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TOMORROW'S FUEL, TODAY
BIODIESEL AT JANSSEN ORTHO LLC

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This report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of Janssen Ortho LLC or Worcester Polytechnic Institute.

This report is the product of an education program, and is intended to serve as partial documentation for the evaluation of academic achievement. This report should not be construed as a working document by the reader.

ABSTRACT

This project was performed in Gurabo, Puerto Rico at Janssen Ortho LLC (JOLLC), part of the Johnson & Johnson family of companies. The WPI project team helped JOLLC research and implement a biodiesel fuel test trial using a diesel forklift. This research and testing aided the team in making recommendations for future, full-scale biodiesel usage at JOLLC. We tested biodiesel fuel in a forklift, interviewed other companies in Puerto Rico that use biodiesel fuel, researched a biodiesel fueling infrastructure, and created a cost analysis. The full report makes recommendations to JOLLC concerning how to continue using biodiesel fuel in the future.

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1.0 Introduction

In 1898, Rudolph Diesel introduced to the world his compression ignition engine powered by peanut oil. Diesel used peanut oil in his engines because he envisioned biomass fueled engines to be a superior replacement for the only 12% efficient steam engines of the time. Various vegetable oils were used well into the 1920s, when engine modifications allowed for the use of better performing, and cheaper fossil fuels. Since then, petroleum based diesel #2, hereon referred to as diesel, has become the standard fuel source for compression ignition engines.

Nearly 100 years later, the toxic effects of diesel on the environment and human health are common knowledge because of widespread research on the subject. For example, diesel engines are known to emit large quantities of carbon dioxide (CO_2) that trap heat in the Earth's atmosphere and significantly contribute to global warming. Other harmful emissions such as black smoke and sulfur have further contributed to environmental and human health problems such as acid rain.

The use of nonrenewable energy sources such as diesel is also a concern because it depletes valuable natural resources and forces our economy to rely heavily upon foreign crude oil sources. This increasing awareness has resulted in heavy opposition to the reliance upon diesel and motivated the search for new alternative fuel sources. Governments, corporations, engine manufacturers, standard setting organizations, environmentalists, and others have consequently all begun to seriously consider the use of alternative fuels in the interest of protecting energy security and the ecosystem.

An intermediate yet valuable step between searching for viable alternative energy sources and the ensuing acceptance and usage of such sources is an Environmental Management Systems (EMS). Many companies have implemented an EMS in order to improve their energy efficiency and reduce their corporate impact on the environment. An EMS is a continuous cycle of monitoring, reviewing, planning, implementing, and ultimately improving the processes and actions that an organization carries out to meet its business and environmental goals (EPA, ND).

In addition to internal programs such as an EMS, the federal government and organizations like the Environmental Protection Agency (EPA) and American Society for Testing and Materials (ASTM) have established environmental policies and standards for all to abide by. One such example is the Energy Policy Act of 1992 (EPAct), which requires covered fleets to purchase alternative fuel vehicles (DOE, 2001). Although such regulations, standards, and even laws help curb pollution, the inherent threat of diesel emissions to the environment unfortunately remains.

In recent years there has been a growing resurgence of renewable, biomass fuel usage highlighted by large-scale conversions of diesel powered fleets to biodiesel. The majority of this research and implementation has been in public fleets such as school buses, public transportation vehicles, and waste collection vehicles. More biodiesel applications include mobile vehicles, boilers, and generators. These successful pilot programs have helped pave the way for larger biodiesel plants and persuade diesel users that biodiesel is in fact a feasible fuel option.

Every biodiesel initiative, large or small, benefits the environment by merely adding to the support and demand for cleaner burning, alternative fuels. Along with large companies and organizations, biodiesel is rapidly spreading throughout the private sector. Diesel marine vehicles are perfect examples of personal incentives for using biodiesel fuel. The emissions from these onboard motors irritate passengers and pollute the water. The french fry smelling, nontoxic biodiesel exhaust alleviates both of these problems.

Even though extensive testing has proven biodiesel safe and effective in a wide variety of industries, vehicles, and venues, it is still necessary to take certain precautions before pouring biodiesel into any diesel tank. Factors such as engine and infrastructure compatibility, and blending biodiesel with diesel vary on a case-by-case basis. For these reasons, careful evaluation and possible testing is recommended before a final biodiesel action plan is implemented.

Janssen Ortho LLC (JOLLC), a member of the Johnson & Johnson family of companies, has repeatedly demonstrated its commitment by continuously improving air and water quality via waste disposal management. JOLLC's latest venture in environmentally responsible policy is a feasibility assessment of implementing biodiesel at their manufacturing and packaging facility in Gurabo, Puerto Rico. JOLLC plans to work closely with chemical engineering professor, Dr. José Colucci, from the University of Puerto Rico, Mayagüez Campus, who has been the project champion for the introduction of biodiesel to Puerto Rico. He has done this by supplying free samples of the fuel for testing purposes to any Puerto Rican company or individual that is interested in using biodiesel.

The purpose of this project was to research, develop, and initiate a sustainable biodiesel conversion program in a safe and seamless manner. The project is composed of four interrelated objectives: perform a successful biodiesel test trial, compile case studies, propose a permanent biodiesel infrastructure, and conduct a cost analysis. Our main focus for accomplishing these tasks was comparing the advantages and disadvantages of different biodiesel/diesel blends and fueling methods with JOLLC's goals and limitations. In order to integrate biodiesel into JOLLC's daily operations in the least intrusive manner possible, it was essential to successfully complete all four objectives.

We anticipate that this report will provide JOLLC with realistic recommendations and serve as an implementation guide for other companies that want to use biodiesel. As such, this report focuses on the technical and procedural aspects and considerations that must be taken into account when implementing biodiesel. By documenting interviews with other facilities using biodiesel, we can gather valuable, technical information from personal experience case studies not found in the literature. This will hopefully inspire more biodiesel interest in Puerto Rico by simplifying both major and minor decision-making processes.

2.0.0 Literature Review

Janssen Ortho LLC (JOLLC) is deeply committed to environmentally safe practices. For over 50 years, the Johnson & Johnson Credo (Appendix A) has remained a one-page document, mandating the company to “maintain in good order the property we are privileged to use, protecting the environment and natural resources”. A closer look at JOLLC’s environmental policy shows that the company strives to integrate environmental goals into their everyday business practices. Along with their onsite implementation of environmentally proactive policies, such as International Standards Organization (ISO) 14001 certification and the creation of an onsite forest reserve, JOLLC also strives to support “conservation and community-based programs worldwide” (Johnson & Johnson, ND).

JOLLC’s commitment to and respect for environmentally safe practices does not stop at a “lofty” credo. The company has enacted many programs and projects to bolster their efforts for building a better, more environmentally aware global community. An important step in realizing their goals and beliefs was becoming ISO 14001 certified (Appendix B).

ISO 14001 was established in 1996 with the goal of creating a framework for companies seeking to enact Environmental Management Systems (EMS). The purpose of an EMS is to quantify a company’s environmental awareness, policies, and accident recovery plans. The resulting data serves to implement a set of environmental standards that the organization will follow. By enacting a set of standards, the creators of ISO 14001 sought to facilitate international trade. This provided companies with guidance concerning pollution prevention, sustainable development, and compliance assurance

(Delmas, 2002). These standards play a key role in the environmental policies of a variety of industries including automotive, electronics, aerospace, and pharmaceutical. ISO 14001 certification can be a prerequisite for doing business with dominant, successful firms, and even entire countries. This is a result of the strong statement that ISO 14001 certification makes about a firm's loyalty to the well being of the environment, as well as being an indication of product quality (Schaarsmith, 2002).

In May 2000 JOLLC sponsored a project that aimed to increase environmental awareness by surveying each employee at their facility, and assessing the environmental aspects of their daily work (Johnson et al, 2000). This survey assessed JOLLC's current EMS, and converted it to an improved EMS that was in accordance with ISO 14001 environmental standards. The survey quantified JOLLC's environmental challenges, the quality of resources they have, its level of environmental preparedness, and the ability of the staff to comply with a sustainable environmental management system. These aspects of ISO 14001 better prepared JOLLC for the standardization of their EMS.

Along with their commitment to environmentally sound business practices, JOLLC has also dedicated itself to improving the quality of life in the surrounding community. Their credo states that they "are responsible to the communities in which we live and work and to the world community as well". By having strong ties with the community, as well as being environmentally responsible, JOLLC believes it can attain a competitive business edge. In 2001 JOLLC sponsored a project to establish a forest reserve on the grounds of their Gurabo, Puerto Rico facility. The purpose of this project was to provide an educational forest reserve for the public to enjoy. JOLLC employees take time out of their schedules to give tours of the forest reserve to the surrounding community, and even children from a nearby elementary school (Fuller et al, 2001). Projects like this demonstrate JOLLC's strong commitment to the community.

The current project is an extension of both JOLLC's commitment to bettering the community, and their dedication to lessening their impact on the environment. The use of biodiesel in lieu of diesel #2, hereon referred to as diesel, significantly reduces negative impacts on the environment, and the community directly benefits from this reduction. The purpose of this project is to conduct a biodiesel test trial, and recommend a biodiesel infrastructure (handling, storage, transportation) specifically tailored to JOLLC's needs.

To accomplish this project, we will be working closely with the University of Puerto Rico, Mayagüez Campus (UPRM). Specifically, we will be in close contact with Dr. José Colucci, a chemical engineering professor at UPRM. Dr. Colucci advocates the use of biodiesel fuel at companies across Puerto Rico. To accelerate the acceptance and usage of biodiesel, he provides each company with a free test supply of up to ten 55-gallon drums of pure biodiesel, also known as neat biodiesel or B100 (100% biodiesel). Dr. Colucci can also provide each company with a fuel pump to extract the fuel from the drums.

2.1.0 Diesel Fuel Background

For the past 30 years policies at the national government, state government, and even the private corporate level have sought to reduce the impact of their daily activities with respect to environmental aspects, like air and water quality, ecosystems, and flora and fauna. Government regulations such as the Energy Policy Act of 1992 (EPAct)

(Appendix C) and the American Society for Testing and Materials (ASTM) D 975 (Appendix D) set standards for diesel emissions and impact the use of diesel fueled vehicles, which account for the second largest mode of transportation in the US (Sheehan et al, 1998). A different set of standards apply to diesel #1 commonly known as kerosene fuel. It is a common misconception that diesel vehicles are better for the environment, simply because they can travel 30% more miles per gallon than gasoline. Although diesel engines have better fuel economy, they also emit 18% more carbon dioxide (CO_2) than gasoline powered engines (Levy, 2001). Diesel engines also differ from gasoline engines in that the fuel auto-ignites because of its higher fuel compression ratios. Diesel fuel is injected, either directly or indirectly, into a high temperature, highly compressed air chamber, where it does not immediately ignite. Instead, the fuel must first heat up and undergo chemical transformations, a process known as the ignition delay (Van Gerpen, 2002). Most of the emissions associated with diesel fuel are formed during the ignition delay and are hazardous to humans and the environment, as they add to global warming and can harm lung tissue.

2.1.1 Disadvantages of Diesel Fuel

One of the biggest problems that result from diesel combustion is the smoke, or particulate soot, that is emitted. Toxic, microscopic particulate matter released into the air during diesel combustion can become lodged deep inside lung tissue, and once inside can only be removed by the immune system. The removal of these particles often takes months, or even years. Since the toxic particles can get stuck in the human body for such long periods of time, they essentially prolong our exposure to the toxins emitted by combustion (National Renewable Defense Council, 2003). Consequently, it is estimated that diesel soot accounts for health costs of $160,000 to $2,000,000 per ton emitted, and experts estimate that approximately five million tons of diesel soot is emitted into the air each year (Levy, 2001).

Along with potential threats to human health, diesel fuel negatively effects the environment. Fossil fuel emissions have been quantified and divided into CO_2, carbon monoxide (CO), total hydrocarbons (THC), unburned hydrocarbons (UHC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and other particulate matter (PM or soot). As mentioned before, diesel combustion releases CO_2, which greatly contributes to global warming via the greenhouse effect. This occurs when the CO_2 emitted into the atmosphere traps heat from the ground by first absorbing it and then releasing it into the air. Studies have shown that the particulate soot released during diesel combustion also contributes to global warming. Simply put, the small particles are heated by the sun and radiate heat back into the atmosphere (Levy, 2001). The soot particles only have a lifetime of a few weeks in the air, so controlling the amount of soot in the air can significantly reduce global warming and risks to human health.

