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Algae-Based Biofuels Attract Incentives and Investments

Authors:

Mark N. Duvall
Principal
1350 I Street, N.W.
Suite 700
Washington, DC 20005
(202) 789-6090
mduvall@bdlaw.com

Russell N. Fraker
Associate
1350 I Street, N.W.
Suite 700
Washington, DC 20005

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Algae, the lowest point on the food chain, may yet prove to be among the principal "green" alternatives to petroleum-based fuels. This, at least, is a view that appears to be gaining currency among key federal agencies, legislators, and several prominent companies that have recently announced substantial investments in algae-based (or "algal") biofuels.

Background on Algae-Based Biofuels

Algae have long been recognized for their potential as a fuel source, as illustrated by nearly two decades of federally-funded research under the U.S. Department of Energy ("DOE") Aquatic Species Program, which focused largely on the development of algal biodiesel. However, the relatively high cost of large-scale algal fuel production as compared to petroleum diesel costs was found to be a critical obstacle to algae's commercial viability.[1] Now, more than ten years after the DOE program, the forecast appears to be changing. At the time of the program's closure, DOE analysts projected that algal biodiesel could be produced for $1.40 to $4.40 per gallon, which was nonetheless deemed uncompetitive with the projected near-term costs of petroleum diesel.[2] Although other estimates place the cost of algal biodiesel as high as $8 per gallon using currently available technology,[3] changing assessments of the full costs of fossil fuels -- in terms of geopolitical stability, climate impact, and resource depletion, for example -- may justify production of algal fuels even at the higher price estimates.

Algae are among several plant sources, or feedstocks, currently the subject of research and development for the production of biofuels, but they have some distinct advantages over their competitors. While many other feedstocks are limited to the production of either ethanol or biodiesel, certain forms of algae naturally generate hydrocarbons that can be refined to produce "green" gasoline and aviation fuel. Recent tests have shown that algal versions of these fuels are compatible with existing engines. In January 2009, for example, Continental Airlines successfully test-flew a Boeing 737 passenger jet using a blend of algal and traditional aviation fuel.[4]

The algae in question are microalgae: microscopic, typically single-celled plants that grow abundantly in most aquatic environments. Their productivity can be tremendous, doubling their mass as often as several times per day under optimal conditions.[5] Most significantly, many species produce quantities of lipids, particularly triacylglycerols, that can be used as the precursor material to manufacture high energy liquid fuels -- which makes algae, in effect, a renewable replacement for petroleum.[6] Beyond their potential to replace fossil fuels, algae perform an additional service to the environment: as they grow, the tiny plants absorb twice their

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Algae-Based Biofuels Attract Incentives and Investments, *continued*

own weight in carbon dioxide.[7] This capacity has led to hopes that algal fuels could surpass "carbon neutrality" to reach the point of net sequestration of greenhouse gases ("GHGs").[8] If so, it could make algae the "greenest" of all alternative fuels, both literally and figuratively.

While a handful of other crops also produce similar types of lipids, the productivity of algae per unit of land in cultivation is much greater. Compared to its closest competitors, algal fuel production has been estimated at five times greater than palm oil, fifteen times greater than jatropha, thirty times greater than sunflower, and sixty times greater than soy beans.[9] Besides these higher yields, algae have additional practical advantages in being highly adaptable to conditions not suitable for other crops. Algae tanks or impoundments can be located on marginal, non-arable lands, and supplied with either fresh, brackish, saline or even contaminated water.[10] Moreover, algae cultivation does not divert resources from food production, thus removing it from the "food-versus-fuel" controversy surrounding the first generation of biofuels, such as ethanol derived from corn or sugar cane.

Despite algae's recognized potential as a fuel feedstock, and notwithstanding the work of numerous research programs and entrepreneurial ventures to exploit it over the past thirty years, cost-effective industrial production of algal fuels has remained elusive. Algae may be farmed in numerous ways: for example, in either open or closed systems, and using any of legions of species.[11] Once a batch of algae reaches its optimal density, the challenges lie in efficiently harvesting, "de-watering," and isolating the compounds that are refined into fuel. Each of these steps can be accomplished readily in the laboratory with small quantities, but technological barriers remain in the effort to "scale up" to commercially viable mass-production.

An array of new initiatives recently unveiled by both the private and public sectors, along with the formation of industry trade groups like the National Algae Association and the Algal Biomass Organization, marks an unprecedented gathering of resources aimed at overcoming these challenges. Among the potential partial solutions is to maximize the use of harvested algae by developing "co-products": commercial uses of the leftover, non-lipid constituents. Also widely discussed is the potential for genetic manipulations to develop new strains with higher lipid content and other features that would improve the efficiency of processing.

