# THE LAW OF ALGAE
## —Introduction to Algae Biofuels: Selecting Algae Species, Algae Production Issues, Harvesting Algae and Extracting Oil, and Converting Algae Oil to Biofuels—


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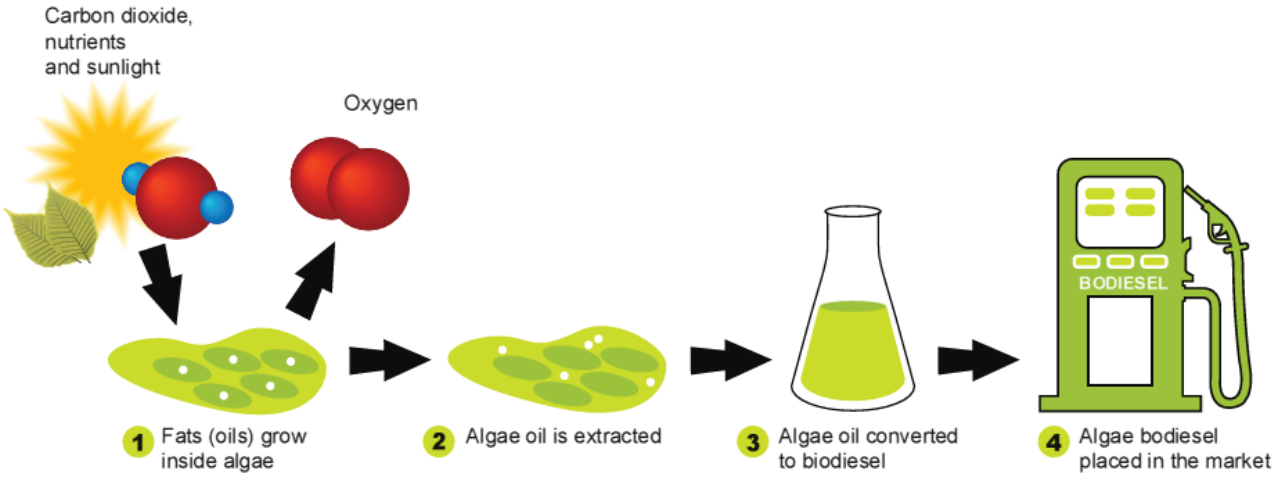
THE LAW OF ALGAE is a guide to the business and legal issues in developing an algae biofuels facility. While algae or algal biomass can be processed to create a variety of biofuels, including ethanol or methanol, this book focuses on projects that will produce algae oil for conversion to biodiesel. A full-scale algae biofuels project developer will need to consider issues related to producing algae oil on a commercial scale and converting the algae oil into biodiesel.




**I. Algae Production Issues**. The commercial-scale production of algae requires careful consideration of many issues that can be broadly categorized into four main areas: selecting algae species that produce high oil levels and grow well in specified environments, algae growth methods, water sources and issues, and nutrient and growth inputs.


**A. Selecting Algae Species**. Scientists have identified thousands of forms of algae, but certain algae strains are more suitable for biofuels use than others because of their high oil yield and other qualities. The University of Texas at Austin hosts a large collection of algae cultures that have been utilized recently for algae biofuels development. Algaebase.org contains a database about different species of algae. The characteristics of the strain (growth rate, oil content, salinity tolerance) should be taken into consideration along with the climate in which the algae will be grown.

Genetically modified strains of algae are being developed for algae biofuels, especially high lipid-content algae. Certain companies have developed algae strains with unique characteristics. Algenol Biofuels has worked with technologies to develop a proprietary form of algae that produces ethanol at a rate of over 6,000 gallons per acre per year. Solazyme is commercializing technology that utilizes a proprietary strain of genetically modified algae

that grows in the dark. Companies that use genetically modified algae will need to review local laws related to the discharge of genetically modified organisms, as discussed in Chapter 5.

**B. Algae Growth Methods.** Algae companies are using several different systems in which to grow the algae, including open ponds, covered ponds, raceways, and bioreactors. Algae grows naturally in fresh, brackish, or salt water, depending on the algae species. An algae biofuels company should evaluate the cost and availability of water at the location of the production facility. Water evaporation issues may be significant depending on the climate and whether the system used to grow the algae is open or closed. Another significant issue related to water is whether the algae biofuels company will use genetically modified algae. If so, it will be important to conduct a careful review of the local laws pertaining to genetically modified organisms. Please see Chapter 5 for more information related to water usage issues.

