

Sustainable Fuels: Lessons from an Algal Biodiesel Student Project

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Abstract

Students and faculty from many disciplines are motivated by the idea of sustainability, but encouraging, creating, and maintaining sustainability-themed projects on a small campus is challenging. This paper focuses on the experience of three undergraduate students as they attempt to start a functioning algal biodiesel production facility. As the project evolves, it is becoming a campus test case for projects involving sustainable innovation and environmentally responsible technology. In a small university setting, the flexibility and cross-disciplinary collaboration available has helped take a more holistic approach to the project. The external expertise of the business community and internal support in the form of faculty champions has also been critical. Finally, the institutional support available through a multidisciplinary entrepreneurship center has provided a common place where faculty, staff, and students alike can conveniently strategize and pool information on the project, and look for funding.

Introduction

Our “addiction to oil” in the US is understandable; traditional crude oil is a highly efficient means of utilizing energy. Yet there are many external costs associated with oil use. For example, the climate is changing as a result of excess carbon dioxide emitted as a byproduct of energy use, much of it caused by activity in the housing and transportation industries. The US imports a large part of its oil from the politically unstable Middle East, and has spent billions of dollars in tangential activity in these regions. Furthermore, the end of oil as we know it is not far in the future. Although the specifics are subject to debate, many experts now see the peak happening relatively soon—within decades. In short, our oil addiction will become very expensive soon, whether we internalize “negative externalities” or not.

Renewable energy sources are increasingly attractive, particularly if prompt action today can help to mitigate the most catastrophic climate change scenarios. In fact, the potential “clean-tech revolution” could help preserve modern human progress and other forms of life for a long time to come. Clean technology, which minimizes ecological impact while providing similar services to today’s dirty technologies, represents a golden opportunity for entrepreneurs.¹ In universities, there is a growing number of faculty, staff, and students seeking to be involved.

This paper illustrates the evolution of a sustainability project centering on the production and use of biodiesel fuel. The Student Led Algae Fuels (SLAF) Project at the University of Portland (UP) in Portland, Oregon consists of a team of students and faculty dedicated to advancing sustainability through research into the production of algae-derived biofuels. The first section provides a brief introduction to the idea proposed by the SLAF Project, how it was developed, and the case for algal biofuels. The next section focuses on the process involved in the development of the SLAF Project, focusing on the initial research process, then the interdisciplinary approach to the subject, and finally the importance of broadening horizons with industry contacts. Finally, the paper concludes with some of the lessons that we think may be applicable to other institutions.

Ideas

The Idea

The concept of the SLAF Project is based on the potential for the production of fuel, particularly diesel fuel, from one of the planet’s simplest, yet most well adapted organisms—microalgae. Algae are critical to the majority of the Earth’s systems, and in some cases produce vast quantities of lipids relative to their total biomass. The SLAF Project ultimately grew out of a short section of the book, *From the Fryer to the Fuel Tank*, by Joshua Tickell. In an overview of potential future biodiesel feedstock, Tickell mentions the potential of algae-derived fuels as

a solution to many supply issues. As a literature review of algal biodiesel potential progressed, the student team became convinced of the viability and the economic potential of algae-based fuels.

Based on particular areas of expertise among advising professors, the team also has begun to realize the possible niche they might play in biodiesel production. Algae produce oil, and it makes sense to select algae species that are productive in this way. On the other hand, algae also produce biogenic emissions that include greenhouse gases, and no one had studied this very carefully. If we are serious about “sustainable” fuels, it makes sense to select and produce an algae species that can be productive both in terms of oil and that is also relatively low in greenhouse gas emissions.

Portland is also rich with businesses experimenting with more sustainable products and processes, and fuels are no exception. The economic potential of the project has been facilitated through connections with Portland-based biofuel industry members. This includes investigation into small scale production of algae diesel as well as the potential for industrial scale developments in the future.