Along with the negative effects on the environment and human health, it is also relevant to examine problems concerning the diesel life cycle. Petroleum fuel is derived from crude oil extracted from dry ground or the ocean floor. There are many techniques for accessing this natural resource, but the fact is that 50% of the US's crude oil supply comes from foreign sources (Sheehan et al, 1998). This is notable because increasing the use of biodiesel fuel would considerably lower US dependence on foreign oil sources. Since the US already produces all the necessary ingredients to make biodiesel, we will no longer need to rely on foreign countries for diesel resources. The combined animal fat and vegetable oil production in the United States is 35.3 billion pounds, and it takes about 7.6 pounds of these ingredients to make one gallon of biodiesel. At this rate, the United States could produce around 4.64 billion gallons of biodiesel if all the resources were collected (Van Gerpen, 2002). Buying biodiesel from US suppliers, rather than foreign sources also helps our own economy by creating biodiesel production facilities, which in turn create jobs.

2.2.0 Biodiesel Fuel and Diesel Engines

Having seen the negative effects of diesel emissions on human health and the environment, it is important to consider alternative fuel sources, such as biodiesel. An alternative fuel is defined as a substantially non-petroleum fuel source that yields energy security and environmental benefits (DOE, ND). Biodiesel fuel, an alternative fuel, has the potential to establish new worldwide markets for nontoxic, safe and readily available animal fats. It is important to analyze the composition of biodiesel fuel, its standards, and its environmental and non-environmental advantages to understand JOLLC's interest in this fuel. The following sections elaborate upon these topics, but anyone who is seriously interested in using biodiesel should also read *Biodiesel Handling and Use Guidelines* (Appendix E).

Biodiesel was being used even before the advent of automobiles, because it is easily produced from domestic biomass feedstocks, which are any renewable, organic materials used for creating energy (The Public Utilities Commission of Ohio, 2003). Even though people have been knowledgeable about biomass energy since the late 1800s, fossil fuels have been prevalent until now because of the political and economic influences of industrial tycoons when diesel fuel was introduced.

Today, research and analysis on biodiesel fuel is conducted worldwide and has become the leading contender for the diesel fuel alternative of the future (Hofman et al, 2002). For example, biodiesel fuel has been used in Europe since 1985, and it is even estimated that Europe is six to ten years ahead of the United States in terms of production and use (Harden, ND). Germany, Europe's largest consumer of biodiesel, is expected to use up to 750 million gallons of biodiesel this year. Most European countries also have a system of credits, or tax breaks, for people who use B100 in their personal vehicles.

The advanced use of biodiesel in Europe is partly a result of the diminishing supply of fossil fuels. Figure 1 is a graph illustrating the Earth's diminishing fossil fuel supply, the increasing usage of renewable energy sources, and the difference that could be filled with newly discovered energy sources.

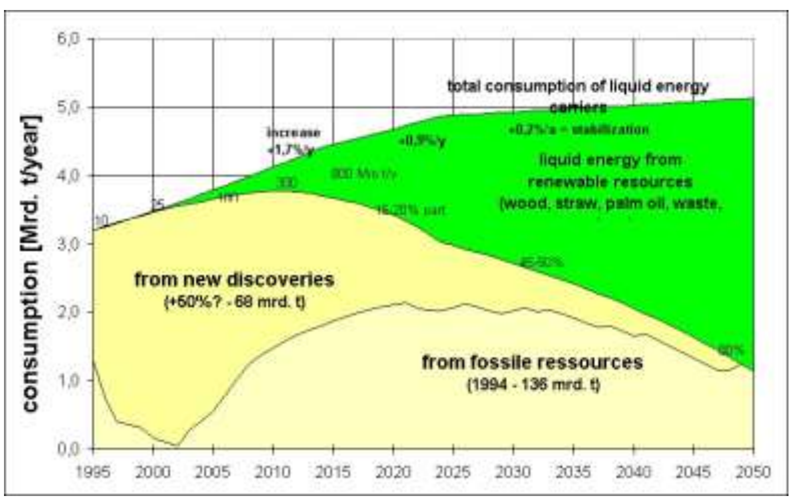

Figure 1: Energy Source Prediction (J.Connemann, 1996)

The results of research concerning biodiesel and diesel fuels, in this report, along with reports of successful worldwide biodiesel infrastructures, provide convincing arguments for why biodiesel should be accepted and as an alternative fuel (Appendix F). Although the use of biodiesel is commonplace in Europe, it is still necessary for us to research the properties and applications of biodiesel in order to make suitable recommendations to JOLLC.

Biodiesel is composed of alkyl monoesters of vegetable oils or animal fats, two sources readily available in the United States. In order to make biodiesel, a reaction of oil and alcohol (i.e. methanol or ethanol) is induced in the presence of a basic catalyst (i.e. NaOH or KOH). The only products of this reaction are glycerin, which is both natural and non-toxic, and biodiesel fuel. The relevance of this biochemical analysis for this report is to show how biodiesel fuel is a natural, biodegradable, and renewable source. The fuel is renewable because it can be produced from recycled ingredients such as used cooking oil and vegetable oil.

2.2.1 Biodiesel and Emissions

Biodiesel is currently registered with the Environmental Protection Agency (EPA) and the ASTM as a fuel and a fuel additive (ASTM International, ND). The EPA has evaluated the usage of biodiesel as a diesel substitute and deemed it less hazardous to human health than traditional petroleum diesel. It has been confirmed that exposure to biodiesel emissions carries a potential cancer risk 80% lower than diesel.

Emissions from pure biodiesel combustion also release 90% less toxins into the air. A B20 blend (20% biodiesel and 80% diesel) reduces emissions 20% compared to B100. Specific air emission comparisons between B100, B20, and diesel combustion are illustrated in Figures 2 and 3. Personal testimonies have reported that biodiesel emissions are less irritating to the eyes, and produce a more pleasant smelling exhaust than diesel emissions (Lang, 2001).

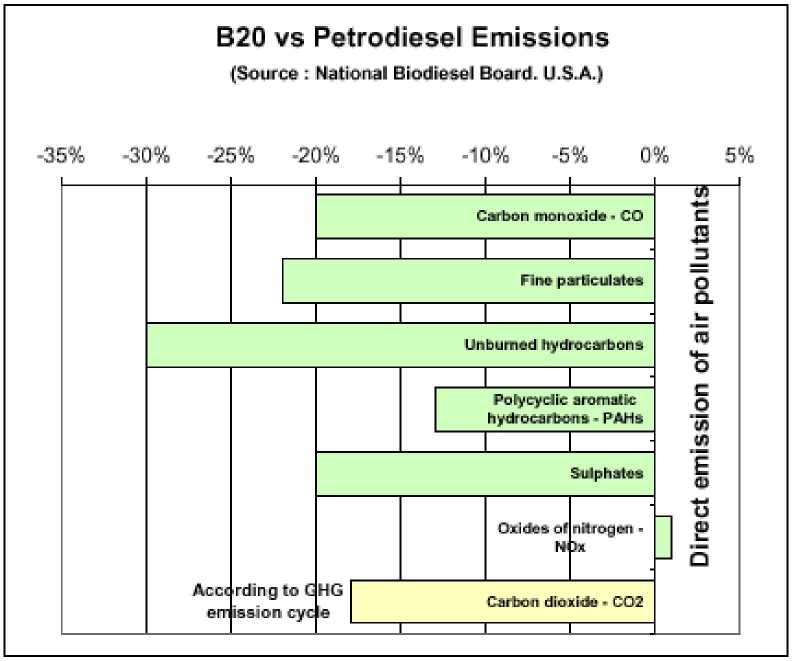

Figure 2: **B20 vs. Diesel #2** (National Biodiesel Board, 2002)

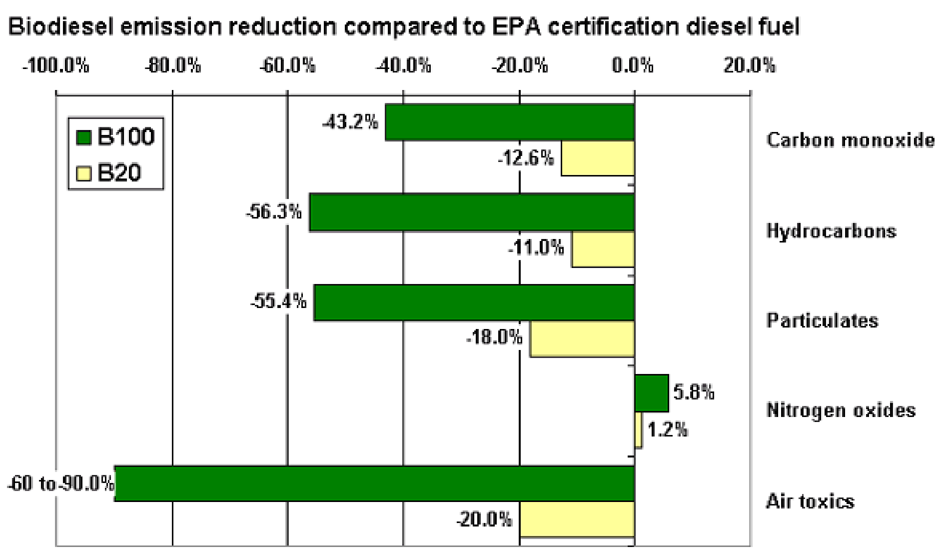

Figure 3: B20 vs. B100 (National Renewable Energy Laboratory, 2002)

Diesel engines are notorious for their production of black smoke and invisible toxins. Biodiesel is noticeably different from diesel in its ability to considerably reduce PM emissions (i.e. dust, smoke, soot, soil particles etc). Unlike diesel, there is no sulfur present in biodiesel, thus no SO_x is emitted during combustion. CO, THC, and UHC are also reduced with biodiesel, but depending on the engine, emission levels of NO_x increase (Durbin et al, 2000). Preliminary data has shown that certain additives and adjustments to engine injection timing can counterbalance the NO_x emission increase without affecting other emissions. The lack of sulfur in biodiesel allows for these modifications that would otherwise be unsuitable for diesel fuel containing sulfur (Ferrone, 1995).

Along with reducing the diesel related risks to human health, biodiesel reduces the damage done to the environment by diesel combustion. An important chemical to note is CO_2. B100 reduces CO_2 emissions by approximately 78% compared to diesel. The remaining CO_2 is attributed to carbon loss during the manufacturing and transport of biodiesel (Figure 4). Using a B20 blend (20% biodiesel and 80% diesel) subsequently reduces CO_2 by approximately 15%. The CO_2 released during biodiesel combustion is recycled by the same plants used to produce the oil stock for biodiesel, hence biodiesel is said to emit no net CO_2 into the atmosphere (Figure 5).

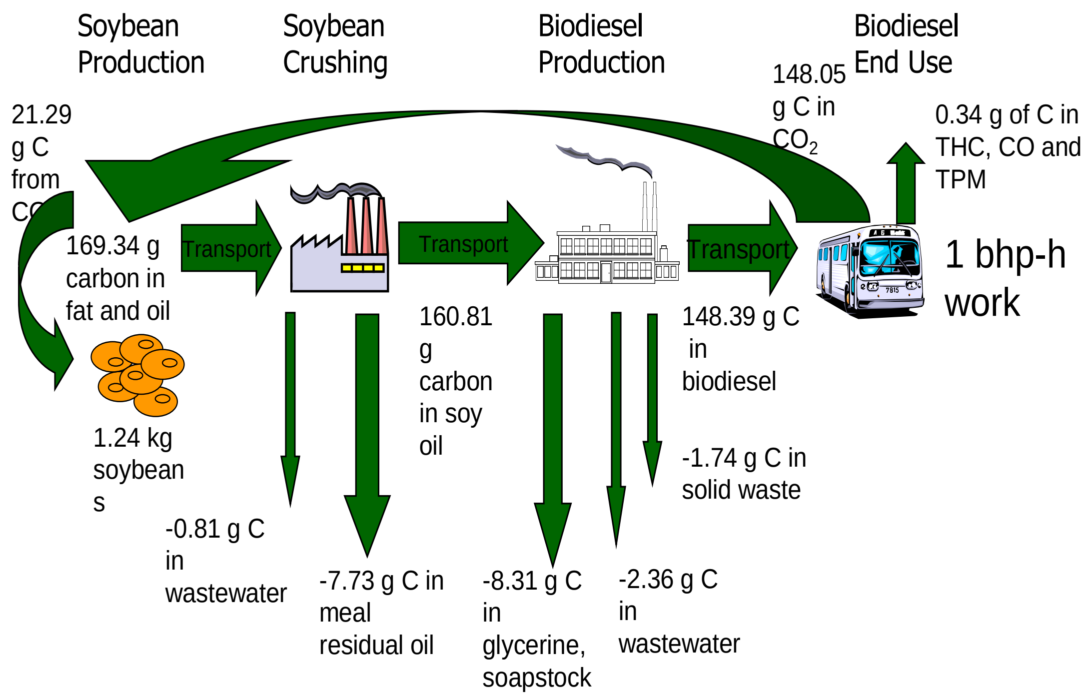

Figure 4: Biodiesel Carbon Life Cycle (National Renewable Energy Laboratory, 2000)

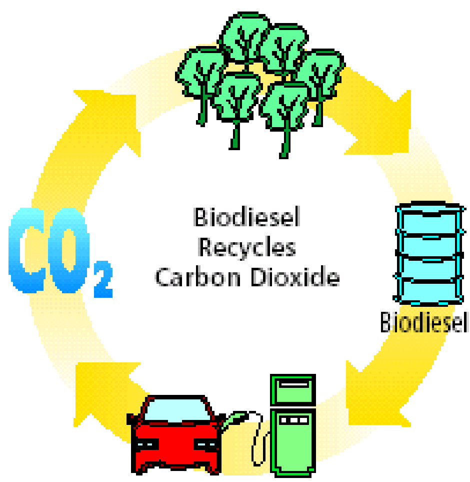

Figure 5: Biodiesel CO_2 Cycle (National Renewable Energy Laboratory, 2000)

2.2.2 Biodiesel Performance

Biodiesel's non-environmental advantages compared to petroleum diesel is demonstrated by biodiesel's cetane numbers, flash point, lubricity, and engine performance. These factors, combined with the fact that biodiesel fuel is perfectly compatible with almost all diesel engines with no extra costs or modifications, are grounds for a very convincing biodiesel fuel argument.

