Towson University: GREEN FLEET FORWARD

ENVS 491
Senior Seminar
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Forward

The Environmental Science and Studies (ESS) Senior Seminar class is taken by students who are completing their academic major and getting ready to graduate. The course consists of a semester long project. The course objective is for the students to bring to the project the knowledge, skills and abilities they have developed through their academic study and use them to address a specific question or problem. This year Mr. Harry Hughes, the Director of the Physical Plant at Towson University and the person responsible for managing the TU fleet, requested that we look at the TU fleet with an eye towards helping them 'green' their operation. We accepted this challenge knowing that our exploration of the topic would help the University towards its goal to become carbon neutral by 2050.

The challenges associated with 'greening' the Towson Fleet led us to consider a range of topics from the engineering and physics of different types of engines to the potential for conflict between where an organization might want to go and the rules and regulations that define what it can actually do. Our exploration of the fleet and the policies that govern it led us to deal with many current topics: greenhouse gas inventories, greenhouse gas emissions, economic and environmental costs and benefits of different fuel sources, limits and potential of new technologies, etc. Finding the 'best' possible sources of energy for vehicles drove home the idea that 'there is no such thing as a free lunch.'

The students have worked on their own. I provided limited guidance and help as requested. The students deserve the credit for their success.

Jane L. Wolfson, Ph.D., Director, Environmental Science and Studies Program
Professor, ENVS 491 Senior Seminar, Fall 2009

INTRODUCTION

Global climate change and increasing oil prices are two major issues that world governments are dealing with. In the United States, the Energy Policy Acts (EPAct) of 1992 and 2005 and more recently, the Energy Independency and Security Act (EISA) of 2007 have set guidelines for exploring and implementing alternative fuel use in the United States with the intention of lowering dependency on foreign oil and reducing greenhouse gas (GHG) emissions contributing to global climate change (Meyers 2008). Actions are also being taken at a more local level.

The Regional Greenhouse Gas Initiative (RGGI) is a voluntary carbon cap-and-trade program aimed at achieving a 10% carbon dioxide emissions reduction by 2018 in the power use and distribution sectors of the Region (RGGI 2009). So far, the RGGI has been the collective effort of ten Northeastern and Mid-Atlantic States (RGGI 2009). Maryland is one of ten states involved in the Regional Greenhouse Gas Initiative (RGGI). Since 2008, when Maryland joined the Initiative, the State has raised millions in funds through RGGI regulations and programs (Wheeler 2009). These monies are being used to aid in the implementation and facilitation of Maryland's own state legislations and aimed at promoting energy efficiency and energy conservation (Wheeler 2009).

Maryland has been a leader in enacting legislation that helps to deal with the anthropogenic factors contributing to environmental pollutants and has recently put into legislation its own Greenhouse Gas Reduction Act committing to reducing GHG emissions 25% by 2020 (Maryland 2009a). The Act is part of Governor Martin O'Malley's *Smart, Green and Growing* planning guide, initiated in 2009. The Governor's new plan expands on the Green Car Act (implemented in 2007) requiring that all new vehicle models after 2011 reduce volatile organic compounds and nitrogen oxides (Maryland 2009b) and the EmPOWER Maryland Energy Efficiency Act of 2008, aiming to reduce per capita energy consumption 15% by 2015 (Maryland 2008). These Acts along with more recent State initiatives are estimated to contribute 12.5% of the 25% total reduction in GHG emissions that the State is requiring (Maryland 2009a). In conjunction with Maryland's Climate Change Commission's *Climate Action Plan* released in

2008 that sets the goals and timetables for achieving legislative implementation (MDCCC 2008), Maryland expects to reach the goals set forth by the GHG Reduction Act (Maryland 2009a).

Towson University is doing its part to help the Nation and the State gain fossil fuel independence and reduce GHG emissions. In 2007, TU's president, Dr. Robert L. Caret, signed the American College & University Presidents' Climate Commitment (ACUPCC) pledging Towson University to carbon neutrality by 2050. The ACUPCC focus is not just on organizing colleges and universities in reducing GHG emissions, but also to encourage research and education about environmental issues and solutions (ACUPCC 2009). In accordance with the provisions of ACUPCC, Towson University commissioned a Greenhouse Gas Inventory conducted by ARAMARK Higher Education during the 2007/2008 years. In October, 2009 Towson University released its Carbon Action Plan (CAP), required by ACUPCC, to set the guidelines by which the campus will reach carbon neutrality (ACUPCC 2009).

The results of TU's GHG inventory indicated that 28% of campus carbon emissions were from transportation; of this, 3% was produced by the University Fleet. In spite of this small percentage, we were asked by TU's Fleet Management to explore and evaluate ways in which the Fleet can be improved in terms of its overall efficiency. While the Fleet is not a major source of GHG, overall reduction will help bring the University towards its carbon neutral goal.

We present our findings in the following document. It is obvious that the task of GHG reduction by the Fleet is not trivial or simple to resolve. It appears to us that much of the Fleet's ability to reduce its carbon footprint will depend on technologies and policies that are still under development.

CURRENT STATE OF THE FLEET

Harry Hughes, Physical Plant Director for Towson University, requested that a ten-year plan be developed to facilitate Towson University's Fleet transition to a green fleet. The fleet can be broken down into five sub-fleets: Police vehicles, Transportation vehicles (buses mostly for on-campus use), Fleet vehicles (sedans and vans mostly for off-campus use), Maintenance vehicles, and Landscape vehicles. Within these various sub-fleets there are about 70 different models of vehicles, allocated among approximately 40 different departments (Table 1). Mr. Hughes supplied general information about the current state of the Fleet, and a tentative budget that ultimately limits options.

The data and information used to analyze Towson University's Fleet were gathered from the Towson University Fleet Roster for 2009, obtained with the assistance of Mr. Hughes. Vehicle age and total mileage data were used to determine the average annual miles per Fleet vehicle. The roster also provided corresponding model types that allowed us to infer proportionality of usage among vehicle types in each department.

The current Fleet at Towson University consists of over 150 vehicles of different makes, years, and models. Vehicles are allocated to departments based upon need and availability. Vehicles are used to their fullest potential and the use is often dynamic. It is not uncommon for a vehicle to start off in one department, find a home in another, and serve intermediate purposes based on seasonal or departmental needs. This means that as the needs of the department or the Fleet's composition change, so may the vehicle assignments. Based on conversations with several managers, vehicles are used until they have little, if any, life in them.

Towson University's Fleet vehicles have a wide range of mileages and ages. The average mileage per vehicle is 42,095, with the least used vehicle having only 15 miles and the most used having 152,997 miles (as of fall 2009). Of the 150+ vehicles, 13 have 100,000 miles or more, nine have between 90,000 to 100,000 miles, and eight have between 80,000 to 90,000 miles. The vehicles that have 100,000 miles or more were mainly put into operation between 1993 and 1998, but there is one from 2002. In some cases, older vehicles have fewer miles than newer vehicles because of high-demand or a specialized function. Some vehicles such as snowplow trucks have seasonal demands and are used less often.

The average age of Towson University's Fleet vehicles is seven years old, placing the mean model year at 2002. The oldest vehicle in the Fleet is from 1986. Seven vehicles were purchased between 1986 and 1990, 52 vehicles were purchased between 1991 and 2000, and 41 vehicles were purchased between 2001 and 2005. Each year, the average vehicle is driven 6,013 miles. Although this number is highly variable, the majority of the Fleet vehicles are relatively close to this figure, which is based on age and total mileage. This relatively low mileage might reflect the restricted on-campus use of some of the vehicles.

In order to address the needs and wants, both practically and economically, Towson University's Fleet must remain within the constraints of a budget. We were asked to work within a ten-year plan that includes a budget to be used toward redesigning only the Maintenance, Landscape, and Fleet vehicles in Towson University's Fleet. The base budget we were given to work with for the purpose of the project was not to exceed $100,000 for the year 2010, with a potential 2-4% budget increase following 2010. We were also allowed to consider an additional $80,000 over the ten-year period which is available for modification of vehicles, and $75,000 with a 1-3% annual increase which is available for vehicle and infrastructure maintenance.

Regulations governing the purchasing and replacing of vehicles are outlined in the State of Maryland Policies and Procedures for Vehicle Fleet Management manual of 2005. This document is based on the Federal Energy Policy Act of 1992 (EPAct of 1992) that describes what agencies are involved in vehicle purchasing, the parameters that must be met for a vehicle to be replaced, and the state fueling locations and requirements. This document dictates Towson University's Fleet composition, since vehicle purchasing and replacing must be done in accordance with manual's requirements.

Table 1: The components of the Towson University's Fleet vehicle that we were asked to examine.

Sub-fleet	# Vehicles	Mean Year	Mean Mileage
Fleet/Pool	20+	2004	40,979
Maintenance*	46	2001	37,591
Landscaping	14	2001	37,251

*Includes: HVAC, Carpenters, Electrical, Plumbing, Facilities management.

POLICIES REGULATING THE TOWSON UNIVERSITY FLEET

The Towson University fleet is regulated according to the State of Maryland Policies and Procedures for Vehicle Fleet Management manual of 2005, also known as "The White Book." This manual sets restrictions on what types of vehicles can be purchased, says where or how they can be purchased, provides guidelines and determines procedures for vehicle replacement. In addition, "The White Book" governs where vehicles should be refueled and which fuel type(s) are to be used. The main goal of the EPAct of 1992 was to improve the nation's energy efficiency and decrease its dependence on foreign fuels (EPAct 1992).

Acquisition and Replacement of Towson University Vehicles

The Department of Budget and Management (DBM) develops specifications for each class of vehicles that an agency of the state might wish to purchase during a given year (DBM 2005). These specifications are then sent to the Board of Public Works for approval (DBM 2005). Upon approval, the Department of General Services (DGS) receives bids from dealers for vehicles that fill the specification requirements, and then vehicles are purchased through the most competitive bidder (Ruley 2009). All vehicles purchased by Towson University must be purchased through the state contracts negotiated by DGS, unless there are no vehicles under contract which are capable of fulfilling the University's needs. All vehicle purchases must be approved by DBM (Ruley 2009).