The Case for Algal Biofuels:

Biofuels represent a unique opportunity to bring back a domestically based fuel supply. Fuels derived from terrestrial or aquatic biomass have the potential to revitalize the domestic economy by paying for billions of gallons of energy locally rather than exporting money to support other economies, many of which have been historically unstable. The idea of a biofuel-based energy economy is to engage underutilized agricultural and other lands to literally grow fuel and chemical derivatives using the ever-present power of the sun. We can stop extracting stored solar wealth in other countries, which is non-renewable, and start living on the solar income that is available each year domestically through plant growth. Indeed, biofuels have the potential to establish the US as a long-run world renewable energy leader.²

Current biofuel supply is referred to as Gen 1, in that it is truly the first American experiment in large-scale biofuel cultivation, and many of the resulting fuels do not fully exploit the potentials that they can theoretically reach. The possibilities of Gen 2 and further biofuels become apparent when looking at the potential efficiencies already embodied in the next generation of technologies. Indeed, the Intergovernmental Panel on Climate Change’s *Fourth Assessment Report Working Group III Summary for Policy Makers* highlights the necessity of second-generation biofuels for addressing issues of global climate change. Biofuels derived from microalgae are a prime example of the potential of Gen 2 biofuels.

According to the National Biodiesel Board, biodiesel sales for 2006 amounted to 250 million gallons, resulting in a displacement of approximately .415% of distillate fuel demand.³ Even the most optimistic estimates of potential biodiesel sales, given Gen 1 technology, range from only 500 million to 1 billion gallons annually (.826% to 1.64% of total distillate demand). Although it is clear that “assessing the total domestic production of biodiesel today is akin to the difficulty of assessing the potential of the personal computer when it was first invented,” Gen 1 technologies are not sufficient to provide a significant proportion of diesel fuel demand in the US.

The reason for the apparent inadequacy of current biodiesel production is not a matter of availability of processing and distribution technology. The National Biodiesel Board estimates current biodiesel production capacity to be 1.85 billion gallons annually, with another 1.37 billion gallons of capacity scheduled to come online by March 2009. So, in the near future, biodiesel producers will have the capability to provide 5.09% of diesel demand.⁴ Although most of these producers plan to source feedstocks from foreign countries, the potential exists to produce feedstocks domestically that would more than meet this future demand. The table below provides an analysis of productivities for current and potential biodiesel feedstocks. Currently the majority of domestic US biodiesel production is dependent on soy, and worldwide production of oil from soybean and oil palm make up over 50% of total available feedstock.

Table 1: Biodiesel Feedstock Yields Comparison

Crop (M ha)	Oil Yield (gal/ha)	Land area needed ⁵	Percent of existing US cropping area required
Soybean	113	531	290
Canola	314	191	104
Jatropha	500	120	65.6
Coconut	710	84.5	46
Oil Palm	1572	38	21
Microalgae (70% lipid)	36,165	1.659	0.907
Microalgae (30% lipid)	15,507	3.869	2.114

This table illustrates just how appealing algae is. With current domestic production scenarios more arable land than exists in the entire United States would be required to meet 100% of US diesel and distillate annual demand. Jatropha, a non-edible weed type plant, would consume a sizable proportion of land, and coconut and palm (ill-suited for most American growing conditions) again slightly less. However, with microalgal lipid content of between 30% and 70%, only 0.907 to 2.114% of cropping area would be required to meet demand based on the results of small-scale testing.⁶ These potential yields are feasible given the appropriate strain of algae under optimal growth conditions.

The beautiful thing about algae fuels of course is that nature has already figured out complex processes for converting algal biomass to fuel, and the production of vegetable oil biofuels is actually a massive simplification and acceleration of these processes. The majority of the crude oil supply currently being extracted from the ground is the result of millions of years of pressure and decay exerted on ancient blooms of microalgae in prehistoric oceans. This process of pressure and decay altered the carbon chains of those algae to produce the precious fuel that we depend on today. By growing algae for fuel and extracting its vegetable oils it is possible to quite literally turn this multi-million year process into one that occurs multiple times each day, with no pressure of decay required.

High lipid content algae have already been cultivated on a large scale in several instances. However, most estimates of algal fuel productivity estimate that with current production technologies algal diesel can be manufactured for, at best, \$4.54 per gallon using high density photobioreactors. In order to compete economically with petroleum diesel costs—and not accounting for any potential subsidy scheme, which is a likely possibility—requires the reduction of these costs to near \$1.81 per gallon relative to 2006 fuel prices. These cost reduction figures take into account the fact that materials input and refining of fuels (in this case the algae vegetable oil) account for roughly 71% of total at pump fuel cost.⁷ Algal biodiesel becomes even more plausible given the potential for greenhouse gas regulation in the near future. Since for every ton of algal biomass produced, approximately 1.83 tons of carbon dioxide are fixed while petroleum diesel carries a massive negative balance, the competitiveness of algae diesel increases as GHG externalities are taken into account. Given certain research objectives these cost reductions are achievable in the near future.