The only problem of any significance is biodiesel's ability to degrade rubber parts (i.e. fuel hoses, fuel pumps, gaskets, seals etc.) found in diesel engines. This is a result of biodiesel's solvent properties. However, most diesel engines manufactured since 1993 use rubber substitutes (i.e. viton, silicon etc.) in lieu of rubber because of their durability in the presence of solvents (Ferrone, 1995).

The cetane number simply implies how well the fuel will burn when injected into the combustion chamber of an engine. It is one of the most highly referenced measures of diesel fuel quality used today. The cetane number is directly measured by the chemical composition of the fuel, and thus has primary affects on engine stability, emissions, and noise (O'Brien, 2001). A high cetane number, similar to octane numbers associated with gasoline, is an indication of better fuel quality thus making the fuel more expensive. Although there are many different rating systems for cetane numbers, some more reliable than others, current data consistently shows that biodiesel has higher cetane numbers than diesel resulting in smoother ignition at engine startup.

An important factor that directly affects the cetane number is the fatty acid ester composition of the biological source. Different biological sources will contain varying fatty acid compositions. The influencing factor of fatty acids on the cetane number has been linked to each carbon chain's degree of unsaturation, as determined by the number of carbon-carbon double bonds present. In general, biodiesel fuels with higher degrees of unsaturation will have lower cetane numbers (Van Gerpen, 2002).

B02 (2% biodiesel), B20 (20% biodiesel), and B100 (100% biodiesel) are common biodiesel/diesel blends being tested and applied in industry (Van Gerpen, 2002). Biodiesel has been found to have a noticeable yet insignificant impact on engine power, torque, and fuel economy. However, all factors may fluctuate with varying biodiesel blends and the fuel's primary feedstock (Lang, 2001). Thus, a question to be answered for this project is which blend of biodiesel will be most appropriate for JOLLC. It is also important to investigate and compare biodiesel cetane numbers of different blends and sources to each other and to diesel fuel before implementing any large-scale biodiesel usage. Biodiesel fuel is currently more expensive than petroleum diesel in the US. However, with increasing government support, we hope to see more subsidies and incentives, which would cause biodiesel fuel to be cheaper than diesel in the future. B20 has become the benchmark blend for industrial vehicles. This is because B20 minimizes cost by using a limited amount of biodiesel, while not sacrificing engine performance (Tyson, 2001).

In addition to reducing the human health hazard, the physical risk involved in storing, transporting, and using diesel fuel is less with biodiesel because of its higher flashpoint. A flashpoint is the temperature at which the fuel will ignite. In terms of flashpoint, diesel fuel is relatively safe with a National Fire Protection Association (NFPA) flammability rating of 2, whereas biodiesel has a flammability rating of 1. Therefore biodiesel could be subjected to higher temperatures without increasing the risk of a potential fire or explosion. On the other hand, diesel fuel has a “gelling” effect when exposed to cold temperatures. There are a number of remedies for this, however precaution must still be taken to avoid cold flow problems. Biodiesel has been tested at extremely cold temperatures with evidence of similar cold flow problems. In fact, biodiesel has been found to gel at slightly higher temperatures than diesel (Van Gerpen, 2002). In Puerto Rico’s tropical climate cold flow is not a concern, and is thus an irrelevant factor in the determination of biodiesel implementation there. However, the higher flashpoint of biodiesel fuel can only benefit biodiesel usage in warm weather.

Research has shown that biodiesel can benefit a diesel engine’s performance and durability due to its exceptional lubricating qualities. The fuel used to power a diesel engine must provide a certain amount of lubrication, for lubrication helps keep the wear and tear of internal components to a minimum. Since biodiesel fuel has superior lubricating capabilities, it has been confirmed that it reduces the wear on the engine. Although small amounts of biodiesel will not significantly reduce emissions or affect the cetane number of the fuel, using only a 1%-2% biodiesel/diesel blend can improve diesel lubricity up to 65% (Lang, 2001).

In relevant case studies, biodiesel converted vehicles have been reported to decrease an engine’s idle vibration with negligible reductions in horsepower or fuel consumption at the B20 level. Other test studies have shown that biodiesel fueled engines may experience a power loss of up to 9% when using B100 (Hofman et al, 2002). Still other studies have found fuel consumption to increase at the following rates when compared to diesel B20 @ 1.3%, B35 @ 2.3%, B65 @ 7.1%, and B100 @ 12.7% (Schumacher, 1995).

Currently, there is no substantial evidence that biodiesel has a longer, or shorter shelf life than diesel fuel. Industrial recommendations for storage of diesel and biodiesel fuel do not extend past 6 months. Programs are in development to research the long-term storage of such fuels using various storage enhancing additives (Lang, 2001). Water content in petroleum fuel carries a risk of bacterial contamination. Thus, a storage problem to assess is microbial growth within storage tanks, which can occur with both diesel and biodiesel fuels.

In order for biodiesel to be produced and sold, the government stipulates that the fuel must meet the provisional standards set forth by the ASTM in D 6751 (Appendix D), the most recent version of the ASTM's standard for biodiesel fuels. ASTM approves all biodiesel blends up to B20, but higher blends are subject to evaluation on a case-by-case basis. Thus far, no problems have arisen from using ASTM D 6751 approved B20 fuel in a wide variety of vehicles for over 45 million miles (National Biodiesel Board, ND).

The manufacturers of diesel engines issue warranties that cover the parts and workmanship of their products, but not the fuels used to power them. Although most diesel engine manufacturers have stated that blends up to and including B20 are perfectly acceptable, not all biodiesel is ASTM D 6751 certified. Until the complete adoption of ASTM D 6751 is realized, engine manufacturers should always be consulted before fueling their products with biodiesel (National Biodiesel Board, ND).

2.3.0 Biodiesel Production Facilities

Before the complete adoption of biodiesel standard ASTM D 6751 can occur, biodiesel production needs to become commonplace in the United States. Once full-scale production of biodiesel is established, manufacturers will be much more comfortable backing the fuel. For over 30 years, biodiesel has been produced for experimental and research purposes throughout the world. In the early 1970s research began in Austria, which quickly proved biodiesel fuel to be an environmentally friendly and cost effective means of fueling various types of vehicles.

As word of biodiesel spread throughout Europe, a demand developed for its mass production. In 1985 the first pilot plant for producing biodiesel fuel was constructed in southern Austria using rapeseed-oil methyl ester. Since then six more biodiesel production plants have been built in Austria alone, including two industrial-scale plants. Austria became the first country to develop standards for producing biodiesel from rapeseed oil methyl esters in 1992 (Mittelbach, 1996). Today there are biodiesel production plants scattered throughout Europe and the mainland United States. These plants produce biodiesel from a number of different sources, depending on availability, such as restaurant grease, oils from soybean crops, and many other agricultural products. New standards for biodiesel fuel and its production are developed every year, and government subsidies may play a big part in the future production of biodiesel in the United States.

The United States Department of Agriculture (USDA) recently implemented a 300 million dollar biodiesel/ethanol initiative that provides money for manufacturing facilities that produce renewable fuels. Along with this government subsidy, there is a proposed tax exemption that would reduce the amount of tax on biodiesel/diesel fuel blends depending on the percent of biodiesel in the mixture. For example, if one were to use a B05 blend, the tax on the fuel would be reduced by five cents (up to 20 cents with

B20). State subsidies can also increase the demand for biodiesel. A recent law passed in Minnesota requires biodiesel to be used with diesel fuel. The Minnesota government hopes this will bolster the biodiesel industry. (Coltrain, 2002)

Puerto Rico has also begun its own unique biodiesel initiative. The University of Puerto Rico, Mayagüez Campus (UPRM), in collaboration with Panzardi-ERM has done extensive biodiesel marketing and research on the feasibility of a biodiesel production facility in Puerto Rico. This research is based primarily on resource availability and demand for biodiesel (Figure 6). According to this study, the most feasible resource for the production of biodiesel in Puerto Rico would be used cooking oils and recycled restaurant greases. Currently, 5 to 10 million gallons of used cooking oil, which could potentially be used to produce biodiesel, are generated from Puerto Rico each year. Yet only 1 to 1.5 million gallons of that is collected, the rest simply goes to waste (Colucci et al, 2003). In order to implement the widespread use of biodiesel fuel in Puerto Rico, the available supply of cooking grease must be collected. However, Puerto Rico should not rule out the possibility of using imported resources such as vegetable oils. Puerto Rico could employ soybean oils from the United States, which produces idle crops of soybeans every year (Higgins, 2002). The main conclusion of this study was that Puerto Rico would need a facility capable of producing 10 to 15 million gallons of biodiesel per year in order to be cost effective.

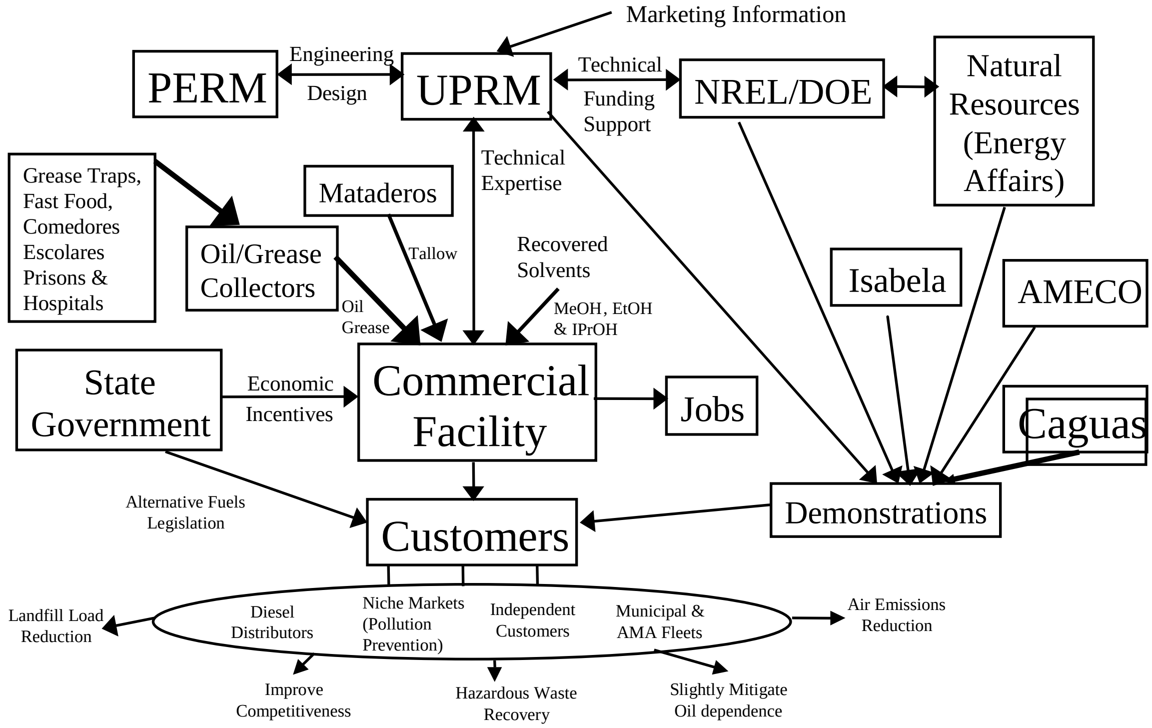

Figure 6: Puerto Rico Biodiesel Commercialization Players (UPRM, 2003)

More important than the source for biodiesel production is the overall demand for biodiesel. Biodiesel usage is slowly increasing in Puerto Rico, but unfortunately there is currently not enough demand to warrant the installation of a biodiesel production facility. As more and more municipalities, companies, and individuals continue to experiment with and implement biodiesel, the sooner the concept of a Puerto Rican biodiesel production facility can become a reality (Figure 7). If and when this happens, it is estimated to cost between 6 and 10 million dollars for the construction of a new production facility (Colucci et al, 2003).