**C. Nutrient and Growth Inputs.** Algae generally requires light to grow. If the primary light source is natural sunlight, it may be advisable to secure solar rights, as discussed in Chapter 5, for the project site. Many companies are developing systems and technologies using artificial light sources. OriginOil has developed a Helix BioReactor™ that features a rotating vertical shaft with low-energy lights arranged in a helix pattern.

Phosphorous, nitrogen, and certain micronutrients are used in growing algae. The cost of these nutrients should be taken into consideration when evaluating the overall cost for an algae biofuels plant. Algae also require carbon dioxide which can be purchased or, if the plant is co-located next to a carbon dioxide generating facility, captured from the flue gas and directed to the algae growth system. Algae also can grow using atmospheric carbon dioxide. The amount of nutrients and carbon dioxide required to grow algae will vary depending on the algae species.

**II. Harvesting Algae and Extracting Oil.** While algae grows rapidly and produces large amounts of oil, harvesting the algae and extracting the oil present challenges to the commercial-scale development of algae. Many new technologies are being developed to address the harvesting and extraction challenges. The key will be whether the technologies are cost-efficient.


New technologies are coming online that have potential to drive down the cost significantly to produce algae oil so that it is competitive with the market. These technologies include innovative algae growth systems and extraction processes. In some cases, the "new technologies" are technologies from existing applications that have been creatively applied to the algae biofuels production process. Ultrasonic cavitation, for example, is a process for extracting trace amounts of minerals or nutrients from algae and other compounds in the nutraceuticals industry. Algae companies now are experimenting with using ultrasonic cavitation for harvesting algae oil. Despite the challenges of harvesting algae oil on a commercial scale for algae biofuels production, there is a significant advantage in using a feedstock that is not subject to the swings of the commodities market.

Research efforts recently have been focused on developing technologies that extract oil from the algae cells while leaving the cells intact. U.S. Department of Energy Ames Laboratory, in partnership with Iowa State University, is one entity working on this type of research.

**III. Converting Algae Oil to Biofuels.** Algae oil can be processed into biodiesel, jet fuel, and biocrude. Biofuels developers will want to consider the amount of algae oil they will produce and the scale of the production process. A biorefinery, for example, would require at least a 150-million-gallon-per-year plant to meet the economics for a biorefinery. Traditional biodiesel processes can be used to convert algae oil into biodiesel. New technologies like the Mcgyan® Process offer flexible feedstock options that could work well if an algae biofuels facility was not able to produce enough oil to fully supply a plant. The algae oil could be easily supplemented with another type of oil. Algenol has developed a Direct to EthanolTM technology using genetically modified algae that excrete ethanol.

Algae biofuels plants will generally produce a new type of fuel that has not yet been commercialized, and the plant backers will need to clear significant hurdles to achieve success. It is in recognition of these challenges that the federal government policy supports advanced biofuels that conform to existing specifications and serve as a substitution for petroleum-based fuels.

There are significant regulatory barriers to new fuels that warrant consideration. Fuels that are already commercialized fall into two distinct categories: (1) traditional fuels that have been grandfathered in by virtue of establishing market dominance prior to the modern regulatory era and (2) new fuels that have withstood the rigor of current regulatory requirements. Typically the ASTM International, a private organization, is the primary deliberative body defining fuel specifications. ASTM International committees are primarily composed of technical experts from petroleum companies, biofuels companies, engine manufacturers, and fuel injection equipment manufacturers, and others with sufficient interest and knowledge to determine standards for transportation fuels. Federal and state governments routinely integrate ASTM International standards into their regulations and laws.

To the extent that fuels produced from algae meet the biodiesel specification D6751, the fuel will be able to enter the biodiesel marketplace. While not as established as petroleum diesel, the biodiesel industry has worked with ASTM International for over a decade and has a recognized place in the fuel world. As will be discussed in Chapter 8, the new Renewable Fuel Standard (RFS 2) provides additional market opportunities for new fuels though the RFS 2 program are still being defined.

**IV. Conclusion**. THE LAW OF ALGAE contains information that highlights the many legal and business issues associated with the algae production process described above. THE LAW OF ALGAE is organized into the following chapters: