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Sustainability of sustainability: exploring alternatives in alternative energy

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SUSTAINABILITY OF SUSTAINABILITY:

EXPLORING ALTERNATIVES IN ALTERNATIVE ENERGY

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Introduction

"The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become, in the course of time, as important as the petroleum and coal tar products of the present time."
-Rudolf Diesel, 1912

When Diesel gave this address in 1912, he had no idea that the potential of biofuels would hardly be tapped into almost 100 years later. Not until the oil scare and the most recent surge in 2008 has the dialogue regarding the energy crisis viewed biodiesel as a viable alternative to the petroleum-based fuels that have dominated the market for so long. Biofuels synthesized from vegetable products not only have potential as a fuel source, but also can be used in a wide variety of applications from soap to industrial lubricants. Utilizing a well-defined chemical conversion, waste by-products from the food service and agriculture industries can be repurposed and converted into a natural, sustainable, carbon-neutral fuel (Pahl, 2005). Nearly identical to its petroleum counterpart, biodiesel fuel requires few modifications to existing diesel engines. In fact, many states such as Minnesota require every gallon of diesel sold to include a percentage of biodiesel (Minnesota, 2008). Biodiesel, unlike its counterpart ethanol, is a clean burning, efficient fuel with the potential to be a major part of a sustainable energy economy.

At the same time, as our society becomes more and more technological, we are beginning to realize the impacts of our prolonged foray into industrialization and technical complexity. In order to keep up, the students of today are facing more pressure than ever to become productive contributing members of society. Today, we find ourselves in an awkward position; our society is more educated than ever in terms of degrees awarded, but is lacking in concrete technical skills. In 2013, the ManPower Group released a study showing the mismatch between the skills employers need and the ones applicants have in the job market. They cite that American employers find the biggest mismatch lies in the lack of technical skills in their applicants (ManPower Group, n.d.). In short, there is a dearth of technical training opportunities for students in most university settings. As a society, we are ill equipped to tackle the technical work and challenges that will be unique to the 21st century.

For years small brewers have been making their own biodiesel on their own, often in garages or small industrial operations. Taking advantage of the abundance of waste vegetable oil (WVO) and other waste produced by the food industry these home-brewers have successfully been making their own fuel, saving money while reducing their carbon emissions. This fever has spread across the country to municipalities, commercial industries, and educational institutions. In 2004, Harvard announced that it was blending 20% biodiesel in all of its diesel vehicles and equipment (Pahl, 2005). In this spirit, the last few years have seen pockets of highly dedicated students at universities and community colleges implement wildly successful biodiesel conversion programs. Large consumers with dining facilities such as American universities produce quite a bit of waste vegetable oil (WVO) and often pay for its disposal. Rather than paying for this disposal, these student groups have worked with their colleges and communities to implement conversion programs that turn this waste into fuel and find uses for it on campus. Often educational in nature, these groups not only create awareness about biodiesel as a fuel source, but also serve as a vehicle to develop student technical skills and apply learned concepts. In finding ways to use the fuel around the campus community, they reduce the environmental impact of the university while simultaneously generating savings in the form of reduced fuel and waste disposal costs. This is a rare instance of a “win-win-win” for the triple bottom line; students develop technical skills, the college saves money, and emissions are reduced.

However, in seeking to implement such programs, students have come across and surmounted a variety of unique challenges. While the chemistry may be simple, getting a program up and running seems like a daunting task. Between complying with safety regulations, ensuring fuel quality, and managing schedules there are many places where an unresolved problem can sink a program. In many instances, programs undergo a period of success before the original students graduate, grant money runs out, or research is concluded and the program folds.

Considering the high start-up costs, both financial and personal, for getting a program off the ground, the sustainability of such sustainability initiatives must be carefully considered. In our efforts to mitigate climate change and care for the environment, we seek to be as efficient and effective as possible. With the sober realization that university communities and students are increasingly strapped for resources, communities must be prudent with the time and energy of students. Sustainability affects all aspects of our lives, and every community has unique opportunities to integrate sustainable solutions. Beyond biodiesel production, there are many other worthy sustainability initiatives worth pursuing. It is the task of students and educators to work creatively to make their communities more sustainable. Understanding this, some universities and students would be better served focusing limited financial and human resources on other initiatives they may serve their community better than a biodiesel program. Given the nature of the biodiesel production process's high startup costs, it is critical that potential producers have a long-term sustainable vision when they implement a program.

Different models of these programs exist, reflecting the diverse nature of the genesis of these projects. Projects begin based around research goals, student projects for class, or as entrepreneurial endeavors by motivated students. Each program's organization and operation bears resemblance to their beginning, and shape the future of the program. This, combined with institutional and group values, can be used as a comparative tool to identify characteristics common to sustainable operations.