The National Renewable Energy Laboratory outlines many such research objects including: increasing photosynthetic efficiency of algae species for high lipid production, control of mechanisms of algae biofoculation, understanding the effects of non-steady-state operating conditions, and methods of species selection and control.⁸ These objectives, along with others, are the driving force behind the SLAF Project, and their achievement presents tremendous entrepreneurial potential.

Processes

Initial Research Process: The Literature Review

As mentioned, Joshua Tickell's book was the original inspiration for the SLAF Project. In it he cites a National Renewable Energy Laboratory publication entitled *A Look Back at the US Department of Energy's Aquatic Species Program: Biodiesel from Algae* as the source of information. The document cited is the cumulative

summary of the NREL's study on algae-derived fuels, known as the Aquatic Species Program (ASP), that ran from 1978 to 1996, when its funding was exhausted. The document proved incredibly valuable in uncovering the structure of the U.S. Government's research program.⁹

The next step in the initial research process was obtaining the various NREL subcontractor reports, and attempting a comprehensive synthesis of their disparate techniques and results. The university was a critical component in this step, and put our research team at a distinct advantage to researchers in industry. Through the university library's systems we were able to request materials from over 10,000 libraries worldwide, at a cost that was primarily absorbed by the university. Since these libraries in general only lend to other institutional libraries, obtaining the variety of information that we did would have been nearly impossible without the assistance of the university's systems.

Interdisciplinary Approach

An investigation of the viability of a large-scale algal biodiesel operation requires input from a variety of disciplines. Without the broad basis of support that the SLAF Project has established at UP, continuing research and development would not be possible. At a small university such as UP, reaching across departments was relatively easy for this project. We have been able to include faculty and student input from some nine different academic disciplines. Although coordinating actions between departments was sometimes difficult, faculty with knowledge of the university's policies and practices were always helpful. In our view it is impossible for a single individual or discipline to have a full understanding of all of the implications of such a complicated issue as sustainable fuel production. The help of UP's biology, business administration, chemistry, economics, engineering, entrepreneurship, environmental science, mathematics, and physical sciences departments have been critical to the project's success up to this point.

In particular, the support that students received from the UP's nationally recognized entrepreneurship program, including keycard access to the campus entrepreneurship center, facilitated project growth. Laura Steffen, UP's Coordinator of Sustainable Entrepreneurship, assisted the students in researching grant opportunities in addition to coordinating with industry members. The entrepreneurship center also served as the central location where the students would conduct research, meetings, and brainstorming sessions. The center also served as a place where faculty from different disciplines could pool and share information related to our project.

For the scientific research portion of the project, the students approached the biology and chemistry departments for technical support and supplies. Dr. Raymond Bard, a chemistry professor, assisted the students in accessing the environmentally controlled growth chambers in which to culture the algae. Along with Dr. Michael Snow from the Biology department, Dr. Bard also supplied the students with the various instrumentation and supplies needed to conduct the experiments. Without the support and, more importantly, trust of the biology and chemistry departments, the students would not have been able to conduct research of the same quality.

Dr. William Barnes of the economics department provided unyielding support and much needed guidance in economic analysis. Ultimately, contribution from all of the university's departments was a key component of in the continued success of the SLAF Project.

One of the primary benefits of all of this interdisciplinary work is that we are better able to see the whole picture on algae biodiesel. We started out on a well-trodden path, investigating how to make biodiesel from algae, which algae would produce the most oil, and what might be economically feasible. However, during this process, one of the professors pointed out that algae can vary dramatically in its greenhouse gas biogenic emissions, and that if we were serious about creating algae-based biofuels that were a better environmental alternative, we needed to pay attention to this. This caused our focus to shift from algae that maximizes on oil to algae that produces enough oil but also is low in damaging biogenic emissions. We think this is a smart strategic move in the long run.

Industry and Governmental Contacts

Although interdisciplinary work was probably enhanced at a smaller, collegial university, there were some constraints we had to work around. Despite the commitment and dedication of members of the university community, it

became clear early in the project lifecycle that success would be predicated on developing relationships with industry members and exploring opportunities outside of research at UP.