According to the Policies and Procedures for Vehicle Fleet Management (DBM 2005), a vehicle may only be replaced if it meets one of these requirements:

- Must have at least 100,000 miles.
- Must be at least ten years old and has been approved by DBM for a replacement.
- Has been determined by DBM to have repair expenses beyond acceptable parameters.

Therefore, the University (or any other state agency) must receive permission from the state prior to replacing vehicles. In order to replace any vehicle with less than 100,000 miles, the University (or any other state agency) must first submit a request to DBM for approval (DBM 2005). A vehicle may not be replaced until approval is granted.

Towson University Fueling Requirements

State vehicles are expected to be refueled from the Statewide Automated Fuel Dispensing and Management System whenever possible (DBM 2005). However, in the case of an emergency or when it is not possible to obtain fuel from the state, the cheapest available fuel should be purchased and accurately reported through Maryland's online fleet information system, WebFleetMaster (DBM 2005). Fuel may be purchased in bulk through DGS contracts if it is reported through WebFleetMaster. Alternative fuels should be used whenever possible if driving a dual-fuel or flex-fuel vehicle (FFV) (DBM 2005). Alternative fuels are defined by the EPAct of 1992 as:

> mixtures containing 85 percent or more (or such other percentage, but not less than 70 percent, as determined by the Secretary, by rule, to provide for requirements relating to cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; electricity (including electricity from solar energy); and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits….

"The White Book" lists Baltimore County as an area in which vehicles can access central fueling stations, or a covered area. At least 75% of the time, vehicles from covered areas are expected to be refueled at a state refueling station (EPAct 1992). Currently, there are 13 statewide refueling stations located within Maryland which provide 85% ethanol (E85) and gasoline (DGS 2008) but none of these is close to campus. The closest station is only 10 miles away but is in the middle of Baltimore City; it would be inefficient to expect University vehicles to travel through this congested area to fill up when there is a central fueling station next to campus which we can use. Unfortunately the only gasoline the local station offers is E10 gasoline.

Alternatively Fueled Vehicle Requirements for Towson University

The EPAct of 1992 developed specific rules and guidelines to improve the nation's energy efficiency and decrease its dependence on foreign fuels; one of the mechanisms is through requiring use of alternative fuels and alternative fuel vehicles (EPAct 1992). EPAct of 1992 defines a light duty vehicle as a vehicle with a gross vehicle weight of 8,500 pounds or less. A non-excluded vehicle is any vehicle that is not an emergency vehicle, a non-law enforcement vehicle, a non-road vehicle, or a vehicle which is taken to a private place of residence at the end of the day (DBM 2005). Seventy-five percent of light duty fleet vehicles that are annually purchased by any state agency that owns at least 50 light duty vehicles that are non-excluded and operates at least 20 of these vehicles in a covered area must comply with the Alternative Fuel Vehicle (AFV) requirements (DBM 2005). In order to be considered an AFV, a vehicle must either be a dedicated AFV or a dual-fuel vehicle. A dedicated AFV is identified as a vehicle that runs solely on an alternative fuel. A dual-fuel vehicle is classified as a vehicle that is capable of running on either an alternative fuel or petroleum based fuel (EPAct 1992).

The 75% AFV requirement does not stand alone in evaluation purchase options. The EPAct of 1992 also requires that vehicles which are capable of having the greatest emission reduction per dollar spent should be considered in evaluating purchase options (EPAct 1992). Conversions can only be made to existing fleet vehicles if the conversions do not void the manufacturer's warranty. Preferences should be given to vehicles using domestic fuels as opposed to foreign fuels when conversions are made (EPAct 1992).

Conflict Inherent to the Alternatively Fueled Vehicle Requirements

Towson University must comply with the 75% AFV requirement set forth by EPAct (EPAct 1992). Unfortunately this regulation, which was intended to decrease dependence on foreign oil and increase efficiency, contains a loophole that impacts all state agencies which are obligated to adhere to its requirements. EPAct simply says that all state agencies must have alternatively fueled vehicles on their lots (EPAct 1992). State agencies can only purchase vehicles that are commercially available. Most AFVs that state agencies purchase are flex-fueled vehicles, which meet the requirements set forth by the EPAct of 1992. Although these vehicles are designed and engineered with good intentions, to reduce emissions created from gasoline burning cars, flex-fuel vehicles while capable of burning 85% ethanol fuel are not required to be fueled with E85 fuels and can run quite nicely on fuels containing much lower levels of ethanol. These vehicles are required, as stated above to be refueled with an alternative fuel whenever possible (EPAct 1992). The current conditions in Maryland prevent some state agencies from refueling their flex-fueled vehicles with E85; extensive E85 infrastructure is not available within the state so that E85 pumps are not always conveniently located near state agencies. This is the situation that Towson University is in; our fleet is fueled at the nearby Baltimore County fueling station but this station does not provide E85. The only other way to supply E85 to the TU fleet would be to drive to the nearest E85 fueling station which is located on Preston Street in Baltimore City. Because flex-fueled vehicles are only required to refuel with alternative fuels when possible as stated above, this allows fleets to bypass refueling their vehicles with alternative fuels. Therefore, a loophole through which an agency can comply with the regulation by purchasing flex-fuel vehicles but not, in fact, using the vehicles as they were designed to be used, i.e., with E85 fuel, was created and can be taken advantage of by many state agencies. This loophole can be rectified with the Alternative Compliance Amendment within the Energy Policy Act of 2005 (EPAct of 2005), if the state agency chooses to take advantage of this amendment (EPAct 2005), which it currently does not (L. Williams 2009).