Federal Government Incentives Under Consideration

In recent months the federal government has announced or proposed several significant measures intended to promote the growth of an algal fuel industry. These include grant programs, tax incentives, technological coordination, analysis of the fuel's GHG impact to qualify for existing renewable fuel incentives, and the

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Algae-Based Biofuels Attract Incentives and Investments, *continued*

proposed economy-wide cap-and-trade program to limit GHG emissions, which would greatly enhance the market demand for carbon neutral fuels.

Department of Energy "Technology Roadmap" and Grant Program

To address the technological challenges that have thus far hindered the commercial development of algal fuels, DOE has initiated a program designed to maximize the potential for collaboration between the public and private sectors. The program began in December 2008 with an "Algal Biofuels Workshop" in which all interested parties were invited to help set the collective research agenda.[12]

The resulting draft National Algal Biofuels Technology Roadmap[13] ("Roadmap"), released on June 3, 2009, provides a systematic overview of the current state of the art, concluding with recommendations on the role that public-private partnerships can play in the development of this industry, and advocating for, among other things, a "sizeable, strategically structured and sustained investment" in the development of an algal fuel industry.[14] The Roadmap observes that despite strong evidence of algae's potential, there remains an as-yet unbridged gap between the laboratory and production on an industrial scale. The draft document organizes its discussion of the nascent industry's technological deficits into the following categories: algal biology; algal cultivation; downstream processing; extraction and fractionation; and biofuel conversion.

On July 16, 2009, DOE announced a grant allocation to provide a total of $85 million to support the collaborative research projects envisioned in the Roadmap.[15] The program is intended to have a narrow focus, supporting only two or three large-scale projects, each of which should draw on the expertise of public and private sector entities as well as universities. The program complements existing grant and loan guarantee programs established by the U.S. Department of Agriculture under the 2008 Farm Bill.[16] Most of the Farm Bill's incentives are directed to more traditional crops, but algal fuels qualify for some of its funding opportunities -- specifically, the Biomass Research and Development[17] and Biorefinery Assistance[18] grant programs.

Renewable Fuel Standard Program

The federal government's core programmatic incentive for the development of biofuels, whether from algae or from terrestrial plants, is the Renewable Fuel Standard ("RFS") program. The RFS was established by the Energy Policy Act of 2005[19] and modified in the Energy Independence and Security Act ("EISA") of 2007.[20] It presents a mandate for producers and refiners of liquid fuels to ensure that increasing quantities of renewable fuel are used each year. Under EISA's calendar of benchmarks, at least 9 billion gallons of renewable fuel must be included

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in the gasoline sold in the United States in 2009. In 2022, the last year on its schedule, EISA mandates a minimum of 36 billion gallons of renewable fuel.

An important modification of the RFS program under EISA is the requirement that renewable fuels qualify for the program based on EPA's analysis of their lifecycle GHG emissions. Generally, to count toward the benchmark totals, a renewable fuel must release at least 20 percent less (and in some cases as much as 60 percent less) lifecycle GHG emissions when compared to average emissions from petroleum fuels. As proposed by EPA, this lifecycle emissions analysis incorporates both direct emissions from the fuel itself, as well as indirect emissions from the processes by which it is produced, refined and distributed -- including indirect land use changes that may occur in other countries as a result of the increased production and importation of biofuels in the United States -- balanced against the uptake of carbon in the generation of the feedstock.[21]

Whereas EPA had originally planned to conduct its lifecycle analysis of algal fuels in a future year, recent remarks indicate that key EPA personnel anticipate completion of the analysis in time to be included in an RFS program final rulemaking scheduled for November 30, 2009.[22] In light of the claims made regarding the carbon neutral profile or even carbon sequestration potential of algal fuels, their eventual qualification for the program seems certain. Nevertheless, a formal finding by EPA will provide additional certainty to investors that algae-based products will qualify as renewable fuels under the RFS program.

Bills in the 111th Congress

Three bills under consideration in the current Congress would provide additional incentives for private investment in algal fuels.

S. 1250, the "Algae-based Renewable Fuel Promotion Act of 2009," introduced June 11, 2009, by Sen. Bill Nelson (D-FL), is a narrowly focused measure that would amend the Internal Revenue Code to make algal fuel producers eligible for the same tax benefits currently bestowed on the producers of cellulosic biofuels (i.e., fuels made from cellulose rather than traditional food crops such as corn and sugar). The bill would achieve this by expanding the Code's definition of "cellulosic biofuel" to include algae-based fuels. The change would make algal fuel producers eligible for a tax credit of up to $1.01 per gallon of fuel produced,[23] as well as a depreciation allowance for the properties used in the production of algal fuels.[24] The credits currently apply to cellulosic biofuel produced in the years 2009 to 2012.