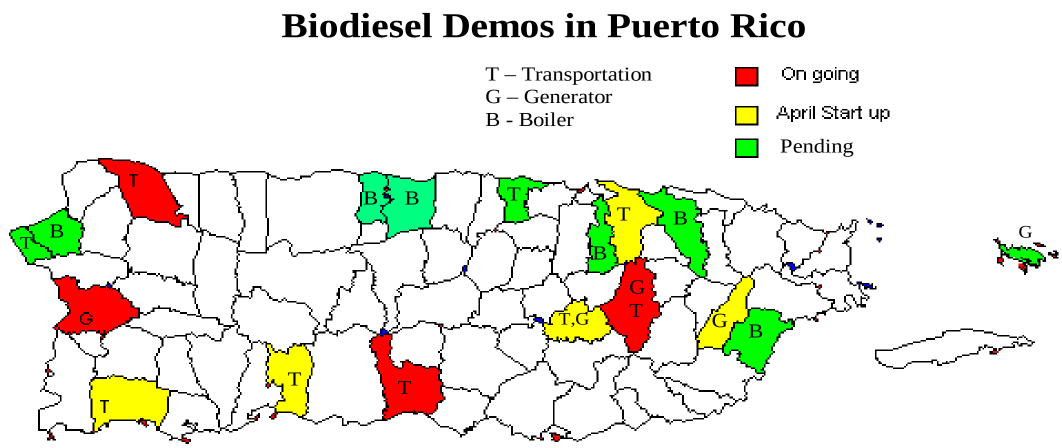

Figure 7: Puerto Rican Biodiesel Demonstration Locations (UPRM, 2003)

Puerto Rico currently imports its biodiesel from the United States, primarily Florida, but the ability to produce biodiesel domestically would have a great economic impact on the community surrounding the plant. Specifically, Dr. Colucci purchases his supply of biodiesel from Western Petroleum, a fuel distributor in Puerto Rico. The presence of a biodiesel production facility in Puerto Rico would provide jobs for operation and construction. In similar studies, biodiesel production facilities offer about 31 permanent jobs. These facilities have been found to increase investments in plant and equipment as well as reduce imports of liquid petroleum (Van Dyne et al, 1996).

2.4.0 Fleet Management

JOLLC is taking steps to ensure that their fleet management practices are in accordance with their dedication to the environment and surrounding community. Fleet management is the process of maintaining an efficient and valued fleet of engines. There are three topics focused on during this process: environment, waste, and cost

(Government of Canada, ND). The environmental aspect of fleet management is driven by environmental policies of the plant, the larger corporation, and the government. Compliance with government environmental standards can provide companies with tax breaks or other incentives.

The next part of maintaining an efficient fleet deals with the reduction of waste. Reduction of waste is a "lean" practice and can directly benefit the environment. A lean practice involves "changing a work area or a business process to maximize efficiency, improve quality and safety, eliminate unnecessary motion and inventory, and save time" (Boeing, ND). Reduction of waste obviously increases efficiency, while also improving the quality of products and helping maintain a healthy work environment. All of these aspects of waste reduction are important to JOLLC.

In order for a fleet management program to be efficient, costs must be kept as low as possible without sacrificing the quality of production. Currently, the demand for biodiesel fuel in Puerto Rico is not high enough to run a cost-effective biodiesel fleet. JOLLC will need to decide whether the positive environmental results of using biodiesel, or if the cost issues of biodiesel, will dictate their fleet management policies.

Fleet management is not a black and white protocol, but rather a list of universally accepted best practices. Practices for making fleets more efficient include using low energy, low emission fuels. Fleet management is a careful balance of environment, waste and cost. One of the main objectives of the biodiesel implementation project is to analyze this balance and determine how JOLLC should behave, taking into account the financial interests of the company and the Puerto Rican community alike.

2.5.0 Government Concerns about Fleet Management

On October 24, 1992 Congress passed the Environmental Policy Act (EPAct), the government's first monumental step toward leading a nation-wide mission to improve environmental quality and decrease foreign dependence on imported petroleum. EPAct essentially forces specified fleets to begin purchasing alternative fuel vehicles (AFV) as part of their yearly vehicle acquisitions. The fleets are broken into three categories: state and alternative fuel provider fleets, federal fleets, and private and local government fleets. EPAct goes on to define non-petroleum derived alternative fuels as any of the following:

- Methanol, ethanol, and other alcohols;
- Blends of 85% or more alcohol with gasoline;
- Natural gas and liquid fuels domestically produced from natural gas;
- Liquefied petroleum gas (propane);
- Coal derived liquid fuels; and
- Hydrogen and electricity

(DOE, 2001) The act also has an alternative fuel petition program where the developer of a new fuel can formally petition the Department of Energy (DOE) to add said fuel to EPAct's list of acceptable fuels. Most recently, biodiesel was added to the list.

On January 9, 2001 the Biodiesel Fuel Use Credit Interim Final Rule was enacted. This allows the purchase of biodiesel to help EPAct covered fleets meet their AFV requirements. Each category of fleets has different AFV requirements, but the same biodiesel stipulations apply to each category. The credit system is as follows. One biodiesel credit equals the purchase of 450 gallons of pure biodiesel (B100). One biodiesel credit counts as one AFV acquisition. Biodiesel only counts for credits if it is used in B20 form or above, but the credits are only based upon the volume of B100 purchased. Also, fleets can only use biodiesel credits to account for up to 50% of their total AFV requirements (DOE, 2001). There are other minor factors regarding the use of biodiesel to meet EPAct regulations. All this information and more can be found in Appendix G.

EPAct addresses the environmental and economic concerns associated with petroleum fuel, but fails to address personal safety issues for those working with the fuels. The US Department of Labor has installed the Occupational Safety and Health Administration (OSHA) to protect American workers from avoidable health risks and injury. They accomplish this via onsite safety inspections and employee surveys. "OSHA is determined to use its limited resources effectively to stimulate management commitment and employee participation in comprehensive workplace safety and health programs" (OSHA, ND). Diesel exhaust has received a lot of attention from OSHA because of its widespread exposure to workers and scientifically proven, adverse health effects. Unfortunately, OSHA has not yet set permissible exposure limits for diesel exhaust, but does recognize the importance of such controls. OSHA claims that more information regarding current technology for controlling and monitoring diesel particulates must be researched before such legislation can be drafted (OSHA, ND).

2.6.0 Summary

> As society furthers its understanding of the limits of an ecosystem's assimilatory ability, and as technology increases our ability to produce zero to low polluting means of transportation and manufacturing products, the closer we will be to setting sustainable rates of emission releases and product consumption. Until that information is in hand, it is necessary to set targets that get us closest to our best estimates of what we know our sustainable rates of resource consumption and emission releases. (ICLEI-US, 2001, Ch.4 Pg. 2)

Research into the negative effects of diesel emissions on the environment, human health, and the economy demonstrates a need for a cleaner burning, renewable, domestic fuel source. With its increasing interest in sustainability, and the creation of environmental goals and targets, it is no surprise that JOLLC is interested in biodiesel fuel as a substitute for conventional diesel fuel. Firstly, biodiesel fuel is safer than diesel as it is non-toxic, biodegradable, and it has a higher flashpoint than diesel. It is also more environmentally friendly than diesel, since it is a renewable energy source, reduces the CO_2 lifecycle, reduces soot, particulate matter, hydrocarbon, and sulfur emissions. Lastly, the use of biodiesel helps the economy by putting farmers to work, decreasing our foreign dependence on oil, and creating new jobs. As a result of some of the aforementioned reasons, JOLLC will lead the way in converting to alternative, renewable, and domestic fuels, such as biodiesel.

We learned from the background chapter the differences between the current fuel and the proposed biodiesel fuel. These differences were taken into account before testing and implementation can occur. Emissions data, chemical properties, safety issues, performance statistics, will all be considered in order to make an appropriate recommendation for JOLLC. In preparation to utilize our research, the literature review sought to describe JOLLC's rationale for, and interests in its biodiesel initiative.

Throughout each phase of this project, there were key sets of goals and objectives that guided our methods for implementation. We analyzed each mobile diesel vehicle to ensure safe conversions to biodiesel. After researching the vehicles, it was necessary to choose an appropriate test vehicle and fuel blend. Once these decisions were made, we tested the vehicle with biodiesel fuel. Depending on the outcome of the test trial, we proposed recommendations to JOLLC regarding a permanent biodiesel fueling infrastructure at their facility. Data was collected and a cost analysis was written in order to make final recommendations to JOLLC. The following chapters seek to provide a more detailed explanation of our purpose, goals, methods, results, recommendations, and conclusions of this project.

3.0 Purpose and Objectives

We will research, initiate, and develop a sustainable biodiesel program in a safe and seamless manner.

Janssen Ortho LLC (JOLLC) prides itself upon being an environmentally conscious corporation that makes strides to uphold the ideals stated in its credo. When an opportunity arises that JOLLC's management sees as both a reasonable and justified environmental approach to the betterment of their operational procedures, they take full advantage.

JOLLC currently consumes more than 500,000 gallons of diesel fuel on a yearly basis (Appendix H). This fuel is used to power factory machinery involved in the manufacturing and packaging of nine different pharmaceutical products produced at the facility in Gurabo, PR. For reasons previously discussed in this report concerning the use of diesel fuel, it is evident why JOLLC concerns itself with the toxic emissions.

JOLLC has been confronted with the option of using biodiesel as a diesel additive to significantly reduce diesel emissions. Numerous companies in Puerto Rico have already initiated biodiesel programs with successful results. Therefore, as an environmentally responsible corporation, JOLLC has decided to investigate and hopefully implement biodiesel fuel at their pharmaceutical plant. Interviews with said companies were conducted to gather information and ideas that could be useful in formulating a biodiesel plan for JOLLC.

The onsite diesel machinery at JOLLC can be divided into large immobile equipment (i.e. boilers and generators) and smaller mobile equipment (i.e. trucks and forklifts). A long-term goal for JOLLC is to eventually have all diesel machinery running on biodiesel. However JOLLC's facility operates 24 hours, 7 days a week, and it is hardly reasonable to create and implement a biodiesel fueling infrastructure for the large-scale equipment without any previous experience with the fuel. Although the diesel fuel consumption and emissions of the mobile fleet hardly compare to that of large-scale equipment, it is crucial to initiate the biodiesel program with the smaller mobile diesel engines. This biodiesel testing will inevitably pave the way for accurate recommendations, and possibly a smoother transition into the factory-wide implementation of biodiesel.

The final recommendations that we make to JOLLC are a result of the completion of certain objectives. Our particular process for the conversion of JOLLC's mobile diesel fleet to a biodiesel fleet is comprised of four objectives. The first is to sustain a biodiesel trial run in one diesel vehicle providing hard evidence of JOLLC's fleets' capability of supporting biodiesel. The second is to conduct interviews with other companies in Puerto Rico about the motives, procedures, and results pertaining to their personal biodiesel experiences. This information, combined with our already existing knowledge of biodiesel, will serve as a foundation for the third objective. This is to design and recommend a sustainable biodiesel fueling station capable of fueling the entire mobile fleet. The fourth and final objective is to develop a cost analysis that will enumerate the inherent costs of conversion to biodiesel and compare them to the benefits of using it. The following section contains the methods and reasoning for realizing JOLLC's short-term biodiesel goals in a safe, cost effective manner.

4.0 Methodology

In the background section the important aspects of diesel and biodiesel fuels were explained. General topics concerning fleet management and environmental management were discussed, and insight was given on JOLLC's specific policies and programs. The state of biodiesel in Puerto Rico was examined in order to give a better understanding of what JOLLC can expect for the future of biodiesel at their facility in Gurabo. These topics provided background information about the driving forces behind JOLLC's proposed conversion to biodiesel. The next step is to discuss the appropriate methods to expedite JOLLC's conversion to biodiesel fuel.

Four specific project objectives structured the flow of this methodology. The project's first objective was to develop a temporary a method for sustaining one mobile diesel test vehicle on biodiesel until a permanent biodiesel fueling station is developed onsite at JOLLC as later discussed in the third objective. This test trial was designed to be as simple as possible and non-intrusive to JOLLC's employees, current procedures, and infrastructure. The second objective was to interview companies that currently use biodiesel, and document them as case studies. The purpose of this was to provide guidance for developing recommendations for a biodiesel infrastructure at JOLLC. With this data, and an evaluation of the current diesel infrastructure at JOLLC, we were able to complete the third objective of proposing a fueling procedure and infrastructure that would enable JOLLC to fuel their entire mobile fleet with biodiesel. Coinciding with the third objective, the fourth objective consisted of conducting an analysis of the costs of converting to biodiesel compared with the advantages we spoke about in the background chapter. Upon the completion of all four objectives we made final recommendations to

JOLLC about the economic feasibility and practicality of using biodiesel in all diesel mobile vehicles and static diesel powered equipment at JOLLC.

Figure 8 is a schematic representation of the methodology employed for this project. The boxes highlighted in yellow represent the four objectives detailed earlier.