EPAct 2005: Alternative Compliance Amendment

The EPAct of 2005 provides amendments to the original EPAct of 1992. One such amendment, the alternative compliance and flexibility provision, is contained within section 703 of the EPAct of 2005 (EPAct 2005). This amendment allows for covered fleets to apply for a waiver, allowing them to fulfill the requirements of the original act by reducing their annual petroleum usage through a plan they devise (EPAct 2005). This is in contrast to having 75% of the total annual vehicle purchases qualify as AFVs, as required by the 1992 act (EPAct 2005). With the alternative compliance option, the annual reduction in petroleum usage is to be equal to the reduction that would occur if all the AFVs in the fleet were to be exclusively fueled with the designated alternative fuel (EPAct 2005). The annual petroleum reduction is calculated by a state agency representative who follows this formula: multiply the total number of alternative fuel vehicles by the light duty vehicle average fuel consumption (DOE 2009a). Secondly, all fleet vehicles must meet the current vehicle emissions standards set forth by the Environmental Protection Agency (EPA) Administrator (EPAct 2005).

Should a fleet apply for and receive an alternative compliance waiver, a covered fleet must meet the respective petroleum reduction requirements that are established by the waiver (EPAct 2005). Failure to meet the requirements of the waiver will result in a revocation of the waiver and potential fines for the covered entity (EPAct 2005). A first time violation is subject to a maximum $5,000 fine per violation (EPAct 1992).

TECHNOLOGY

Historically, transportation in the United States has relied heavily on internal combustion engines- powered by petroleum based fuels. The two most common forms of internal combustion engine are gasoline and diesel engines. Along with steady improvements in the efficiency of internal combustion engines however, the use of fuel cells, improved batteries, and alternative fuels has given rise to new and exciting methods of powering both the vehicles of today, and tomorrow. In addition to an exploration into today's internal combustion engines, this section will explore some of the more promising alternative fuel vehicle technologies, many of which could be utilized in a modern day fleet.

Internal Combustion Engine

Internal combustion engines are commonly found in two forms: gasoline and diesel. Although the two engines differ in both their source of ignition and their fuel type, they operate under many of the same principles. Both gasoline and diesel engines of modern automobiles operate under similar "four stroke" processes and consist of six main mechanical parts: the cylinder, piston, crankshaft, intake valve, fuel injector, and the exhaust valve (Brain 2000b, DOE 2003). A typical car engine has between four and eight cylinders. As fuel is ignited within these cylinders, pistons capture the energy of the small explosion by turning the crankshaft and, ultimately, the vehicle's wheels (History 2009).

At roughly $30/kW, the cost of purchasing and operating an internal combustion engine remains the standard for which all other alternative vehicles are compared to in the automobile industry (DOE 2008b). The problem with combustion engines is the large quantity of moving parts and their overall inefficiency (DOE 2008a). Much of the energy from the fuel mixture is lost as heat (DOE 2008a). Likewise, the environmental cost associated with combustion engines is sometimes overlooked. Combustion engines utilize fossil fuels which releases greenhouse gases (GHG) and other toxic gases that are harmful to the environment. The polluting nature, dwindling fuel reserves, and lower comparative efficiency of internal combustion engines may limit their usefulness as an engine type in the future.

The Four Stroke Cycle

The basic four stroke cycle of an internal combustion engine is comprised of four steps, or strokes: An intake stroke, a compression stroke, a combustion stroke, and an exhaust stroke (Brain 2000a). The step at which fuel is introduced to the cylinder may vary, depending on the type of fuel injection system found in a particular vehicle (Brain 2000a).

In the first stroke, the engine's piston is pulled down, creating a vacuum, which causes outside air to enter the cylinder through an open air intake valve (DOE 2003). In the second stroke, the piston is forced back up into the cylinder, compressing the air contained within it. Third, the fuel within the cylinder is ignited (DOE 2003). As the fuel ignites, the gases within the cylinder expand with great force, driving the piston back down and subsequently turning the engine's crankshaft (DOE 2003). Lastly, the piston again moves back up into the cylinder, forcing exhaust gases to exit through the open exhaust valve; enabling the four stroke process to repeat itself.

***Diesel vs. Gasoline Engines*:** The two engines share the same basic principle of igniting a compressed air-fuel mixture to ultimately drive the vehicle's wheels (DOE 2003). As was mentioned previously, however, the two engines differ in both their source of ignition and their fuel type.

