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# biomass PRODUCTS & TECHNOLOGY

Products. Processes. Ideas.

## The next generation biofuel feedstock

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### Introduction

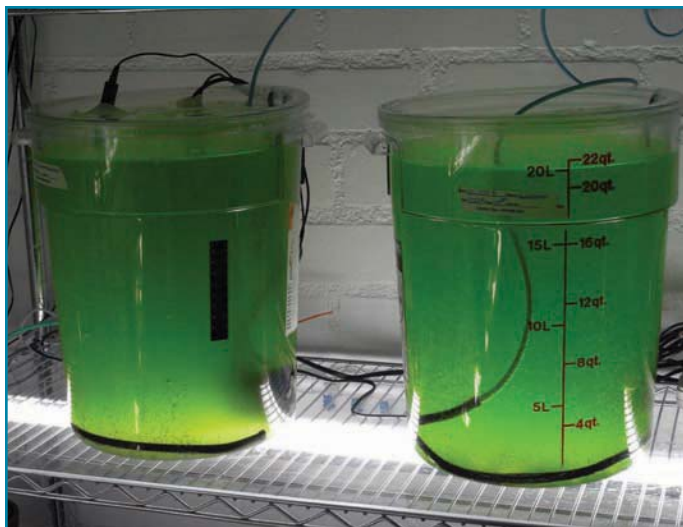
Rising oil prices, global warming and the rapid industrialization of countries such as China and India have increased demand for a renewable alternative to petroleum. The National Petroleum Council projects 50-60 percent growth in energy demand during the next 25 years that is unlikely to be met by the global supply of oil and natural gas. The Energy Information Administration forecasts global oil demand of 43 billion barrels per year by 2026, which greatly exceeds the predicted petroleum supply. Carbon dioxide regulation is likely to further limit petroleum use in the coming years as well.

The U.S. government has committed to new energies, both as a national security mandate and for job creation, targeting 10 million jobs in the next decade and 30 million net new jobs by 2030. OriginOil forecasts explosive growth opportunities as a result of a projected world biofuels market of \$105.4 billion by 2018 and the potential to garner a share of petroleum's multi-trillion dollar world market.

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*Two incubations of nannochloropsis algae, separated for parallel testing.*

Much of the world's oil and gas is made up of ancient algae deposits. OriginOil is developing technology to produce "new oil" from algae, through a cost-effective, high-speed manufacturing process. This new oil can be used for many products such as diesel, gasoline, jet fuel, plastics and solvents without the global warming effects of petroleum.



