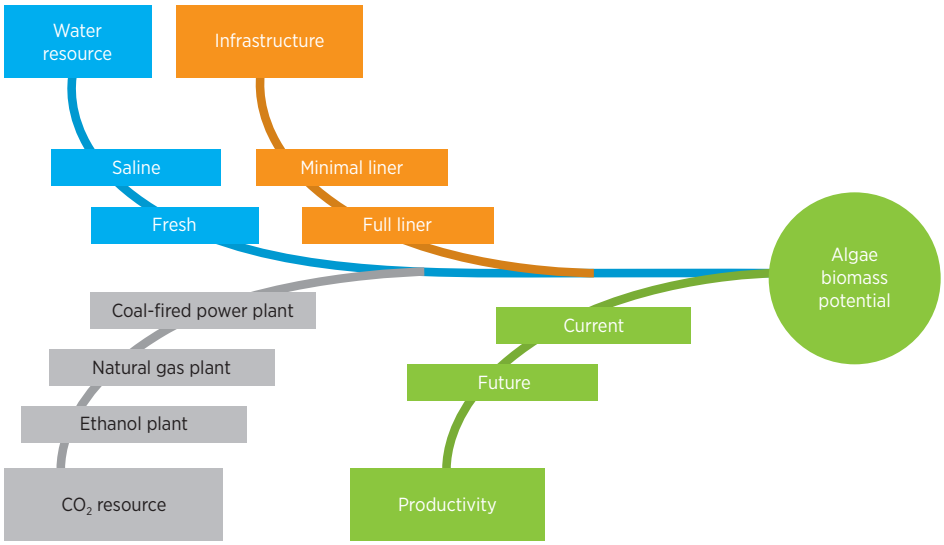
In addition to further research on GHG emissions and water availability in the context of regional needs, research, including field studies and modeling, is needed to evaluate potential aquatic and terrestrial biodiversity, air quality, water quality, and primary productivity effects of growing diverse species of algae at the commercial scale. A better understanding of environmental effects will allow future resource assessment, techno-economic analyses, and life-cycle analyses to evaluate tradeoffs and to quantify more environmentally sustainable potential biomass. Such an understanding will help industry place facilities in the best locations and continue to develop good management practices.

[1] The information in this fact sheet is further discussed in *BT16* volume 2 chapter 12.

Research needs for algae production include quantifying the environmental effects that are only described in qualitative terms in this report and estimating environmental effects in additional contexts beyond those in the scenarios. As algae-produced food (protein) and feed become commercially viable, understanding the interactions between profitability, food security, energy security, and water availability will become paramount, just as current research is investigating the water-energy-food nexus.

Background

The environmental effects analysis for algae emphasizes scenarios from volume 1 of *BT16*, wherein open-pond biomass-production facilities are co-located with coal-fired power plants, natural gas power plants, or ethanol production plants to reduce cost and to use waste CO_2 that would otherwise be emitted directly into the atmosphere. GHG-emission and water-quantity indicators are emphasized, though other indicators are discussed. Variables include freshwater and salt-water algal strains, current and future high-productivity scenarios, and fully and minimally lined ponds.



Key variables in the algae analyses in *BT16* volume 1. Full liners were not considered for the freshwater cases. The freshwater algae strain was *Chlorella sorokiniana*, and the saline algae strain was *Nannochloropsis salina*.

Scenarios of cultivation systems use 1,000 acres composed of 100 ponds, each 10 acres in size at a water depth of 30 cm. Algae is assumed to be dewatered to 20 weight percent solids content.

Another design consideration is the extent of plastic pond liners, with some scenarios assuming fully lined ponds and others assuming minimally lined ponds.

Soils below unlined pond areas are assumed to have low hydraulic conductivity from physical, algal, or other microbial processes.

Water-quantity indicators are emphasized because the scenarios in *BT16* volume 1 tracked consumptive water use, and more research has focused on effects of algae production on water quantity than on potential impacts to water quality.

This fact sheet refers to the following documents:

U.S. Department of Energy. 2017. *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1*. R. A. Efroymson, M. H. Langholtz, K.E. Johnson, and B. J. Stokes (Eds.), ORNL/TM-2016/727. Oak Ridge National Laboratory, Oak Ridge, TN. 640p.

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