

1. Executive Summary

In recent years, interest in algae as a renewable fuel feedstock has been quickly growing. As renewable energy advocates and ventures alike have concluded that lack of suitable feedstock is a strong barrier to the growth of renewable fuels made from biomass, the high yield potential and low impact on existing agriculture have made algae a strong candidate for renewable fuel production.

The US Renewable Fuels Mandate calls for 36 billion gallons of biofuels to be blended with the US gasoline supply by 2022, with 21 billion gallons coming from advanced biofuels. The potential demand for algae-based advanced fuels is quite strong.

Microalgae are known for their photosynthetic efficiency — they are among the fastest growing substances on earth, as those who have experienced algae blooms can attest. Microalgae also contain lipids, which can be extracted and refined into fuel oils. With lipid content as high as 70 percent in a few of the more than 30,000 strains of microalgae so far identified, estimates of algae fuel yields have consistently been projected in the 2,500-10,000 gallon per acre range. This compares to 400 gallons per acre for corn ethanol, the primary source of US biofuels. Plus, algae can be cultivated in otherwise non-arable land, requiring only sunlight, CO₂ and trace nutrients to thrive.

For all these reasons, since the late 1970s there have been multiple attempts to develop a means of producing renewable fuels from algae. Also research lagged following the collapse of oil prices in the 1990s, a new surge in oil prices, coupled with a post-2001 consciousness of climate change and energy security has added new urgency to algal fuel development.

In 2009, the first algae-to-energy systems are approaching commercial scale, and there are 11 competing models and more than 100 companies and institutions pursuing renewable fuels from algae.

The appeal of Louisiana comes from the availability of the basic needs for an algae-to-energy system, ample low-cost land, good sunlight, an array of CO₂ sources including power plants and petrochemical industry, a rainfall rate that exceeds the evaporation rate, experience with aquaculture, and support systems in the form of infrastructure and research capabilities adaptable for algae-to-energy production.

Accordingly, in the winter and spring of 2008-09, KEMA was engaged by Louisiana Economic Development to conduct the most in-depth survey of commercial algae-to-energy ventures ever attempted, and report on the market potential for Louisiana as a location for algal fuel development, based on the criteria established by the ventures themselves as they looked for suitable sites for their pilot-stage, demonstration-stage, and commercial-stage algae-to-energy projects.



Having carefully surveyed the opportunities in Louisiana compared to other regions, we can conclude:

1.1 Louisiana is the leading US state for scaled open-pond, freshwater algae development, based on temperature, land availability and suitability, CO₂, water, sunshine and infrastructure. Its water resources, rainfall and evaporation rates make it uniquely suited to this low-cost technology.

1.1.1 CO₂ sources dictate locations within 10 miles of a viable CO₂ source for the fuel capacity, if the venture decides to supplement atmospheric CO₂. An alternative system, which utilizes 70+ percent atmospheric CO₂ and the remainder from CO₂ captured from burning natural gas for the algae drying process, has been successfully piloted in Louisiana by Aquatic Energy in the Lake Charles area.

1.1.2. Water needs are plentiful throughout the states, from rivers, aquifers, and wastewater from industrial sources including power plants.

1.1.3 Parcels of former rice plantation acreage are available in the \$2,000 per acre range in Louisiana. Aside from the attractive development cost, the former rice plantations offer, in the southwestern sections of the state, a proven land base for aquaculture, as well as some existing infrastructure and the clay soils that reduce the cost of algae-to-energy systems.

In addition, parcels of abandoned or marginal cattle grazing land is available in the state, providing land for additional algae production.

1.2 Louisiana is a highly competitive location for scaled, open-pond, saline algae development, along with 8 other southern states, and may see development of brackish-water algae farms between 2015-2020. There are permitting issues with the introduction of large-scale, land-based systems involving saline water because of the potential for leakage and salt-water intrusion. Remediation of these risks involves potentially costly heavy-duty double liner systems for open-ponds that are not understood to be economically feasible at this time.

