

Alternative Fuels in Puerto Rico

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Abstract

Puerto Rico relies completely on imported fossil fuels for transportation fuels. This has had negative impacts on the environment and the economy. The Puerto Rico Energy Affairs Administration (PREAA) is interested in adopting an alternative fuels policy similar to the EPA's Renewable Fuel Standard (RFS). The alternative fuels that this project focuses on are biodiesel and ethanol. The goal of our project was to determine what federal and state policies exist in the United States and how these fuel policies could be applied to the Commonwealth of Puerto Rico in an effort to introduce biodiesel or ethanol as a transportation fuel.

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Authorship Page

As with any collective project, the ideas presented within the report reflect the understanding of the authors as a whole. Due to the size of this project, individual sections of writing were separated among members to complete the report in a timely fashion. Individual authors wrote about various topics and chapters as follows:

Sean Dillon contributed to the Abstract as well as Background sections titled ‘The Use of Biodiesel’, ‘The Use of Ethanol’, ‘Other Alternative Fuels’, and ‘Other Energy Policies Around the World’. Additionally he contributed to the Results and Analysis sections ‘Biodiesel as an Alternative Fuel for Vehicles’, ‘Ethanol as an Alternative Fuel for Vehicles’, ‘Available Incentives for Biofuels’ and Summary. Mr. Dillon also collaborated with Fatima Zahra Mahhou on the Recommendations chapter.

Fatima Zahra Mahhou contributed to the Background sections ‘Other Alternative Fuels’ and ‘Alternative Fuel Adoption in Puerto Rico’. Ms. Mahhou wrote the Objectives chapter. She also contributed to the Results and Analysis section ‘Transportation Policies’. Additionally she collaborated with Sean Dillon on the Recommendations chapter.

Kortni Violette contributed to the Executive Summary and the Introduction chapter. Ms. Violette also contributed to the Background sections titled, ‘Legislative Efforts to Promote Alternative Fuels in the U.S.’ and ‘Other Energy Policies around the World’. She also contributed the Methodology section ‘Public Knowledge of Transportation Related to Alternative Fuels’. Additionally she contributed to the Results and Analysis section ‘Public Knowledge and Opinion’, and wrote the Conclusion chapter.

The Appendices were written in collaboration by Sean Dillon, Fatima Zahra Mahhou, and Kortni Violette. The report was edited and revised as a group.

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Executive Summary

Countries all over the world are experiencing an increasing need for fossil fuels to meet their energy requirements. Each year, a large percentage of this fossil fuel is used in virtually all segments of the transportation industry. Many countries, including the U.S., have started implementing policies regarding alternative transportation fuels. The renewable fuel standard (RFS) in the U.S., for example, requires that a certain amount of alternative fuel be combined with gasoline. However, Puerto Rico has not taken any initiatives towards introducing these alternative and renewable fuels. Even though it is a U.S. territory, Puerto Rico was excluded from the RFS.

Two well-known alternative biofuels are biodiesel and ethanol. Not only are they cleaner burning, which is better for public health and the environment, but they are also renewable, which means they are capable of being replenished naturally. There are other forms of alternative fuels including natural gas, hydrogen, and electric energy; however, for the scope of this project they are excluded due to their high cost and the lack of available infrastructure.

We, a team of students from Worcester Polytechnic Institute, were asked to determine what federal and state policies exist in the United States that supports the use of alternative fuels. Following a thorough review, we formulated recommendations as to how these policies could be modified and applied to the Commonwealth of Puerto Rico. Our assessment included factors such as public knowledge and opinion of alternative fuels, technical review of the fuels, and current energy production and challenges. Data analysis, interviews with government agencies, and surveying allowed us to determine the most feasible renewable fuel for the island and to assess current public perceptions on adopting these policies.

First, in order to determine public knowledge and opinion of using alternative fuel in vehicles, we carried out a survey using a convenience sample, as well as an online survey. This survey contained multiple choice questions regarding general public information such as income, current means of transportation, and weekly gas expenditures. The survey also included more in depth questions about the incorporation of alternative fuels, such as ethanol, natural gas and biodiesel, into the current fuel infrastructure. It was made available in both English and Spanish in order to accommodate the participants and obtain as many results as possible.

Next, we interviewed personnel from the Environmental Quality Board as well as from the Environmental Protection Agency in order to determine what transportation energy policies exist, and which ones may be beneficial in Puerto Rico. From these interviews we learned what forms such a policy, and what type of data is needed to justify it. We asked the personnel about the feasibility and challenges associated with introducing biofuels to Puerto Rico. We were also informed of current efforts to produce biofuels in Puerto Rico.

Finally, we interviewed representatives from various companies such as oil distributors and Puerto Rico's Electric Power Authority, the local electric power provider. The interviews allowed us to determine Puerto Rico's current fuel infrastructure, as well as the feasibility of establishing alternative fuel plants. Also we discussed the challenges associated with incorporating a new fuel into the existing energy infrastructure of the island. These interviews elucidated opinions regarding the costs and efficiency of introducing alternative fuels. This process helped us gain insight into the energy sources available in Puerto Rico and how they are managed. We used this information, along with other data, to ascertain the possibility of using biofuels in Puerto Rico.

Between the choices of biodiesel and ethanol, biodiesel is more feasible for the island, although the use of both is possible. This is because there is already a large market for diesel in Puerto Rico, and low biodiesel blends such as B20 do not require a change in infrastructure. However, the use of ethanol would present many challenges including a change in infrastructure and a loss in engine efficiency.

There is a lack of public understanding and awareness when it comes to the use of biofuels, which can lead to negative perceptions towards alternative fuel policies. Advertising the use and effects of biofuels would provide consumers with an understanding, which in turn would foster broader acceptance of biofuels in the public.

In our opinion, the government must provide incentives to oil distributors and consumers in order to facilitate the transition to biofuels because of the high cost. Tax incentives would allow oil distributors to import blended fuel. Importation is needed because there is not adequate land mass to produce biofuels locally. Rebates would allow consumers to affordably purchase biofuels; this would provide the much needed initial stimulus for biofuel to gain market acceptance.

Chapter 1: Introduction

Now more than ever, countries all around the globe are seeking alternative energy sources due to their current dependence on fossil fuels. The use of fossil fuels has had harmful effects not only on the environment, but also the economy. This is a major concern; for example, 85% of the energy produced in the United States is derived from fossil fuels such as coal and oil (U.S. Department of Energy, 2010). There are many industries in which new technologies using alternative fuels and having greater fuel efficiency are being developed, such as building construction, power utilities and transportation systems. Fossil fuels still provide nearly all the energy used to power various modes of transportation (U.S. Department of Energy, 2010). However, there are several different options for providing energy for vehicles that are currently not widely used and fully researched, but that have potential. These alternative biofuels include biodiesel and ethanol. Not only are they cleaner burning, which is better for public health and the environment, but they are also renewable, which means they are capable of being replenished naturally. Countries such as the U.S., U.K. and China are implementing policies designed to increase the use of renewable fuels in vehicles in order to decrease dependence on fossil fuels and improve the transportation sector and the environment.

The increase in price of importing fossil fuels has had a negative impact on Puerto Rico's economy. Ideally, Puerto Rico should have policies that seek to introduce alternative and renewable fuels. In the long run, this would be beneficial for Puerto Rico's economy once the cost of switching to new technologies has paid off. Also, this could give Puerto Rico increased energy security because it would allow the island to not have to worry about a diminishing fuel supply (Caribbean Business, 2006). Additionally, cleaner burning transportation fuel would have

a significant positive impact on the environment and air quality, especially since there are over 2.5 million vehicles registered on the island with a population of about 4 million. Currently, no government agencies in Puerto Rico have directly promoted the use of renewable and alternative fuels within the transportation sector. So far there are no policies that address petroleum reduction or fuel economy on the island. Implementing a new energy policy in Puerto Rico regarding transportation fuel is one possible solution to the aforementioned problems.

Many countries like the U.S. have adopted legislations promoting alternative fuels and hybrid vehicles to improve the air quality and fuel efficiency. In particular, the Obama Administration has implemented many policies aimed at reducing energy use, like the program New Energy for America (Obama For America, 2009, p. 4). Government organizations such as the Environmental Protection Agency (EPA) and the Department of Energy (DOE) have also made regulations designed to promote renewable energy sources. The PREAA is trying to form an alternative fuel policy as well.

Legislators in Puerto Rico want to develop fuel policies to reduce the dependence on fossil fuels. Alternative fuels, such as natural gas, are already being used to generate electric power, but are not used for transportation. There has not been any research about alternative and renewable fuels in the transportation sector. At present, they do not know if it is even feasible to introduce alternative fuels into the transportation sector, but the legislators feel it is necessary. It is not clear what the public's opinion is on alternative fuels, or whether such opinions will be a barrier to pass policies that promote alternative fuels, or if those opinions will be the support needed to approve a policy. The underlying issue that will be addressed in our research is the lack of any existing policies in the renewable fuel market for the island of Puerto Rico.

Our goal is to determine which alternative fuels and fuel policies can be implemented in Puerto Rico's transportation sector. Objectives that we set to achieve this goal included: determining current fuel infrastructure, evaluating the current production of alternative fuels in Puerto Rico, determining if there is a market for alternative fuels and flexible fuels vehicles, and identifying policies on alternative fuels used in other countries. To pursue these objectives, we surveyed Puerto Rican residents, interviewed oil distributors and government representatives from the Environmental Quality Board, U.S. EPA, and The Puerto Rico Electric Power Authority (PREPA).

Our recommendation should be useful for the Puerto Rico Energy Affairs Administration as it develops policies for the renewable fuel market in order to decrease the island's economic and environmental problems that result from its dependence on imported fuel. The organization of our research is as follows:

- Chapter 2 provides a literature review of necessary background knowledge
- Chapter 3 states our goals and objectives for our project
- Chapter 4 presents the methods used to complete our objectives
- Chapter 5 investigates the results we obtained
- Chapter 6 delivers the conclusions that we drew from the analysis of our results
- Chapter 7 details our recommendations to the PREAA based on our research

Chapter 2: Background

Currently, Puerto Rico does not have any existing energy policies pertaining to public and private transportation. Because of this, nearly all forms of transportation are powered by fossil fuels, which contribute to the island's economic and environmental problems and dependence on imported fuel. For this reason, the Puerto Rico Energy Affairs Administration (EAA) has tasked our team to explore and evaluate existing policies concerning renewable and alternative fuel markets in order to make recommendations as to which policies could be most effectively proposed in Puerto Rico.

In this chapter we will discuss a number of topics that will help explain the context for our project. These topics include Puerto Rico's transportation infrastructure, current energy policies and alternative fuels.

2.1 The Use of Biodiesel

An important subcategory of alternative fuels currently being used in motor vehicles is biodiesel (Knothe, 2010. Section 1). Biodiesel is an alternative to diesel and is used to fuel diesel engines. This fuel is made from vegetable oils, animal fats, and natural plant oils. Biodiesel is formed when these oils or fats undergo trans-esterification, which can occur when a triacylglycerol reacts with an alcohol in the presence of a base catalyst. Trans-esterification reduces the viscosity of the oil, making it usable in engines. This process is usually conducted by base catalyzed trans-esterification, which is a fairly quick process (about 2 hours) (Demirbas, 2008). This is the most advantageous method of direct conversion because it occurs at a low temperature and pressure, and has a high conversion rate of about 98%.

Biodiesel is becoming a widely used fuel source in many European countries, as well in the United States. In 2005, Europe accounted for 89% of biodiesel produced in the world, and each European biodiesel plant produced up to 1.5 million gallons per year. In Europe, slightly more than 50% of all the automobiles are diesel powered as opposed to petroleum. The major difference in biodiesel production between Europe and the United States is that while Europe uses rapeseed oil, the United States relies on soy bean oil and yellow grease. Although biodiesel is becoming widespread in these regions, it is not yet widely used in Puerto Rico. Small processing plants have emerged, for instance in Guaynabo, with relatively modest production capacity. Figure 1 depicts two pressurized tanks that yield up to 50,000 gallons of biodiesel per year (Feliu-Mojer, 2011). When considering employing a new energy source, many economic, environmental and additional considerations must be examined, such as where the fuel comes from, where and how it is used and whether or not the current infrastructure is sufficient. The following sections discuss the advantages and disadvantages that other countries have encountered with the use of biodiesel as transportation fuel.



Figure 1 Biodiesel Facility in Guaynabo. The two pressurized tanks produce 50,000 gal. of biodiesel per year.

2.1.1 Advantages of Using Biodiesel

Using biodiesel as a fuel sources has many environmental and technical benefits. Since biodiesel is made from natural products such as plant oils, it is renewable and biodegradable (Demirbas, 2008). If crops are grown locally, the renewable aspect of biodiesel provides increased energy security from politically unstable Middle Eastern and African countries. Energy security refers to the national security risks that arise from purchasing foreign energy supplies, such as petroleum. Biodiesel can reduce greenhouse gas emissions by up to 41% when compared to conventional diesel because the increased oxygen content makes it cleaner burning (Hill, 2006, p.1). Other toxic and carcinogenic emissions such as sulfur and aromatic compounds are also diminished. Moreover, biodiesel has a higher flash point than petroleum, making it safer to store and transfer because of its nonflammable properties (Knothe, 2010, section 1).

In the U.S. diesel engines are mainly used for trucks and commercial vehicles (Knothe, 2010, Section 3). Diesel engines can use fuel containing up to 20% biodiesel before any further technology or conversion is needed (National Biodiesel Board, 2009, Commonly asked questions). In fact, this amount of biodiesel is healthy for engines, since it can clean out debris, extending the life of the engine and causing less wear on the engine. As well as being compatible with current engines, biodiesel is also compatible with most current diesel storage and distribution infrastructures. Finally, biodiesel produces less soot during the startup process than traditional diesel; and it can incrementally be introduced in the economy. Interestingly, biodiesel has a net energy gain: it produces about 5.5 units of energy for every unit of fossil energy used to produce biodiesel. This means that the amount of biodiesel required to give 5.5 BTUs of energy would only require 1 BTU to produce. (National Biodiesel Board, 2009, Commonly asked questions).