There are a number of reasons why our project in particular stands to benefit from industry contacts. First, the ability of already overworked staff and faculty members to dedicate additional time to research is limited. By expanding the network of contacts, necessary time commitments can be lessened for each individual. Additionally, since the ultimate goal is to eventually bring algae-derived biofuels to market, the expertise of industry members is an important aspect of the project that cannot be gained from research reports and academic studies, despite the obvious overlaps. Finally, another key component of project success can be gained from industry in the form of capital dedicated to research, be it in the form of land, workers, or investment dollars. By establishing a connection with industry members early in the research process, firms will gain a vested interest in the success of the technology, and, with the appropriate framing, may be able to contribute or help locate the extra capital that will eventually be required to take the technology to market.

The process of establishing industry connections for our project began organically, and has grown into a web of contacts that cover a broad range of professionals in various industries. Fortunately, the state of Oregon, and the city of Portland in particular, has a thriving biofuels industry that is ripe for growth. Despite the relatively low volume of in-state biodiesel production (approximately 1 million gallons/year the time of publication)¹⁰, the fuel is front-page news in Portland, and biodiesel-powered vehicles are extremely common. Given the local environment of a booming biofuels industry, one industry contact has often led immediately to dozens of others, and a continued broadening of our contact base.

Concrete connections between the project and industry members began as a result of a referred contact from one of the project's primary advising professors. The initial meetings with this contact person were mainly conceptual, but introduced the students to dealing with members of the biofuels industry, and communicating the science of algae biodiesel in applied terms to industry members.

The next step in the evolution of industry connections took place through a three-part course offering in the process of biodiesel production that was offered at a local community college. The course introduced members of the research team to both the founder of Sequential Biofuels, the largest biodiesel producer in Oregon, as well as the owner of Star Oil Co., the largest biodiesel distribution fleet in the Portland region. These two individuals were extremely enthusiastic about the potential of the project and proceeded to provide a list of additional contacts within industry and government that ultimately allowed the research team to pursue further contacts in the industry.

Currently these contacts have resulted in plans for the building of a small scale photobioreactor, as well as potential for city and state funding of the project and additional test-scale projects at various locations. Additionally, feedback from industry members and government officials has resulted in a continual redefinition of the project itself, with ever-increasing sensitivity to the realities of the market and its needs.

Lessons

First, flexibility and adaptability is a key aspect of entrepreneurial projects like this. Without flexibility in the plan for research and potential commercialization, the SLAF Project would never have succeeded to the degree it has. Indeed, the one thing all the researchers involved learned as the project went on was how little we actually knew about this immense subject. As this knowledge was developed, the potential of the technology began to come into a new light. Many of these new parameters and possibilities were not readily apparent at the start, and the willingness and ability to change the course of research drastically improved effectiveness.

Second, by spanning nine different university disciplines over the course of present research, the SLAF Project was able to develop a much more nuanced view of the potential and the problems with algae biodiesel. In the beginning stages of this project, the access to so many interested professors helped us to see a more holistic picture. Another key ingredient was that so many disciplines were willing to work with us—there were no “turf” issues. Many of the aspects of the technology would not have been recognized without this interdisciplinary approach.

Third, in addition to the interdisciplinary approach, one of the main characteristics of the SLAF project has been the relationship developed with industry. Those involved in the biofuels industry in Portland have been able to offer unique insights about market conditions and methods of commercialization that simply are not present in textbooks. Additionally, by developing industry contacts, the members of the SLAF Project have established a basis for the eventual large-scale production of algae diesel by connecting with interested investors and industry resources.

Fourth, entrepreneurship centers can help make sense of all of the disparate information by serving as a pooling mechanism, particularly in a smaller university setting with limited resources. The ability of the project to work in concert with a dedicated center for entrepreneurship at the university proved invaluable. Members of the center challenged us to explore new ideas and encouraged us to pursue grants. They helped us gain access to research laboratories and provided space for brainstorm sessions.

Finally, finding faculty champions is critical. In the case of the SLAF Project there were multiple faculty members who showed unyielding interest in the research being conducted and helped in navigating the complex world of university policies. Additionally, these faculty members were essential in keeping the project on schedule to the degree possible, in addition to actively participating in research. University professors at smaller institutions are already overburdened with the loads of teaching, research, and service, and the presence of individuals specifically designated to assist student research would have been valuable. There were times when we had to hunt down faculty members to help us. However, more often than not, faculty members were willing to advocate for us at critical junctures.

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