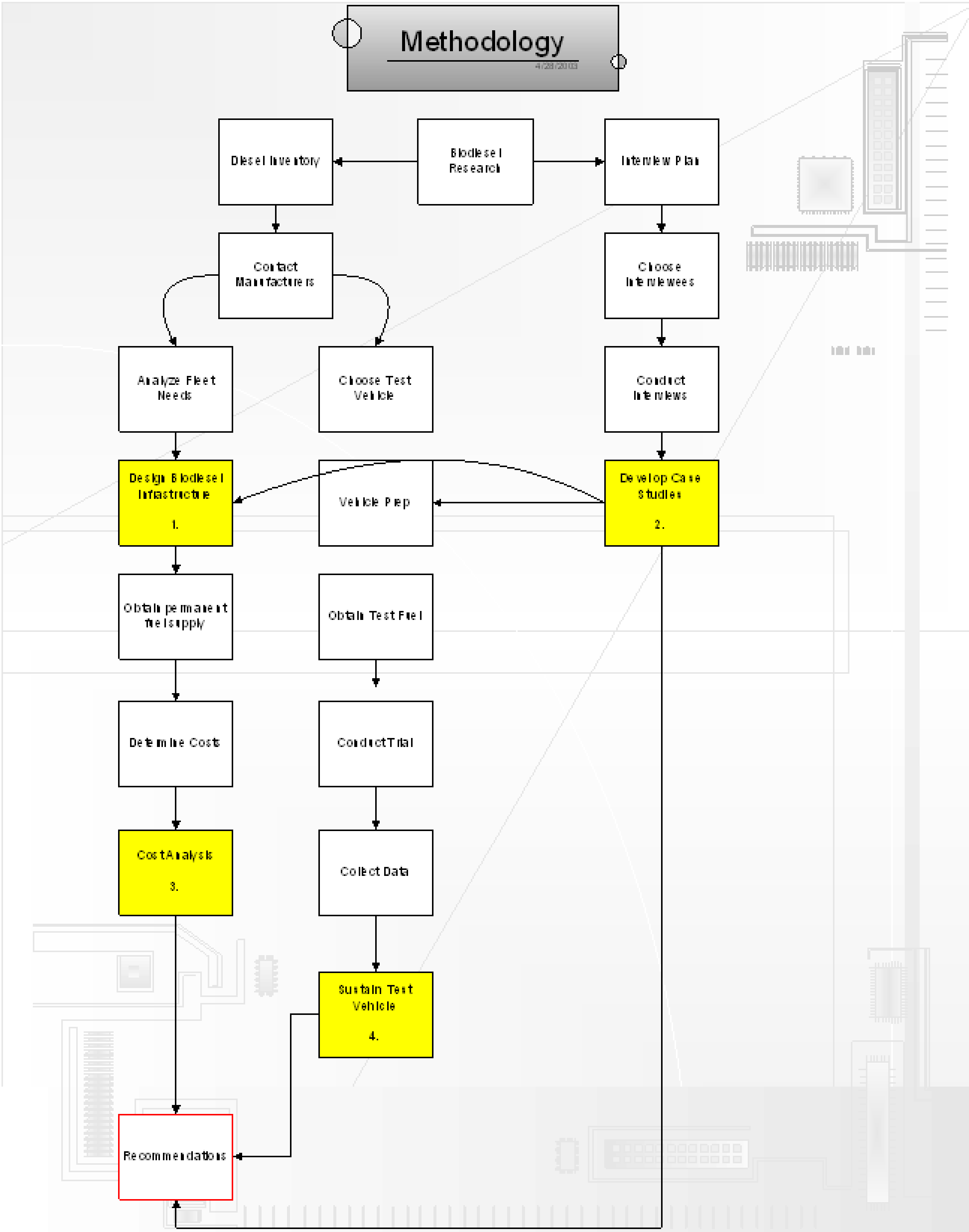
Methodology
Diesel Inventory
Biodiesel Research
Interview Plan
Contact Manufacturers
Choose Interviewees
Analyze Fleet Needs
Choose Test Vehicle
Conduct Interviews
Design Biodiesel Infrastructure 1.
Vehicle Prep
Develop Case Studies 2.
Obtain permanent fuel supply
Obtain Test Fuel
Determine Costs
Conduct Trial
Cost Analysis 3.
Collect Data
Sustain Test Vehicle 4.
Recommendations

Figure 8

4.1 Test Trial

Preliminary data had to be collected at JOLLC before conducting the biodiesel test trial. We first took inventory of JOLLC's mobile diesel vehicles. The make, year, and engine type of each vehicle was documented in order to make some feasibility assessments of using biodiesel in each vehicle. This required contacting the engine and vehicle manufacturers for questions regarding warranties, and each company's opinion of biodiesel usage in their engines. We wanted to gather as much information as possible to avoid any potential legal and mechanical problems. Below are some sample questions.

1. Will warranties cover the use of biodiesel? If so, at what specific blends?
2. Has biodiesel been tested in JOLLC's engine models?
3. Do you know if anyone else in industry has used biodiesel in these models? If so, can they be contacted for information?
4. Have there been any reported problems experienced with biodiesel in these models?

Depending on the responses that we were given from the engine manufacturers, we assessed the risks of using different blends of biodiesel in each mobile diesel vehicle. This assessment helped us choose which vehicle and fuel blend would be best suited for JOLLC's biodiesel test trial. Testing only one vehicle made it easier to formulate a recovery plan if problems arose. We made sure that if any engine parts needed to be bought, replaced, or cleaned, it was done so by JOLLC's vehicle service providers. The test vehicle was also provided with a reserve of fuel filters in case filter clogging became an issue.

After modifications were made and maintenance measures were taken, we acquired the test supply of fuel from Dr. Colucci from UPRM. We worked closely with Dr. Colucci to ensure that adequate biodiesel was supplied to sustain the vehicle for the testing trial. Once we obtained our test fuel, the experimental design was formulated. Proper safety measures were taken in regards to biodiesel storage, transport, blending and fueling. The fueling procedures were explained in detail to the forklift operator and approved by safety manager. We made sure that all procedures complied with OSHA and the generally accepted biodiesel usage guidelines.

We designed the data collection methods to keep quantitative and qualitative records of the biodiesel test vehicle. The ultimate goal was to compare biodiesel to diesel in terms of maintenance, fuel economy, performance, and safety. We could approximate fuel economy by recording mileage from one full tank of diesel and comparing that to B20. Qualitative data was dependent on comments from the vehicle operators. Only time could tell if there were overlooked maintenance or safety issues regarding biodiesel.

4.2 Case Studies

We obtained important information about biodiesel blends, blending, fueling, storage, and suppliers by interviewing representatives from various companies using biodiesel in their diesel machinery. To start, UPRM and JOLLC provided the team with a list of institutions/companies using biodiesel in Puerto Rico. Subsequently, the list of companies was narrowed because of time constraints. We chose companies to interview based on criteria related to their biodiesel applications, their industrial similarities to JOLLC, and future biodiesel goals.

Prior to onsite visits and interviews we formulated a comprehensive interview plan with detailed questions designed to help JOLLC develop a biodiesel program. In order to conduct an informative interview, we gathered background information about each company via email and telephone. This was necessary in order to become knowledgeable of their biodiesel applications and to mold our questions prior to the onsite interview. Next, the team traveled to each company's location to conduct the interviews and obtain first-hand knowledge of their biodiesel operations. The data collected was then transcribed into case studies that were sent back to the source to confirm the accuracy of our accounts. These case studies significantly contributed to decisions made for the first and third objectives by providing benchmarks for industrial biodiesel usage.

4.3 Infrastructure

A biodiesel infrastructure was developed to meet the needs of JOLLC, based on the results of the first two objectives. By conducting an inventory of JOLLC's fleet, and contacting the engine manufacturers of each vehicle, we could then begin to assess the overall ability of JOLLC's mobile diesel fleet to convert to biodiesel. We evaluated the fleet's fuel consumption and fueling methods before developing an infrastructure design specific for JOLLC. We estimated the mobile fleet's fuel consumption by multiplying each vehicle's fuel capacity by the frequency of refueling. We obtained the fleet's current fueling infrastructure through discussion with the appropriate JOLLC employees.

After these issues were analyzed, we searched on the Internet for consultants that could provide equipment and price quotes for our proposed biodiesel infrastructure. Once we were offered a reasonable quote from a contractor to fit JOLLC's budget, we researched biodiesel fuel suppliers for the mobile fleet, beginning with JOLLC's current diesel supplier. The costs of the fueling system, as well as costs for a stable supply of biodiesel provided us with information that aided the completion of the fourth objective that follows.

4.4 Cost Analysis

In order to better judge the possibility of long-term usage of biodiesel at JOLLC, we conducted a cost analysis. This cost analysis enumerated the inherent costs of converting to biodiesel and compared those costs to the potential benefits. These costs included the biodiesel fuel supply, infrastructure, and engine/vehicle preparation. The possible benefits included tax breaks, environmental benefits, and legal savings. Along with biodiesel benefits with respect to costs, there are also the intangible benefits. We examined the benefits of the environmentally friendly engines using biodiesel. All factors were noted and analyzed in order to make recommendations about the economic feasibility of future biodiesel usage at JOLLC.

4.5 Summary

The completion of these four objectives provided the team with concrete quantitative and qualitative data. Once the data we collected from engine manufacturers was analyzed, we were able to come to conclusions about which vehicle we were going to use, and which engine preparatory work needed to be done. The data gathered from our offsite interviews provided us with valuable advice for fueling our test vehicle. The data collected from both the first and second objectives was used to research a biodiesel fueling infrastructure. We came to our conclusions stated in the next chapter by contacting various consultants and requesting price quotes for JOLLC's system. The last objective was completed by compiling all of the costs we will need to endure for the implementation of biodiesel, compared to all of the data we collected from interviews that show the inherent benefits of biodiesel. The next chapter seeks to transcribe the data we collected into final results about our proposed biodiesel program. Once the results are finalized, we can formulate final recommendations to JOLLC about the best possible biodiesel program for their facility, as well as the economy viability of full-scale biodiesel usage in the future.

5.0.0 Data Analysis and Results

This chapter presents our collected data in the same objective-structured format as the previous methodology chapter. The analysis and results of this data is detailed in the following four sections: Inventory & Test Trial Results, Interviews and Case Studies, Mobile Biodiesel Fleet Infrastructure, and Cost Analysis. These objectives and their completion are interrelated, and all serve to make recommendations to JOLLC.

5.1.0 Inventory &Test Trial Results

5.1.1 JOLLC Inventory Assessment

The mobile diesel fleet consists of the following:

- 2001 Ford F750 truck, Caterpillar engine
- 1993 GMC 3500 HD truck, GMC engine
- 1990 Komatsu forklift, Nissan engine
- 1989 Drexel forklift, Perkins engine
- 1998 Advance Machine Company Retriever 5800 street sweeper, Kabota engine
- 1994 Denyo BLW-300SS mobile generator, Denyo engine

Most of the vehicles were found to have separate vehicle and engine manufacturers so it was necessary to contact both companies in many instances for information about biodiesel and warranties. Some companies had formal statements regarding biodiesel usage in their engines, but most had little to no information regarding biodiesel (Appendix I).

Based on the above information, we chose to test with B20 because of its cost effectiveness, noticeable environmental impacts, and several of JOLLC's vehicles were manufactured prior to 1993. It proved extremely difficult to verify the materials of different engine components, and it is hardly cost effective or reasonable to replace the old engines with newer engines that were perhaps more tolerant of biodiesel/ diesel mixtures. Given these conditions the best approach for JOLLC was to test whether or not B20 could be successfully implemented in a pre-1993 engine that might contain rubber parts.

5.1.2 Vehicle Choice

Ten gallons of B100 is enough fuel to fill a small forklift's fuel tank with B20 multiple times; therefore we chose to perform our test trial with a forklift. Our seven-week time constraint forced us to begin our testing as soon as possible with the fuel provided. The forklift has an hour gauge that records how long the engine has been in use, and a fuel gauge. The 1991 Komatsu forklift is used more often than the Drexel forklift, thus testing with the Komatsu forklift would expedite our initial testing plans of first measuring diesel fuel economy, and then preparing the engine for biodiesel and measuring B20 fuel economy. The Komatsu forklift has one consistent operator who is in constant close contact with the engine and other moveable parts, which makes performance an easy factor to measure. The Komatsu's 9.1-gallon tank is refueled approximately every two weeks. The forklift's fuel tank was filled to its capacity and the hours were recorded. We planned to record the hours again when the fuel gauge reached empty. Unfortunately, because of an oil leak, the forklift was scheduled for maintenance while the tank was still relatively full with diesel. In the interest of saving time and money, we overlooked the diesel fuel economy test and had the biodiesel preparatory work performed at this time. To do this expeditiously, the forklift was taken offsite by

Diversified Equipment Corporation (DIVEQCO). DIVEQCO made the necessary repairs, cleaned the fuel tank, changed the oil, and replaced the fuel and oil filters (Appendix J). No rubber engine components were replaced at this time because the labor would have been too costly. This maintenance took the forklift out of operation for two days.