2.1.2 Disadvantages of Using Biodiesel

One of the primary factors preventing the widespread use of biodiesel is that it is not economically competitive with standard diesel (Demirbas, 2008). Biodiesel can be up to twice as expensive as traditional diesel fuel. This is due to the fact that biodiesel is produced from expensive feedstock such as soybean oil. However, the price of biodiesel is dependent on many factors such as crop production, geographic area, and base stock. Biodiesel can also be produced from other less expensive oils such as restaurant waste and animal fats, but these often contain fatty acids that cannot be converted into fuel. Another problematic factor associated with biodiesel is that since it is produced from vegetables like corn and soy plants, there is the danger that production of biodiesel could negatively impact the food supply (Hill, 2006, pp.1 & 3).

There are several technical drawbacks of using biodiesel in diesel engines (Demirbas, 2008). Because biodiesel is oxygenated, it produces slightly less torque when compared to traditional diesel. This increases the amount of fuel required to travel the same distance as conventional diesel. Also, biodiesel loosens hydrocarbon deposits left from diesel fuel, which can clog the fuel filter. Moreover, biodiesel has a tendency to freeze in colder weather; however, this is not applicable to Puerto Rico's warm climate. Although biodiesel is compatible with most of the current fuel infrastructure, high percentage blends can eventually degrade fuel hoses and pump seals. Similarly, transportation and storage of biodiesel requires slight alterations.

2.2 The Use of Ethanol

Another viable biofuel is ethanol, which originates from plant biomass. Biomass refers to biological materials that come from various plants. Specifically, the materials can come from sugar based feedstock like corn grain, sugar grain, or from cellulosic feedstock such as grass, wood or newspapers (Department of Energy, 2011a, ethanol basics). Ethanol production requires many steps such as collection and transportation of feedstock, followed by fermenting and distilling these plant materials. After ethanol is produced in specialized plants and delivered to the refineries, the ethanol-gasoline fuel becomes available to drivers at the fueling stations through the existing distribution network.

Ethanol is widely used as a special form of transportation fuel in both Brazil and the United States. Brazil mainly uses sugar based ethanol, while corn based ethanol is more common in the U.S. (Nag, 2008). Ethanol created from cellulosic feedstock is more challenging than using sugars directly because the materials first need to be broken down into their sugar components. Blended fuel is now a major component of fuel in the U.S., with 70% of the fuel containing

ethanol. The U.S. has been selling ethanol blends of 10% at over 500 stations since 1979 (Rand, 2010). In fact, 9 billion gallons of ethanol was produced in 2008 in the U.S. alone. The following sections will discuss the advantages and disadvantages that the U.S. and Brazil have encountered with the application of ethanol as a fuel, as well as the current technology.

2.2.1 Advantages of Using Ethanol

One of the many advantages of using ethanol is that it is a renewable transportation fuel, which helps to reduce dependency on imported oil and increases energy security. To reduce air pollution, the U.S. oil companies oxygenate their fuel by mixing gasoline with ethanol (Department of Energy, 2011a, ethanol basics). Oxygenating gasoline with ethanol makes it a cleaner burning fuel, which reduces harmful greenhouse gas emissions such as carbon dioxide and nitrous oxides. In a lifecycle analysis, which includes production and use, ethanol reduces about 52% of the carbon dioxide released compared to gasoline. Additionally, ethanol is a comparatively safe fuel because it is nontoxic and biodegradable; therefore, it poses much less of a threat than petroleum to the surface and ground water if a spill were to occur. Similarly, its high flash point is safe for warm climates such as Brazil and Puerto Rico (Nag, 2008).

There are many technical aspects that also make ethanol an ideal fuel. Ethanol has a high heat of vaporization compared to gasoline, increasing engine efficiency (Nag, 2008). Also, for low blends of ethanol such as the 10% blend, no engine modification is needed, and there is little effect on gas mileage. This E10 blend has the capability of reducing oil imports by 10%, which would have a positive impact on the economy by reducing spending on foreign oil. Another benefit of using ethanol is that it is a new industry, so it creates jobs in rural areas where employment is needed.

2.2.2 Disadvantages of Using Ethanol

One of the major disadvantages of using ethanol is that it is produced from feedstock, so fuel production competes with food production (Hill, 2006, p.1). Food based ethanol can also be problematic because it is derived from crops that are sprayed with pesticides. While ethanol is cleaner burning than gasoline, the amount of pesticides as well as the nitrogen and phosphorus in ethanol can cause negative health effects. Cellulosic ethanol requires little or no pesticides but requires a longer time period to grow (pp. 2-3). Similarly, ethanol production requires a substantial amount of land able of supporting the agricultural needs necessary to grow enough crops (Nag, 2008). Puerto Rico is not capable of producing enough crops to fulfill this need due to the small size of the island. In order to incorporate ethanol as transportation fuel, Puerto Rico would either need to import the necessary feedstock to produce it, or import ethanol directly. Overall, this would likely be an expensive endeavor.

Ethanol presents many technical challenges when used in large percentages such as the E85 blend. Using ethanol in conventional engines can cause problems with corrosion and phase separation in the gasoline mixture (Laval University, 2004, Advantages and Disadvantages of using Ethanol). Also, due to ethanol's corrosive nature, it dissolves and carries dirt inside the tank and fuel lines, thus contaminating the car engine system. In order to use ethanol effectively in large amounts, engines must be converted to flexible fuel vehicles made of corrosion resistant metals.

2.2.3 Flexible Fuel Vehicles

Flexible fuel vehicles (FFVs) are alternative fuel vehicles with internal combustion engines engineered to operate on gasoline or a blend of up to 85 percent ethanol (E85) (Department of Energy, 2011a, Flexible Fuel Vehicles). Apart from a few modifications of the engine and fuel system, they are similar to conventional internal combustion engines. They contain a single fuel tank, fuel system, and engine. They are also available in a wide range of models such as sedans, pickups, and minivans. Light-duty FFVs are seasonally adjusted for cold weather, and are designed to operate with at least 15 percent gasoline in the fuel to ensure that they start in cold weather. Major auto companies everywhere are developing FFVs (E85vehicles.com, 2011). Popular vehicles that are now sold as FFVs include the Dodge Charger, Buick Regal, Cadillac Escalade, Chevrolet Impala, and the Ford F150 shown in Figure 2.

FFVs operating on E85 experience no loss in performance when compared to gasoline-only models. The fuel composition gets automatically adjusted by the sensors in the FFV so that emissions and standard performance areas (power and acceleration) are not affected by E85. However, since ethanol contains less energy per volume than gasoline, FFV typically achieve about 25-30 % fewer miles per gallon when fueled with E85. Regardless of the fuel blend used, the fuel mileage is affected by driving habits, weather, and other factors. Even though FFV's fuel economy on E85 is somewhat less than when operating on gasoline, a positive feature is its lower greenhouse gas emissions. E85 reduces carbon dioxide emissions as well as many other harmful emissions such as benzene; however, it does increase emissions of acetaldehyde, a toxic pollutant.



Figure 2 Ford 150 Flexible Fuel Truck. This is one of Ford's FFVs capable of using up to 85% ethanol as a fuel source. It produces fewer emissions when compared to a conventional combustion engine (Siuru, 2007).

2.2.4 Ethanol Infrastructure

Puerto Rico currently does not have ethanol pumps for flexible fuel vehicles on the island. However, this could change in the future with the increasing demand for alternative fuels and the actions being taken by several fuel companies. Cosan, a Brazilian company that leads the world in processing sugar has sold half of their core assets to Shell, the number 2 oil producer in Europe (PR-USA.net, 2011). Cosan is one of the leading biofuel producers in the world and Shell intends to use this production to add biofuel pumps to its service stations worldwide. Shell plans to open 2,740 pumps for vehicles that run on ethanol or a mixture of gasoline and ethanol. Cosan has a lot of experience producing ethanol for fuel, but only distributes in Brazil. Brazil already uses ethanol as a major transportation fuel. It is mandated in Brazil that gasoline must contain 20% ethanol. Brazil produces about 25 billion liters of ethanol per year which is mostly derived from sugar, unlike the U.S. which primarily produces corn based ethanol. Most of Brazil's ethanol has remained in the country until this point, but with Shell's involvement

Brazil’s resources will likely become widely distributed, allowing biofuels to become more accessible worldwide.

2.3 Other Alternative Fuels

There are other forms of alternative fuels being developed, in particular natural gas, hydrogen, and electric energy. Although these alternative fuels are also renewable and beneficial for the environment, the scope of this project will focus on biofuels. We narrowed our focus to biofuels because we believe they are the most feasible fuels for Puerto Rico at this time, and we wanted to conduct an in-depth analysis of biofuels. Due to time constraints, we would not have been able to fully analyze the following fuels. Table 1 displays a qualitative analysis of the emissions, infrastructure and cost associated with the various fuels. This section is meant to be informative and display other possible alternatives that may be used in different countries and maybe in Puerto Rico in the future.

Table 1: Comparison of Transportation Alternative Fuels in Critical Categories

	Biodiesel	Ethanol	Hydrogen	Natural gas	Electric Vehicles
Emissions	Great	Good	Excellent	Excellent	Excellent*
Infrastructure	Yes	Yes	No	No	No
Cost	Somewhat Expensive	Somewhat Expensive	Very Expensive	Very Expensive	Expensive

*Electric vehicles themselves have zero emissions; however, the source of their power may not

2.3.1 Natural Gas

Natural gas is an inherently clean-burning fuel. It can produce significantly fewer harmful emissions than gasoline or diesel when used in natural gas vehicles. It is a mixture of hydrocarbons, primarily methane (CH₄) (Department of Energy, 2011a, Natural Gas basics).

Natural gas is non-toxic, non-corrosive, and non-carcinogenic. It presents no danger to soil, surface water, or ground water. These characteristics make it one of the cleanest, safest, and most useful of all energy sources. Most natural gas is extracted from gas and oil wells formed over millions of years by the action of heat and pressure on organic material from dead plants and animals. Currently only about one tenth of one percent is used for transportation fuel in the US.

Using natural gas in vehicles would improve public health and the environment (Department of Energy, 2011a, Natural Gas benefits). It helps protect the public health and protect the environment, by producing significantly lower amounts of harmful emissions such as nitrogen oxides and the greenhouse gas carbon dioxide than other fuels, like gasoline. Another benefit of using natural gas in vehicles is that it is paving the way for cell vehicles powered by hydrogen, which could evolve into the future of transportation. Natural gas vehicles and infrastructure would facilitate this transition since natural gas and hydrogen are both gaseous fuels. Developing natural gas technologies would eliminate some of the issues associated with the hydrogen fuel such as fuel storage, training and public acceptance. In this sense, natural gas is making progress towards a hydrogen-based transportation network. More countries are using natural gas vehicles, and some of the owners report that the vehicles last two to three years longer than gasoline or diesel fueled vehicles.

Natural gas is the one of the cleanest burning of all the fossil fuels; however it remains a non-renewable energy source, making its long-term viability limited. It has other disadvantages too regarding safety (Fossil Fuel Resources, 2011). It requires strictly enforced safety procedures since it is a highly flammable substance. Natural gas can present a significant amount of danger if leaked, since it is colorless, tasteless and highly flammable.

2.3.2 Hydrogen Fuel Cells

Hydrogen is an environmentally friendly fuel that has the potential to significantly reduce the dependence on imported oil. It is an emissions-free fuel that can be produced from domestic resources (Department of Energy, 2011a, Hydrogen). It has not been widely used as a transportation fuel, but there are major research and development efforts for producing hydrogen vehicles practical for widespread use due its clean-burning qualities, its potential for domestic production, and its high efficiency. The hydrogen fuel cell operates similar to a battery (How Fuel Cells Work, 2011). It has two electrodes, an anode and a cathode, separated by a membrane. Hydrogen fuel is fed into the anode of the fuel cell and oxygen in the other. Helped by a catalyst, hydrogen atoms are split into electrons and protons. The flow of the electrons creates electrical energy.

The use of hydrogen as fuel presents many benefits (Department of Energy, 2011a, Hydrogen Benefits). It is produced domestically from several sources, such as natural gas, coal, solar energy, wind, biomass, and nuclear energy, which reduces the dependence on petroleum imports and increases energy security. It is also environmentally friendly because hydrogen produces no air pollutants or greenhouse gases when used in fuel cells, and only emits water. However, the use of hydrogen presents many challenges since it is still a new industry (Department of Energy, 2011a, Hydrogen Research and Development). The fuel cell vehicles are very expensive, and hydrogen itself is extremely expensive to produce. Other challenges include fuel cell performance, customer acceptance, hydrogen transport and bulk storage.

2.3.3 Electric Vehicles

Electric vehicles (EVs) use electricity as their primary fuel by powering an electric motor with rechargeable battery packs (Department of Energy, 2011a, All-Electric Vehicles). The EV batteries are charged using an electric power source. Although electricity production might indirectly contribute to air pollution, electric motors have several advantages over internal combustion engines (ICEs) such as better fuel economy, lower emissions, lower fuel costs, and increased energy security (Department of Energy, 2011a, All-Electric Vehicles Benefits). The electric vehicles are environmentally friendly because they are considered zero-emission vehicles since their motors don't produce emissions. The electric vehicles are also energy efficient since electric motors convert 75% of the of the chemical energy from the batteries to power the wheels while internal combustion engines convert only 20% of the energy stored in gasoline. Because EVs do not use any fuel other than electricity, which is a domestic source; this helps reduce imported petroleum dependency and thus increases energy security. In addition, EVs have performance benefits over the ICEs; the electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance. However, EVs face significant challenges related to their batteries (U.S. Department of Energy, 2011b). EVs are limited by the driving range, most EVs can only go about 100-200 miles before recharging while gasoline vehicles can go over 300 miles before refueling. The EV batteries are very expensive and may need to be replaced more than once. They are also heavy and take up a lot of the vehicle's space. Researchers are currently working on improving the battery technology which will determine the future of EVs.

2.4 Legislative Efforts to Promote Alternative Fuels in the U.S.

For many years, the United States has been a leader in innovation, constantly finding ways to improve and become more efficient. This has been no different when it comes to energy advancement. The Obama administration has passed many policies aimed to reduce energy use. Also, other government organizations such as the Environmental Protection Agency (EPA) and Department of Energy (DOE) have made regulations designed to promote renewable energy sources. Although Puerto Rico is a U.S. territory, these policies have not been implemented in Puerto Rico.