Today's gasoline engines rely on a spark plug to ignite the air-fuel mixture in the third stroke of the four stroke process (History 2009). In contrast, diesel engines rely on the heat created by compression within each cylinder to ignite the fuel mixture (Ristinen and Kraushaar 2006). A diesel engine achieves this by compressing the air trapped within each cylinder to a temperature of around 1,000 degrees Fahrenheit (Ristinen and Kraushaar 2006). Once the optimal temperature and pressure is sensed, fuel is injected directly into the cylinder, where it immediately ignites (Ristinen and Kraushaar 2006). The higher compression of a diesel engine enables it to be roughly 5% more efficient than a gasoline engine in converting chemical energy into mechanical energy (Ristinen and Kraushaar 2006)

As the two engines' names imply, gasoline engines are fueled by gasoline fuel whereas diesel engines are fueled by diesel fuel. Because diesel engines operate at significantly higher internal pressures, they must be constructed of stronger materials (TheDiselpage.com 2009). As a result, diesel engines have a significantly greater upfront purchase cost than gasoline engines (TheDiselpage.com 2009). This stronger engine, however, combined with the better lubricating features of diesel fuel, enables diesel engines to last nearly twice as long as gasoline engines (TheDiselpage.com 2009).

Today's diesel engines are managed by an electronic control module (ECM) that determines the right mixture of air and fuel (DOE 2003). This is done by controlling the amount of fuel injected and when it is injected into the cylinder (DOE 2003). By controlling the timing and amount of fuel, the ECM is able to maximize efficiency and lower emissions by ensuring that no excess fuel is burned (DOE 2003).

Superchargers and Turbochargers

Superchargers and turbochargers are fans that compress and force air into the cylinders within the engine (FuelEconomy.gov 2009a). This compression of air enables additional fuel to be added into the cylinder, while still maintaining an optimal air/fuel ratio (FuelEconomy.gov 2009a). A normal turbo or supercharger will compress the air 6-8 pounds per square inch (psi) which can equates to a 30-40% gain in power (FuelEconomy.gov 2009a). This has allowed many car manufactures to equip vehicles with smaller and lighter engines, while still achieving performance characteristics similar to larger engine.

The main difference between a turbocharger and a supercharger is how they are powered. A turbocharger uses exhaust from the engine to turn a turbine at about 150,000 rotations per minute (rpm), spinning an air compressor (Nice 2000). The more exhaust that goes through the turbines, the faster they will spin. Superchargers differ from turbochargers in that they are powered by the engine's crankshaft (Harris 2006).

Electric Vehicles

Two basic types of motors used in electric vehicles today are Direct current (DC) and Alternating current (AC) (Brain 2000d). In DC motors, the electrical current maintains constant polarity and direction, whereas in AC motors, the current changes polarity and direction over time (All about Circuits 2009). The two most common types of DC motors are brushed and brushless. The brushed motor is comprised of a rotor, or communicator, that has coils of wire wrapped around its core (Brain 2000d). The brushes attach to the rotor. These brushes connect the electrically charged wires from the battery to the rotor itself to conduct the electric current. The purpose of the rotor is to prevent the polarity from shifting as the rotor rotates through the electric field (Nave 2006). Without the rotor holding the polarity stable, the rotor would simply rotate back and forth over only 180 degrees as opposed to making a complete turn of 360 degrees which is imperative to maintain the magnetic field. Figure 1 explains how the magnetic force applied to the field produces a rotating force, or torque, to spin the motor (Nave 2006). Electrical currents are generated through the rotor which is attached to a coil passing through the electromagnetic field (Nave 2006). The field is generated by two magnets of north and south polarity, which repel each other in opposite directions (Nave 2006). This electromagnetic force causes the motor to spin inside the electromagnetic field (Nave 2006). An electromagnetic current is produced when an electric power source is connected to the rotor and its brushes (Nave 2006). The brushes are important because friction helps them generate a magnetic field (Nave 2006). One disadvantage of the brushes is that at

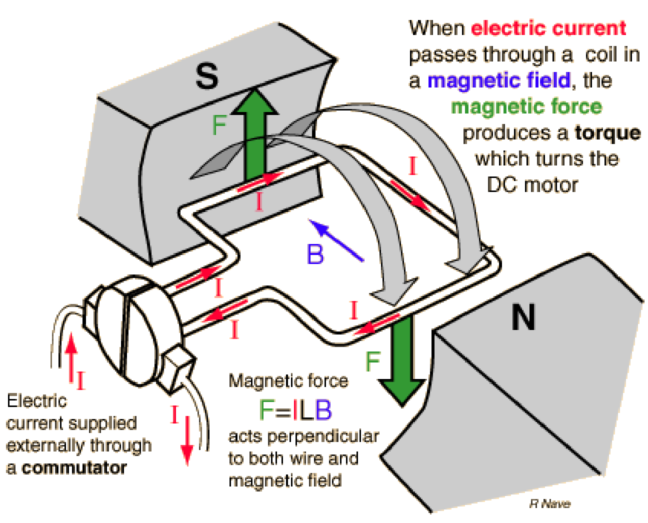

Figure 1: Magnetic force applied to the magnetic field produces torque (Nave 2006).

higher speeds, the brushes have trouble staying in contact with the rotor (Brain 2000d). This causes the motor to lose power due to the reduced strength of the electric field (Brain 2000d).