Thesis Focus: Sustainability On Campus

In light of a gap in the literature of what makes or breaks student biodiesel conversion programs, this thesis will give a review and analysis of select existing biodiesel conversion programs and suggest a model reflecting the characteristics of successful student programs.

The study's research questions are:

1. What are the common themes or factors successful programs exhibit?
2. What institutional factors create a productive environment for biodiesel programs?
3. Can the tactics of successful programs be generalized?

Firstly, I define successful programs as programs that are financially feasible, develop student skills, lower the environmental impact of universities and foster community relationships. Institutional factors that may affect biodiesel production are demographic factors, university mission, relative climate, WVO production and diesel use.

The criteria used to determine a sustainable model will serve as an example for similar universities looking implement programs and as a guide for others looking to establish conversion programs. The synthesis of this model will be followed by an analysis of the University of Northern Iowa (UNI) and whether a biodiesel conversion program is sustainable, and what such a program would look like given UNI's unique circumstances.

Literature Review: What is Biodiesel?

Why biodiesel? Remembering the claim that diesel engines were originally built to run on vegetable oil, biodiesel presents itself as an ideal alternative fuel that can be integrated into the energy economy with minimal changes. Most diesel engines produced today require no special modifications to run on biodiesel, and some states have begun requiring minimum blends of biodiesel such as Minnesota. This makes biodiesel an attractive alternative to petroleum-based fuels as our society attempts to move away from a fossil-fuel based energy economy. The US department of energy calculated that biodiesel burns substantially cleaner than petrol diesel, emitting 86% less greenhouse gases (Biodiesel, 2013). Unlike its controversial cousin ethanol, biodiesel also does not produce any greenhouse gases during its production. Compared to other alternative fuel sources, biodiesel stands ready to meet the needs of US energy demand with minimal or no infrastructure modifications (Pahl, 2005).

Biodiesel does have its own unique properties and limitations. As it is chemically different from petrol diesel, the “gelling” point of biodiesel is much higher than petrol diesel. Gelling is the temperature at which fuel becomes viscous and can no longer be pumped through fuel lines. Gel points for petrol diesel begin at about 15 degrees Fahrenheit, while 100% biodiesel (B100) begins to gel at 27 degrees F (Biodiesel, 2013). This disparity calls for special precautions in colder weather as well considerations for perennially cold climates. While diesel engines will work at and below these temperatures, they require fuel additives and fuel heating lines. With this in mind, prospective biodiesel producers should take their climate into their consideration when determining the viability of a biodiesel production program.

The chemistry regarding biodiesel conversion is well-established, but a working knowledge of the process is integral to understanding the potential and limits of biodiesel production. The original model for Rudolf Diesel’s 1893 engine ran on peanut oil, but the conversion process itself is flexible in that biodiesel can be produced in a variety of ways from a variety of feedstocks (National BioDiesel Board, 2014).

Recent research on biodiesel has uncovered a new variety of methods and catalysts for conversion. Emerging developments include using sonic emitters, large conversion towers, and even 'growing' oil with algae (Walsh, n.d.) . This recent research is most applicable for conversion projects happening at the industrial level, a setting outside the scope of this study.

Due to the temporal and financial realities of these processes, most programs in the university setting would be well advised to start with the more traditional conversion methods before looking to scale-up production. In virtually all the programs I reviewed, the conversion process followed the traditional method of producing biodiesel with a heated reactor. Using the operations manual from Iowa State's BioBus program and chemistry described in Greg Pahl's chapter "Biodiesel 101" from his book *Biodiesel: Growing a New Energy Economy*, I will summarize the chemical aspect of the conversion process.

Formally known as transesterification, the chemical reaction itself follows a generic reaction. The conversion process begins with the by-product, waste vegetable oil (WVO), and combines it with an alcohol (usually methanol) and catalyst to start the reaction. The resulting reaction produces fatty acid methyl esters (FAME), known as biodiesel, and glycerin. Glycerin is a common ingredient in a wide array of products, such as soap.

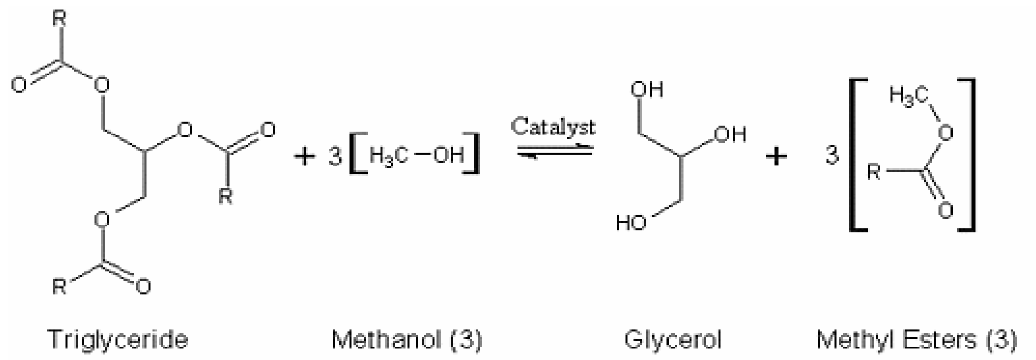

image source: http://en.wikipedia.org/wiki/File:Generic_Biodiesel_Reaction1.gif

Waste vegetable oil (WVO), the by-product of cooking grease, is comprised of three fatty acids called triglycerides that are held together by a glycerol molecule. To make biodiesel, the three fats in WVO must be broken down into single fatty acids that then combine with the alcohol to form FAME molecules. This reaction is accelerated by a catalyst that breaks the glycerin off of the initial WVO molecule. Historically, common catalysts are sodium hydroxide (lye) or potassium hydroxide (Pahl, 2005).

To determine the correct ratios of the reactants above, a chemical test called titration must be carried out. This test is used to determine how much catalyst and alcohol reactants are needed to complete the reaction. Expressed as a conversion factor, the amount of catalyst is small compared to the volume of WVO, only a fraction of a gram per liter (BioBus, 2014). It is important to note that the catalysts described are highly basic chemicals that will cause chemical burns on unexposed skin. This calls for careful safety precautions in regard to handling and storing the various ingredients necessary to carry out the conversion process.

In spite of the catalyst, the solution of reactants needs to be heated within a particular temperature range to be successful. If excessively cold the reaction will go very slowly and will yield less biodiesel. If kept too warm, the alcohol reagent will boil off transesterification. Due to the conversion process being an exothermic reaction, the reactants should be added slowly so as to not drastically alter the temperature of the solution (BioBus, 2014).

As a consequence, the solution must be kept heated continuously during the entire reaction process. As a well-defined reaction, most texts suggest keeping the solution at 65 degrees Celsius. At this temperature, the reaction will be complete within the span of several hours, depending on the size of the solution (BioBus, 2014). This aspect of the conversion process presents a unique constraint to would-be producers in that a consistent heat source must be maintained for the duration of the reaction. Often, this means that the reaction must be constantly supervised in order to prevent disastrous spills or other calamities. This can present a challenge for many organizations that are strained personnel-wise on the number of person-hours they have available.

In summary, the conversion process begins with WVO, methanol, and a catalyst in a heated reactor. The solution is then heated and mixed until the glycerol separates from the FAME biodiesel, settling to the bottom. After the initial conversion, the primary task of the producer is then to 'clean' the fuel to insure fuel quality.

Once the biodiesel has been converted, it is necessary to "clean" it, or separate it out from the leftover reactants and products. In addition to removing the glycerin, unreacted alcohol and other contaminants must be removed from the product before the biodiesel is usable. Getting glycerin out is only a matter of letting it settle to the bottom of the solution and draining it. For the remaining contaminants to be removed, the biodiesel must be 'washed'. This can be achieved by running water through the solution after conversion. Running water through the solution causes other contaminants and unreacted products to bind to the water and are removed when the water is drained (BioBus, 2014).

In general, it takes several gallons of water washing per gallon of biodiesel. This is an unfortunate side effect of the production process, creating waste water. While there are ways of reusing this water, waste water must be handled according to safety and environmental standards. Alternative methods of conversion avoid this waste water, but logistically create their own set of problems. These methods usually implement what is called a ‘wash tower’ where the solution is strained through a solution that binds to particulates in the fuel (Pahl, 2005).

After washing, it is then necessary to “dry” the biodiesel to remove any excess water. This is usually done by heating up the solution and mechanically mixing the solution until the water separates from the biodiesel. Biodiesel is less dense than water and glycerin, so when the solution settles the waste products can be drained from the bottom of the solution container.

Cleaning biodiesel is an essential aspect of ensuring high fuel quality. There are a variety of chemical techniques to determine the content and quality of the fuel. Called chromatography, analysis methods are often the impetus for research projects. The quality of the fuel is a critical factor to assure fuel consumers as well as to achieve high fuel efficiency. High water content in particular is hazardous in fuel, as it will raise combustion temperatures and place stress on diesel engines (Pahl, 2005).

With regard to violate chemicals, heated solutions, and waste management, a dedicated lab space is critical in order to ensure that the process is as safe and effective as possible. In the university setting, lab space may be hard to come by and this presents a large hurdle in getting programs off the ground. The myriad of health and safety concerns associated with this process make partnering with an institution’s health and safety compliance officer from the outset a critical factor to success.

A dedicated space is also critical in maintaining and securing equipment. A standard ‘appleseed’ reactor setup costs several thousand dollars depending on its size, and producers need to keep their equipment out of the weather as well as prevent theft and vandalism (Pahl, 2005).

Methodology

In looking for biodiesel programs past and present, there are unique challenges and choices I had to make as I collected information on these programs. In particular, it was rather difficult to obtain information on programs that are no longer running. Due to their nature, often all that remains are research papers, equipment, and memories. In identifying programs no longer in operation, I relied on email and phone correspondence with former members and support staff.

In my analysis I chose to go for a qualitative approach in favor of a quantitative analysis. This is due to several factors, including the absence of information on old programs. The nature of these projects are complex, and identifying quantitative factors to analyze would not likely lead to discernible correlations. In light of the gap in the literature regarding these programs, there is no consensus on what quantitative factors (if any) would be useful to measure. Rather, I instead favored the qualitative approach which captures a more complete picture of what makes different programs thrive. There is an essential human element in these projects that defies quantification, and I feel that a qualitative analysis is more useful for future producers and as a basis for discussion of these programs.

To collect my data, I relied on information from third party sources, such as the National Biodiesel Board, press/news releases from programs, and first-hand accounts of how programs are structured and function. Preliminary inquiries yielded a surprising amount of feedback from listserv sources, but with exceptions were not a reliable source of information. In several instances I was able to find a wealth of information about a few particular programs, in addition to willing current and former producers willing to share their story and perspective.

This analysis focuses on the structure of various programs in regard to how they begin, sustain themselves, and grow. Programs get started for a variety of reasons, and the transition from genesis to production was of special interest. In general I divided my analysis into three categories of factors: financial, logistical, and personal. Financial factors included how the project covered startup costs, compensated staff, and covered operating expenses. Logistical factors focused on the ‘nuts and bolts’ of the program, such as equipment operation/maintenance, lab space, and navigating the producing cycle from waste to product. Personnel factors concentrated on the human aspect of these programs, from organizational structure, staffing, safety, outreach, and recruitment.

After identifying and collecting data on over thirty programs, I narrowed my analysis to several programs for which substantial information was readily available. I chose four programs; Pomona College, Dickinson College, Iowa State University, and Loyola University Chicago, which demonstrated four distinct models of biodiesel production programs. After reviewing these programs, I offer a synthesis of common success factors that constitute a series of essential elements for a successful program. This model serves as a robust starting perspective for potential producers to take as they embark on their own institutional analysis.

Data Summary

Overall I identified 25 individual programs for analysis, of which 12 are still operated by students. In three cases, programs begun by students are now run exclusively by university facilities staff. Below in figure 1 is the matrix listing the programs and their attributes. They are organized by university type, and program status. The size of the school alone did not appear to have any effect on the potential outcome of a program, as programs have been shown to be successful across all university types.

Institution	Program Name	Status	School Type
Iowa State	ISU BioBus	Active	Public Research 1
Loyola University	STEP: Biodiesel	Active/expanding	Private Liberal Arts
Wake Forest		Inactive	Private Liberal Arts
SUNY ESF		Facilities run	Specialized Private
Stony brook University		Inactive, 2009	Public Research 1
Dickinson college	Dickinson College Biodiesel Shop	Active	Private Liberal Arts
University of Illinois	Illinois BioDiesel	Active	Public Research 1
Applicacian State University	Collaborative Biodiesel Project	Active	Public Comprehensive
Haywood Community College		Inactive	Community College
UMBC (Maryland)		Inactive	Public Research 1
Ponoma College		Inactive	Private Liberal Arts
University of Washington	University of Washington Biodiesel Cooperative	Active	Public Research 1
Central Carolina Community College		Active	Community College
Mt. Mercy		Inactive	Private Liberal Arts
Messiah College		Inactive	Private Liberal Arts
University of Colorado, Boulder	CU biodiel	Active	Public Research 1
UC San diego	Biofuels Action and Awareness Network	Inactive	Public
Villanova		Inactive	Private Liberal Arts
Luther College		Facilities run	Private Liberal Arts
Kansas University	KU Biodiesel Initiative	Active	Public Research 1
Berea College		Inactive	Private
Butler University	Center for Urban Ecology	Active	Private Liberal Arts
Clark University	BioHeat Project	Active	Private
Macaclester College, St. Paul		Inactive	Private
Auburn University		Facilities run	Private Research 1

Figure 1

What will now follow is a discussion of four programs that particularly demonstrate methods that are common as well as highlighting the respective strengths and weaknesses of each approach.

The four schools in consideration are of note for several reasons. Pomona College, Dickinson College, Iowa State University and Loyola University Chicago all had programs that began fairly recently, and all except Pomona have active or expanding programs. The inclusion of a now-discontinued program was critical in providing comparative context for the discussion of what makes or breaks respective programs. These programs were also selected for pragmatic reasons, as they had ample information I was able to access. Collectively, these schools also represent how these programs operate in different university climates in regard to size and available resources.

Pomona College[1]

Located outside of Los Angeles in California, Pomona College is the founding member of the five-member Claremont Colleges (commonly referred to as the "5C's"). With a total undergraduate population of 6,900 across the consortium, Pomona's undergraduate enrollment is merely 1,590. The consortium of colleges was founded to support the environment of a private college while securing the resources of a large university. With a faculty ratio of 8:1 and yearly tuition of $43,255, Pomona serves as an example of how biodiesel programs can get started in institutions of all sizes.