2.4.1 Reformulated Gasoline

In 1990, the Clean Air Act was amended to include laws pertaining to Reformulated Gasoline (RFG) (U.S. Environmental Protection Agency, 2007, Reformulated Gas). Reformulated gasoline is regular gasoline mixed with different substances to make it burn cleaner to reduce toxins in the air. Basically, the gasoline was required to have more oxygen in it, 2% by weight to be exact. Substances generally added to oxygenate the gasoline are methyl tertiary butyl ether (MTBE) and ethanol (Renewable Fuels Association, 2011). In some cities, smog and pollution from vehicles was so abundant that it was considered unhealthy to breathe the air. This pollution even contains toxins that are carcinogens, such as benzene. This amendment was adopted in 1995 in 17 states, including California, New York, and Illinois, to name a few (U.S. Environmental Protection Agency, 2007, Reformulated Gas). There are also many other areas that are required to partially use RFG. RFG not only remarkably improves air quality, but also reduces the amount of pure gasoline used.

The RFG program has had two main phases to improve air quality (U.S. Environmental Protection Agency, 2007, Reformulated Gas). In the first phase, the amount of smog from pollution that was eliminated was comparable to removing emissions from at least 10 million vehicles. The second phase began in 2000, and the pollution eliminated this time was comparable to removing emissions from over 16 million vehicles. The impact of the reduced emissions is substantial and is estimated to have reduced the risk of cancer from gasoline by up to 19%, and has allowed approximately 75 million people to inhale cleaner air. About 30% of the gasoline currently used is RFG. This program has since been removed, following the EPA's national Renewable Fuels Standard.

2.4.2 Renewable Fuel Standard

One program created by the EPA is the Renewable Fuel Standard (RFS) (U.S. Environmental Protection Agency, 2010, RFS). This program was created in 2005 under the Energy Policy Act in collaboration with oil refineries, producers of renewable fuel, and other key people involved in transportation fuel. The main purpose of the program is to ensure the United States sells transportation fuel containing a certain amount of renewable fuel. The original program stated that by 2012 gasoline producers must mix in 7.5 billion gallons of renewable fuel. Since 2005, there have been many additional standards and details added to this program.

In 2007, the RFS was further refined under the Energy Independence and Security Act (EISA) to include many key components; it continues to be updated regularly (U.S. Environmental Protection Agency, 2010, RFS). Instead of only combining renewable fuels with gasoline, renewable fuels will also be combined with diesel fuel. The 7.5 billion gallons of

renewable fuel to be mixed into gasoline has since been increased to 9 billion gallons in 2008, and the current goal is now is to reach 36 billion gallons by 2022. Also, because the renewable alternatives have different properties, they have been divided into various categories, each having a controlled percentage requirement. Part of this categorization was related to ensuring that the fuels met the greenhouse gas performance threshold standards. These standards guarantee that the renewable fuels do not emit more greenhouse gases than the fuels they take the place of. This steady increase in integrating renewable fuels has helped the US to begin reducing emissions, as well as reducing its reliance on fossil fuels.

2.4.3 New Energy for America

There are many parts of the Obama Administration's mid to long term energy policy that address topics such as fuel efficiency in vehicles, and reduced energy usage. This policy is part of a 10 year plan to lower oil consumption, which is a necessity because 96% of vehicle fuel in 2009 came from crude oil (Obama For America, 2009, p. 4).

There are several actions currently underway to increase fuel efficiency in vehicles (Obama For America, 2009, pp. 4-5). As part of this bill, the Obama Administration is working with auto companies in order to ensure Americans have access to flexible fuel vehicles. This means that vehicles will be compatible for consuming biofuels, as well as gasoline. Additionally, the current U.S. administration is tightening the standards of fuel economy. The objective of this is to increase standards by 4% every year, which is estimated to conserve half a trillion gallons of gasoline, as well as lower greenhouse gas emissions by 6 billion metric tons. Also, the Administration is working to develop an infrastructure for sustainable biofuels such as ethanol and biobutenol. The goal is to integrate at least 60 billion gallons of biofuels into the current fuel

supply by 2030. Similarly, they instituted a National Low Carbon Fuel Standard (LCFS). This standard started in 2010 and requires fuel suppliers to lower carbon levels in fuel by 5% by 2015 and 10% by 2020. This will not only reduce carbon emissions, but also oil dependency.

The U.S. is merely 22nd in the rank of the United Nations' most energy efficient countries list (Obama For America, 2009, p. 7). As part of the energy bill, Obama aims to build and develop more sustainable communities (Obama For America, 2009, p. 8). This would imply improving sidewalks, bridges, and roads, which in turn would make alternative transportation such as walking and biking easier and safer. Also, public transportation would be improved, making public transit more accessible. Another way to lower greenhouse gas emissions and generate revenue for renewable energy sources is to put a cap and trade program into effect (Obama For America, 2009, p. 2-3). What this does is auction off air pollution credits, which ensures that industry is paying for all its greenhouse gas emissions. This will produce 15 billion dollars per year. The money would then be used to further develop biofuels and clean energy vehicles.

2.5 Other Energy Policies around the World

Dependence on fossil fuel is not only a problem in the U.S., it is a problem seen all around the world. There are many concerns associated with relying on fossil fuels, such as the environment, the economy, and energy security. Although there is no clear solution to this problem, there are many actions countries are taking to reduce the associated impacts. Countries are implementing policies aimed to reduce mobile emissions from vehicles, as well as policies designed to use alternative fuels. If these policies are effective in other countries, they have the potential to work in Puerto Rico.

2.5.1 China's Fuel Economy Standard

Like many other countries, China has realized the growing demand for fossil fuel and has begun taking steps to reduce its dependence (Oliver, 2009, pp.1-2). China was the first country to develop and enforce a national fuel economy standard (FES) in 2004, with a goal of reducing the average fossil fuel based economy of vehicles by 15% by 2010. China's fossil fuel dependence has been increasing exponentially due to a growing vehicle market, with an estimated demand of 10 million new vehicles by 2010. About 37% of China's total oil consumption is used in the transportation sector. This figure is projected to rise to 43% by 2030, which is more than 350 million tons per year. As with implementing any policy, China has faced many obstacles in developing the FES. Several government agencies had to collaborate along with automakers in order to produce a policy that would satisfy most needs.

The development of China's policy was run by the Standardization Administration of China (SAC), which operates under the supervision of the General Administration of Quality Supervision, Inspection and Quarantine (GAQSIQ) (Oliver, 2009, pp.3-4). Other organizations played key roles in developing the FES such as the State Economic and Trade Commission (SETC) and the National Development and Reform Commission (NDRC), because they are responsible for developing China's auto industry. These organizations performed extensive research to determine current fuel consumption, the feasibility of implementing the new policy, and how to set achievable vehicle fuel economy standards. Fuel consumption data were obtained from auto makers and vehicle testing centers and opinions of auto companies were also taken into account. Furthermore, China looked into fuel policies in other countries. Once this background was completed, the China Automotive Technology and Research Center (CATARC) drafted the FES, which was put into effect 2 years later in 2004.

The FES has several categories that differentiate between different types of vehicles and set certain standards according to classification (Oliver, 2009, pp. 4-7). First, the FES limits fuel consumption by weight. It is interesting to note that the Chinese chose stricter standards for heavier vehicles to discourage the use of SUV's. This is contrary to a growing trend witnessed in the U.S. for more SUV's. Furthermore, vehicles are classified as either "normal structure" or "special structure". Normal structure includes vehicles that have manual transmissions and 2 or less rows of seats. Special structure therefore defines automatic transmission vehicles with at least 3 rows of seating. Overall, normal structure vehicles reduced their fuel consumption by 7-17%, while special structure vehicles reduced their fuel consumption 10-20%. An important note is that these standards apply to both gasoline and diesel engines, and not alternative fuel vehicles.

The FES was applied to all new vehicles produced after 2004 (Oliver, 2009, p.7). In order for a new vehicle model to begin production, a permit must be obtained which certifies that it meets all requirements. China decided to go with weight based standards because of the design of their automobile industry. The weight standard made it easier for manufacturers and provided incentives to produce smaller fuel efficient vehicles. Although it was a complicated process, this policy helped China to save fuel by enforcing vehicle fuel efficiency.

2.5.2 United Kingdom Policy

The U.K. is another country that has realized the need to use alternative fuels for transportation. They also suffer from many of the problems that Puerto Rico possesses, including increasing costs of oil, the fear of climate change due to greenhouse gasses, and questions of energy security (Patterson, 2010, pp.1-2). The country uses a very significant portion of its fossil fuels for transportation. Specifically, the energy used in the transportation sector in 2008 was

equal to about 38% of the total energy consumed in the country that year. The U.K. has developed policies intended to reduce their dependence on fossil fuels. The Biofuels Directive was passed in 2003 to promote the use of renewable fuels, specifically biofuels to replace a portion of the diesel and petroleum fuels used for transportation. The U.K. used the Renewable Transport Fuel Obligation (RTFO) to set targets for the amount of biofuels to be included in transportation fuels by certain dates. Initially they said 5.75% (by energy) of the nation's transportation fuels should be biofuels or renewable fuels by 2010 and 10% by 2020. They also specified that 3.75% was the biofuel specific goal in 2009/2010, rising to 5% by 2010/2011. This was later changed to 3.25% in 2009/2010, 3.5% in 2010/2011, 4% in 2011/2012, and 5% in 2013/2014 for the biofuels content; the overall renewable fuels standards were not changed.

The U.K., like most countries, has mainly focused on biodiesel and bioethanol (Patterson, 2010, pp.1-2). Until recently that is. Biomethane is becoming a more popular candidate to replace petroleum in the transportation sector in the U.K. It is believed that biomethane has more advantages than biodiesel or bioethanol; however, it cannot immediately be implemented on a large scale. Biomethane has to undergo a rather tedious process to become useable as a transportation fuel. It is also difficult to store and transfer because it is a gas, and there currently are not any refueling stations capable of delivering biomethane in the U.K. The U.K. has made efforts to reduce the dependency on fossil fuels, and some of their policies could possibly be adopted in Puerto Rico.

2.6 Alternative Fuel Adoption in Puerto Rico

With the increase of energy costs and the impact of fossil fuels on the environment, it is becoming necessary to “go green”. The island of Puerto Rico is facing significant problems with its dependency on fossil fuels and lack of progress toward sustainable energy sources.

2.6.1 The Island of Puerto Rico

Puerto Rico is an unincorporated territory of the United States located in the Caribbean, east of the Dominican Republic and west of the British Virgin Islands, and it is the easternmost and smallest island in the Greater Antilles (Puerto Rico Energy Affairs Administration, 2011, Background). The Commonwealth of Puerto Rico, which includes the islands of Vieques, Culebra and Mona as well as several islets, has a land area of 3425 square miles and a population of about 4 million with a literacy rate of 94.1% (U.S. Energy Information Administration, 2010). About 70 to 80 percent of Puerto Rico is considered hilly or mountainous (Puerto Rico Energy Affairs Administration, 2011, Background).

The weather in Puerto Rico is typically warm, as it is located in the Caribbean Sea. The heaviest rainfall occurs from May to October, which also coincides with hurricane season. Statistically, the north coast gets twice as much rain as the south coast.

Puerto Rico’s economy is moving away from agriculture to one based on a diverse industrial sector and tourism (U.S. Energy Information Administration, 2010). Tourism represents a major revenue generating industry for Puerto Rico since the island has diverse natural attractions. As for energy, Puerto Rico relies primarily on external sources of petroleum to meet its energy demand (Puerto Rico Energy Affairs Administration, 2011, Background). In

fact, imported petroleum products are the dominant energy source for the island. Puerto Rico had one petroleum refinery, located in Yabucoa on the southeastern tip of the island. It was supplied with crude oil shipped on through Humacao, a port on Puerto Rico's east coast. However, these facilities are no longer operating as a refinery. A few ports around the island allow for the shipment and distribution of crude oil and a variety of petroleum products, including motor gasoline, residual fuel oil, distillate fuel oil, jet fuel, and other petroleum fuel types. Over the past decade, oil prices have spiked due to global political unrests and increased demand. This has created an extremely negative impact on Puerto Rico's economy.

2.6.2 Transportation in Puerto Rico

Puerto Rico has a wide network of transportation. Its infrastructure consists of airports, seaports, highways and some railways (Caribbean Business, 2006). They are run by various agencies, which include Puerto Rico Department of Transportation & Public Works along with various public corporations such as the Highway & Transportation Authority and Metropolitan Bus Authority.

Maritime transportation constitutes an important part of the transportation system in the Caribbean, and the Port of San Juan is considered to be the busiest and largest harbor in the Caribbean (Caribbean Business, 2006). The island's ground freight transportation consists of many trucks. It has more than 30,000 truck drivers and about 12,000 vehicles. Puerto Rico has approximately 7,384.6 km of Commonwealth system roads, 258.5 km of highways, 190.2 km of expressways and 17,046.7 km of municipal system roads. Puerto Rico's roadways suffer from one of the highest ratios of automobiles per capita in the world, since there are more than 2.5

million vehicles registered with the Puerto Rico Department of Transportation & Public Works. This equals an average of 2.5 vehicles per household.

As for air transportation, Puerto Rico has a total of 30 airports (Caribbean Business, 2006). Luis Munoz Maris International Airport is considered one of the major airports in the Caribbean. Approximately 40 domestic and international airlines fly into it every day.

Another form of transportation is by bus, with signs for *paradas* everywhere, see Figure 3. Buses in Puerto Rico are relatively cheap with fares ranging from 25 to 75 cents (U.S.). Outside San Juan buses are available, but they are not very reliable, and one often has to wait a long time for a connection. The public buses in Puerto Rico are operated by the Bus Authority, but there are also private companies that provide transportation. In San Juan you can find *Públicos*, which are private vans that are a cross between a bus and a taxi. They will take you to almost anywhere on the island for about \$10, but they make many stops and are usually very slow, but if you do not mind the wait, they are comparatively inexpensive. Although there are other options like these, if you want the freedom to go where you want when you want in Puerto Rico, your only reliable option is to own a car.



