The Potential for an Algae-Based Biorefinery

The term "algae" is commonly used to describe a variety of organisms found throughout the world in or near bodies of water. The number of species of algae is estimated to be in the tens of thousands, though their classification and study is still at an early stage.

The natural abilities of algae to rapidly replicate and to produce oils, proteins, alcohols, and biomass have attracted the attention of biotech researchers and industrial producers. An algae-based biorefinery – making multiple end products from algal feedstocks, just as an oil refinery makes multiple products from petroleum – could exploit the natural qualities of algae for diverse concurrent product streams, including biofuels, chemicals, food ingredients, and drugs.

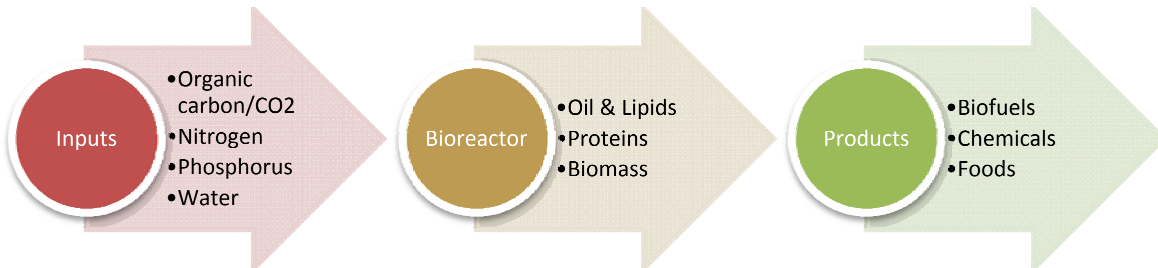


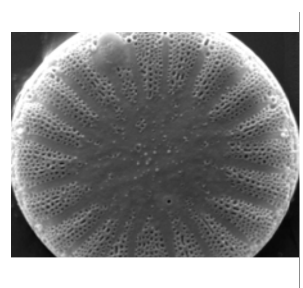
Figure 1: An Algae Biorefinery Process

Through genetic and metabolic engineering, including synthetic biology techniques, algae could become a production platform for proteins, enzymes and other molecules. Biotechnology is currently being employed to study and characterize algae, increase the reproductive rate of target species, improve metabolism of inputs, and enhance the production of desired oils, fuel–grade alcohols, or proteins.

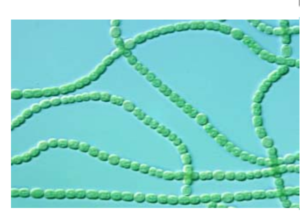
Algae Strains and Classification

Macroalgae or seaweeds are used in a number of countries as food sources and fertilizers. They also provide environmental benefits, including habitats for aquatic animals.

Microalgae are often classified according to color, in categories such as green, yellow-green, golden, red, and brown. **Diatoms**, dinoflagellates and picoplankton – including **blue-green algae**, or cyanobacteria, which are photosynthetic microorganisms related to the chloroplasts in eukaryotic algae – are also considered microalgae.



Though most algae are photosynthetic, some derive energy from the uptake of organic carbon, such as cellulosic material. Algae thrive on organic carbon or CO_2 and nutrients such as nitrogen and phosphorus. They are found in diverse ecosystems, including seawater, freshwater, brackish water, snow, hot springs, soil and biofilms. A few, such as lichens, occur in symbiotic relationships with other organisms.



Bioproducts from Algae

Some algae naturally produce as much as 50 percent of their weight as oil – fatty acids and lipids.

Both the oil and fuel alcohol production potential of algae have been estimated to exceed that of currently grown agricultural crops on a per-acre basis. And algae production facilities can be located in diverse locations on non-arable land.

Table 1: Oil Production Potential for Biofuel Feedstocks	
Crop	**Oil yield (gallons/acre/year)**
Soy	48
Camelina/Mustard Seed	62
Sunflower	102
Rapeseed	127
Jatropha	202
Oil palm	635
Algae	>1,000

Some strains of algae produce primarily hydrocarbon molecules or isoprenoids, similar to petroleum, while others produce molecules that resemble vegetable oils. These oils can be converted to biodiesel or even "cracked" to form a variety of fuels and chemicals that directly replace petroleum-derived products currently in use for cosmetics and personal care products. Other strains, such as cyanobacteria, produce alcohol through fermentation. Ethanol, for instance, can be used as biofuel or to make plastics such as polyethylene.

Because some microalgae are high in Omega-3 fatty acids, they are used as health foods or supplements (such as spirulina) and as animal and fish feeds. Algae are also composed of polysaccharides, starches, and proteins and they produce pigments and antioxidants, such as the carotenoids lutein and beta carotene. The current market for these products is estimated at $6.25 billion.