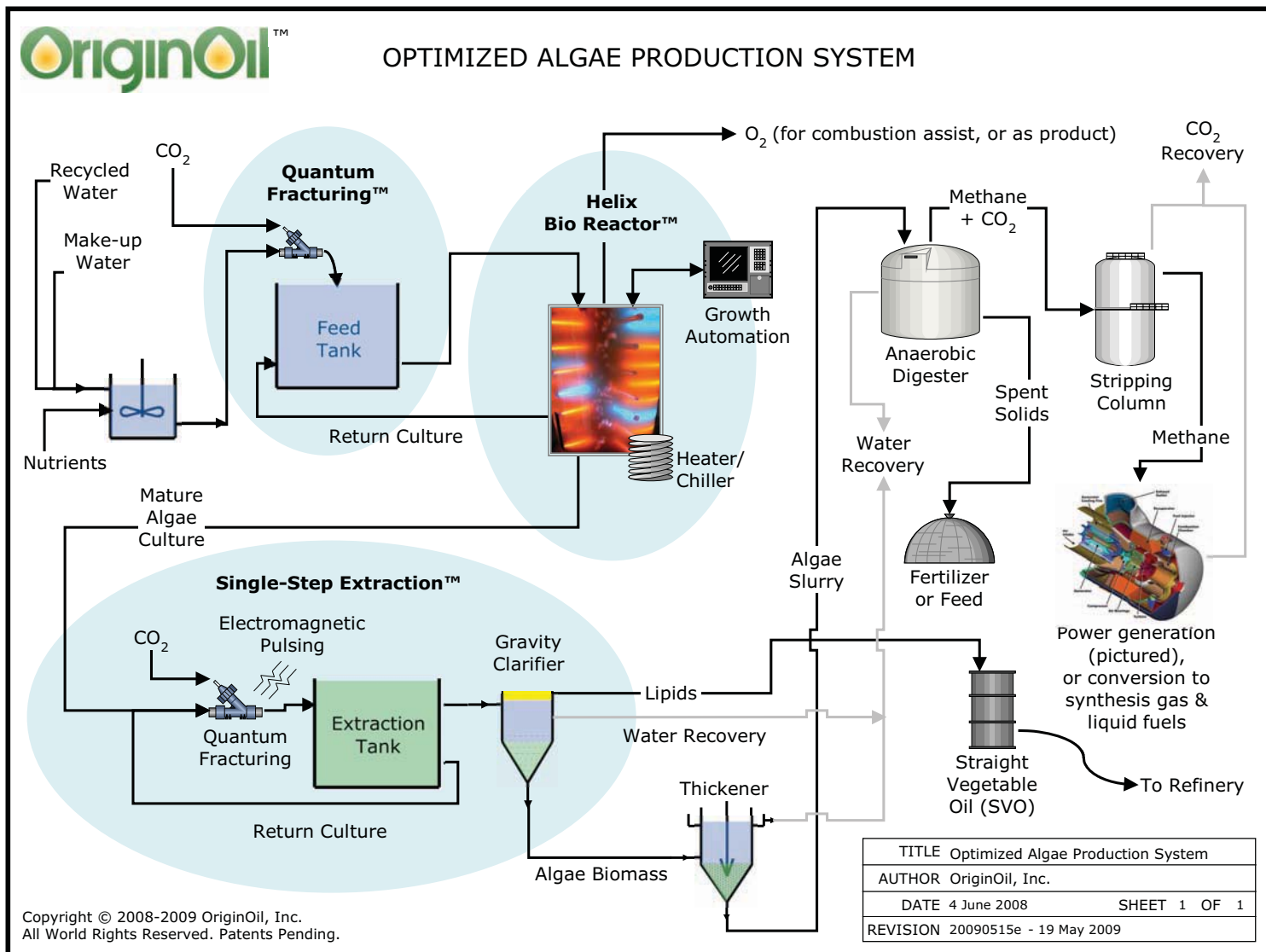


Figure 1: OriginOil's concept of an optimized algae production system. Shaded areas indicate OriginOil's technology enhancements to implement "industrialized" and scalable algae-to-energy systems.

### Algae – A sustainable biofuel feedstock

First-generation fuel-producing feedstocks, such as corn and sugarcane, often destroy vital farmlands and rainforests, disrupt global food supplies, and create new environmental problems. Second-generation non-food biofuel feedstocks, such as grass, forests and jatropha, eliminate food chain dislocations, but still face major issues of land and water use.

Algae solves these issues because it requires minimal land compared to other biofuel feedstock, and can grow in waste, brackish or salt water, while also cleaning that water in the process. Rapid harvests permit industrial-scale production, thus, algae oil is the first truly sustainable renewable oil and the most promising third-generation biofuel.

Algae are a highly efficient biological factory capable of taking CO<sub>2</sub>, a waste product, and converting it into high-density natural oil through photosynthesis. Algae cells might contain up to 60 percent oil that can be refined into liquid fuel.

Remaining algae biomass can be converted into biogas, such as methane, and liquid fuel. Algae oil can be a carbon-neutral biofuel, since it typically absorbs twice its weight in CO<sub>2</sub> during the growth process. The OriginOil system with pre-certified carbon credits can therefore be a financing resource in areas with carbon trading in effect.

### Technology

The two main technical challenges for converting algae to fuel are rapidly-growing large quantities of algae biomass and separating oil-producing lipids and residual algae biomass to produce valuable products, or generate energy through anaerobic digestion from large volumes of water. OriginOil has addressed these challenges through a suite of process innovations to achieve adaptability, cost-effectiveness and scalability. OriginOil's solutions are modular, parts of which can be applied to other algae growth systems, including open ponds. As a result, OriginOil can provide technology for most algae producers.

The basic biochemical process in the schematic shown in Figure 1 is photosynthesis, where CO<sub>2</sub> combines with water to form glucose, which is further converted into various cellular organic compounds, and oxygen is released.

The production system consists of three main components.

- 1. Quantum Fracturing™:** In this step, the ingredients of water, nutrients and CO<sub>2</sub> are micronized into small bubbles to create a very large surface area. Mass transfer from the gaseous phase into the liquid phase is directly proportional to the gas-liquid interfacial area; thus Quantum Fracturing achieves very rapid distribution of nutrients and CO<sub>2</sub> into the algae culture.
- 2. Helix Bioreactor™:** In a natural pond, the sun only illuminates one layer of algae growth that is exposed to natural sunlight; deeper layers are shaded by the algae cells at the top. To overcome this challenge, OriginOil developed a photobioreactor (PBR), known as the Helix Bioreactor, that provides light throughout the depth of the vessel. Low-energy lights are arranged inside the PBR to allow multiple growth layers. Each lighting element is engineered to produce specific light waves and frequencies for optimal algae growth.
- 3. Single-Step Extraction™:** OriginOil's SSE process separates lipids, water and biomass without the need for dewatering or use of chemicals. Conventional oil extraction processes necessitate drying of algae biomass to less than 10 percent moisture. Algae cultures contain upward of 99 percent moisture, which makes dewatering very energy-intensive. The SSE process brings down the energy requirement, and the cost of oil extraction, by an order of magnitude.

Upon separation, the lipids can be converted into biodiesel or other specialty products after further processing. The biomass can be digested in anaerobic digesters for conversion to methane, which can then be used as a fuel for power generation. In some cases, the biomass can be dewatered and converted into high value protein products or specialty materials. Water also can be recycled in the process. To power the lights in the PBR, a combination of waste energy specific to the host site, and renewable energy such as solar panels, can be used. Sunlight can also be directly piped into certain PBR designs, which can provide free lighting during the day.