Figure 3 A Local Bus Stop in San Juan. The sign states that four public busses are scheduled to arrive every 20 minutes . However, they are not always reliable, and one often has to wait a long time for a connection. These busses are operated by the Bus Authority, and follow routes in the San Juan and Old San Juan area.

The Department of Transportation has attempted to improve public transportation with the construction of trains. The Tren Urbano, which operates through San Juan and surrounding areas, was originally destined to be a \$1.25 billion project that would carry over 100,000 passengers per day. The railway was completed in 2004 and ended up costing the island \$2.5 billion, a major expense for the taxpayers. The metro-class train is fully automated and extends over 10.7 miles. The train is not so popular as one might expect; it attracts only about 40,000 riders per day, well below the projected 100,000. Plans to extend the rail line have been drawn up, but it is questionable whether they will materialize. There is a new plan now, proposed by San Juan’s Mayor Jorge Santini, named the “Walkable City plan.” Under the plan, which seeks to redevelop the *Isleta* region of San Juan, a new light rail, or Tren Liviano, will run from the final stop of the Tren Urbano in Sagrado Corazón to Old San Juan which is a 5.3 mile distance.

In conjunction with the construction of the railway, several streets will be converted into pedestrian and transit malls. There are already concerns that this project will be as big a disappointment as the Tren Urbano. People are also worried that they will be forced to change their mode of transportation on their daily commute. While this may be a step in the right direction by providing more public transportation and getting cars off the roads, it does not seem to go far enough. So far there are only trains in the area immediately around San Juan, and there is really only one route that goes straight through the city. There is no way that these trains can bring everyone where they need to go, which is why other forms of transportation are necessary.

2.6.3 Fuel Infrastructure and Energy Use

Puerto Rico depends heavily on imported fossil fuels. In fact, an estimated 69% of the island's energy comes from petroleum, and about 15% comes from coal (Economics Week, 2010). Puerto Rico has seven petroleum-fueled power plants, and one coal-fired power plant (U.S. Energy Administration, 2010). Efforts have been made, however, to integrate alternative fuels into the power generation system with the addition of six hydropower plants. Puerto Rico also gets about 15% of its power from natural gas. The amount of power produced from renewable fuels is lacking, however, accounting for only 1% (Economics Week, 2010).

Puerto Rico purchases a large volume of fossil fuels to supply to the power plants and provide energy for vehicles (Welcome to Puerto Rico, 2010, Economy). In 1999 Puerto Rico purchased 35,631,482 barrels of petroleum. This was mainly used to produce 2,550,000 metric tons coal equivalent of gasoline and 1,690,000 metric tons coal equivalent of electricity. However, refining facilities on the island have not been operating since 2008. Instead, 100% refined fuel products are imported (Puerto Rico Energy Affairs Administration, 2011,

Petroleum). As of 2010, Puerto Rico, unlike almost every state in the U.S., does not require the use of motor gasoline blended with ethanol. Obtaining all of this fuel for electricity and transportation is putting a strain on the island's economy (U.S. Energy Information Administration, 2010). Puerto Rico has already taken steps towards using alternative fuels for electricity. By 2015 Puerto Rico plans on using renewable fuels for at least 20% of its energy demands. The island is currently developing wind energy projects, estimated to produce 50 megawatts which unfortunately accounts for only approximately 0.5 percent of Puerto Rico's total energy budget. They are also investigating additional resources, which include a 135 megawatt solar project, equivalent to 1.25 percent of the total energy, and additional hydropower capacity. However, the area where no real effort has been made to "go green" so far is transportation.

2.7 Summary

Transportation is very important in the modern world, because people need to be able to travel quickly from one place to another. For more than a century, fossil fuels have been the leading transportation fuel. Like many countries, the government of Puerto Rico has begun taking the initiative towards incorporating sustainable energy sources that are more beneficial to the environment. Their dependence on imported fossil fuels is harming their economy and their environment. As we have seen, there are policies that could help change this situation, and alternative fuels may be a feasible option. Biodiesel and ethanol are advantageous in several ways, but are they right for Puerto Rico? In the next sections we will outline our objectives, as well as explain the methodology used to determine which solutions we recommend for Puerto Rico.

Chapter 3: Objectives

The goals of our project were to first sample global approaches to alternative fuel use and then examine what federal and state policies exist in the United States and how these fuel policies could be applied to the Commonwealth of Puerto Rico. Our sponsor tasked us to investigate various alternative fuels with special emphasis on biodiesel and ethanol. Specifically, we were asked to research the most feasible renewable fuel for the island and assessing current public perceptions on adopting these policies. Our goals were pursued through the following specific objectives:

- Interview personnel from the Environmental Quality Board and the Environmental Protection Agency to determine current transportation policies
- Conduct surveys with Puerto Rican residents to identify key issues concerning awareness and perception of using alternative fuels in Puerto Rico
- Assess Puerto Rico's current energy infrastructure to explore the feasibility of introducing alternative fuels in the market by interviewing representatives from private companies, such as oil distribution chains and the Puerto Rico Electric Power Authority.

Chapter 4: Methodology

Consistent with our project goals, our methodology included surveying Puerto Rican residents, evaluating current alternative fuel infrastructure, and interviewing personnel within the private transportation sector. The following sections describe these methods in more detail and how they meet each of the objectives discussed in Chapter 3.

4.1 Current Transportation Policies

The Environmental Quality Board (EQB) is responsible for working with various companies to ensure that the environment is protected. The EQB addresses safety issues and regulations regarding various chemicals, including fuel. The Environmental Protection Agency (EPA) is responsible for the regulations on alternative fuels in the U.S. Its office is located in New York; consequently, the interview was conducted by phone. The interviews allowed us to obtain answers to our most important questions, as well as additional information that arose from the conversations. Interviews with these organizations helped us to formulate recommendations for the PREAA.

4.1.1 Environmental Quality Board Interview

The first interview that we arranged was with EQB, represented by Jorge Nina, the Environmental Quality Inspector, who explained to us the role of the EQB in Puerto Rico. The main objective of this organization is to protect the environment by maintaining standards of water quality, air pollution control, waste management, and disposal of hazardous and nonhazardous solid. They inspect facilities that contain chemicals, for instance jet fuel, in order

to make certain they are being properly handled so that chemical spills are avoided. We decided to conduct an interview with the EQB because they are knowledgeable on the subject of fuel and fuel standards. Also, they support the use of alternative fuels and currently have research programs geared towards developing alternative fuels. After giving a brief overview of our project, we asked Mr. Nina several questions regarding fuel policies, and the feasibility of implementing alternative fuels in Puerto Rico. We also inquired about what kind of data is needed to justify the creation of such a policy, and the associated challenges. The interview protocol used for this interview can be found in Appendix I.

4.1.2 Environmental Protection Agency Interview

With the help of the PREAA, we were able to get a contact person from the EPA in New York to assist us to with our project. The EPA has similar goals to the PREAA. They aim to reduce pollution and protect the environment as well as the people living in it. We talked to Daniel Birkett, an Environmental Scientist, about the Renewable Fuel Standards that took place in the US. This is important to Puerto Rico because they are considering implementing policies very similar to the EPA. We also asked Mr. Birkett why Puerto Rico was excluded from these standards and how they can adopt similar standards. Refer to Appendix C for the interview protocol.

4.2 Public Knowledge of Transportation Related to Alternative Fuels

We used methods of convenience sampling and an online survey. This survey contained multiple choice questions regarding general public information such as income, current means of

transportation, and weekly gas expenditures. The survey also included more in depth questions about the incorporation of alternative fuels, including ethanol, natural gas and biodiesel, into the current fuel infrastructure. Overall, the survey was designed to help us develop an understanding of the awareness and acceptability of implementing these alternatives in Puerto Rico. Appendix E summarizes the questionnaire form.

4.2.1 Public Survey

Our first method of surveying was conducted by personally distributing the survey to car owners in the parking lot of La Plaza de Las Americas. We decided to incorporate face-to-face surveys in order to receive an immediate response, and to begin identifying any clear trends in data among the public. In order to accommodate for the language barrier, we first wrote the survey in English, then had an employee of PREEA translate it into Spanish to ensure correct grammar. We distributed the survey in Spanish, but had English copies available as well. Our goal was to get feedback from at least 100 drivers. The data is to be used in addition with responses from an online survey, in order to get a relatively accurate representative idea of public knowledge and opinion. However, due to problems obtaining proper permits and authorization, we were only able to survey at La Plaza de Las Americas for two days, collecting a total of 42 responses. In order to receive more face-to-face survey responses, we obtained approval and surveyed for a day at the Department of Treasury in Old San Juan. This was also an ideal location because of the steady flow of people in and out of the building. We received 72 responses over a two day period, for a combined total of 114 face-to-face surveys.

4.2.2 Online Mailing List Survey

Another way in which we obtained public opinion was through the use of an online survey. This method was chosen in order to get a large number of responses conveniently compiled. This survey was created in *Google Documents*, a free online surveying program that allows for easy data collection and analysis. We created the survey, again in both English and Spanish for best possible results. We first sent out the survey to about 40 employees of PREAA as a trial; our objective was to get any feedback to ensure the survey was as clear and effective as possible. Although we only received 4 responses, we used their inputs to reword several questions, making it comprehensible and straightforward for the public. Overall, the process of drafting, translating, uploading, and revising took approximately a week to prepare a finalized survey ready to be emailed to various recipients.

The PREAA has a list of about 8,000 people that we emailed explaining the purpose of our project, along with the survey. From these 8,000 surveys sent out, we expected to receive about 400 completed surveys. The people from the mailing list are more educated on the subject of energy conservation, and are from various fields such as engineering and architecture. By surveying a more knowledgeable population we can expect that these responses will accurately reflect the opinions of the upper-class people of Puerto Rico.

4.3 Energy Infrastructure

It is important to understand the energy infrastructure in Puerto Rico in order to determine the viability of implementing new policies concerning alternative fuels. By interviewing representatives from private companies, such as oil distribution chains and PREPA

we were able to determine their opinions and ideas regarding the use of alternative fuels in Puerto Rico. These interviews evaluated the companies' views on the current infrastructure, and the challenges of changing this infrastructure to accommodate alternative fuels. We elucidated opinions regarding the costs and efficiency of introducing alternative fuels. This process helped us gain insight into the energy sources available in Puerto Rico and how they are managed. We used this information, along with other data, to ascertain the possibility of using biofuels in Puerto Rico.

4.3.1 Conference with the Top Oil Distributers in Puerto Rico

With the help of the Energy Affairs Administration, we were able to conduct a conference with three of the top oil importers and distributers in Puerto Rico. We spoke with representatives from Shell-Sol Petroleum, Total Petroleum and Chevron with the objective of determining how fuel is obtained and distributed. Also, we discussed the feasibility of introducing alternative fuels into the current fuel infrastructure and market, along with the challenges associated with doing so. We first introduced ourselves and gave the companies a brief presentation on our project in order to give them a clear understanding of our goals and objectives. Prior to this meeting, we compiled a list of questions to ask these companies, ensuring that we obtain the necessary data. We used this interview protocol, which can be found in Appendix G, to guide the discussion.

4.3.2 Interview with the Puerto Rico Electric Power Authority

Through contacts at the Energy Affairs Administration, we were able to arrange an interview with Yolanda Jusino, head of the Planning and Research Division of the Puerto Rico Electric Power Authority (PREPA). PREPA is the sole provider of electricity on the island, which is why we chose them as a resource to discuss energy generation and fuel use in Puerto Rico. We asked questions related to fuel usage and costs. Also, Mrs. Jusino shared with us PREPA's plans of switching to natural gas as an alternative fuel. This led to the discussion of the use of alternative fuels such as biodiesel and ethanol in the transportation sector. We also discussed the implications associated with using alternative fuels, such as the economic incentives and land space needed. Mrs. Jusino provided us with important literature used for case study examination in the results and analysis chapter.

4.4 Summary

Several steps were involved in our methodology. These steps included the collection of data on the current transportation policies. We gathered information from the EPA and EQB, surveyed Puerto Rico drivers to gain insight into the public knowledge, and interviewed oil distributors and the electric authority to explore the feasibility of introducing biofuels in the current infrastructure. Once these steps were taken, we had to carefully analyze the data received in order to draw valuable conclusions.

Chapter 5: Results and Analysis

Through our research, interviews, and surveys we have obtained data about the biofuels of biodiesel and ethanol. A technical background knowledge of these fuels is essential for our sponsors if they wish to draft an alternative fuels policy. We have also investigated the steps required to write a policy. We have collected data about Puerto Rico that should be helpful to policy makers, as well as information about U.S. policies which have already been established. We have reviewed the surveys to find trends in public opinion and knowledge. This chapter is a compilation and analysis of our data, obtained through interviews and surveys.

5.1 Biodiesel as an Alternative Fuel for Vehicles

Biodiesel is a renewable biofuel that could be used to offset diesel consumption. We have researched biodiesel and talked to knowledgeable people in order to obtain data. To develop a policy that would replace a portion of diesel use in Puerto Rico with biodiesel, the fuel must first be analyzed to make sure it is an acceptable and justifiable alternative. The legislators must know the benefits and shortcomings of biodiesel before they develop a policy because they have to be able to justify it with concrete data. There are certain key aspects of transportation fuels that we have researched for biodiesel; these include emissions, efficiency, technology, and challenges with production and use.

5.1.1 Fuel Efficiency of Biodiesel

When considering the use of a new fuel, efficiency is an important factor for both distributors and consumers. Biodiesel has a higher density than conventional diesel and therefore

produces slightly less energy per gallon (National Renewable Energy Laboratory, 2009, p.9). Conventional diesel produces about 129,050 Btu/gallon when burned. In comparison, biodiesel only produces about 118,170 Btu/gallon. This means that using 100% biodiesel results in an approximate loss in efficiency of about 8.4%. However, this does not have a large impact on the fuel efficiency of diesel vehicles because there are currently no fuel blends containing more than 20% biodiesel. The difference in the power, torque, and fuel economy between B20 and No. 2 diesel is only about 1% to 2%, which is generally not noticeable to the average driver. At lower levels such as B5 blends, there are no noticeable differences in power, torque, and fuel efficiency.

