

# **AC 2007-2824: THE INNOVATIVE DEVELOPMENT OF SUSTAINABLE TECHNOLOGIES IN UNDERGRADUATE PROGRAMS: CASE STUDY ? BIO-DIESEL PROJECT**

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## **The Innovative Development of Sustainable Technologies in Undergraduate Programs: Case Study – Bio-Diesel Project**

### **ABSTRACT**

Sustainable principles and the so-called “green” technologies apply to all building systems from planning to design and from construction to operations and deconstruction. The construction industry has recently realized the necessity of having their engineers to get acquainted with green building practices. In this paper, a project has been developed and is aimed at developing two pedagogical models within the curriculum; one is to cover the theoretical and practice-oriented sustainability components, and the other is for implementing applied research in the area of sustainability. Many students undertook both models during their program of study and as a result reaped the benefits of their developed skills in a fairly new realm of engineering, i.e. sustainable engineering and green construction. The outcomes of implementing these two models were visible and appeared in the students’ efforts to create and invent new products, some of which have been already built and utilized by them. Some of the students who decided to continue their exposure and hands-on experiential learning in this field have completed the development of a working prototype to produce bio-diesel fuel as an example. This paper summarizes the development stage of the contents of such courses in engineering that led to innovative products and to a positive empirical scholarship. This paper provides presents the outcomes of such combined pedagogical and scholarship encounter along with the lessons learned.

### **Key Words:**

Bio-diesel, green technologies, sustainability, recycling, reuse, prototype, LEED, USGBC.

### **INTRODUCTION**

Since 2003, a pilot program at the department was initiated to offer a series of courses that addressed sustainability principles and philosophies. One of these courses was intended to cover the planning, design and construction of green buildings and facilities. This course achieved a number of pedagogical goals to include the design and construction of buildings that are resource-efficient, safe, healthy, comfortable, durable, and adaptable to the environment and to the future. Major concepts in construction management, construction materials, energy efficiency, air/water quality, and other state-of-the-art sustainable practices were covered in this course. Furthermore, a number of case studies from the local industry will be analyzed and presented. The LEED<sup>TM</sup> Green Building Rating System 2.0 that was developed by the U.S. Green Building Council was used as a source document in this course. It provided an advanced model for evaluating buildings and is becoming an industry standard. Various innovative technologies and governmental standards to rate the sustainability of buildings were also used. A major term project and couple site visits and guest speaker lectures were also conducted during

this course. Because this course was considered as a design course, a number of spin-off models were allowed to further test the students' ability to come up with innovative solutions in this area. Upon the visit of an expert in green construction from a nearby national laboratory, an interest in sustainable practices was further developed by the students. One application that drew a lot of interest was the production of bio-diesel fuel.

## **PURPOSE AND SIGNIFICANCE**

The purpose of the developed pedagogical model was to plan, engineer, and develop a demonstration unit for the production of biodiesel fuel from used cooking oil. The project was conducted in our labs at the School of Engineering and Computer Science at the University of the Pacific. Both the Soil lab and manufacturing lab were utilized. This project is cross disciplinary in nature as it combines expertise from the green construction field within civil engineering and renewable energy technologies. It is conducted in part within the Research Seminar Series CIVL 197 accounting for 3 units. The author of this paper supervised this project and provided guidance to three civil engineering seniors.

As the world is becoming more dependant on diminishing fossil fuel resources, businesses are searching for alternative ways to produce inexpensive and renewable fuel. Biodiesel is an alternative fuel made from vegetable oil (or animal fat) that can be used in most diesel engines without the need for any modifications. Biodiesel is more superior to conventional fossil diesel because it reduces toxic emissions by nearly 90% when compared to regular diesel. Biodiesel is known to have an overall positive life cycle energy balance of 3.2:1, while regular diesel has only 0.86:1. There are a number of benefits for using biodiesel fuels to power diesel engines; one is that its tailpipe emissions are carbon-neutral and sulfur-free. Furthermore, the technology of producing biodiesel is within reach and far less complicated when compared to the production of other evolving energy sources such as Hydrogen [Gerpen 2004].