5.1.3 Fuel Source

Dr. Colucci of UPRM, and Jorge Ros, General Manager of JOLLC signed a Memorandum of Understanding (MOU), for an agreement that UPRM would supply JOLLC with 500 free gallons of biodiesel, a total of ten 55-gallon drums. Two 5-gallon containers of B100 were initially provided by UPRM until larger quantities were available. A Material Safety Data Sheet (MSDS) for B100 was obtained in order to bring the fuel into JOLLC (Appendix K), and a B20 MSDS was needed in order to use said blend at JOLLC (Appendix L).

5.1.4 Initial Testing

Our original plan was to fuel the forklift with B20 ourselves once it returned from maintenance, but DIVEQCO informed us that they needed to put some fuel in the tank in order to move the vehicle from place to place at the service station. They were aware of our plans for a biodiesel test trial so they asked if we had any specific directions for fueling the forklift. We gave DIVEQCO one of our 5-gallon biodiesel containers and they filled the tank with B20 as per our instructions: seven gallons of diesel followed by two gallons of B100. This was actually B22, but we expected that the extra 2% biodiesel would have a negligible effect on test trial results. Immediate feedback from the forklift operator was less irritating exhaust and less black smoke. Even though no quantitative fuel economy data was collected, the operator felt the forklift had better than average mileage from a full tank of fuel with no performance loss.

In spite of the fact that a permanent biodiesel fueling system has not yet been installed, JOLLC wanted to continue fueling the forklift with B20. Since the forklift's fuel capacity is small, it would be simple to make a B20 mixture in a small plastic fuel container and fuel directly from the handheld container. Dr. Colucci delivered our first 55-gallon drum of B100 a week into our test trial. To help avoid problems and safety concerns, we also discussed with them the potential problems associated with using blends higher than B20 and improper fuel mixing. In addition to verbal explanations of biodiesel safety, mixing and forklift fueling processes, a detailed, one-page document was drafted and approved by the safety manager of JOLLC (Appendix M). Copies of these instructions were given to the operator and safety manager, as well as placed in the forklift and next to the biodiesel storage area.

5.2.0 Interviews and Case Studies

A list of companies using biodiesel was provided by JOLLC and UPRM. We obtained a brief description via email and phone of each company's biodiesel program. From these descriptions, UPRM and three other companies were chosen for onsite interviews at their facilities. The criterion for choosing these companies was based on company backgrounds, biodiesel goals, and handling processes of interest to JOLLC.

A detailed interview plan was formulated in order to organize information that will serve JOLLC's purposes (Appendix N). The qualitative data collected from these interviews was eventually summarized in case study form and sent back to the appropriate company for comments or content revisions, and appropriate changes were made. The finalized case studies can be found below. Case studies will provide whoever reads them with reassurance of the practicality and feasibility of biodiesel. This information will also serve as a benchmark for the biodiesel program at JOLLC.

5.2.1 Environmental Power Case Study

Date: March 25, 2003
Company: Environmental Power of Puerto Rico, Inc.
Location: Juana Diaz, PR
Website: www.eppri.com
Contact/Title: Alex A. Flores Caldera, PE, Environmental Engineer
Telephone: (787)-260-1490
E-mail: aflores@eppri.com

Background

Environmental Power of Puerto Rico collects waste products for treatment, reuse, and disposal. A notable project is the collection of grease from several food service companies and the processing of that waste through their onsite treatment plant.

Establishing Project

Environmental Power is actively involved in environmental projects being conducted at the University of Puerto Rico, Mayaguez (UPRM). Consequently when Dr. José Colucci of UPRM needed companies to be involved in his biodiesel project, he contacted the president of Environmental Power, Mr. Erick J. Rodríguez Toro. It was explained that the project encompassed the testing of biodiesel and the potential for a biodiesel production facility. The selling point for Environmental Power was that this project could potentially have a positive impact on the environment, as well as be an excellent business venture for them. After making the decision to join Dr. Colucci's biodiesel project, Environmental Power decided which of their vehicles would be used for testing. The conclusion was to run a Ford F150 truck/wagon on a B20 mixture. Environmental Power's reason for using B20 fuel is because it is so commonly used.

Prior to Testing

Environmental Power stores 55-gallon drums of biodiesel attained from Dr. Colucci within a dike and uses a 115-volt automated Fill-Rite pump and fuel gauge to pump and measure the fuel. Environmental Power chooses to mix the B20 prior to fueling the truck. This is done to make the mixing process a standard procedure. The method for mixing is a two-phase process in which they put 20 gallons of diesel in the drum followed by 5 gallons of B100 and repeat for a total of 50 gallons of fuel maximizing the capacity of the drum. The purpose of the two-phase mixing is to provide a consistent blend of B20. Prior to fueling with B20 for the first time, Environmental Power cleaned the truck fueling system using B100, which serves as a very powerful solvent. After cleaning, the fuel filters were replaced and the oil was changed as a precautionary measure.

Testing

At this time Environmental Power has been running a Ford F150 truck on B20 for approximately nine months. During that time the operator has observed that there are fewer fumes, the engine is cleaner and the truck runs smoother. The fuel filters were checked monthly during the testing phase because the solvent properties of biodiesel can degrade susceptible parts of the engine which can get caught in the filters.

Post Testing

Although Environmental Power has many diesel consuming vehicles, the plans to increase biodiesel use at their facility are limited by the B100, B20 storage capacity. Environmental Power feels that the cost of biodiesel will be more comparable to the cost of diesel when a biodiesel production facility is built. In the meantime, they will continue testing various biodiesel-diesel mixtures.

When asking our interviewee what is the best application for biodiesel, he made it clear that he felt marine use should be a priority. There are varying reasons why marine applications are so important, including the affects on the marine life, as well as marine operators and the potential market that marine applications represent.

In closing, Mr. Flores left us with some important testing advice. He recommended that before using biodiesel, we have a mechanic open the engine to document the "before" condition and take pictures. Then after a few months of running on biodiesel, it would be a good idea to have the same mechanic open the engine again to check the condition and document with more pictures. It would be helpful to let the mechanic make a report of their findings, experiences and impressions on the "after" condition. Flores also gave us some advice on advertising, and it was suggested that a banner be displayed on the gate to the facility so that the community would be aware of the biodiesel initiative.

5.2.2 Baxter Healthcare Corp. Case Study

Date: March 26, 2003
Company: Baxter Healthcare Corporation of Puerto Rico
Location: Aibonito, PR
Website: www.baxter.com
Contact/Title: Evet Vera, Environmental Engineer
Telephone: (787)-735-8021 x2228
E-mail: evet_vera@baxter.com

Background

Baxter's facility in Aibonito manufactures medical devices for the administration of fluids, drugs, blood and irrigating solution, plus ancillary medical devices. Their onsite diesel fleet includes two boilers, one fire pump, four emergency generators and several trucks.

Establishing Project

Baxter heard about biodiesel through their environmental products supplier, Xpectek, approximately three years ago. Xpectek is a local distributor of Gemtek, which is a company in Arizona that produces dieselight, a plant based diesel fuel. Baxter was immediately interested in biodiesel because of its independence from petroleum and impact on the environment. Unfortunately, Gemtek was unable to provide biodiesel at a price comparable to diesel, so the idea of using biodiesel was put on the back burner. A few years later, Environmental, Health and Safety Managers of the Baxter facilities in

Puerto Rico gathered together for a meeting with Dr. Colucci. At this meeting, Dr. Colucci gave a presentation on biodiesel and some of his plans for biodiesel's future in Puerto Rico. This was Baxter of Aibonito's first contact with Dr. Colucci and his biodiesel project. With a free supply of 500 gallons of biodiesel from UPRM, Baxter decided to test the fuel on their diesel Ford F700 truck. This was a practical starting point since the boilers are much too large for a simple test and would require a permanent system before implementation.

Prior to Testing

Before testing occurred, the diesel tank was drained in the truck and visually inspected. It was concluded that the tank was clean and therefore ready to fuel with biodiesel. Their fueling process is simple: they pour ten gallons of B100 in the 50-gallon tank and then drive to a local diesel distributor to top it off.

Testing

The testing phase at Baxter has been in progress for approximately three months thus far. The initial results were the immediate elimination of black smoke, improved smell, and reduced engine noise. Every time the engine is refueled the mileage is recorded. The refueling process is the same each time, ten gallons of B100 followed by the diesel. As a result of using this fueling process, the actual blend ratio changes each time the tank is refilled. It has been requested that the truck operator bring the truck to a local mechanic for a standard car emissions test.

Post Testing

The next stage at Baxter is to test the use of biodiesel in their boilers, which will be performed in conjunction with the Office for the Administration of Energy Affairs.

The main goal of this type of test is to measure the change in emissions produced by the boiler. One of the two boilers is significantly newer and therefore will serve as the test subject. Their boilers run on alternating schedules, so they will be testing the newer boiler while the older one is out of service. Before this testing can begin, Baxter will need to attain the proper permits from the Environmental Quality Board of Puerto Rico. They will also need to develop and install some sort of infrastructure for fueling and determine where they will get their fuel.

5.2.3 Añasco Precision Manufacturing Case Study

Date: March 28, 2003
Company: Añasco Precision Manufacturing, Inc.
Location: Añasco, PR
Contact/Title: Luiz A. Pérez, President
Telephone: (787)-826-2620
E-mail: perezla@caribe.net

Background

Añasco Precision Manufacturing (APM) produces precision parts using methods such as machining and wire cutting. The company when founded in 1981 consisted of Luiz Pérez, the president of the company, and an assistant. Now they serve many of the pharmaceutical companies of Puerto Rico and they are beginning to branch out as an international company. The only diesel machinery at APM is a diesel generator and a diesel truck. Pérez owns a personal diesel boat.

Establishing Project

Pérez heard about biodiesel from Dr. Colucci and then proceeded to gather more information on the Internet. He learned that there is a significant reduction of harmful toxins when converting from diesel to biodiesel, therefore he felt there was great potential for the use of biodiesel and wanted to be part of the initiative. A contract was established with Dr. Colucci for a free sample of B100. Next, Pérez began testing his three pieces of diesel powered equipment.

Prior to Testing

The engine mechanics at APM were very familiar with the testing engines so there was no hesitation with putting biodiesel in the engine. The blending process was done in external containers and then poured into the fuel tanks. The first stage of testing was performed using B20 because it is the most common blend. Increasing blend ratios were later tested to find the optimal blend for each individual engine.

Testing

Testing began in October 2002 and since then the program at APM has consumed 200 gallons of B100. Pérez has tested various blend ratios in all three of his diesel vehicles.

Pérez is currently running his boat on B20. The 3800 RPM, series 31 Volvo diesel engine powering this boat is approximately twenty years old. Pérez attempted to test different blend ratios in this particular engine and found that any blend higher than 20% biodiesel had a tendency to clog the turbo. The engine was not hot enough to burn the biodiesel, so the diesel was burned and the biodiesel simply leaked out. Pérez would not recommend using anything higher than B20 in a high performance engine.

There is also a 4 cylinder, John Deer, 1800 RPM generator at APM that runs on biodiesel. This generator is approximately eight years old and uses B30 with no problems thus far.

The third machine at APM is a Ford F250 pick-up truck. The truck, manufactured in 1999, is the newest of the three diesel engines. Because it is a newer engine, APM is able to run it on a higher biodiesel blend ratio, B50.

Post Testing

Pérez is very pleased with the results he has seen since making the switch to biodiesel. There have been noticeable changes in the emissions/exhaust fumes and performance of all three machines both positive and negative. After finding the most appropriate biodiesel blend, there have been only positive effects on the boat or generator engines. Pérez noted that the fumes from these two engines have a much more pleasant smell, and they are much quieter once they warm up. Pérez explained that because biodiesel has a higher flashpoint, the engine must warm up in order to reach the proper combustion temperature. There have also been similar positive effects on the truck. However, Pérez has noticed that the truck's mileage has decreased slightly, one or two miles per gallon less, and the truck takes a little longer to start up. These are among the few negative changes that have been documented from other experiments using blends with high biodiesel concentrations. Despite the few negative changes noticed at APM, Pérez is very positive and enthusiastic about the use of biodiesel. He will continue to use Dr. Colucci's biodiesel in his machinery until his contract runs out, at which point he will look to other sources no matter the cost.

5.2.4 Summary

Once all the information from our interviews was organized into case study form, it provided a benchmark for the biodiesel program at JOLLC. Some of the interviewee recommendations proved useful for our test trial, while others were noted and will be combined with our recommendations to JOLLC.

Receiving the above information was important, but sharing it with those directly involved was more so. We advised the forklift operator to let the forklift warm up before operating. In the fueling instructions drafted for JOLLC, we included blending tips and stressed the importance of being thorough and accurate. The 2-phase blending method used by Environmental Power motivated us to consider how we were going to ensure that the fuel used at JOLLC was thoroughly blended. Pérez made it clear that an external mixing method was the best way to guarantee that the proper blend ratio is used.