Pomona College implemented their on-campus organic farm in 2005, utilizing unused green space on campus for growing local food for university dining needs as well as serving as an academic resource. The farm saw the hiring of a full-time Farm Manager who would coordinate student and community efforts on the farm. Adam Long, the Farm Manager, was my primary contact for information regarding the biodiesel program and contacting former students of the program.

Pomona's biodiesel program began in 2006 at the behest of two students collaborating for a joint chemistry research project. After purchasing equipment with a grant, they collaborated with Mr. Long and recruited interested student to begin production in fall of 2007. Initially struggling to secure lab space, they would store their reactor equipment on the farm at Pomona when not in use. During production, the students would work in the open air behind utility buildings on

[1] I was able to obtain information about Ponoma's program through extensive email correspondence with Ponoma Farm Manager Adam J. Long. Mr. Long was able to describe the life of the project from beginning to end and provided documentation from Ponoma as well as a report by students at Claremont College.

farm property. To prevent ground contamination in the event of a spill, they would keep the equipment on a concrete slab.

As an all-volunteer operation, the initial group run by five student officers was able to sustain production through 2008. By partnering with sister colleges, they were able to easily obtain WVO as well as find uses for it with the grounds keeping staff of the 5C system. Despite their size, the 5C system produced about 600 gallons of WVO per week. With a 40 gallon reactor, the Pomona program looked to expand within the community, and they were able to seed another program at sister college Claremont in 2007.

As the years went by, student interest in the program waned. A combination of graduating students and a continual struggle for dedicated space led the program to cease production in 2008. Sister program Claremont was able to sustain operations due to a couple new research projects, but also folded in 2009. While the equipment remains on Pomona's campus, it has not been used for several years and is in disrepair. Correspondence with Farm Manager Adam Jackson indicated that once the original research goals of the project had been met, there was little in regard to long-term planning for the program. As student interest waned, motivated students became engaged in other projects related to the organic farm. As an all-volunteer operation, there was no financial pull for students as well as an operating budget for the program.

In spite of their favorable climate and apparent institutional resources, the Pomona program serves as an all-too-common example of a program with a promising start but that is unable to sustain itself. This was sadly the typical outcome of many of the programs I identified, characterized by a founding group of dedicated students that is unstable to survive the graduation of the founders.

Dickinson College[2]

Dickinson College is a private Liberal Arts college in Carlisle, PA. With an undergraduate population of 2,339 and tuition of $41,520, it is similar to Pomona College in many respects. Dickinson College in particular is nationally respected for its emphasis on sustainability education and sustainability initiatives on campus. In their latest strategic plan update, Dickinson cited sustainability as an emphasis in their curriculum. In addition to an on-campus farm, Dickinson College's Center for Sustainability Education (CSE) serves as a hub to coordinate sustainability efforts on campus and in the community.

As an emphasis on campus, Dickinson develops sustainability on campus through initiatives like "Living Laboratories." Laboratories provide opportunities for students to engage in hands-on work with faculty, staff, and community members and to develop sustainability initiatives. Supported financially by way of student internships through the CSE, Living Laboratories provide an opportunity for interested students and faculty to get involved in campus sustainability.

In 2006, two Dickinson undergraduates began working with Facilities Management to identify a lab space for a biodiesel production program. Located in a part of the Facilities garage, the Dickinson program obtained equipment and "Living Laboratory" designation from the CSE. With this administrative and financial support, the "Biodiesel shop" had students collecting WVO from local restaurants in addition to campus dining facilities.

[2] Extensive information about Dickinson's program was provided on their website: https://www.dickinson.edu/centers/sustainability/content/Biodiesel_Program/ as well as email correspondence with Tyce Herrman, Project Coordinator at Dickinson's Center for Sustainability Education. Mr. Herrman also provided me with the program's strategic plan, which was authored by David London.

In light of Dickinson's efforts to integrate sustainability in the classroom, the program gained visibility through classroom integration from departments ranging from art to biology. Admissions staff were trained to give tours of the shop to prospective students as an example of Dickinson's sustainability focus. Overseen by facilities staff, the CSE sponsors the program with two academic and three paid internships for students to operate the program. These internships have students pursue personal projects related to the shop in addition to day-to-day operations. These projects have addressed educational/outreach initiatives, increasing shop efficiency, and producing soap from glycerol by-product.

Much in part to this institutional support, the program has been active and underwent an expansion in 2011. An equipment donation from the community doubled the original production capacity from 54 gallons/ batch. Accordingly, the shop wrote a strategic plan in 2012 charting the operation of the program through 2017. Among the plan's goals are producing 100% of Dickinson's diesel needs, as well as establishing a dedicated staff member for the program.