H.R. 3460, introduced on July 31, 2009, by Rep. Brian Bilbray (R-CA), contains the same provisions as S. 1250, but also includes an additional provision incorporating algal fuels into the RFS program by adding algae to the Clean Air Act's definition of

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Algae-Based Biofuels Attract Incentives and Investments, *continued*

"cellulosic biofuel." Under the existing statute, algal fuels can be counted under two of the three categories of renewable fuel that are eligible to count toward the program's benchmarks, so the effect of this bill's proposed change would be to permit EPA to count algal fuel under any of the RFS categories.

The other bill that could substantially benefit the algal fuel industry is H.R. 2454, the "American Clean Energy and Security Act of 2009," introduced May 15, 2009, by Reps. Henry Waxman (D-CA) and Edward Markey (D-MA). H.R. 2454 is currently the leading congressional proposal for imposing GHG emissions restrictions through a cap-and-trade system. It passed the House on June 26. The cap-and-trade system as a whole is designed to limit total GHG emissions to ever-decreasing amounts, making the use of fossil fuels increasingly expensive over time, and therefore should stimulate the development of alternative fuels that are based on a balanced carbon budget.[25] As noted above, algal fuels have been credited with net absorption of GHGs, which, if sustainable over the expansion to commercial production, could make cap-and-trade a powerful incentive to the algae-based fuel industry.

Recent Announcements of Investments in Algal Biofuels

Private sector interest in algae-based fuels has grown rapidly in recent years, with major oil and chemical companies among the most ambitious new investors. In 2007, for example, Chevron initiated a research and development collaboration with DOE's National Renewable Energy Laboratory to generate transportation fuels, particularly jet fuel, from algae.[26] Soon afterward, Royal Dutch Shell announced a joint venture with the University of Hawaii and the start-up HR BioPetroleum to launch a demonstration project to grow marine algae and refine its oils into biodiesel at the Natural Energy Laboratory of Hawaii.[27] A series of similar algal fuel project announcements have followed, with the principals including traditional oil companies like BP and ConocoPhillips, Department of Defense contractors General Atomics and SAIC, and alternative energy start-ups such as Sapphire Energy and Solazyme.[28]

In July 2009, ExxonMobil announced a $600 million investment in algal fuel research and development.[29] In addition to its size and the resources of its proponent, ExxonMobil's project is also noteworthy in light of the collaborative involvement of Synthetic Genomics. This bioengineering company was founded by J. Craig Venter, well-known for launching the commercial venture that mapped the human genome. Synthetic Genomics has been experimenting with algae genetics to develop strains that produce ever-higher quantities of oil, reducing the cost and effort required to extract the refinable materials.

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Algae-Based Biofuels Attract Incentives and Investments, *continued*

Another algal fuel project that stands apart, in terms of both scale and concept, is Algenol Biofuel's $850 million collaboration with BioFields to build an algae-to-ethanol factory in Sonora, Mexico.[30] The technology for this project is dramatically different from the approach used elsewhere: in this case, algae grown in "bioreactors" exude ethanol as a vapor, which is then captured in its finished form without any need for refining.[31] Dow Chemical recently formed a joint venture with Algenol to construct a similar algal ethanol plant among Dow's facilities on the Texas coast.[32]

Whereas algal fuel was once the exclusive domain of organic chemists working for eclectic start-ups or obscure government laboratories, this latest round of investments makes it seem plausible that someday the economy will be running on pond scum.

For more information, please contact Mark Duvall at mduvall@bdlaw.com. Russell Fraker assisted in the preparation of this article.

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[1] *See*, e.g., JOHN SHEEHAN ET AL., NATIONAL RENEWABLE ENERGY LABORATORY, A LOOK BACK AT THE U.S. DEPARTMENT OF ENERGY'S AQUATIC SPECIES PROGRAM: BIODIESEL FROM ALGAE (1998), *available at* www.nrel.gov/docs/legosti/fy98/24190.pdf.

[2] *Id.* at 19.

[3] U.S. DEPT. OF ENERGY, BIOMASS PROGRAM, ALGAL BIOFUELS FACTSHEET (2008), *available at* http://www1.eere.energy.gov/biomass/pdfs/algalbiofuels.pdf.