For testing purposes, we chose to send the forklift offsite to have the fuel system cleaned by a professional. After receiving instructions from Flores for cleaning the fuel system with B100, we felt confident that the procedure could be performed in house avoiding the expenses of sending the machinery offsite. This cleaning method could potentially save JOLLC money if and when they decided to convert other engines to biodiesel. Flores also suggested we publicize by hanging a banner outside the facility to inform the local community of the ongoing biodiesel project at JOLLC. We found that another way in which companies publicize the use of biodiesel is to place a decal on all vehicles using the fuel. Environmental Power and Baxter both have biodiesel decals on their vehicles, which inspired the design of JOLLC's biodiesel logo.

It is critical that JOLLC stay in contact with Baxter in the future, because they both have intentions of using biodiesel in boilers and will be able to aid one another. While at the Baxter facility we sat down and discussed how to perform a biodiesel test trial on a boiler. Designating a permanent tank with biodiesel was deemed impractical. It was suggested that a biodiesel fuel truck pump fuel directly into the boiler fuel lines. This solution seemed to be the most practical. This is a key example of how the communication between companies about the use of biodiesel will benefit all involved.

5.3.0 Mobile Biodiesel Fleet Infrastructure

Before the entire JOLLC mobile fleet can be fueled with biodiesel, some investigation was necessary and certain executive decisions needed to be made. The current diesel fueling system was first evaluated. From there, we explored different storage and blending options until one was found that best suited JOLLC's safety standards. JOLLC wanted all of the mobile engines to be fueled from one onsite B20 source. Issues concerning fuel sources (diesel and biodiesel), blending, and amounts of fuel were all assessed before making a final recommendation for JOLLC.

JOLLC has one 125,000-gallon diesel tank onsite used to fuel all of the large industrial equipment. This tank has not been cleaned for over fifteen years, and an estimated four inches of diesel matter and rust lay at the bottom of the tank. The diesel fuel is so dirty that the fuel is filtered before fueling the forklifts. The valve on this particular tank is one foot from the bottom so no serious problems have occurred as a result of the solid matter, but dissolved particles further contaminate the fuel source.

The diesel distributor, Western Petroleum, refills the tank once a month and the tank is never empty when filled. The fuel that is pumped into the tank once a month is quality grade low-sulfur diesel #2, however once in the tank, the fuel becomes contaminated because of afore mentioned reasons. Thus all industrial equipment (i.e. forklifts, street sweeper, mobile generator, static generators and boilers) is fueled from this tank, but the commercial diesel trucks need to be fueled offsite at a gas station with which JOLLC has a contract. Since JOLLC desires that all of their mobile biodiesel equipment be fueled from the same line, the diesel fuel from the big tank cannot be directly used to make B20. However, the fuel from Western Petroleum can potentially be used for B20 so long as it comes directly from the diesel tank truck and not JOLLC's diesel tank.

There is currently no biodiesel production plant in Puerto Rico, thus all biodiesel is imported from the mainland. It is imported in 55-gallon drums of B100, and is easily attainable from local fuel distributors in Puerto Rico including Western Petroleum. Purchasing preblended B20 would be ideal, but it is too costly in Puerto Rico at this time. Therefore the next best option is to buy pure biodiesel in 55-gallon drums and preblend onsite. We determined that 55 gallons of B100 could last the fleet at least one month. Since biodiesel should not be stored more than six months, we decided that receiving one drum every month, or as needed, would serve JOLLC's mobile diesel sources well.

It was suggested by Dr. Colucci that B20 be mixed within the vehicle by splash blending. However, this method presented JOLLC with concerns such as who would make sure the proper volume of diesel and biodiesel was pumped into each vehicle every time, and how would the biodiesel consumption status would be monitored. This method not only left room for error, but also was more laborious and inefficient than JOLLC's requirements. Therefore we suggested a more consistent and automated fuel delivery system that delivered B20 directly from a small aboveground storage tank.

Since biodiesel is still relatively uncommon, we found no similar models in our research or interviews of a biodiesel system that would suit JOLLC's requirements. By means of our own biodiesel knowledge, we designed and presented JOLLC with a general plan for a biodiesel infrastructure. The system included a 600-gallon, B20 tank with a level gauge that would receive diesel and biodiesel once a month from Western Petroleum's already scheduled shipments. We chose 600 gallons because it can accommodate up to two 55-gallon drums of B100 and the supplemental volume of diesel (440 gallons) to make B20. Each time the tank is refilled, exactly one drum of B100 and 220 gallons of diesel would be added. This avoids the risk of contamination and spills from having partially full B100 drums onsite. We employed the help of two different tank-consulting companies for suggestions on equipment and installation. We chose to pursue our infrastructure design with the help of Tank Management Services located in San Juan, Puerto Rico over other consultants because they were able to offer us onsite service and the lowest price. The other infrastructure proposals were too sophisticated and costly for JOLLC's current biodiesel applications (Appendix O).

Once a month, when the diesel tank truck arrives for delivery, a designated biodiesel manager for refueling will evaluate the B20 tank. JOLLC then has the option of refilling if the manager feels that there is not enough fuel to last the month, or vice versa. This decision will be based upon the reading on the tank's level gauge and fuel consumption data for the mobile diesel fleet. Currently, no data is reported for the mobile vehicles. Therefore we created a fuel consumption log that will be filled out every time a vehicle is fueled from the B20 tank (Appendix P). The log will be placed at or next to the B20 tank.

5.4.0 Cost Analysis

The data collected during the testing, interviewing, and infrastructure design periods contributes to the cost analysis. The following section outlines the data received and its sources. The quantitative data is compared in the form of charts and graphs. A written analysis was made of the qualitative data. The section is divided into costs and benefits of using biodiesel fuel.

5.4.1 Costs

The cost section is a financial assessment intended to highlight the investments required by JOLLC in converting to biodiesel. We contacted our fuel supplier for price quotes of biodiesel at varying quantities and blends in order to make a fuel price comparison chart. The final quote from the tank system contractor was used to show the cost of the intermediate step between testing and moving onward through a full-scale conversion. The invoiced items from the forklift for the preventative engine maintenance give an estimation of the cost to convert each individual diesel engine.

<u>Fuel</u>

JOLLC's current diesel distributor is Western Petroleum. They also provide B100 in 55-gallon drums to Dr. Colucci at UPRM. Therefore, Western Petroleum was a convenient and logical option as a biodiesel distributor. We did look into other distributors, but at this time Western Petroleum is the only one that provides biodiesel to Puerto Rico. Each drum of B100 costs $233.75, which is the equivalent to $4.25/gallon. Western Petroleum has stated that pure biodiesel can be bought at $3.00/gallon in quantities greater than 10,000 gallons (Appendix Q). The drum and bulk cost are inflated prices because the biodiesel fuel has to be imported (related charges include freight, taxes and storage). JOLLC received a free test fuel supply from Dr. Colucci, that will power the test vehicle for a full year (500 gallons). Dr. Colucci has done an assessment of building a biodiesel production facility and from that study, his personal experience, and US pricing he has approximated that if the fuel were to be distributed from a local source it would cost $1.25/gallon for B100. Therefore that is the assumed price if a biodiesel production facility was built in Puerto Rico. Preblended fuel was requested from Western Petroleum, but it was clear that it would be far too expensive. The approximate price of diesel distributed by Western Petroleum is $1.02/gallon. Thus with B20, 20% of the biodiesel cost was added to 80% of the diesel cost in order to make our estimations. The following graph shows the overall comparison of fuel.

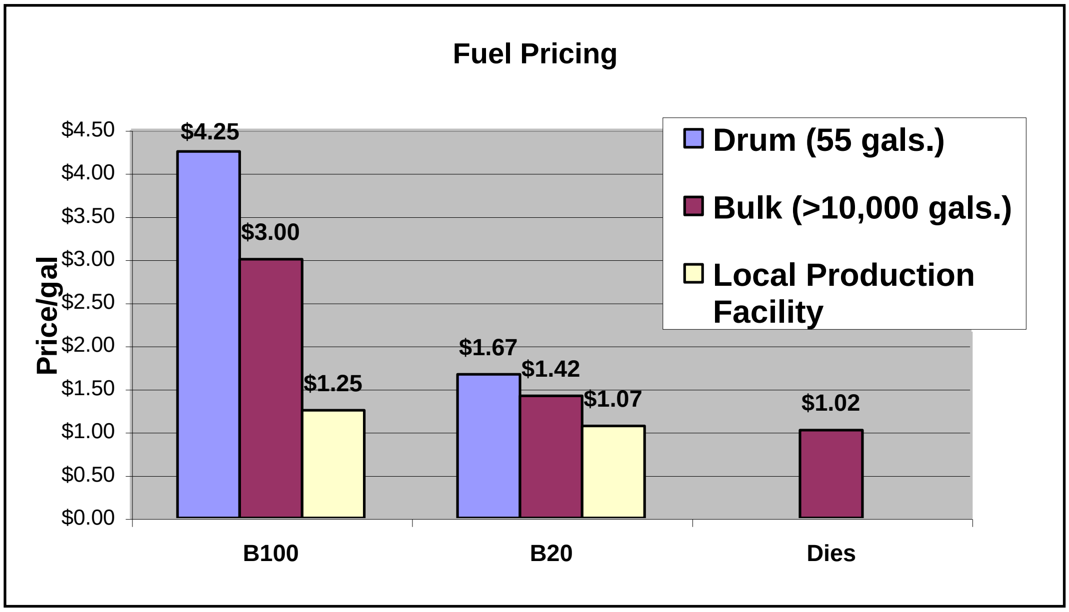

Figure 9: Fuel Prices with Varying Blends

<u>Vehicle Preparation and Maintenance</u>

Before putting biodiesel in the fuel tanks of the engines, preventative measures were taken to ensure a smooth transition. These measures included cleaning the fuel tank, changing the oil and filter, and replacing the fuel filter. It is assumed that these measures will be taken before putting biodiesel in any of JOLLC's engines. Diversified Equipment Corporation (DIVEQCO) is the designated contractor for unscheduled maintenance of vehicles at JOLLC. They performed all said maintenance on the dates of March 26th and 27th of 2003. DIVEQCO had to do the B20 fueling of the forklift to be able to move it. That incurred an additional cost for the specialized fueling. The invoice totaled $174.76 for all the work performed (Appendix J).

Infrastructure

The temporary infrastructure developed for the test trial had minimal costs. The only additional equipment acquired for the process was a small storage container. The larger intermediate infrastructure for the mobile fleet is a more substantial project and has been farmed out to an outside contractor. Tank Management Systems has designed an infrastructure specifically for JOLLC's needs. The Aboveground Storage Tank (AST) Biodiesel Fueling System will cost $6,542.00 (Appendix O). This does not include consulting or installation fees.

5.4.2 Benefits

With diesel there are serious health, environment, and economic concerns that are relieved by using biodiesel. Biodiesel significantly reduces overall emissions. The government provides tax incentive to those companies who use alternative fuels. There is the potential to decrease the dependence on foreign suppliers. JOLLC's involvement in the biodiesel movement in Puerto Rico will help increase overall demand and the potential for a production facility. All these things are important to JOLLC.

Emissions

The difference between diesel and biodiesel emissions was discussed in great detail in the background chapter. There was also a graph (Figure 2) that showed the percent change in emissions from diesel to B20, our chosen mixture. The emissions data specific to JOLLC is drawn from their permitting data (Appendix R). These values were calculated using emissions factors, horsepower ratings and hours. The hours are over inflated in order to account for maximum possible usage. This means that all numbers represent their maximum allowances for the facility's static diesel sources and do not represent actual emissions. Note that the mobile fleet is not included in this data. The permitting forms do not require the inclusion of mobile vehicles and therefore consumption data and emissions are not recorded for them at JOLLC. The reason for the exclusion is because the mobile fleet is insignificant in comparison to the static sources. The values for B20 emissions are based on percentage change values from diesel to B20 based on data provided by the EPA (USEPA, 2002). Below is a table of the percent change values and a chart that represents the emission changes for JOLLC.