5.1.2 Technology for Producing Biodiesel

There are many methods, as well as technology, currently being developed to produce biodiesel. The second generation of biodiesel production is done through chemical treatment of organic materials, such as trees or anything with cellulose, to create cellulosic biodiesel (Jorge Niño, personal communication, April 5, 2011). Cellulosic biodiesel can also be made from wood waste or municipal solid waste. This is an advantageous process because it reduces waste while creating fuel (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009, p. 10). The chemical bonds in the cellulose can be difficult to break. Research progress on cellulosic biodiesel could lead to much greater production of biodiesel. The third generation of biodiesel production uses enzymes instead of chemicals to break the chemical bonds of cellulosic feedstock. This could potentially have a greater positive impact on the environment because it would create fuels using only natural resources, while disposing of waste.

5.1.3 Emissions Data for Biodiesel

When implementing a new fuel, emissions is an important factor since one of the main objectives is to improve the quality of Puerto Rico's environment. Biodiesel reduces emissions of harmful chemicals in the air when used in place of diesel (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009, p. 32). Table 2 summarizes the pollutants and the achievable reduction when using B20. Specifically, Table 2 documents the amount of emission reduction that can be achieved when using a blend of 20% biodiesel 80% conventional diesel. Some of these pollutants are carbon monoxide (CO) a toxic gas produced from incomplete combustion of hydrocarbons, particulate matter (PM) small particles that are invisible to the naked eye, similar to soot that are harmful to human health, and nitrous oxides (NO_x) a combination of nitrogen monoxide (NO) and nitrogen dioxide (NO₂). These are toxic chemicals also capable of creating acid rain. Figure x shows how much biodiesel reduces emissions of these as well as the reduction of unburned hydrocarbons which limit overall efficiency and contribute to the formation of harmful byproducts.

Table 2 B20 Tailpipe Emissions Reduction of Harmful Pollutants Using B20 in a Conventional Diesel Engine (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009, p. 32)

Pollutant	Amount Reduced by Using B20
CO	11%
PM	10%
NO_x	2%
Unburned hydrocarbons	21%

5.1.4 Challenges Associated with the Use of Biodiesel

There are many challenges associated with growing biomass. Biomass requires large amounts of land to grow, which can deplete the soil over time (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009, p. 33). Removing large quantities of residue can lead to a loss of soil carbon, resulting in lower crop production and profitability. Other problems include reduced soil quality and erosion. Puerto Rico is a very small island and does not have the space for farmland to grow crops for biomass production. There is also potential to upset the ecosystem by growing plants in areas not native to them. It is not likely that this will be a problem in Puerto Rico; however, the plants may take resources away from other agricultural developments.

Agricultural feed stocks sometimes require chemical fertilizers, pesticides or herbicides (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009, pp

34-35). Whenever these chemicals are used, there is a risk of harming the environment or pollute the water. Fertilizer runoff can enter groundwater or surface water and contaminate it. Fertilizer can also greatly increase the rate of algae growth in water, which can be problematic if the algae takes up so much oxygen that plants start to die and the dissolved oxygen content in the water becomes dangerously low. This condition, which is fatal to many aquatic species, is called hypoxia. Herbicides and pesticides can also contaminate the water through runoff. The water used to irrigate the crops themselves can also be problematic if water supplies in the region are low.

5.2 Ethanol as an Alternative Fuel for Vehicles

Ethanol is another renewable biofuel that can be used in transportation. Ethanol can be mixed into gasoline to create ethanol blends of varying compositions. Some of the most common are E10, which is 10% ethanol and 90% gasoline, E5 and E85. Currently there is no ethanol mixed into the gasoline in Puerto Rico at all (Oil Distributors, personal communication, April 3, 2011). We have researched ethanol as a transportation fuel, and interviewed knowledgeable personnel to gain data about the efficiency, emissions, technology and challenges of ethanol as a transportation fuel. This information is invaluable when writing a fuel policy incorporating the use of ethanol in transportation fuel.

5.2.1 Fuel Efficiency of Ethanol

Ethanol contains less energy per volume than gasoline, which means that the fuel efficiency of ethanol is lower (Department of Energy, 2011a, Flexible Fuel Vehicles). When compared to pure gasoline, vehicles running on E85 generally experience a loss in gas mileage of about 25-30%. In lower ethanol content blends the fuel efficiency is much better (U.S. Department of Energy, 2011b). Vehicles operating on E10 experience fuel efficiencies of about 3-4% lower than traditional gasoline.

5.2.2 Emissions Data for Ethanol

The major intent of using alternative fuels is to benefit the environment. When compared to gasoline, ethanol would have positive effects in terms of emissions. Ethanol contains oxygen, which allows for more complete burning of fuel when added to gasoline (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 p. 31). This reduces the amount of hydrocarbon byproducts. Ethanol can reduce the emissions of CO by about 20 to 30 percent. Ethanol in small amounts, such as E10 can actually increase the emissions of NO_x, however ethanol in larger quantities such as E85, does not produce excess NO_x. Volatile organic compounds (VOC's) are toxic, sometimes even carcinogenic. Gasoline contains certain exhaust-related VOC's such as benzene. Ethanol does not contain exhaust-related VOC's reducing these emissions. However ethanol does contain other air toxins, such as formaldehyde, acetaldehyde, and 1,3-butadiene, and it can increase the emissions of these non-exhaust VOC's.

Table 3 compares several ethanol blends to gasoline as well as biodiesel blends to conventional diesel. Information about both emissions and efficiency are included in the chart.

Emissions are categorized by pollutants, and the percentages refer to the amount of pollutant reduced compared to fossil fuels. Efficiency refers to the percent of efficiency lost when compared to fossil fuels. B100 and E100 are not used as transportation fuels, they are only included for reference. The data used for Table 3 comes from various sources and is present in our report in chapters 2 and 5.

Table 3 Comparison of Various Ethanol and Biodiesel Blends with Regards to Efficiency and Emissions

	B20	B100	E10	E85	E100
Efficiency	1 to 2%	~8.4%	3 to 4%	25 to 30%	Over 30%
CO	10%		Decrease	Decrease	Decrease
PM	11%		Decrease	Decrease	Decrease
NO_x	2%		Slight increase	No change	No change
Exhaust VOCs	Decrease	Decrease	Decrease	Decrease	100%
Non-exhaust VOCs	No Change	No change	Increase	Increase	Increase
Unburned Hydrocarbons	21%	100%	Decrease	Decrease	100%
Total GHG		Up to 41%			Up to 52%

5.2.3 Challenges Associated with the Use of Ethanol

One of the biggest concerns in the U.S. concerning ethanol is the fact that it comes from corn, and it consequently competes with the food supply (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 p. 35). The U.S. is the number one corn producer in the world, producing 307,383,552 metric tons of corn in 2008 (Geohive, 2011). The production of ethanol from corn in the U.S. could potentially limit the amount of corn available for food (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009, p. 35). The large amount of land used for corn ethanol can also take away land resources for other agricultural needs, thus limiting the food production as a whole. For example, in order to produce enough ethanol feedstock to fuel 20 million cars, it would require half the land mass of Germany (Nag, 2008, p. 194). If this was to be compared with Puerto Rico, it would require

more that the whole land mass of the island to provide fuel for Puerto Rico's vehicles. As with any crop, there is also the potential for over farming which can take nutrients out of the soil and lead to problems such as erosion and loss of soil carbon (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 p. 33).

Another challenge of using ethanol would be the transportation and distribution of the fuel. The cheapest and most efficient way to transport fuels from refineries to refueling stations is via pipeline (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 p. 37). However, transportation of ethanol through pipelines can pose major problems. Ethanol easily absorbs water, which can cause two problems. If water accumulates in the pipeline, the ethanol will absorb it and become useless as a transportation fuel. When one pipeline is used for a number of different petroleum products, water is used in between to separate the fuels. This would pose a problem when transporting ethanol because of its absorptive properties. Ethanol is also a solvent, which makes it a useful cleaning agent. This can have adverse effects if ethanol picks up residue in pipelines, contaminating the fuel. Furthermore, ethanol is a corrosive chemical, which means it can damage pipeline parts and storage tanks. Because of these challenges ethanol is usually transported by more expensive and less efficient methods such as trucks or trains. The cost of cleaning general pipelines to make them usable for ethanol transportation is one of the main concerns of the oil wholesalers (Oil Distributors, personal communication, April 3, 2011).

5.3 Transportation Policies

We gathered essential data to devise a policy incorporating alternative fuels by talking to different agencies in Puerto Rico, such as PREPA, EQB and the oil distributors. The next sections detail our findings about the current energy production and the challenges with introducing alternative fuels in it.

5.3.1 The EPA's Creation of the Renewable Fuel Standard

In a phone interview with Daniel Birkett from the US Environmental Protection Agency, we discovered that Puerto Rico along with Alaska, Hawaii and the other US territories are not automatically included in the Renewable Fuel Standard program. However, the state/territory governments have the ability to "opt-in" to the program as Hawaii did.

Due to the adoption of the RFS, Hawaii's ethanol production is increasing (BBI International, 2003). This has created a positive impact not only in the environment but also on the economy. The RFS has encouraged construction and operation of ethanol plants on Hawaii. It is estimated that they will produce 40 million gallons of ethanol annually for the local gasoline market. The ethanol plant construction and operation will involve expenditures, income, employment and payment of taxes. This will increase household earnings and employment.

5.3.2 Current Projects

The Environmental Quality Board (EQB) is the principal environmental protection regulator in Puerto Rico. In an interview with Jorge Nina, a representative from the EQB, we learned that although there are no policies supporting the use of alternative fuels in Puerto Rico, there are innovative businesses that are working on producing biofuels. Mr. Nina is the president

of BFFuels de Puerto Rico, a project aiming to develop bioethanol for gasoline and an ethanol blend from waste cellulosic materials. This endeavor is specifically targeting the Flex Fuel market by the production of 23,809 barrels per year of bioethanol, while the total oil consumption of the island is 35,054,953 barrels per year (Puerto Rico Energy Affairs Administration, 2011, Petroleum). This project consists of three stages, with a final goal of large-scale bioethanol production. The first step is to produce bioethanol on a micro scale. The second step involves research and development to ensure that the air emissions from the biofuels meet the current standards. Finally, a proposal with the results and analysis will be submitted to the Department of Energy (DOE), Department of Agriculture and the EPA. If this proposal is approved, the project will precede to the last stage which is to construct a bio-ethanol plant.

As for biodiesel in Puerto Rico, there are plans to produce it from algae in ponds near Bayamon. Mr. Nina believes that biodiesel may be a better option for Puerto Rico, especially if produced from palm oil. One of the reasons why biodiesel may be more feasible than ethanol is that it is less expensive and less volatile. Also, although diesel is not widely used in consumer vehicles, it is used to fuel the trucking industry and military vehicles in Puerto Rico. Considering these factors, biodiesel may be more practical for Puerto Rico.

Through our meeting with Jose Colucci, a professor at the University of Puerto Rico at Mayagüez, we discovered that there is a commercial biodiesel plant at Guaynabo. However, they are currently not producing biodiesel because of the high cost of production (Colluci, 2002). Carlos Gonzalez, one of the owners and engineers of the biodiesel plant, confirmed that this is true. The cost of waste vegetable oil is currently \$0.46 per pound which is equivalent to \$3.50 per gallon. Considering the production cost of biodiesel it would not be profitable to produce biodiesel in Puerto Rico, especially if there are no incentives. A joint effort was made by the

University of Puerto Rico, the Department of Energy-National Renewable Energy Laboratory, Panzardi-ERM, the Municipal Government of Caguas and Isabela, the Puerto Rico Senate Energy Committee, and the Puerto Rico Energy Affairs administration to study the transesterification process to convert waste greases, used cooking oil, and animal fats into Biodiesel. The goal of the project was to establish a Biodiesel Industry in Puerto Rico in two phases. In the first phase, objectives included developing a laboratory capable of using available raw materials, conducting case studies of potential customers in Puerto Rico, and engineering analysis for large scale development. The second phase objective was to establish an aggressive demonstration program. Over 20 demonstrations were performed that included four municipalities, a state government agency, eleven companies, six private citizens and two sites at the University of Puerto Rico. The purpose of these demonstrations was to increase public knowledge. Press conferences, TV and radio interviews, documentaries, and newspaper articles were also used. When considering all of this it was estimated that tens of thousands of people should have heard about the biodiesel initiatives on the island. The Guaynabo biodiesel plant is operational and is producing small amounts of biodiesel, however due to the high expenses of producing biodiesel, Mr. Colucci is concerned about its feasibility in Puerto Rico. As for ethanol, he thinks that it is much more complicated than biodiesel. He also informed us about another biodiesel plant in Jayuya, but he believes that it is in collaboration with the municipality. We were unable to contact anyone from this biodiesel plant.

5.3.3 Energy Production and Infrastructure

The top oil suppliers for Puerto Rico are Sol Petroleum-Shell, Total Petroleum and Chevron. These companies provide the island with about 50% of the total oil used to fuel public

and private vehicles (Oil Distributors, personal communication, April 4, 2011). In an interview with representatives from Sol Petroleum, Chevron, and Total Petroleum, we were informed about the trends in oil importation. Currently, they are importing and distributing a combined total 25 million barrels per year, 7% of which is diesel fuel. We also discovered the process of how this fuel is obtained and distributed throughout the island. Oil based imports are received by ship through several terminals distributed along the north, south, east, and west coasts of the Island : San Juan (Puerto Nuevo), Cataño, Yabucoa, Guyama, Salinas, Ponce Peñuelas, Guayanilla and Mayagüez (Puerto Rico Energy Affairs Administration, 2011, Petroleum). The oil product is transported using a series of pipelines, and also by trucks, depending on the particular company and type of fuel. For instance, Total Petroleum obtains its fuel from the Hovensa Terminal in St Croix U.S. Virgin Islands, and receives it at its Puerto Nuevo terminal. Fuel distribution for ground transportation, emergency diesel generators, and other end uses occur mostly via trucking from the terminals to intermediate storage facilities and retail distributors. The Island does not have any commercial rail infrastructure for this purpose. The US Coast Guard provides security and control access from the sea, while the Puerto Rico Ports Authority, the Puerto Rico Public Service Commission and terminal owners share security responsibilities on land.