They recognize the benefits of a dedicated staff member, both in helping mitigate student turnover as well as guide the development of individual student projects. Currently to make better use of limited student hours, the Dickinson program only collects WVO from on-campus sources. The plan called into question its viability as a financially self-sustaining program, and calls for increased efforts to partner and integrate biodiesel into class curriculum.

Dickinson's program is an excellent example of how biodiesel programs can thrive as an educational partnership. In their model, classroom integration was key to the development and expansion of their program. Institutional support by way of the CSE is essential to their functioning, especially with student internships. These positions offer unique opportunities for students, but also limitations. Due to the limited number of internships, only so many students get involved with the program which causes problems with turnover and training. Recognizing this, the students know full well the advantages of a dedicated staff member. In light of this, the Dickinson program serves as a model of educational integration supported by partnerships with on-campus Sustainability offices.

Iowa State University[3]

Iowa State University, located in Ames, IA is the only public school that I've selected for particular analysis. Now the largest in Iowa, ISU has an undergraduate enrollment for 27,659 with almost 5,000 graduate students. As a Research 1 institution with an engineering school, ISU enjoys a plethora of technical resources and a highly proactive Environmental Health and Safety (EH&S) department. With tuition of $6,648, ISU also represents a campus environment more accessible across the US compared to small private schools.

Iowa State has a partnership with the city of Ames to run the busing system. As the buses all run on diesel, a biodiesel program had the potential to meet a need while providing a high-visibility example of implementing alternative fuel. To this end, in 2009 two PhD candidates established the ISU BioBus program. Initially a group of dedicated interdisciplinary students, they worked closely with EH&S, faculty, and the campus sustainability coordinator to advocate for dedicated lab space to begin production.

After writing grants for entrepreneurship and sustainability efforts, the group was awarded grant money in 2010 to purchase a reactor. With this, they successfully acquired lab space in the third floor of Gilman Hall, which provided unique logistical challenges. In order to transport WVO from dining facilities to their lab space, the group built their own transport tank dubbed the "Super-

[3] David Correll, founder of the BioBus program, provided a great deal of information and insight related to the BioBus program. In addition to email correspondence, I was able to meet with David on ISU's campus over the summer of 2013 where he gave me a tour and demonstration of BioBus' process. David provided me with BioBus' operating manual as well as their organization's constitution.

Sucker." After a year in Gilman, BioBus was allocated space in the brand-new Biorenewables Laboratory Building.

Run completely by students, BioBus functions as a student group recognized by the university. Aside from a faculty advisor, the BioBus operation is 100% volunteer student run. Producing one batch from their 40 gallon reactor a week, BioBus provides the fuel for a dedicated bus that operates around Ames.

Priding themselves on the diverse majors involved in their program, BioBus also focuses on educational and outreach events that advocate for alternative fuels. Governed by an executive board, the group is divided into two halves: Engineering and Business. Meeting once per week during the semester, the engineering group focuses on the aspects of fuel production and maintaining lab safety. On the business side, they focus on scheduling demonstrations, outreach and media relations, recruiting, and maintaining the finances of the program. Due to the wide range of activities the program is involved in, the twenty-plus students in the program find ways to contribute regardless of their major.

In addition to their high visibility bus program, BioBus also does regular demonstrations for local schools and community groups. By widening their focus beyond biodiesel production, the group is motivated to grow in new ways and stay involved in the community. This not only helps with recruitment efforts, but also creates opportunities for students with a variety of skills.

While being a completely student-run operation, BioBus does require a graduate student to be present during biodiesel production. Benefitting from a close working relationship with EH&S, BioBus is able to operate essentially independent of the university. The BioBus program serves as a compelling example of how the human element is critical to the longevity of a program. Conceived from the start as a student group with definitive purpose, the group has been able to sustain itself financially and overcome logistical challenges. It also underscores the power of working closely with appropriate university entities as a way to give the program a robust presence on campus.

Loyola University Chicago[4]

Loyola University Chicago is a historic college in urban Chicago founded in 1870. With ten colleges across four urban campuses, Loyola's undergraduate population was 10,168 in 2013. A private school with a tuition of $35, 503, Loyola completed construction of their Institute of Environmental Sustainability (IES) in 2013. This comes on the heels of several successful sustainability initiatives and represents Loyola's recent shift to embrace sustainability.

Prior to this, Loyola's Office of Sustainability had been coordinating several sustainability focused classes. One of these, Solutions To Environmental Problems (STEP), combined lectures by community members with semester-long student projects to improve campus sustainability. These projects are meant to be successive, so that students build upon the work of others to tackle large issues. In the past STEP classes have focused on energy, water systems, and food systems. Emphasizing the interdisciplinary nature of environmental problems, STEP classes cater to a wide array of majors while providing a forum for students to analyze campus sustainability issues. This class is able to complement the Liberal Arts mission of the university while encouraging students to think beyond their respective major.