However, the potential exists for off-shore saline based algae-to-energy development, which would utilize ambient atmospheric CO₂ and sunlight; project management would add nutrients, provide a closed barrier to limit competitive species intrusion, and provide a harvesting system. The potential is theoretical at this time: no pilot of such a system is currently in existence for an algal fuel project.

1.3 Louisiana is a competitive location for closed photobioreactor (PBR) algae production, but PBRs are not expected to be commercially viable for 5+ years, if ever. PBRs will play a role as systems used in large-scale algae farms for R&D, strain testing and growing the initial pond inoculum. PBRs may also emerge as a practical means of producing limited

amounts of algae for higher-value nutraceutical markets, but the global market for these oils is less than 10,000 tons per year.

1.4 With plentiful water and solar radiation, the constraining factors in feasibility for open-pond algae-to-energy development in Louisiana are CO₂ availability, and location.

A 60 Mgy algae fuel facility can be supported with the CO₂ from a 120 MW power plant, or by 656,000 tons per year from other sources with a lipid content of 40 percent. Louisiana algae farms operating at pilot scale have been able to supply up to 70 percent of their CO₂ from the atmosphere, supplying the remainder from natural gas burned on site in the algae dewatering process, maintaining a yield of 2,500 gallons per acre per year.

At a rate of 2.1 pounds of CO₂ per pound of algae, **Louisiana has a theoretical capacity of 24.339 million tons of algae** (based on existing industrial and power plant CO₂ emissions Based on an algae strain with a 40 percent oil content, and assuming conversion to algal oil for biodiesel production, **the theoretical maximum for Louisiana is 2.520 billion gallons of oil using captured CO₂.**

Assuming that 60 percent of CO₂ from power and industrial sources is recoverable (loss of 20 percent due to facilities being too small to justify construction of CO₂ pipeline, and 20 percent from sites being too far from economically feasible farm locations), **we can project a potential capacity for Louisiana in algae-to-energy of 1.512 billion gallons** of fuel per year.

This translates into 25 sixty million gallon per year facilities, with 15 that could be associated with CO₂ from power plants and the remaining ten from industrial sources of CO₂ or low-cost systems utilizing on-site CO₂ from natural gas burn, or ethanol production, plus atmospheric CO₂. Power plants represent lower emissions but are typically found in more remote areas where suitable land is more likely to be located at affordable prices.

Based on a long-term wholesale price for diesel fuel of \$3.00 per gallon, this translates into an **economic opportunity of \$4.536 billion** for the state in added revenue from fuel, 13,750 direct jobs, 252,000 acres of development (using a target production figure of 6000 gallons per acre), and \$2.52 billion in construction and project development capital expense based on a conservative cost of \$10,000 per acre.

In addition to fuel, algae meal from the remaining protein can be sold into the feed market. While sale of mass quantities of algae as animal feed is subject to FDA approval, the value of soybean meal can be expected to be in the \$300 per ton range, opening up an opportunity to add a \$270 per ton co-product. The value of algae meal, based on the remaining 60 percent of biomass after the 40 percent lipid content is extracted, would be an additional **\$2.296 billion** based on 8.5 million tons of feed.



There are opportunities to extend the production further through the use of atmospheric CO₂. A successful 3-acre pilot project in Lake Charles, Louisiana by Aquatic Energy has resulted in yields of 2,500 gallons per acre using no other CO₂ source than natural gas burned during the algae drying phase. Should this approach be successfully demonstrated at the 30+ acre level and subsequently be deployed on a farm-scale (12,000+ acres per system) basis, the major limiting factor in algae cultivation in Louisiana is likely to be land availability.

However, we have based our forecast on the more conservative approach of using industrial CO₂, until the Aquatic Energy system is proven at larger scale.

To request a complete copy of the Algae Report, please contact:

Kelsey Short, Director Agriculture, Food & Wood Products

Louisiana Economic Development

Email: short@la.gov

Phone: 225.342.5892