When discussing the use of alternative fuels in Puerto Rico, there were conflicting arguments, and a general negative response from the representatives. The representative from Chevron stated that because fossil fuels have been around for so long and Puerto Rico's transportation system is built around it, the switch to alternative fuels will be very difficult. One of the main reasons for their opposition was due to land shortage required to produce biofuels. Because of the lack of land to grow crops for biomass production, biofuels would have to be

imported. Puerto Rico already imports fuels, so the representatives argued that importing biofuels would not be beneficial for the economy and would not provide fuel security. Puerto Rico currently imports 80% of its food supply, so the small size of the island cannot support such large agricultural demands. This land constraint is also an issue when considering building biofuel plants and refineries, which would hinder any large scale production.

The oil company representatives also had many concerns regarding compatibility of biofuels with their current infrastructure. One representative was apprehensive about using ethanol because of its properties. Ethanol has a high evaporation rate, which could lead to a loss of fuel and therefore profit. The same representative also believes ethanol is risky because of the fact that it is easily damaged by water, requiring a change of infrastructure. This could also tarnish their reputation if they distributed tainted fuel, damaging the engines of their customers. A representative from Sol Petroleum explained that service stations would have to be prepared to use ethanol. With 1,200 service stations in Puerto Rico, this would be a costly endeavor because he estimated that each station would cost \$3,500 to prepare.

Overall, the general opinion of the oil distributors regarding alternative fuels was negative. Without incentives and tax breaks available from the government, alternative fuels would not be profitable for distributors, which would decrease the market and production of them. Although this information that we received from this interview was helpful, it is potentially biased. Big oil companies do not want to lose business, nor lose profit by adapting to the necessary infrastructure.

5.4 Available Incentives for Biofuels

Puerto Rico does not have any financial incentives for the production or use of biofuels, however many U.S. states provide incentives for the use of biofuels because of their positive environmental impacts (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 pp. 70-73). Some states provide renewable energy credits (RECs) to companies who use biofuel technology. The concept behind RECs is that there are laws regarding the amount of emissions each company can produce, and air standards that everyone is responsible for. If a company uses a certain amount of renewable fuels and is well below the allowed emissions standard, it can sell RECs to companies that do not meet the standards. RECs can make biofuels profitable as a source of energy. Puerto Rico currently uses RECs for renewable energy generation as well, but they do not generate any of this energy from biofuels. If biofuel technology was used in Puerto Rico, this could allow companies to sell more RECs, resulting in greater profit.

Some U.S. states provide financial incentives for biofuel use (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 pp. 70-73). These incentives include low interest loans, bond programs, rebates, grants, production incentives, and tax incentives (deductions, exemptions and credits). An example of one of these programs is the Public Benefit Funds (PBFs). They are used to slightly reduce the cost of energy for consumers of bioenergy. State tax incentives are a very popular type financial incentive for biofuels. They generally provide less compensation than federal tax incentives, but they are more common and can often be combined with federal incentives. State grants also help develop biofuel initiatives by covering certain research, infrastructure development, or feasibility study costs.

Grants are also available for energy generation from biofuels, usually on a kilowatt-hour basis. Some states exempt biofuels from state gasoline excise taxes.

The Renewable Fuels Association (RFA) provides some of the tax incentives available for ethanol, as well as other alternative fuels (Renewable Fuels Association, 2011). The Volumetric Ethanol Excise Tax Credit (VEETC) program gives a tax incentive of \$0.45 per gallon of pure ethanol (at least 190 proof) to eligible blenders of ethanol who register with the IRS. There is another tax credit for small ethanol producers who register with the IRS. Small ethanol production is considered to be less than \$60 million gallons at any time. The small ethanol credit is for \$0.10 per gallon of ethanol. The Alternative Fuel Mixture Credit is for anyone selling alternative fuels mixed with taxable fuels; it is for \$0.50 per gallon of mixed fuel. Cellulosic biofuels can be more profitable if they meet the standards of the cellulosic biofuel producer tax credit. Cellulosic biofuels can be eligible for incentives up to \$1.01 per gallon. There are also incentives for the installation of alternative fuels pumps in service stations. The alternative fuels infrastructure tax credit will pay up to 30% of the infrastructure cost, not exceeding \$30,000.

The Biomass Crop Assistance Program (BCAP) was created under the Food, Conservation, and Energy Act of 2008 to support the production of crops to be used for bioenergy (U.S. Environmental Protection Agency and National Renewable Energy Laboratory, 2009 p. 28). BCAP gives funding (direct, annual, or cost share payments) to farmers who establish biomass farms within a certain distance of biomass facilities. BCAP contracts for annual and perennial crops last 5 years and contracts for woody biomass last 15 years.

In 2005, ethanol cost an average of \$0.46 per Energy Equivalent Liter (EEL) of gasoline (Hill, 2006). Wholesale gasoline cost an average of \$0.44 per liter. In the same year biodiesel was \$0.55 per diesel EEL, while traditional diesel cost only \$0.46 per liter. To ensure that these biofuels were cost competitive, the U.S. government provided subsidies of \$0.20 per liter of ethanol, and \$0.29 per liter of biodiesel. As seen in table 4, these subsidies resulted in both biofuels becoming more affordable than the fossil fuels they replace. The cost of fossil fuels has increased in recent years making biofuels even more cost competitive.

Table 4 Cost comparison of biofuels and fossil fuels in the U.S. in 2005 (Hill, 2006)

Cost of Biodiesel (\$/diesel EEL)	Cost of diesel (\$/L)	difference (\$/L)	subside (\$/L)	savings (\$/L)
0.55	0.46	0.09	0.29	0.2
Cost of Ethanol (\$/ gasoline EEL)	Cost of gasoline (\$/L)	difference (\$/L)	subside (\$/L)	savings (\$/L)
0.46	0.44	0.02	0.2	0.18

5.5 Public Knowledge and Opinion

The online survey was distributed to two mailing lists, which have a total of approximately 8,000 people. From this survey, we received 81 responses which were imported directly into Microsoft Excel using *Google Documents*. This survey may not have been representative of Puerto Ricans as a whole, because it was distributed to professional societies that are well educated and typically have higher salaries. The face-to-face surveys with the public were conducted at La Plazas Las Americas, the local mall, and also at the Department of Treasury. We received a total of 114 responses, which were collected and input into Microsoft Excel in order to analyze the data. Unlike the survey distributed online, this survey obtained results from a wider demographic since people were randomly selected. However, face-to-face interviews can potentially be biased due to social desirability. For example, people might

respond a certain way to present themselves favorably. These combined results were used to obtain a general understanding of public knowledge and opinion of incorporating biofuels into the market.

5.5.1 General Public Information

The survey began with a few basic questions designed to obtain general information about the respondents. These were simple questions that provided us data about the trends in transportation use. A very large proportion of respondents own a motor vehicle, close to 100%. This may be due to the unreliable public transportation system. More than 50% of these privately owned vehicles are coupes and sedans, with SUVs coming in a close second at 33%, as seen in Figure 4. Public transportation was rarely used; it included busses, trains, and car pools. Also, we gathered trends in economic data such as average income and money spent on gasoline. We received a wide range of responses regarding annual income, but the most frequent answer was more than \$80,000. As mentioned before, this may not be representative due to the fact that the survey was distributed online to professional societies including architects and engineers who tend to have higher annual incomes. As for money spent per week on gasoline, there were a wide variety of responses ranging from less than \$20, to more than \$60.

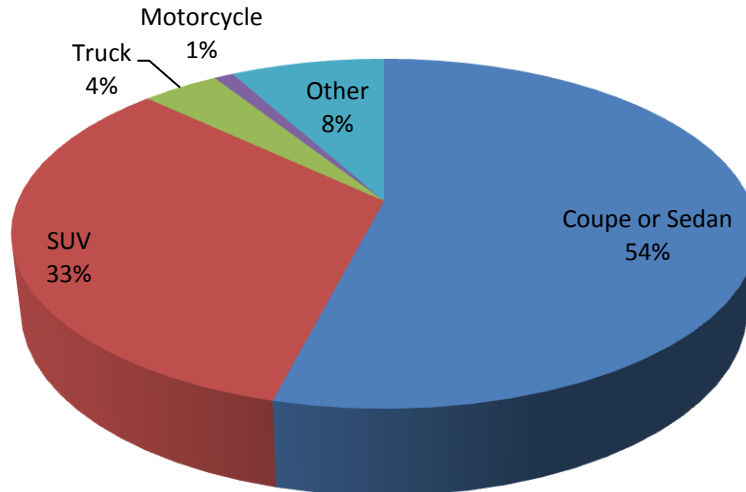


Figure 4 Distribution of Vehicles Owned By Consumers in Puerto Rico. Coupes, sedans and SUVs are popular in Puerto Rico; together they make up 87% of the vehicles driven by those that we surveyed. The high number of SUVs may explain why some people pay more than \$60 per week for gasoline.

5.5.2 Public Knowledge and Opinion on Fuels

Another set of questions on the survey aimed to gauge public opinion and knowledge of fossil fuels and alternative fuels in Puerto Rico. The results clearly indicate that the public believes Puerto Rico is dependent on fossil fuels to power their vehicles. The majority of people “Strongly Agree” with this statement, while several others “Agree”, for a combined total of 86%. As for alternative forms of fuel, a large majority of the population, more than 90%, are familiar with some form including biodiesel, ethanol, natural gas, and hydrogen. The most commonly recognized fuel was natural gas, most likely due to the news of PREPA’s plan to incorporate natural gas as a main fuel source in upcoming years. Figure 5 displays the driver’s familiarity of the various alternative fuels. We note that these values do not add up to 100% due to the option of multiple selections.

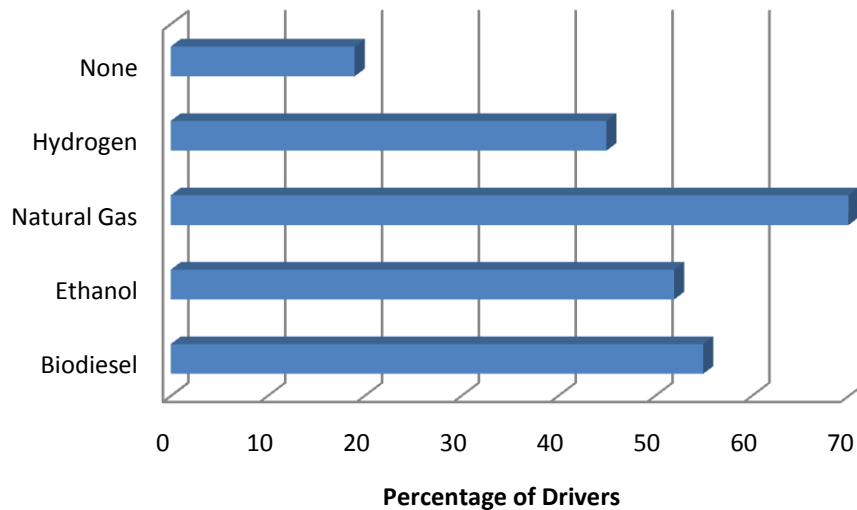


Figure 5 Public Familiarity with Various Types of Alternative Fuels. Many people are familiar with natural gas because of PREPA's Via Verde project. Many of the people who are familiar with biodiesel or ethanol know about both, 40% of drivers have heard of both biofuels. However, just because people are familiar with the fuels, however does not mean they understand the benefits that these fuels provide.

5.5.3 Public Knowledge and Opinion of Upcoming Technology and Policies

The rest of the survey contained questions regarding the use of flexible fuel vehicles, as well as costs and incentives. Although most people do not own or know someone who owns a flexible fuel vehicle, many stated that they would be willing to switch to using one in the future if it would benefit the environment. Once respondents were informed of the relatively low price of \$400 required to convert a normal combustion to a flexible fuel vehicle, 73% stated that they would be willing to do this. There are several factors to consider when purchasing a vehicle, such as cost, but almost all respondents said certain incentives would be influential in their decision. We then asked what types of incentives would be most beneficial when purchasing a new vehicle, and the results showed that rebates and tax incentives would be ideal for consumers, as

seen in Figure 6. It is important to note that percentages do not add up to 100% because of the option to select multiple answers.

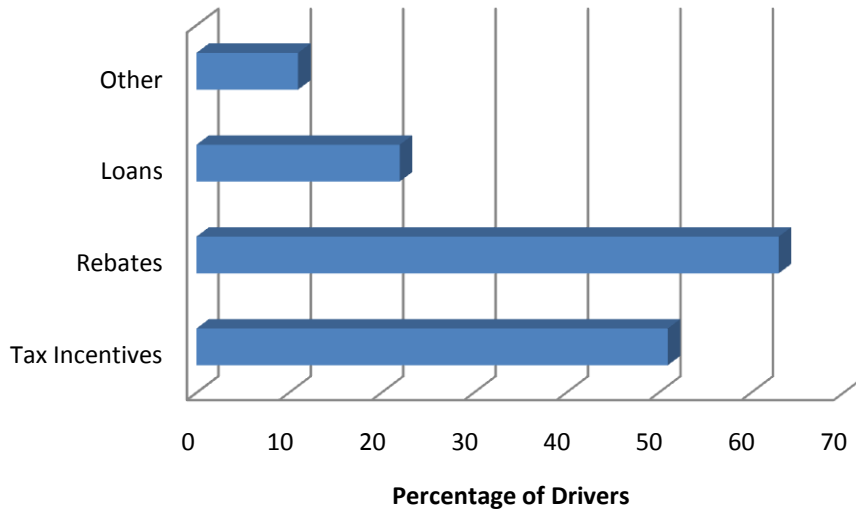


Figure 6 Types of Financial Incentives Favored by Drivers. The most desired form of incentives by consumers is rebates. Citizens also encourage the use of tax incentives. We have taken this into account in our recommendations; however, the conditions of the incentives may change the public’s opinion if one is made more favorable.