### OriginOil's business model and history

OriginOil does not intend to produce and market algae-based oil or fuel as an end-product. During the past 2½ years, OriginOil created new technology and a means of getting that technology to the end-user without requiring direct manufacturing facilities or costs.

OriginOil anticipates multiple revenue streams, including licensing systems and technology; selling proprietary models through OEM and regional suppliers; selling components through channel partners; and selling service training, certifications and service agreements. Partnerships with the Department of Energy's Idaho National Laboratory and Desmet Ballestra, an international leader in oil and fats technology, are expected to further speed commercialization. In September 2009, the company presented the first comprehensive algae production model, developed with the INL under a collaborative research agreement.

As a technology provider to the fast-growing algae-to-oil industry, OriginOil's mission is to help others make algae. Algae are the fastest-growing biomass and are the best candidate for a fuel feedstock that can replace petroleum. While the promise of algae is great, lack of technology has prevented the achievement of that potential. OriginOil has identified key "choke points" in the algae-to-oil process and has developed strategic, proprietary technologies, which if adopted, will lead to the success of algae as a replacement for petroleum.

Focusing its efforts on growing algae and extracting oil, OriginOil has filed a series of patents that it believes can revolutionize the economics and speed by which algae is



OriginOil biochemist Heather Heath adds incubant. Automation software is in background.

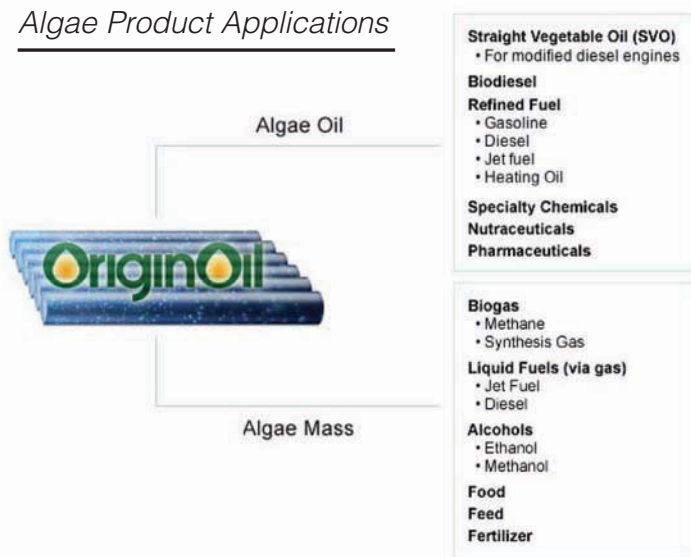
grown, harvested and has its oil extracted. OriginOil's complete, modular system grows microalgae rapidly and extracts its oil content to replace petroleum in various applications. This new technology is a clean and efficient means of collecting new algae oil that has multiple applications, including biodiesel, gasoline, jet fuel, plastics and solvents, while the remaining algae mass can be converted to methane, synthetic gas, liquid fuels, alcohol, food, feed and fertilizer.

## Initial applications

Some key initial target applications offer opportunities to get algae oil in production quickly and do not require heavy investment, infrastructure, distribution networks or transportation:

- Natural gas-fired furnaces: Absorb CO<sub>2</sub>, gasify for on-site combustion as natural gas.
- Biodiesel refining: Captive algae oil production line plus biomass for supplementary power.
- Wastewater treatment: Provide nutrient (Nitrogen and Phosphorus) removal capabilities and rapidly absorb CO<sub>2</sub> generated by energy consumption processes.
- Other applications include waste-to-energy and ethanol production plants.

## Algae Product Applications



## Competition

Many companies in the new algae fuels industry tend to organize themselves as integrated producers and to keep their intellectual property to themselves. OriginOil, however, is unique at this time in being a pure technology provider. The leading companies in algae today are therefore potential customers for OriginOil and several have shown strong interest in its technology.



An array of incubants in various states.

## Conclusion

Algae are the most promising third-generation feedstock for producing biofuel, which would result in multiple benefits. OriginOil has developed breakthrough technology to address the technical challenges of growing algae on an industrial scale with minimal footprint, and extracting oil from algae biomass energy-efficiently.

## About the authors

One of the inventors of OriginOil's technology, Riggs Eckelberry brings his veteran technology management skills to the alternative energy sector. As President and COO of CyberDefender Corporation from 2005 to 2006, he was instrumental in building the company and its innovative product line, helping to achieve initial funding and a public company filing. From 2001 to mid-2005, he helped launch and turn around technology companies as founder and president of TechTransform, a technology-consulting firm. In 2004, he was a member of the team that commercialized YellowPages.com. During the high-tech boom of the 1990s, he was responsible for the global brand success of the software product, CleanSweep; as chief operating officer of MicroHouse Technologies, he drove record sales and a modernization of the company's technology; and as VP Marketing of venture-backed TriVida, he was a member of the team that commercialized the company's technology.

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