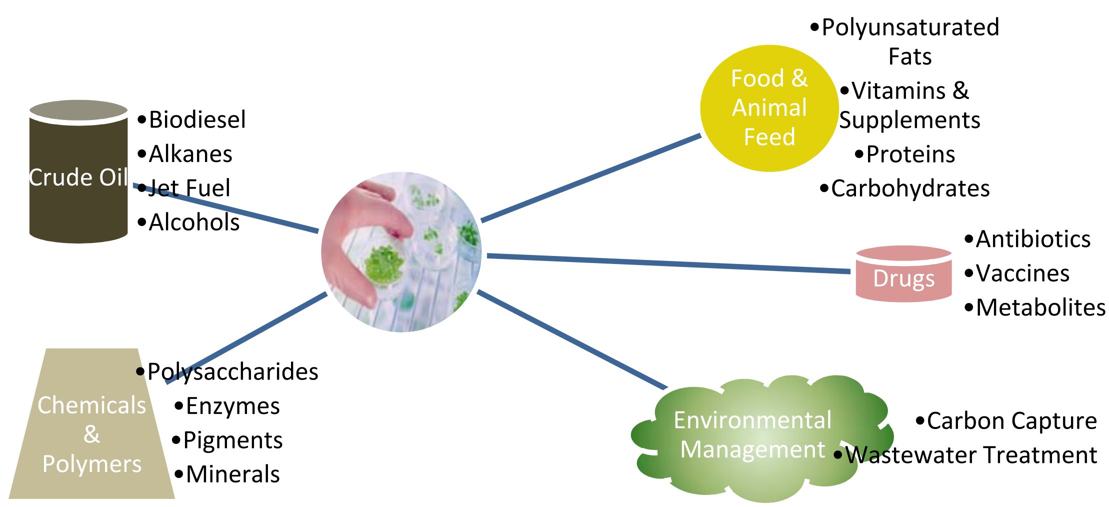


Figure 5: Potential Product Streams from an Algae Biorefinery

The potential for additional products includes biofuels, enzymes, polymers and therapeutic proteins. Biotechnology can enable the commercialization of these products, for example by modifying or selecting algae strains to optimize generation of useful oils, ethanol, and proteins.

Environmental Benefits

Algae already play an important role in the global carbon cycle, enabling the ocean to absorb atmospheric carbon. While algae comprise less than 2 percent of global plant carbon, they absorb and fix up to 50 percent of atmospheric carbon dioxide(30 billion to 50 billion metric tons per year), converting it to organic carbon, and produce up to 50 percent of global oxygen.

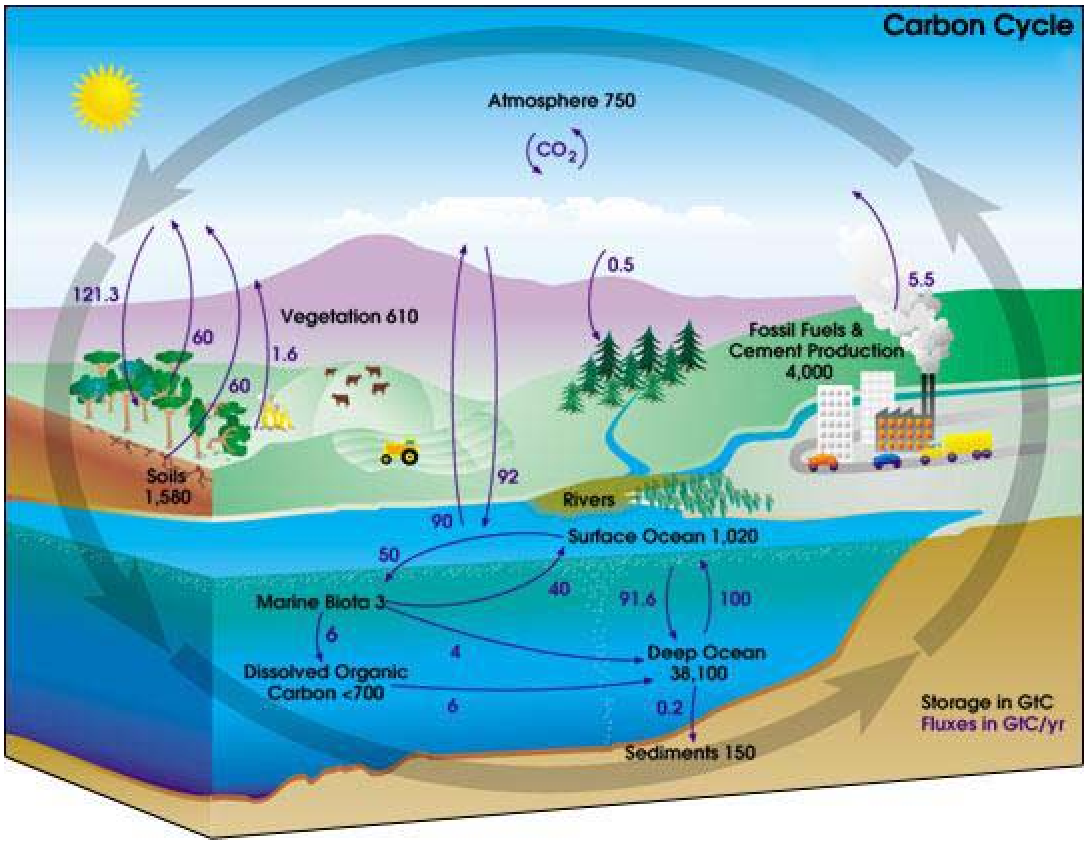


Figure 6: Algae's (Marine Biota) Role in the Global Carbon Cycle

Renewable and Sustainable

Ideal natural growing conditions occur in warm latitudes, and blooms naturally grow and recede on an annual cycle, but algae are not seasonal and so can be cultivated year round. Because they thrive on nitrogen and phosphorus, they can be grown in wastewater. And because algae production facilities can be located on non-arable land, they can avoid utilizing acreage better suited for food and feed production.