[4] Jim Efstathiou Jr. & Mary Jane Credeur, *Algae-Powered Jet Proves Biofuel in Continental Test*, Bloomberg.com, Jan. 7, 2009, http://www.bloomberg.com/apps/news?pid=20601081&sid=ayiWn9Z4EwIM. The airplane used a 50/50 blend of biofuel and traditional jet fuel in one engine and pure traditional fuel in the other, and found that the biofuel blend outperformed the traditional fuel. *Id.*

[5] U.S. DEPT. OF ENERGY, BIOMASS PROGRAM, NATIONAL ALGAL BIOFUELS TECHNOLOGY ROADMAP 15 (draft, June 3, 2009), *available at* https://e-center.doe.gov/iips/faopor.nsf/UNID/79E3ABCACC9AC14A852575CA00799D99/$file/AlgalBiofuels_Roadmap_7.pdf.

[6] *Id.* at 6.

[7] *Id.* at 7.

[8] *E.g.*, Sam A. Rushing, Carbon Dioxide Sequestration Via Algae Biofuels: an Overview, Aug. 21, 2008, http://www.biofuelsdigest.com/blog2/2008/08/21/carbon-dioxide-sequestration-via-algae-biofuels-an-overview/.

[9] U.S. DEPT. OF ENERGY, BIOMASS PROGRAM, *supra* note 5 at 3-4.

[10] *Id.* at 7.

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[11] For example, at its height, the National Renewable Energy Laboratory's Aquatic Species Program studied as many as 3,000 algae species. JOHN SHEEHAN ET AL., *supra* note 1 at 11.

[12] For an overview of the workshop, see http://www.orau.gov/algae2008/summary.pdf.

[13] U.S. DEPT. OF ENERGY, BIOMASS PROGRAM, *supra* note 5.

[14] *Id.* at 13-14.

[15] U.S. Dept. of Energy, Biomass Program, *DOE Announces Recovery Act Funding of up to $85 Million for Algal and Advanced Biofuels*, July 16, 2009, http://www1.eere.energy.gov/biomass/news_detail.html?news_id=12670.

[16] Pub. L. No. 110-246, 122 Stat. 1651 (2008).

[17] This program began with the Biomass Research and Development Act of 2000. Pub. L. No. 106-224, 114 Stat. 224 (2000). The 2008 Farm Bill extends the program and provides additional funding. Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246 § 9008, 122 Stat. 1651, 2079.

[18] Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246 § 9003, 122 Stat. 1651, 2072.

[19] Pub. L. No. 109-58, 119 Stat. 594, 42 U.S.C. § 7545(o).

[20] Pub. L. No. 110-140, 121 Stat. 1492 § 201(I)(vi), 42 U.S.C. § 7545(o)(I)(vi).

[21] For more information about the RFS and the lifecycle GHG emissions requirement, see Beveridge & Diamond, P.C., *EPA Proposes New Renewable Fuel Standard Regulations Using Lifecycle Greenhouse Gas Analysis*, May 8, 2009, http://www.bdlaw.com/news-567.html.

[22] "Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program: Notice of Proposed Rulemaking," 74 Fed. Reg. 24904, 24915 (May 26, 2009) (anticipating date of final rule).

[23] 26 U.S.C. § 40(b)(6)(B).

[24] *Id.* § 168(l).

[25] A small section in this voluminous piece of legislation, § 722(b)(9), is designed to prevent the avoidance of restrictions by shunting GHG emissions into algae production. This provision has the apparently counterproductive effect of withholding a potential incentive for algal fuel investment.

[26] National Renewable Energy Laboratory Newsroom, *Chevron and NREL to Collaborate on Research to Produce Transportation Fuels Using Algae*, Oct. 31, 2007, http://www.nrel.gov/news/press/2007/535.html.

[27] David Ehrlich, CleanTech Group, *Shell to Grow Algae for Biofuel*, Dec. 12, 2007, http://cleantech.com/news/2189/shell-to-grow-algae-for-biofuel.

[28] Josie Garthwaite, Cheat Sheet: Heavy Hitters in Algae Fuel Deals, July 14, 2009, http://earth2tech.com/2009/07/14/cheat-sheet-heavy-hitters-in-algae-fuel-deals/.

[29] Jad Mouawad, *Exxon to Invest Millions to Make Fuel From Algae*, N.Y. Times, July 13, 2009, available at http://www.nytimes.com/2009/07/14/business/energy-environment/14fuel.html.

[30] Martin LaMonica, CNET, *Algae Farm in Mexico to Produce Ethanol in '09*, June 12, 2008, http://news.cnet.com/8301-11128_3-9966867-54.html.

[31] Tyler Hamilton, *Dow to Test Algae Ethanol*, Technology Review, July 16, 2009, http://www.technologyreview.com/business/23009/.

[32] *Id.*