This project was born during a green construction class that was offered to a small group of students in Fall 2005. The discussion of alternative energy sources and sustainable technologies led to a strong interest by the students and Faculty in biodiesel as a potentially renewable energy source. A working paper was written by a group of students to address the technical feasibility and economic feasibility of producing biodiesel out of used cooking oil. Upon passing that class, the same group decided to continue their work and to do further research to refine the process and improve the production methodology by testing it in a real world situation. This group decided to attend a research seminar in the following Spring semester to get further assistance and in-depth support from the two Faculty involved. At this stage, a small model has built and tested to handle about 2 gallons, but plans are now underway to build a 5-gallon biodiesel processing unit. Upon completion of this project in May 2006, the students were able to provide a live demo to the community by running their biodiesel that was made out of used cooking oil into a diesel engine. This project provided citizens of the community with exciting information about the advantages and disadvantages of producing and using biodiesel fuel. Although biodiesel is becoming fairly popular in Europe, low prices for fossil fuels in the US have

prevented biodiesel from competing in the marketplace. Nevertheless, local, state, and federal policies may make biodiesel more financially attractive. For example, the State of Minnesota required that 2% biodiesel be mixed with all diesel fuel sold within the state by 2005 in addition to other tax incentives and production policies.

## DESCRIPTION OF METHODOLOGY

Biodiesel is most commonly made by chemically altering organic oil through the use of a catalyst and an alcohol, typically, methanol. The chemical reaction that occurs through this process breaks down the oil molecules and replaces the glycerin portion of the molecule with an alcohol molecule. The glycerin falls to the bottom and is drained off resulting in Biodiesel. The biodiesel is then typically washed to remove any extra impurities and then used as a fuel in a diesel engine without making any modification to the engine. Biodiesel is known chemically as ‘fatty acid methyl ester,’ which is just a fancy way of saying it’s a product made from methanol and organic oil with fatty acid chains in it. It is intended to streamline the production process to reap many of its benefits including environmentally friendlier tailpipe emissions and improved engine performance. The production cycle is described in Figure 1 below.

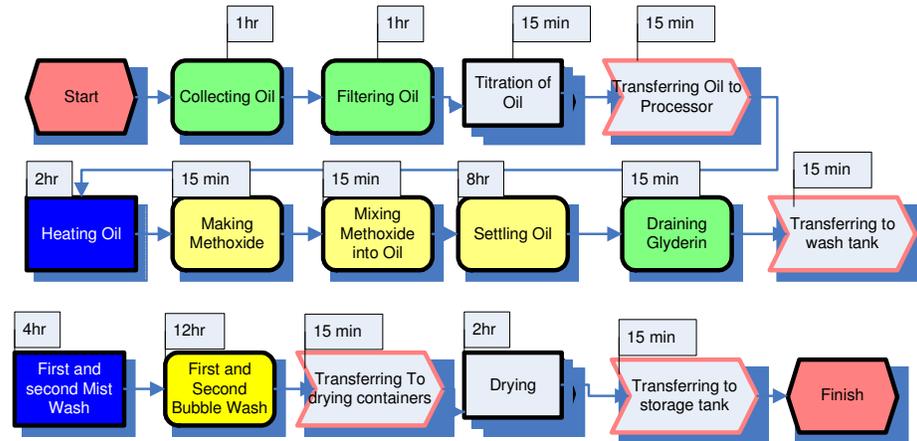


Figure 1: Bio-Diesel Production Cycle

## OUTCOMES OF THE PROJECT

The proposed process resulted in the production of pure biodiesel fuel that was ready to use in a conventional diesel engine. Based on the literature presented and by refining the cycles presented above, it is anticipated that an improved process will be developed by either shortening the time needed to complete each cycle that is illustrated above or by improving each process involved through the use of better equipment or thermal handling, storing and mixing techniques. A full diagram of the prototype as developed by the students is provided in Figure 2.