In the brushless motor, the rotor is replaced by an electronic switch which is powered by direct-current electricity which eliminates the need for brushes (Brain 2000d). This is accomplished by using a simple computer to receive a signal identifying the position of the rotor in the magnetic field (Nave 2006). This computer then switches the polarity of the magnets thereby adjusting the magnetic field which allows the rotor to continue spinning (Brain 2000d). DC instillations tend to be simpler and cheaper (Brain 2000d). They are nice for short bursts of acceleration, but they are prone to heat build-up in the motor (Brain 2000d). The motor may self destruct with too much acceleration (Brain 2000d).

AC motors consist of two basic parts: an inside rotor and an outside stationary stator, which is the stationary part of a rotor (Brain 2000d). The stationary stator has wired coils supplied with a current to produce a magnetic field (Brain 2000d). An induction AC motor is useful during braking because this motor uses batteries more efficiently and can be used to regenerates batteries while braking (Electropaedia 2009). Regenerative braking is a technology where the electric motor itself applies pressure to the drive train causing the wheels to slow down (Electopaedia 2009). The energy transfers from the wheels to the motor causing the motor to spin (Electopaedia 2009). This energy is then stored in a generator or battery and is saved for later use.

The electric car battery has a couple basic functions: it regenerates itself during braking, powers the electric motor, and keeps a steady low current to power electrical devices (Electopaedia 2009). Lead-acid, Nickel-metal hydride (NiMH), and Lithium-Ion (Li-ion) batteries are the most common battery chemistries found in electric vehicles (Electropaedia 2009). Unfortunately, none of these battery types are technologically mature enough to make electric vehicles competitive.

Although lead-acid batteries are by far the cheapest form of energy storage, they are inherently heavy, lose their storage capacity relatively quickly (low cycle life), and have very long charge times (Electropaedia 2009). A NiMH battery system for an electric car may have twice the energy density (energy stored/weight) and last up to six years longer than a lead-acid battery system, but can cost up to

$30,000 (Electropaedia 2009). Lithium-ion batteries outperform lead-acid and NiMH systems in energy density, cycle life and quick charge time, but are a relatively new technology, making them prohibitively expensive. Although the perfect battery may not yet exist, it is predicted that the rising demand of cheaper and better performing battery technology for portable electronic devices, hybrids, and electric cars will rapidly propel research and reduce costs in the near future (Electropaedia 2009).

Hybrid Vehicles

Hybrid vehicles combine the technology of the electric motor and the internal combustion engine. However, the electric motor in a hybrid vehicle is a bit different from the all electric vehicle. In this case there is also a generator in the vehicle, like the one shown in Figure 2. The generator transfers energy from the battery to the motor or vice versa (DOE 2009b). When braking, the generator converts mechanical energy into electricity in order to replenish the battery. When the vehicle is cruising, the generator is also charging the battery by allowing the electric motor to spin, creating energy that is stored in the battery (DOE 2009b). With their smaller capacity battery systems, hybrid batteries never need to be recharged because the everyday use of the vehicle allows for the battery to recharge.

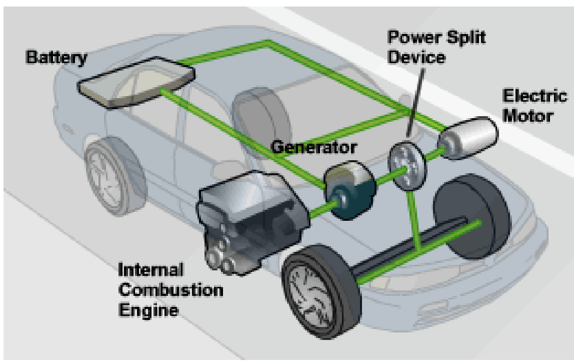

Figure 2: View into a hybrid car showing a generator and a battery (DOE 2009b).

Towson University has the opportunity to buy vehicles off of state contracts. Currently, there are a few electric vehicles that can be found on the DGS website, they are as follows: E-ride EXV2 and EXV4, Vantage EVX1000, EVR1000, EVC1000, and EVP1000, and the Textron EZ-GO ST and Shuttle series (DGS 2009). These vehicles are all on contract under varying percentages of price reduction from retail value. All of these are multi-purpose vehicles that can be used for various maintenance activities. These vehicles are all considered low-speed vehicles and are not intended for use on public roads but would be able to transport personnel and equipment across campus easily.

Fuel Cells

Fuel cells are a novel concept in power generation; they are neither a battery nor a combustion system. They are their own unique form of power generation. Fuel cells may differ in the types of fuel combinations they use, but the way they work is generally very similar. An individual fuel cell consists of an electrolyte sandwiched between an anode and a cathode (DOE 2008a). Bi-polar plates cover the outside of the anode and cathode, serving as gas distributors and current collectors (DOE 2008a). Fuel cells function on a basic level by forcing a gaseous fuel, such as hydrogen, through an anode (DOE 2008a). Here a catalyst causes the electrons to release and flow through the circuit while the protons now pass through the electrolyte to the cathode (DOE 2009c). At the cathode the protons and electrons all reunite with oxygen from the air to form water and heat as exhaust (DOE 2009c).