Beginning in 2007, students in STEP classes began to focus on alternative energy. Subsequent class projects regarding biodiesel production built upon one another, and in 2009 students won

[4] Information regarding Loyola's program was obtained through their web presence at: http://www.luc.edu/sustainability/programs/biodiesel/. I was also able to correspond with Lab Manager Zack Waickman through a series of emails as and several interviews over the phone. Zack provided critical insight regarding the structure of the STEP program as a model for developing programs.

an EPA grant worth $75,000 to begin a biodiesel production program. By building on the work of others, students were well-prepared for the diverse challenges associated with implementing a program.

Before the completion of the IES building, the Loyola program was housed in a “drywall closet,” according to current Lab Manager Zack Waickman. In what is described as a “perfect storm,” a combination of publicity through a student documentary about the program plus the EPA grant led to a surge in student interest in STEP classes and the Biodiesel Club. It was during this time that full-time Lab Manager Zach Waickman was hired, who helps facilitate STEP courses as well as guide the administrative operations of the lab. In 2013, the program was awarded another EPA grant, and was able to expand production capacity to near-industrial levels.

In 2013 with the completion of the IES, the program saw a massive expansion with a brand new lab space in addition to a license to sell biodiesel commercially as well as BioSoap, soap produced from glyercol. Students outside of STEP classes stay involved with the program through the BioDiesel Club as well as a few Lab Fellowships sponsored by IES. Loyola houses a truly explemplary Biodiesel program, and serves as a robust model for the implementation of student-driven sustainability initiatives.

Program Analysis

Taking the aforementioned four schools into consideration, patterns emerge as to what qualities allow programs to flourish. In particular, a sense of ownership from the genesis of a project has a large bearing on the long-term viability of a program. A sense of what the program is *for* has a large bearing on the organizational aspects of a program’s operation. We see how by approaching the production of biodiesel primarily as an opportunity to develop student skills causes the culture of a program to sustain itself.

In terms of Pomona College, we see a ‘classic’ model of how these programs begin as research projects. Primarily academic in nature, these programs are hard to sustain financially and personally once the original research goals are met. These programs have trouble existing after the founding generation of students graduate, and represent an unsustainable model of pursuing biodiesel production.

The Dickinson and Iowa State programs demonstrate how these programs can be run with minimal oversight from administration. While they cause strain on a program’s longevity, Iowa State in particular serves as a testament that students are highly capable of undertaking the variety of challenges that may present themselves. Of particular note is the essential nature of forming close working relationships with university personnel, whereby they justify their independent nature.

In Dickinson’s case, what is particularly troubling is the low amount of student participation. While benefitting from having paid positions by their sustainability offices, as a result no other students are involved with the program. This perhaps shows the downside of offering paid positions, as they may discourage participation for volunteers.

As the example of a highly successful production program, there is much to learn from Loyola’s model. Specifically, the organization and implementation of the STEP course creates the conditions which allow students to flourish. By building upon subsequent projects, students are encouraged to think big while developing a particular aspect of an issue. This class creates a “testing ground” for potential student projects from which the most viable and successful programs will emerge. In Loyola’s case, this resulted in a highly successful biodiesel production program, but also other initiatives. Loyola distinguishes itself with the STEP program, which serves as a useful model for other universities to adopt.

Discussion

Let us now return to the research questions of the study.

1. What are the common themes or factors successful programs exhibit?
2. What institutional factors create a productive environment for biodiesel programs?
3. Can the tactics of successful programs be generalized?

In regard to the first question I've identified four qualifiers that indicate that a program will be successful. First, motivated students with a willingness to engage in sustainability as well as take ownership in a program as an opportunity to enrich their educational experience. Second, on-campus support in the form of sustainability-focused administrative efforts, for providing resources, references, or as a partner in increasing campus sustainability. Third, an interdisciplinary focus. This focus captures the truly interdisciplinary work of the real world, attracts a variety of students, and encourages program flexibility. Lastly, a sense of purpose and ownership ingrained into the program. A dynamic program with continuous goals will last longer than a program with definite goals unrelated to the development of student skills.

What is clear throughout all these programs is that the human element is the most essential aspect driving sustainable programs. Regardless of the type of obstacle, a dedicated groups of students have proven themselves savvy and resilient and the impact of student motivation cannot be understated.

It is also clear that the presence of dedicated sustainability staff, by either an administrative office or dedicated lab staff, has a profound effect on these programs. From providing financial support to serving as a center for coordinating sustainability efforts, these offices serve a critical function for these programs. What must be noted is that there are subtle differences between an advisor, manager, and researcher. It is clear that the presence of staff dedicated to these programs serve an undeniably critical function, especially for exemplary programs.