Percent Change in Emissions from Diesel to B20		
Particulate Matter	PM-10	-18.0%
Sulfur Oxides	SO	-19.0%
Carbon Oxides	CO	-12.6%
Nitrous Oxides	NO	1.2%
Volatile Organic Compounds	VOC	-11.0%

Figure 10: US EPA 2002

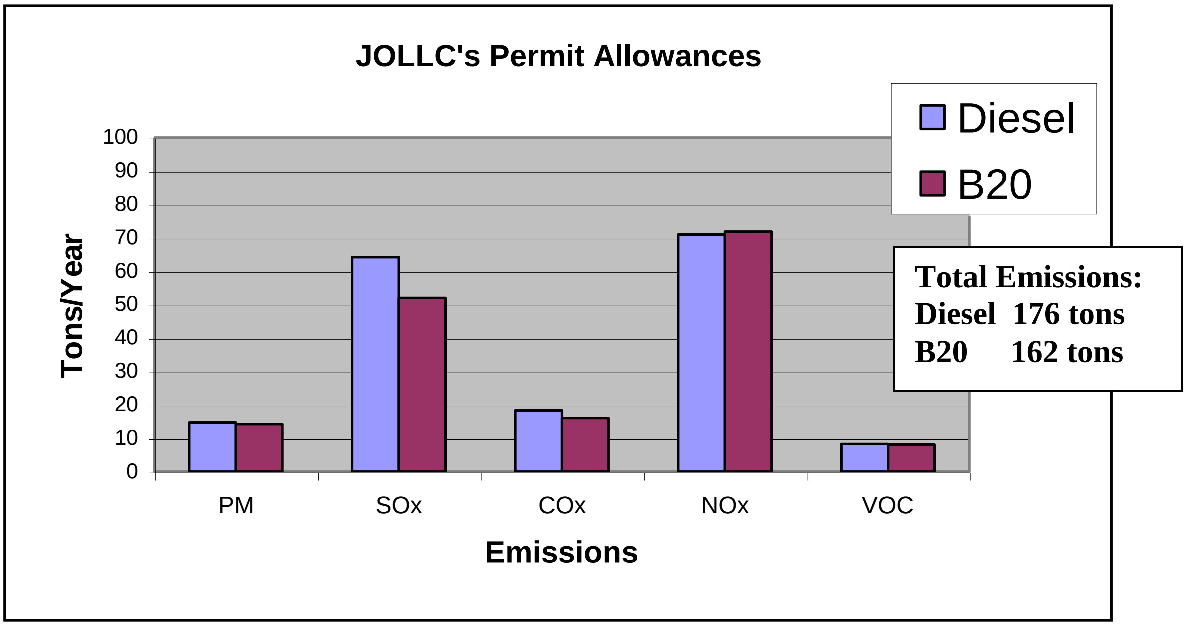

Figure 11: Change in Emissions from Diesel to B20

<u>Permitting</u>

There is a financial cost associated with emissions. JOLLC pays $10 per ton for the permitted emissions. If they exceed these permits there are consequential fines of $25,000 per day per violation. This is why the permitted values are over estimated. Biodiesel can save money in the permitting process. The estimated financial savings value is $143.26 (Figure 12). If Janssen exceeds 100 tons per year of any emission it would trigger Title 5 of the Clean Air Act. This would incur significant costs in the form of more stringent requirements, more aggressive monitoring system, more frequent inspections, additional testing, and more rigorous scrutiny by the regular agencies among others. There are planned expansions for the JOLLC facility that could force the permitting process into a higher classification. The reduced emissions of biodiesel could prevent this from happening consequentially saving a great deal of money.

Johnson & Johnson mandates the reduction of CO_2 by 7% by 2010. We would like to address the predicted CO_2 reduction from converting to B20, unfortunately it is not possible to make an enumerated evaluation. CO_2 reduction is based on the net reduction caused by the life cycle of the fuel and therefore cannot be directly related to the exhaust emissions. The EPA states this clearly in the following excerpt:

> We were not able to identify an unambiguous difference in exhaust CO_2 emissions between biodiesel and conventional diesel. However, it should be noted that the CO_2 benefits commonly attributed to biodiesel are the result of the renewability of the biodiesel itself, not the comparative exhaust CO_2 emissions.
> (US EPA, 2002)

Changing to B20 fuel will contribute to Johnson & Johnson's net CO_2 reduction goal, but at this time a value cannot be placed on this reduction.

Emission Costs						
	PM	SOx	Cox	NOx	VOC	Total
Diesel	$147.18	$642.00	$182.90	$709.70	$82.70	$1,764.48
B20	$142.48	$520.02	$159.85	$718.22	$80.64	$1,621.22
Differences	$4.70	$121.98	$23.05	-$8.52	$2.06	$143.26

Figure 12: Financially Quantified Emissions

<u>Incentives</u>

Government agencies have implemented reward programs to encourage companies to be more conscious of their impact on the environment. There is a tax incentive of 30% for Puerto Rican companies using recycled materials. Since biodiesel is produced from cooking grease and vegetable oils, which would otherwise be wasted, it is clear that biodiesel should be classified as a recycled material. At this time Dr. Colucci is petitioning to have biodiesel listed as a recycled material in the legislative document. There is no confirmed data to show that this tax incentive would apply to JOLLC or how.

At some point the Earth's petroleum reserve will be exhausted. The advantage of biodiesel is that it is a renewable resource. It is renewable because it has a continuous life cycle. The use of biodiesel relieves any foreign dependence on petroleum products. Instead biodiesel requires vegetable oil or cooking greases for its production. These natural products are currently going to waste in the US. If we utilized these sources we would also provide more domestic income for farmers and others. There is also business in collecting the oils and producing the biodiesel. The production of biodiesel also makes the product glycerin, which as an inert substance that has a market in moisturizers and soaps. A production facility in Puerto Rico could make the island less dependent on outside sources for fuel and provide jobs. A local biodiesel source would make the fuel a more comparable price to diesel. This will not happen unless JOLLC supports the cause.

5.4.3 Summary

	Diesel	B20 Mobile Fleet	B20 All	Local Production Facility
Consumption	Bulk	< 10,000	Bulk	Bulk
Costs				
Fuel (cost/gallon)	$1.02	$1.67	$1.42	$1.07
Infrastructure	$0.00	$6,542.00	NA	$0.00
Prep/Maintenance	$0.00	$873.80	NA	$0.00
Benefits				
Permit Fees*	$1,764.48	$0.00	$1,621.22	$1,621.22
SUM	$1,765.50	$7,417.47	$1,622.64	$1,622.29
Percent Change in Fuel Cost	0.00%	63.73%	39.22%	4.90%

***If forced to Title 5 permitting fees will increase significantly

Figure 13: Summary of Costs

It stands out that the hardest step to justify is converting the entire mobile diesel fleet to biodiesel. The values for fuel, infrastructure and maintenance all add up quickly. However, the environmental benefits such as emissions are negligible in comparison to effects of using B20 in the regulated sources. At the same time the mobile fleet is the most important column, because it contributes to the demand that will create a production facility in turn lowering the price for biodiesel fuel in the future. After the successes found in the test trial and the known environmental and financial advantages of using biodiesel throughout the facility it is the right choice for Janssen to make the change. The mobile fleet is the intermediate step towards facility wide use of biodiesel.

6.0 Recommendations to the Management at JOLLC

After spending seven weeks learning about the operations and practice of JOLLC, we feel confident that we can make recommendations fit their work environment. The structure of our report, the objectives, leads us directly towards recommendations for future use of biodiesel at JOLLC. The results found bring us to conclusions and how to approach the next step.

- The next step towards full-scale biodiesel implementation and total emissions reduction at JOLLC is building a permanent, onsite fueling infrastructure for all of the mobile diesel vehicles. Using the information provided in this document, all of JOLLC's mobile diesel vehicles could potentially be running on B20 in less than one month.
    - We recommend purchasing the proposed B20 tank system from Tank Management Services and ordering B100 in 55-gallon drums increments from Western Petroleum, once the supply from Colucci runs out. The system is appropriately priced for the services and benefits it offers.
    - Since no quantitative fuel economy data was collected for the forklift, we recommend that JOLLC attempt to compare diesel and B20 fuel economy data in another mobile vehicle. Currently, diesel fuel economy can still be measured for one of the diesel trucks. They can then proceed to measure B20 fuel economy when a B20 fueling station is implemented at JOLLC.
    - Before fueling any other diesel vehicles with B20 at JOLLC, the fuel tanks of each vehicle must be emptied, opened, and inspected. If there are any visible particles in the tank that could harm the engine, it should be cleaned with B100. It is also advisable to purchase extra fuel filters for each vehicle as a precautionary measure.
- Remain involved in Puerto Rico's biodiesel movement.
    - Keep in contact with Dr. Colucci and UPRM for any new information regarding pricing, availability, or technology.
    - Keep in contact with other Puerto Rican companies using biodiesel. By attending seminars and perhaps creating a mailing list or online forum for biodiesel users in Puerto Rico, JOLLC can gain valuable knowledge and ideas from continuous updates on everyone's progress.

- Publicize JOLLC's biodiesel initiatives and future goals to the public, JOLLC employees included. Increased knowledge and demand for biodiesel are two deciding factors for the construction of a biodiesel production facility in Puerto Rico. Advertising can be as easy as hanging a banner on JOLLC's front gate and sticking biodiesel decals on the sides of biodiesel fueled equipment (Appendix T).

- The biodiesel implementation guidebook that we have constructed should be distributed to those who seek more information about how to implement biodiesel.

➢ JOLLC must first demonstrate its commitment to biodiesel with mobile vehicles before taking further action. A biodiesel test trial on an industrial boiler is important and should follow the establishment of a mobile vehicle infrastructure by no less than six months. This amount of time should be ample for JOLLC employees to become comfortable with the handling and mere presence of biodiesel on the premises. If and when the time comes for large-scale testing on a boiler, JOLLC should fuel the equipment with preblended B20 supplied directly from a fuel delivery truck. Dr. Colucci is eager and capable to help with the logistics of this effort.

Both the environment and the community can benefit from the use of alternative fuels. JOLLC should continue using biodiesel because it has immediate effects on emissions with minimal modification requirements to the engines and infrastructure at the facility. The largest downside to biodiesel in Puerto Rico is its limited availability, since there is currently only one distributor. JOLLC must look past this and continue to be involved in the program because with increased demand a production facility will be built.

7.0.0 Summary

This document outlines why and how this project was performed. The goal of the project is to make recommendations to JOLLC about how to implement biodiesel in their mobile fleet of diesel vehicles, and the possibility of the future use of biodiesel in their static diesel energy sources. The groundwork for this project was established by performing research on diesel fuel, biodiesel fuel, and biodiesel production. The reasons are clear why JOLLC is funding this project. Using biodiesel as a diesel additive is simple and would significantly reduce the manufacturing facility's environmental impacts. By supporting biodiesel, JOLLC contributes to Puerto Rico's overall demand for clean burning alternative fuels. The hope is that one day the demand for biodiesel will be large enough to warrant the construction of biodiesel production facility in Puerto Rico.

The objectives of the project were to implement and sustain a biodiesel test trial using one of JOLLC's mobile diesel engines, conduct interviews and document them as case studies, design a biodiesel fueling infrastructure specific for JOLLC, and perform a cost analysis. The results of our seven-week effort have been successful. The forklift we chose for testing has been successfully running on B20 for four weeks. The case studies were well documented and provided useful suggestions for biodiesel infrastructures to JOLLC. We designed a practical biodiesel infrastructure capable of providing JOLLC's mobile diesel engines with pre-blended B20, logistical issues included. We also provided JOLLC with a reasonable price quote for such a system estimated by a Puerto Rican consulting firm. The price of installing this system and the savings incurred by reducing emissions were part of the basis for our biodiesel cost analysis and final recommendations to JOLLC.

The execution and results of the four objectives of this project were the foundation for making recommendations to JOLLC. Based on our observations, we would like to make the following recommendations about the future use of biodiesel at JOLLC.

JOLLC must remain active in the biodiesel community by doing the following. JOLLC should keep in contact with Dr. Colucci of UPRM so he can relay any new information about biodiesel availability and pricing. JOLLC should also keep in contact with other Puerto Rican companies using biodiesel to gain knowledge about what others are doing to expedite the construction of a production facility in Puerto Rico. JOLLC should also publicize any future biodiesel initiatives since it could provoke other people's interest in biodiesel, and more interest can result in increased demand for biodiesel.

Aside from being active in the biodiesel community in Puerto Rico, JOLLC should build the fueling system proposed by Tank Management Services. This will be the next step toward compliance with Johnson and Johnson's initiative of reducing 7% of the total CO_2 emissions by 2010. Once JOLLC is using biodiesel in their mobile diesel vehicles, it is important to move on to large-scale testing. Dr. Colucci can arrange for a truck from Western Petroleum to come to JOLLC and pump pre-blended B20 into a boiler or any other static diesel fuel source. A test like this could boost confidence in using biodiesel for JOLLC, and other companies in Puerto Rico.

These recommendations serve to accelerate the use of biodiesel at JOLLC and in Puerto Rico in general. The results of using biodiesel thus far have been favorable, with the only drawbacks being a lack of production facilities in Puerto Rico, and a general lack of demand. Once the demand for biodiesel increases, and large-scale testing at JOLLC is completed, there is nothing stopping JOLLC from using biodiesel in its entire group of diesel consuming sources. In the meantime, we have constructed a biodiesel implementation guidebook that is attached to this report. We believe JOLLC should publicize this guidebook because it simplifies many decisions about the implementation of biodiesel fuel and it eliminates certain fears about switching to biodiesel.

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