One of the last questions on the survey briefly explained the renewable fuel standard, asking if the public would be willing to support a similar policy in which a certain percentage of alternative fuels be mixed into the current fuel. Almost 3/4 of the respondents said “Definitely”, while most of the remaining respondents were unsure and replied “Maybe”. These results can be seen in Figure 7. There was a box available to explain why or why not such a policy was supported. The most frequent reason for supporting this policy is to better the environment. Many other responses were recorded and included reducing the dependence on fossil fuels, better the economy, and for health reasons. Respondents who did not support this policy were mainly concerned about using agricultural resources to produce fuel, because it will compete with the

food market. Also, some felt that it simply would not be worth it in the long run because of how complicated and expensive this process would be.

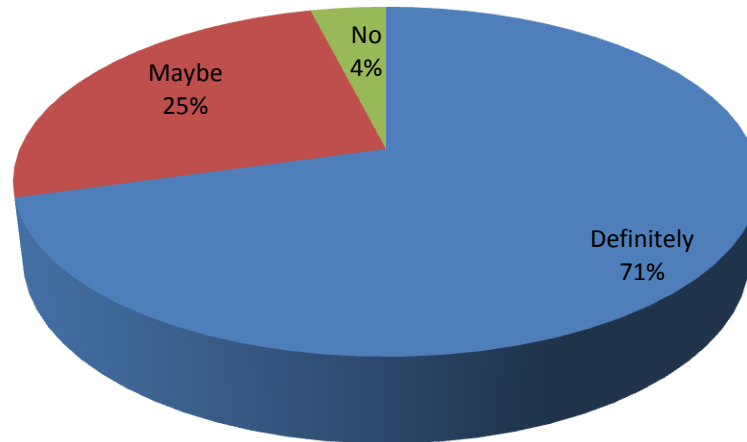


Figure 7 Drivers Willing to Support a Policy Incorporating Alternative Fuels into Transportation. Only a small percent (4%) of people are not willing to support a policy that blends alternative fuels into gasoline and diesel. The respondents who answered maybe could possibly be unwilling to say yes at this point, just because they are not well informed.

5.6 Summary

Although Puerto Rico was not included in the RFS, it has the option to opt-in to the program as Hawaii did. The EPA based the policy on an intensive cost analysis of production and distribution of renewable biomass, and fuel's ability to meet the greenhouse gas reduction standards. The results of the survey showed that 76 % of the public is willing to support standards similar to the RFS and incorporate biofuels in the island. This shows that there is strong support for the adoption of a policy. The public is very aware of the issue; 86% of people agreed or strongly agreed that Puerto Rico relies too heavily on fossil fuels.

Despite the fact that Puerto Rico does not have much land to even produce food, there are innovative businesses that are working on producing biofuels. Currently, there are two projects working on producing ethanol. One project is a non-commercial business and the other is in the developmental stage to start production of bioethanol from waste cellulosic materials on a small scale. As for biodiesel, there are two plants already on the island and two more projects that are still being developed to produce the biodiesel from used cooking oil and algae. However, the expenses are too high which is preventing the projects from developing into large scale projects. Biodiesel could be more successful than ethanol on the island, especially if produced from palm oil or algae, but much more research needs to be done to account for climate changes. The projects need financial support and further research.

Biodiesel is a renewable clean burning fuel. It reduces emission from diesel without sacrificing much efficiency. It can only be used in small amounts without damaging engines, but with 20% or less biodiesel mixed in diesel there is no engine damage. The advantages of biodiesel outweigh the disadvantages; the challenge is producing it on a large scale. Even if it could be produced in large scale in Puerto Rico, there are no refineries on the island. It would be more useful to buy diesel with biodiesel already mixed into it from other countries because Puerto Rico imports its entire supply of diesel.

Ethanol is also a renewable biofuel. It is a cleaner burning fuel than petroleum and reduces emissions of harmful chemicals. One advantage ethanol has over biodiesel is that there are vehicles that can operate on up to 85% ethanol, instead of only 20%. E85 can cause larger losses in efficiency, however, so fuels with lower ethanol contents, like E10, may be a better choice. E10 also does not require special vehicles, which can save consumers money. Ethanol is difficult to transport cheaply, which might be a major challenge. Puerto Rico could buy gasoline

with ethanol already mixed in, but precautions would have to be taken to ensure that the ethanol would not be contaminated or ruined by water.

Currently, none of the fuels used on the island are blended with any alternative fuels. The oil distributors were not supportive of adopting these alternative fuels because of the financial risk. In order to make the use of alternative fuels feasible, they all said government incentives are necessary. They claim that changes in fuel use are directed by taxes, and that the government will need to make available tax breaks for alternative fuels before they will become widely used.

Incentives are important to biofuel policies, because the goal is to have a financially sustainable market for alternative fuels. Biofuels are generally more expensive than petroleum based fuels, but they have large environmental benefits. This has lead countries to develop incentives for the use of biofuels. Whether they are tax credits, rebates, or some form of loan or grant, incentives are an integral part of the biofuels market. If Puerto Rico intends to develop a policy to incorporate biofuels into transportation fuel, incentives will be necessary.

Chapter 6: Conclusions

We have researched alternative fuels to determine if they can be used in the transportation sector of Puerto Rico. The research was done in an effort to reduce greenhouse gas emissions and dependence on fossil fuels. We have collected information from many different sources on all aspects of this topic. After compiling and analyzing this data we have determined the current infrastructure of Puerto Rico, the public awareness of the issue and of alternative fuels, and the feasibility of implementing alternative fuels in Puerto Rico. The following points summarize our findings based on careful data analyses:

- There is a general lack of public understanding and awareness when it comes to the use of biofuels, which
 - can lead to negative perceptions towards alternative fuel policies
- Consumers cannot afford the high costs of alternative fuels, but incentives would stimulate the market Specifically,
 - consumers would like to see incentives including rebates and tax breaks
- Oil distributors are weary of introducing alternative fuels into the market because of the associated risks of
 - high cost, damage to infrastructure, tainted fuel, and negative reputation in the eyes of consumers. However,
 - oil distributors indicated that they would consider the implementation of alternative fuels if incentives made the process affordable and profitable for businesses

- Representatives stated that the fuel market is determined by taxes, therefore a tax break may increase demand for alternative fuels
- There is currently a large market for diesel in Puerto Rico, which would require little change in infrastructure if biodiesel were incorporated in a B20 or lower blend; a number of
 - commercial trucks and military vehicles already operate on diesel engines
- Biodiesel blends are nearly as efficient as diesel and reduce greenhouse gas emissions
- There are many projects related to the research and development of biodiesel, which may lead to advances in biodiesel technology in Puerto Rico
- There are no refineries on the island to blend biodiesel with diesel, or ethanol with gasoline
- Although feasible, ethanol presents many challenges
 - Water contaminates ethanol, which would require changes in transportation, storage and distribution
 - There is a loss of efficiency when using highly concentrated blends of ethanol
 - There is no substantial land mass available to grow ethanol feedstock
- Ethanol reduces harmful emissions when compared to gasoline

Our analysis of the data we collected enabled us to form these conclusions. We believe that this has been a successful process, and that these conclusions enable us to formulate appropriate and necessary recommendations to the Puerto Rico Energy Affairs Administration.

Chapter 7: Recommendations for Alternative Energy Use

Based on the conclusions discussed earlier, we have developed a set of recommendations for integrating biodiesel and ethanol on the island of Puerto Rico. These recommendations should be useful to the PREAA to develop a policy that mandates the use of renewable fuels and decrease the dependency on fossil fuels.

7.1 Data Needed to Form Policy

We recommend that legislators investigate the impact of adopting the Renewable Fuel Standards in Hawaii and how the EPA approved their petition to opt-in.

Hawaii represents a good model for Puerto Rico to follow because Hawaii is also an island and has adopted the RFS. Although Hawaii is larger than Puerto Rico, both islands are exposed to the impacts of climate changes and face unique energy challenges.

We recommend that the PREAA perform case studies similar to those conducted by the EPA.

It is important to perform cost benefit analysis of both importing and producing biofuels on the island. This data will help to determine which blends of biofuels will be more cost effective for Puerto Rico.

7.2 Advertisement of Biofuels

We recommend that the PREAA advertise the benefits of using renewable fuels to educate the public.

There are several ways that the island can advertise renewable fuels that we believe would encourage their use. Some examples of advertising methods are presented below:

Commercials:

Commercials represent the most effective form of advertisement although they can be expensive. Entertaining commercials make people remember the message and share it with others. Radio commercials also could potentially be very effective, since the target audience is drivers, and almost every car contains a radio.

Internet:

Government created websites would be helpful in informing customers. Furthermore, the fuel distributors could advertise the incorporated fuels on their websites.

Physical advertisements:

Another form of advertisement is physical advertisements, such as billboards. Billboards may be a suitable method of advertising because thousands of drivers would drive past every day. Newspaper articles and advertisements may prove effective because many people read the newspaper each day, especially the more educated population that would be more concerned with voting on a policy.

We recommend that the PREAA advertise steps to reduce the use of fossil fuels and the negative effects stemming from them.

There are many small changes people can make in their everyday lives to use less gasoline (U.S. Environmental Protection Agency, 2008, Tips to Save and Improve Mileage). On a nice day, walking or riding a bike can conserve gasoline. Additionally, if a family owns

multiple vehicles, they should try to use the one with better gas mileage, and also try to do all their errands in one trip.

Gas mileage of a car is affected by how it is driven (U.S. Environmental Protection Agency, 2008, Tips to Save and Improve Mileage). Using air conditioning in a car consumes some extra gas. Therefore, unless it is extremely hot, the EPA recommends opening the windows to cool off instead.

If there is a long line of traffic ahead during a traffic jam, turning off the car rather than letting it run in idle will make a significant difference. Additionally, driving at speeds of over 60 miles per hour can decrease gas mileage by 15%. If traveling fast is necessary, such as on a highway, the EPA suggests using the overdrive feature on the car to help conserve gas. Being conscious of what is carried in or on a car is another important factor. Driving around with unneeded additional items in the trunk can weigh down a car, requiring more fuel.

Maintaining a vehicle is also important in conserving gasoline because if the vehicle is in proper working condition, it is more efficient (U.S. Environmental Protection Agency, 2008, Tips to Save and Improve Mileage). Tires that are inflated lower than the recommended pressure, or that are not properly aligned tend to use more gasoline. When it comes time to purchase a new vehicle, the EPA advises taking many options into consideration. For example, recognizing the right size car for a family and buying cars with higher gas mileage such as hybrids.

7.3 Incorporating Biofuels into Puerto Rico's Economy

We recommend that the oil distributors in Puerto Rico start importing already blended biofuels.

If a policy is passed that requires alternative fuel use we are confident that this will be the easiest way to adhere to these standards because Puerto Rico already imports all of its oil and there are no refineries on the island.

We recommend that biodiesel be mixed into diesel in compositions of 20% biodiesel or less.

Compositions containing more than 20% biodiesel can damage diesel engines. B20 is the most common blend of biodiesel. We recommend the use of B20 because the environmental impacts of biodiesel are so significant that it should be blended in high quantities as possible. We also believe that between biodiesel and ethanol, biodiesel is the better option.

We recommend Puerto Rico start with an E10 blend of ethanol because this would not require a change in vehicles.

Once there is a sustainable infrastructure for ethanol, we believe there is potential for the successful use of E85. There are very few flexible vehicles currently on the island so we do not recommend the immediate use of E85. Although E10 can be used in conventional vehicles, it cannot be transported by conventional means. Puerto Rico will need a reliable way of transporting ethanol safely, such as an ethanol only pipe system, or a system that relies on trucks or trains.

7.4 Incentives to Promote the Use of Biofuels

We recommend a tax incentive in conjunction with a policy that mandates that a certain volume of biofuels be blended with diesel and/or gasoline by a particular date.

Tax incentives would make it affordable and profitable for oil distributors to import and distribute biofuels. Currently there is no market for biofuels in Puerto Rico because of the high costs. We believe tax incentives would be the best method to stimulate the economy for biofuels. In order to do this, we suggest a program be created that sets guidelines for these incentives to ensure that they are as successful as possible. Tax incentives must be phased in gradually in order to begin the transition to use biofuels, making it profitable for oil distributors. As biofuels become increasingly popular, the prices should decrease, making biofuels more reasonably priced. Once prices are at this level, the tax incentives will no longer be needed, and the government could begin phasing out these incentives. The oil distributors would then have a steady market for biofuels, and the fuel would be inexpensive for consumers.

We recommend the government of Puerto Rico provide rebates for consumers for purchasing blended fuel.

As the process of incorporating biofuels into the market begins, biofuel will be expensive. Consumers are likely to respond negatively to an abrupt change in fueling prices. Because of this, we recommend the Puerto Rican government provide rebates for purchasing blended fuel. This incentive, like the tax incentives, can also be phased in and out to gauge market acceptance depending on time and driving season.

We recommend that PREAA encourages the private sector, particularly the oil industry, to build refineries on the island by giving incentives.

Even with the innovative business of producing biofuels, without any refiners it would not be possible to integrate them into the current fuel market. Offering incentives would encourage entrepreneurs to create the necessary refinement capacity on the island.

We recommend that the PREAA uses a favorable regulatory environment to support the ongoing projects.

Since projects require financial support and significant research and development efforts, the government of Puerto Rico should offer grants to its universities to investigate the production of biodiesel from algae and palm oil. In-depth academic research would accelerate the discovery of the advantages and disadvantages of using these byproducts. To help reduce the risk of time delay that bioenergy developers face; the PREAA should facilitate the process of obtaining utility interconnection, environmental compliance, and construction permits.

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Appendices

Appendix A: Project Sponsor Description

The Puerto Rico Energy Affairs Administration (PREAA) (2010), or the Administración de Asuntos Energéticos (AAE) in Spanish, is an agency that was created in 1977 by the Puerto Rican government to serve as the state energy office. It was created to develop and enforce energy policies in order to preserve the environment, provide energy security, and promote economic advancement. AAE encourages energy conservation by publishing important information for the public, and by implementing acts that seek to reduce dependence on imported oil and integrate alternative energy sources. Also, the energy policy offers incentives and programs to make Puerto Rico a greener place, for both residents and businesses, such as rebates for energy star appliances.