Of particular interest to me was the sense of ownership conferred on a program during its genesis. Groups with clear, achievable, sustainable goals fare much better than those that lack vision. From the beginning, what a program is *for* creates the culture surrounding the operation and drives (or fails to drive) the program to sustainability. If the primary goal behind the program is to produce biodiesel, the program is missing the point of establishing student-driven productions.

Lastly, it can be inferred that programs that cherish and promote interdisciplinary learning are better equipped to sustain themselves. As in ISU's case, a variety of students enable the group to be dynamic and serve a multiplicity of functions. For the Loyola program, the interdisciplinary emphasis has made the program flexible and allowed them to take advantage of unique opportunities.

In regard to the second question, I was surprised to find that many institutional factors had little bearing on the outcome of successful programs. I initially expected these types of programs to thrive at schools with engineering and technical programs, but many of the most successful programs are on campuses with no engineering program. It is also apparent that the size of an institution also has no bearing on a program's success, as we see programs thrive from the community college level up to the large research-focused universities.

I conclude that many institutional factors will not affect programs negatively, but specific types of institutional characteristics provide a substantial advantage for potential programs. As I mentioned above, dedicated sustainability staff can provide critical administrative vision and assistance. We see in the examples of flagship programs like Loyola where involved dedicated staff can provide the momentum to carry programs through successive generations of students.

The tactics of these programs, understood as specific applications of general concepts, are useful in the way they demonstrate models of success. These concepts, such as ownership and interdisciplinarity, are factors than can easily be integrated into many types of sustainability projects. With this reflection, it then becomes clear that what drives the success of student biodiesel programs actually has very little to do with biodiesel itself. Rather, biodiesel programs represent an example of what motivated engaged students are capable of. In this analysis, it is clear that these tactics can be generalized not only to other campuses but also in other types of student-driven sustainability initiatives.

Future Work at UNI

Synthesizing the factors I've identified from successful programs, these factors can be applied to the University of Northern Iowa for comparison. In terms of on-campus sustainability support, UNI's Center for Energy and Environmental Education housing the Office of Sustainability more than qualify UNI in this regard.

With consideration of the other identified factors, it is unclear whether UNI could support a sustainable biodiesel production program. There certainly exist motivated and engaged students on campus, as well as a diverse range of majors. However, it is unclear at this point whether student interest into biodiesel in particular would outweigh student interest in other areas such as local food and recycling. However, there remains a distinct possibility of this type of program getting started given a 'perfect storm' of student interest.

Rather, what UNI could do is to continue and expand its class offering in sustainability in order to foster projects like those in Loyola's STEP classes. There are several UNI capstone classes that operate similar to this, but UNI lacks a definitive educational emphasis on sustainability that would galvanize student options and interest.

Conclusion

Through a careful analysis of four distinct models of student biodiesel programs, this study represents a first step in determining what drives successful biodiesel programs. As there exists no formal characterization of these programs in academic literature, many more questions remain. These questions are important to probe, for we recognize the powerful opportunity biodiesel programs provide for students of all majors. Given the instances of failed programs, it is critical that potential programs take into account what models have demonstrated success.

It is important to note the scope of this study. In light of the difficulty in finding information about these programs, my analysis represents a perspective limited to the programs I was able to identify. There exists a huge disparity of information about these programs, and as time passes the perspective from inactive programs will be harder to come by. By focusing specifically on biodiesel programs, this study could be missing concepts and patterns that emerge from a wider analysis. It is entirely possible that a study of not only biodiesel programs, but all student sustainability initiatives would yield interesting insight to administrators, educators, and environmentalists.

In spite of this, the wealth of information regarding the four programs emphasized enable us to ascribe patterns that likely are true for many programs past, present, and future. It is undeniable that the human element is an essential aspect of any student program, and biodiesel programs are not exception. Students are creative and ambiguous, and if given the resources they are capable of impressive self-sustaining operations such as ISU's BioBus program. Further, the importance of an interdisciplinary approach cannot be understated. Too often educators and students unwittingly confine themselves to their chosen field and fail to appreciate the opportunities that interdisciplinary learning provides. Lastly, the sense of ownership in a program has been shown to be the best model for a sustainable biodiesel program. When the project is conceived as a tool for furthering student education, skills, and involvement, the program is set up for long term success. The explicit purpose associated with the genesis of a program guides its long-term viability, and programs with persistent goals are programs that last.

This study was conducted with the hope that it would serve to inform potential biodiesel producers of successful models. Through an analysis of how biodiesel particularly represents an opportunity for student growth, environmentally-minded engaged students will be persuaded to examine if biodiesel production is viable on their campus. By taking to heart the strategies in the analysis, these students need not re-invent the wheel. Additionally, it is with confidence that readers will understand how the factors that drive successful biodiesel programs can be applied to a variety of initiatives. In appreciating the perspective offered through this analysis, engaged students and members of the university community will be well-equipped to interpret and integrate this concepts in a variety of applications.

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