## LONG-RANGE BENEFITS

The main focus of this project is to use common thermal processing techniques along with separation and storing methods to produce quality grade biodiesel. It is aimed at the end of this project to prove that small-size production would not only be technically feasible but cost effective. Also we should become more optimistic about the industrial future of biodiesel production in the US. If this type of alternative energy proves to be both economically attractive and technically feasible, then we have a good reason to hope for a better and sustainable planet. This project will provide a working prototype for demonstration of a technology that can improve the quality of our life by going on in our daily life a sustainable way. The finding in terms of improved production processes will be a step forward in the realm of sustainable future and a tool to cooperate with other institution in this important and promising area of research. Results from this research project were first presented at the 6<sup>th</sup> annual research/creativity exhibit on April 20, 2006, and at an upcoming "green construction/renewable energy summit" that will occur in Spring 2007 on campus. Furthermore, other findings will be published in magazines such as Home Power and presented in one of the upcoming Southwest Energy Conferences. Finally, the developed prototype will be showcased in various functions and public function on campus as part of our efforts to develop the concept of sustainability and also to live it.

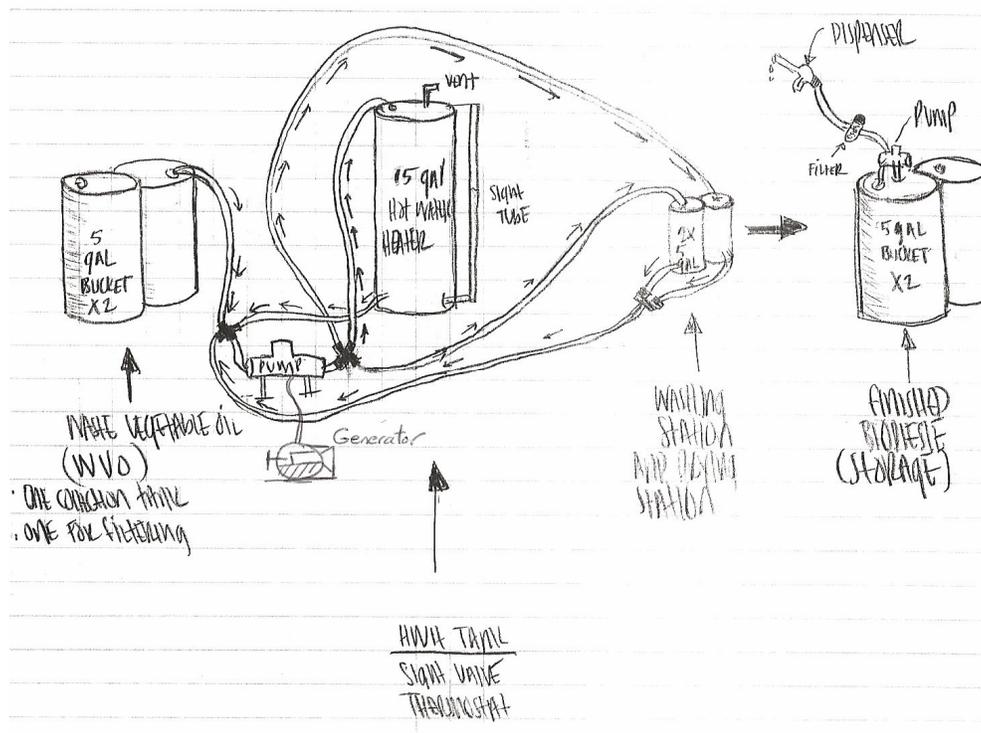


Figure 2: Bio-diesel working prototype

## **OTHER GREEN/SUSTAINABLE TECHNOLOGIES**

Besides the bio-diesel project, undergraduate students were able to actively participate in the research and development of other green technologies. Among these are deconstruction methods and methodologies. A group of undergraduate students cooperated to generate a comprehensive list of sustainable technologies and presented the work during a national deconstruction conference in 2006. In this study for example, they provided evidence that that deconstruction when planned properly will help lead to a sustainable future. Many energy-efficient building materials or “green materials” can be recovered and recycled as a result of deconstruction projects. Products ranging from roofing appliances and insulation, to landscaping products can all be recycled. The quality of information about potential buildings that are destined for deconstruction and/or demolition is vital. A survey conducted by the University of Sheffield in England with demolition experts who are members of the Federation of Demolition Contractors (NFDC) and other consultants in the business; shows that the trend is towards a likelihood of banning the disposal of recyclable materials in England, following a model of waste minimization program that was adopted by Netherlands.