In Polymer Electrolyte Membrane (PEM) fuel cells, which are the most promising to date for vehicular application, hydrogen is pumped to the anode where a platinum catalyst causes the hydrogen molecules to lose their electrons (DOE 2009c). The electrons run through the circuit while the positively charged hydrogen (H^+) ion moves to the cathode (DOE 2009c). The electrons then recombine with hydrogen and oxygen to form water and heat (DOE 2009c). Since an individual fuel cell does not generate enough energy to power a vehicle, the cells are lined up together into fuel cell “stacks” (GM 2009). The cells and stacks are then all wired into one circuit, providing sufficient power to run an electric motor and power the vehicle (GM 2009).

There are a few different types of fuel cells, all which vary slightly from each other. They all work by creating a current via an anode and cathode. The main fuel cell types in use are Alkaline, Phosphoric Acid, PEM, Molten Carbonate and Solid Oxide (DOE 2008a, DOE 2009c). Alkaline fuel cells were one of the first fuel cell technologies developed (DOE 2009c). This type of fuel cell was first widely used in the U.S. space program, supplying power and water to astronauts (DOE 2009c). PEM fuel cells are the most common for use in vehicles (DOE 2009c). This type of fuel cell is both lighter in weight and operates at a lower temperature with a relatively high efficiency of 53-58% compared to the 33-35% efficiency of a conventional combustion engine (DOE 2008a, DOE 2009c). Phosphoric acid, molten carbonate, and solid oxide fuel cells are all used as either a solid or liquid electrolyte and are mainly used for stationary power generators (DOE 2009d).

Viability of Fuel Cells: The current feasibility of fuel cell vehicles is low. Fuel cells are also still very expensive. To be competitive, a power source must be able to produce at $30/kW, which is the cost at which conventional gasoline engines operate (DOE 2008b). Until fuel cells can produce at that level, they will not likely become widespread. The reliability and durability of fuel cell vehicles has still not been established (DOE 2008b). Like their cost, fuel cells will not be competitive until they show that they can last just as long as combustion engines. The weight of the vehicle and the storage of hydrogen fuel may also need to be improved (DOE 2008b, DOE 2009d). The current fuel cell systems in vehicles take up a lot of extra room compared to conventional gasoline engine systems (DOE 2008b). The current high economical cost of fuel cell vehicles is lightened by the large reduction in environmental cost. The clean reaction in a fuel cell only produces heat and water, resulting in large gains towards reducing pollution and helping the environment (DOE 2008c).

Flex-Fuel Vehicles [FFV]

FFVs contain specially designed engines and fuel systems which allow them to run ethanol-gas fuel blends of up to E85 in a single fuel tank (FuelEconomy.gov 2009c). Although E85 blends can be used only with FFV engines, regular gasoline commonly contains ethanol concentrations of up to 10% by volume (E10) to serve as an oxygenate; the oxygenate reduces engine knocking and ensures cleaner and more complete combustion (EIA 2007).

Historically, vehicle manufacturers do not charge extra for flex-fuel engines when compared to regular gasoline engine equivalents (Giametta 2006). However, it is common for a consumer to be forced to opt for a larger engine size if flex-fuel is desired in a particular vehicle model. According to the U.S. Department of Energy (DOE 2009e), the Chevy Express comes standard with a six cylinder, 4.3 liter (L) engine (mpg: 15 city, 20 highway). To get the Chevy Express in a flex-fuel model, a consumer must upgrade to an eight cylinder, 3.5 L engine (mpg: 13 city, 18 highway). Because of the vehicle purchase mandates of Federal Energy Policy Act, the U.S. Postal Service was forced to purchase 37,000 new flex-fuel vans which, due to their increased engine size, consumed 1.5 million additional gallons of gasoline when compared to the old fleet of standard gasoline engines (Kindy and Keating, 2008). In such situations, abiding by the 'letter of the law' clearly seems to undermine the 'spirit of the law' which was to increase efficiency and reduce dependency on foreign oil for gasoline..

Maintenance requirements of FFVs manufactured by General Motors (GM) and Ford do not differ from those of their gasoline counterparts, but other manufacturers may suggest that specific engine lubricants be used (Giametta 2006). The chemical structure of ethanol causes it to act as a solvent, making it harmful to certain materials within a standard engine (Heisner, N.D.). Thus, FFVs differ subtly from standard vehicles in their construction. According to Heisner (N.D.), potential variations of flex-fuel engines from regular gasoline burning engines may include:

- Either plastic or stainless steel fuel tank and fuel lines to avoid corrosion from alcohol.
- A larger fuel tank, fuel lines, and fuel injectors to accommodate the lower energy density of ethanol.
- A specialized fuel sensor to detect the fuel blend in the tank, along with a computer to adjust fuel use and engine timing based on the fuel blend.
- Specialty seals within the engine to accommodate the reactivity of traditional seals with ethanol.

The chemical differences between ethanol and gasoline result in the two fuels having different properties. Pure ethanol has an energy density of 23.5 megajoule per liter (MJ/l) (84,600 British Thermal Unit (BTU)/gallon)—compared to that of gasoline 34.8 MJ/l (125,000 BTU/gallon) (Davis and Diegel 2006). Thus, ethanol contains 32.5% less energy per unit volume than regular gasoline (Davis and Diegel 2006). Any blend of the two fuels will lead to a proportional reduction in energy density when compared to that of 100% petroleum (Roberts 2008).