Currently, the Green Energy Fund (GEF) is a program that is funded by the government and will invest 290 million dollars over the next 10 years to fund renewable energy projects. The GEF just started in 2011 and has a budget of 20 million dollars for this first year (Puerto Rico Energy Affairs Administration, 2010). Another program started in 2010 is the Renewable Portfolio Standard (RPS). This program is aimed to establish goals for renewable energy usage, and is designed to use at least 12% renewable energy by 2015, and at least 20% by 2035. As part of this program, Puerto Rico will also implement a Renewable Energy Credit (REC) system. This system works by larger, more efficient energy production companies selling RECs to smaller companies that do not meet their emission standards. One REC is equivalent to 1 MWh of electricity produced by a renewable source.

PREAA also receives some funding from the U.S. government for renewable energy programs or programs that will improve energy efficiency in Puerto Rico (The Executive Office of the Commonwealth of Puerto Rico, 2010). This money comes from the American Recovery and Reinvestment Act (ARRA)'s State Energy Program (SEP). ARRA was created by Barack Obama in 2009 to stimulate the economy

PREAA (2010) works alongside other government run sectors in order to deal with energy related problems. These partner organizations are the Department of Energy (DOE) and the Environmental Protection Agency (EPA). Many of the documents on AEE's website are published by the EPA, which reflects their close collaboration.

The Puerto Rico Electric Power Authority (PREPA) is another corporation working toward alternative energy sources (Cordero, 2010). PREPA is a public corporation of the Government of Puerto Rico. It is responsible for providing electric services in the most economical and reliable way in Puerto Rico without harming the environment. It is currently moving from petroleum to natural gas as a transition to cleaner sources. They developed a fuel diversification plan that includes the reduction in fuel oil dependency. The use of oil will be cut in half from 2000 to 2015.

PREAA is a small organization that has total of 30 employees. PREAA consists of three divisions: the law division, public division and the energy policy department, which is presented below in *Figure 1*. Our project will take place in the energy policy department, which is directed by Alex Miranda. We will be directly working with Damarys Gonzalez and one of the engineers. These departments work closely together to enforce and create energy policies.

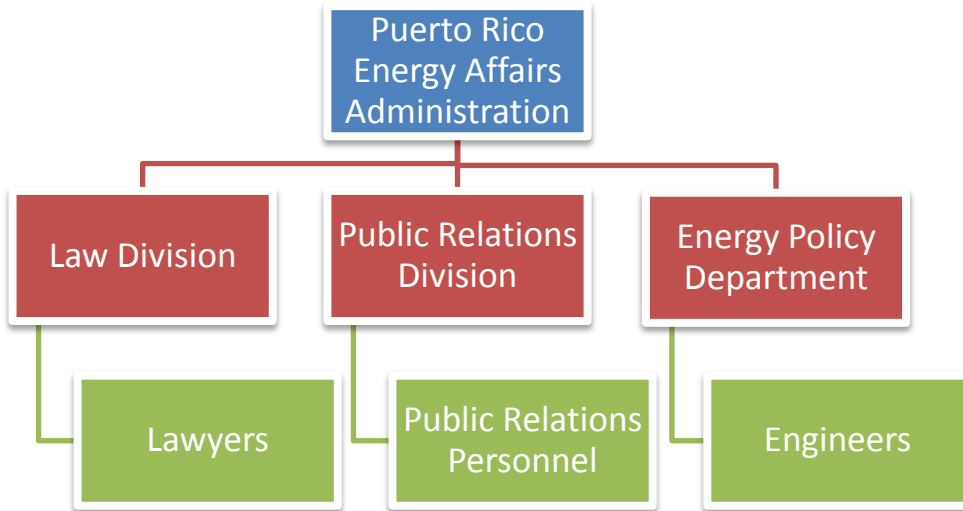


Figure 8 PREAA Organizational Chart

The three main branches of the PREAA, we worked with engineers in the energy policy division

(Adapted from D. Gonzales, personal communication, February 10, 2011)

Appendix B: What is an IQP

WPI (2011) defines the Interactive Qualifying Project as students addressing a “problem that lies at the intersection of science and technology with social issues and human needs. Generally, these projects involve some analysis of how technology affects, and is affected by, individuals and communities” (The Interactive Qualifying Project). Our project was working with the Puerto Rico Energy Affairs Administration (PREAA) to determine which alternative fuels and fuel policies can be implemented in Puerto Rico’s transportation sector, and to provide a preliminary recommendation about how to effectively implement them. Currently, Puerto Rico does not have any existing energy policies pertaining to transportation. Because of this, nearly all forms of transportation are powered by fossil fuels, which only contribute to the island’s economic and environmental problems and dependence on imported fuel. Since fossil fuels contribute to global greenhouse gas emissions and also harm the economy, this project definitely addresses both social issues and human needs. By using science and technology to reduce the dependence on fossil fuels in Puerto Rico, our project qualifies as an IQP.

Appendix C: Glossary

Alternative Fuel - Any fuel that is not considered a conventional fuel. Conventional fuels include fossil fuels and nuclear fuels

B100 - 100% biodiesel

B20 - A fuel that contains 20% biodiesel and 80% conventional diesel

Biofuels - Fuels which are in some way derived from biomass

Biomass - Biological material from living or recently living organisms

Cellulosic Biofuels - Biofuels produced from lignocellulose

Convenience Sampling - A survey method of randomly choosing anyone who has the time to take a survey

E10 - A fuel that contains 10% ethanol and 90% gasoline

E100 - 100% ethanol

E5 - A fuel that contains 5% ethanol and 95% gasoline

E85 - A fuel that contains 85% ethanol and 15% gasoline

Energy Security - Association between national security and availability of energy producing resource

Biofuel Feedstock - Starting materials that are used to make biofuels. For examples corn, or soybeans

Flexible Fuel Vehicle - A vehicle capable of using E85 as a fuel without damage to the engine

Lignocellulose - A structural material that comprises much of the mass of plants. Composed mostly of cellulose, hemicellulose and lignin

Fossil Fuel - Conventional petroleum based fuels, such as oil and coal

Reformulated Gasoline - Regular gasoline mixed with substances that make it burn cleaner to reduce toxins in the air

Renewable Fuels - Fuels produced from a renewable source, such as biofuels and hydrogen

Volatile Organic Compound - Chemicals with a high vapor pressure that are harmful to human health

Appendix D: EPA Interview Protocol



EPA Interview Protocol

1. Why don't the EPA renewable fuel standards (RFS) apply to Puerto Rico?
2. What effects have the RFS had on the U.S. in terms of the environment and the economy?
3. Do you think the RFS can be applied to Puerto Rico?
4. Do you see any challenges in bringing the RFS to Puerto Rico?
5. What was the EPA's motivation for writing the RFS in the first place and what did you intend to gain from them?
6. How did you go about implementing the standards in the U.S.?
7. Do you have any plans for future policies regarding alternative fuels that you are currently working on, specifically transportation fuels?

Appendix E: Public Survey

Mailing List Survey

* Required

1. Do you own a motor vehicle? *

- Yes
- No

2. If you answered "Yes" on Question #1, please answer the following, What type of vehicle do you currently drive?

- Coupe or Sedan
- SUV
- Truck
- Motorcycle
- Other:

3. If you answered "No" on Question #1, please answer the following, What type of collective transport do you frequently use? Check all that apply

- Public Bus
- Train
- Taxi
- Car Pool

4. What is the yearly income of your household? *

- Less than \$20,000
- \$21,000 to \$39,000
- \$40,000 to \$59,000
- \$60,000 to \$79,000
- More than \$80,000

- Prefer not to disclose

5. How much money do you spend on gasoline weekly? *

- less than \$20
- \$21 to 30
- \$31 to 40
- \$41 to 50
- \$51 to 60
- \$61 or more

6. Puerto Rico relies too heavily on imported fossil fuels, such as gasoline *

- Strongly Disagree
- Disagree
- Agree
- Strongly Agree

7. Are you familiar with any of the alternative fuels listed below? * Mark all those that apply.

- Biodiesel
- Ethanol
- Natural Gas
- Hydrogen
- None of the above

8. Do you or any one you know own a flexible fuel vehicle (a vehicle capable of being powered by alternative biofuels)? *

- I own one
- I know someone
- No

9. Would you be willing to switch to a flexible fuel vehicle if it would help the environment? *

- Yes
- No
- I already own a flexible fuel vehicle

10. If you answered "No" to Questions #9, Would you be willing to upgrade your vehicle? On average, upgrading a vehicle costs less than \$400.

- Definitely
- Maybe
- No
- I already own a flexible fuel vehicle

11. Would cost be a deciding factor when considering purchasing a flexible fuel vehicle? *

- Yes
- No

12. Would you consider purchasing a flexible fuel vehicle if certain incentives were available? *

- Definitely
- Maybe
- No


13. What types of incentives would encourage you to purchase a flexible fuel vehicle? *

- Tax refunds
- Rebate
- Loans/Grants
- Other:

14. Would you support a renewable fuels policy that requires that alternative fuel be added to gasoline? *

- Definitely
- Maybe
- No

15. Why or why not, would you support this policy?



Cuestionario de Combustibles Alternos

Declaración: Nota: Toda información completada en este cuestionario es confidencial, anónimo y completamente opcional. Este cuestionario se utilizara para el proyecto de Combustibles Alternos en Puerto Rico auspiciado por la Administración de Asunto Energéticos (AAE) y por el Worcester Polytechnic Institute (WPI) localizada en Worcester, Massachusetts. Hola, Somos un grupo de estudiantes de Worcester Polytechnic Institute localizada en Worcester, Massachusetts (cerca de Boston, Massachusetts). Actualmente estamos trabajando en un proyecto relacionado a combustibles alternos en Puerto Rico y estamos tratando de adquirir más conocimiento sobre combustibles alternos en el sector de transportación. Sería de gran ayuda si pudiese sacar un poco de su tiempo para completar un corto cuestionario relacionado al tema. Toda la información será anónima para proteger su privacidad. Muchas gracias por su cooperación, Combustibles Alternos para Puerto Rico

* Required

1. ¿Usted cuenta con un vehículo de motor? *

- Si
- No

2. Si contesto "Si" a la pregunta #1, favor de contestar la siguiente, ¿Qué tipo de vehículo usted tiene?

- Coupe or Sedan
- SUV
- Camion (Truck)
- Motocicleta / Motora
- Other:

3. Si contesto "No" a la pregunta #1, favor de contestar la siguiente, ¿Qué tipo de transporte colectivo usted utiliza frecuentemente?

- Guagua Publica
- Tren
- Taxi
- "Car Pool" (Pon)

4. ¿Cuál es el ingreso anual de su hogar? *

- Menos de \$20,000

- \$21,000 to \$39,000
- \$40,000 to \$59,000
- \$60,000 to \$79,000
- Más de \$80,000
- Prefiero no revelarlo

5. ¿Cuánto dinero usted gasta en gasolina semanalmente? *

- Menos de \$20
- \$20-\$30
- \$31-\$40
- \$41-\$50
- \$51-\$60
- Más de \$60

6. Puerto Rico depende demasiado en la importación de combustibles fósiles así como la Gasolina *

- Totalmente en desacuerdo
- En desacuerdo
- Acuerdo
- Totalmente de Acuerdo

7. ¿Usted u otra persona que usted conoce cuenta con un vehículo de combustible flexible (vehículo capaz de ser propulsado por biocombustible alternativo)? *

- Posee Uno
- Conozco a alguien
- No

8. ¿Conoce usted alguno de los combustibles alternos a continuación? * Marque aquellos que apliquen.

- Biodiesel
- Ethanol
- Gas Natural
- Hidrogeno

- Ninguno de los anteriores

9. ¿Estaría usted dispuesto(a) a cambiar su auto por uno de combustible flexible, si este ayuda al ambiente? *

- Si
- No
- Ya Poseo Uno

10. Si contesto "No" a la pregunta #9, favor de contestar la siguiente, ¿Estaría usted dispuesto a convertir su vehículo en uno de combustible flexible? * ¿Sabía usted que el costo de convertir un vehículo convencional a uno de combustible flexible es aproximadamente uno \$400?

- Si
- No

11. ¿Sera el costo un factor importante a la hora de tomar la decisión de comprar un vehículo de combustible flexible? *

- Si
- No

12. ¿Consideraría usted comprar un vehículo de combustible flexible, si hubieran incentivos disponibles? *

- Definitivamente
- A lo mejor
- No

13. ¿Apoyaría usted una política de combustibles renovables que requiera que la gasolina contenga un porcentaje de combustible alternativo? *

- Definitivamente
- A lo mejor
- No

14. ¿Qué tipo de incentivos lo animarían a comprar un vehículo de combustible flexible? *

- Desembolsos de Impuestos
- Rebajas

- Prestamos/Subvenciones
- Other:

15. ¿Por qué o Por qué no estaría dispuesto apoyar esta política?

Appendix F: Oil Importer/Distributor Interview Protocol



Oil Importer/Distributor Interview Protocol

1. Where do you get your oil from?
2. Could you describe the process of how you get your oil and what you do with it?
3. Does it contain any alternative fuels? If so, which ones and what percentage?
4. What affects have you felt from the global increase in the cost of oil?
5. Do you think alternative fuel policies would affect your business? How?
6. Do you think it is feasible to mix alternative fuels in Puerto Rico's transportation fuels?
7. Do you think that distribution stations in Puerto Rico can support alternative fuels?
8. Do you think there is a market for implementing alternative fuels?

Appendix G: Environmental Quality Board Interview Protocol



Environmental Quality Board Interview Protocol

1. Could you briefly describe what your agency does?
2. Are familiar the EPA's Renewable Fuels Standards?
3. Have you considered implementing any similar policies?
4. What are the challenges to implementing a policy like this?
5. What do you consider to be the biggest threat to the environment in Puerto Rico?
6. We are trying to begin a policy to incorporate biodiesel and ethanol into the transportation fuel sector. From your perspective what do you consider to be the greatest advantages and disadvantages of these fuels?
7. What do you think are the biggest challenges to implementing alternative fuels in Puerto Rico?

8. What kind of data would need to be collected to justify a policy to mandate a certain amount of bio fuels in transportation fuel? Do you have any of this data?