A number of technologies are researched in this study and show that used materials from deconstructed buildings can be processed and injected back into the market as raw materials for the construction industry. The process requirements and energy needs for each aforementioned technology vary widely. In the case of processing steel, drywall, and shingles for different uses as illustrated in this study, there are various environmental impacts that may determine the sustainability of such technologies.

Emerging markets and arising new technology for reuse and recycling have made it possible to attain reasonable diversion rates of C&D from landfills. Several states and localities have mandated goals for C&D diversion rates and contractors are starting to make money despite the extra handling costs and difficulty of reselling or recycling C&D waste. Larger amounts of materials are finding their way back into the market such as plastics, concrete, paper, bricks, metals, insulation, woods, and others.

In this study, the benefits of deconstruction can be summarized in terms of reducing the impacts on the nation’s virgin materials, energy demand, and landfill space. On the other hand, deconstruction helps create jobs in needy communities. Furthermore, given the large inventory of structures that are destined for demolition, deconstruction has become the only viable alternative.

The students were able to prove that many deconstruction projects had proved to be cost effective when careful planning is performed and adequate market conditions exist in the area. One of the financial drawbacks of deconstruction remains to be the cost of labor training and the liability caused by the nature of deconstruction operations, especially when dealing with hazardous materials such as lead-based paint and asbestos.

## **EVOLUTION AND DEVELOPMENT OF A GREEN CONSTRUCTION COURSE**

Over the past few years, a green construction course has been developed to serve as a clearinghouse for student innovations in building a sustainable future. This course has been provided to a small group of undergraduate students as an elective and it drew a group of enthusiastic students about the environment. This course covers the planning, design and construction of green buildings and facilities. Students learn how to design and construct buildings that are resource-efficient, safe, healthy, comfortable, durable, and adaptable to the environment and to the future. Also, this course serves to be the vehicle to incubate new ideas such as the bio-diesel project presented earlier. Students learn the LEED™ Green Building Rating System that is developed by the U.S. Green Building Council. Various innovative technologies and governmental standards to rate the sustainability of buildings. A major term project and couple site visits and guest speaker lectures are conducted during this course.

## **COURSE BENEFITS AND ASSESSMENT**

The course discussed above served undergraduate students in civil engineering in a number of ways. Most importantly, it helped define emerging concepts in green construction, green engineering, ecological and healthy homes. It also explained the fundamentals of healthy houses, symptoms and diseases, and how to cure them. It used a systems approach to explain green/healthy buildings. The emphasis was placed on materials and components in foundations, roofing, flooring, insulation, etc. This helped broaden the students' comprehension about the green construction industry and how to find ways to contribute to the industry. Concepts of recycling, reuse, and renewable materials were stressed throughout the course. Several renowned guest speakers were invited to address evolving principles of sustainable civil engineering, eco-renovation, ecological home improvements, deconstruction as discussed above, besides many issues.

## **CONCLUSIONS**

The green construction engineering course provides skills and techniques in sustainability that is becoming an essential component of the civil engineering practice. A number of results measured throughout this course include skills in critical thinking, data interpretation and analysis, integrative ability, data collection techniques of various green construction projects. The qualities assessed include curiosity, creativity, appreciation for role of science and technology (e.g., using LEED by the USGBC in design and construction), and a continued interest in learning about civil engineering. Other results measured include knowledge gained in sustainability. The bio-diesel prototype as described above was only one example of many other innovative concepts that the students were able to gain in this course. Future plans are in place to create working models of novel concepts such as geo-spheres, zero-energy housing, design for deconstruction, and many others.

## **REFERENCES**

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