The average fuel efficiency in both highway and city driving was tested by the EPA for 24 different 2009 flex-fuel models. In both driving applications, vehicles running on E85 were found to have 26.6% lower fuel efficiency than that of the same vehicles using gasoline (EPA 2007). Roberts (2008) points out that of the 24 different models tested, E85 fuel efficiency ranged anywhere from 68.3- 81.4% of that of the same model running on gasoline. Comparatively, the energy content of E85 is 71.95% that of regular gasoline. This 13% margin clearly indicates that some engines are better designed to burn E85 than others.

To better understand the discrepancy in mileage of different engines burning E85, one must understand that energy density is not the only characteristic that determines a fuel's ability to power an automobile. A fuel's octane rating determines the temperature at which it will ignite; the higher the octane rating, the higher the ignition temperature. Higher octane fuels are required in high compression sport engines; these high compression engines would cause low octane fuels to ignite prematurely because of the extremely high pressures that are contained within the engine's cylinders (Roberts 2008). Regular gasoline has an octane rating of 84, compared to the 101-105 rating of E85 (Roberts 2008).

The high octane rating of E85 allows this fuel to be used in a higher compression engine; such an engine can increase the efficiency of converting chemical energy to mechanical energy (Roberts 2008). Therefore, with a higher octane fuel a smaller, high compression engine could replace a larger standard engine with no noticeable loss of power. Unlike regular gasoline, E85 has the ability to burn more efficiently in higher compression engines, potentially making up for its relatively low energy density. These attributes are summed up in Table 2.

Table 2: Differences between gasoline and ethanol fuels.

	Gasoline	Ethanol
Energy Density (MJ/l)	34.8	23.5
Octane Rating	84 (regular), 91 (supreme)	101-105
Source	Crude oil (refined)	Fermentation of sugars

Unfortunately, E85 is not used in engines designed to exploit the high octane characteristics of ethanol. Flex-fuel engines are optimally designed to burn lower octane gasoline at the expense of ethanol efficiency. In a study conducted by the Southwest Research Institute (SWRI), the compression ratio of a flex-fuel engine was increased from 9.3:1 (standard flex-fuel engine compression) to 12.0:1 (high compression) in order to better take advantage of the high octane characteristics of E85 (SWRI 2009). The result was an 8% increase in efficiency in comparison to a standard flex-fuel engine (SWRI 2009).

Thus, a dedicated E85 vehicle would be far more efficient. However, it is the demand for the ‘flexible’ nature of the FFV that reduces its efficiency.

High compression engines are the best candidates for burning E85 efficiently. Concerns over losses of potential fuel efficiency in current FFVs are currently being addressed. Engine research and manufacturer, Ricardo, Inc. recently showcased a new “Ethanol Boosted Direct Injection” engine that adapts to its supplied fuel source by subsequently altering compression ratios, thus taking full advantage of the fuel’s octane rating (Roy 2009). Whereas current FFVs lose 30% of their efficiency when running ethanol, Ricardo’s engine is tuned to lose only 15-20% when compared to gasoline (Roy 2009).

Dual-Fuel Vehicles (Propane, Natural Gas, Hydrogen)

A dual-fuel vehicle (DFV) is similar to a FFV in that they have the ability to operate off of two different types of fuel. Unlike FFVs however, the fuels of DFVs have properties that do not allow them to be mixed in a single tank, requiring an auxiliary fuel tank to keep them separated (DOE N.D.). The most common DFVs have gasoline engines, along with an auxiliary fuel tank for natural gas, propane, or hydrogen (DOE N.D.).

No DFVs are available in the U.S. from auto manufacturers (CNGInterstate 2008). Rather, vehicles must be retrofitted to run off of two fuel sources, but the retrofit is costly. Assuming that a vehicle does not have a diesel engine or turbocharger, a compressed natural gas (CNG) dual-fuel retrofit kit for a six cylinder engine can be purchased for approximately $5,380, and there may be an additional charge of $2,000 for professional installation (CNGInterstate 2008). Dual-fuel retrofit kits include sensors which function to determine the correct quantity of alternative fuel needed in the engine, as well as maintaining the correct ignition timing (CNGInterstate 2008).

The only additional maintenance required for a retrofitted vehicle is replacing the fuel tanks, which may last about twenty years (CNGInterstate 2008). The safety of the vehicle is not compromised in the retrofit installation (NGVA 2006). In fact, the compressed natural gas tanks that are installed are actually stronger and safer than regular gasoline tanks (NGVA 2006).

DFVs may appeal to the consumer who is interested in running their vehicle on a cleaner alternative fuel source without being range-limited due to a lack of alternative fuel refilling stations. Likewise, fleet managers interested in extending the life of their vehicles may find certain DFVs attractive. For instance, multiple dual-fuel conversion companies claim that the lower combustion temperature and low level of contaminants in propane can lead to increased engine life (CNGInterstate 2009, Yugo-Tech N.D.).

FUEL SOURCES: PETROLEUM BASED FUELS

Crude petroleum is the raw material from which fossil fuels are derived. This petroleum is often trapped in layers of impermeable rock, and is accessed through drilling the rock and pumping it out (Ophardt 2003). Once the oil has been collected, different petroleum based substances are separated by fractional distillation, which essentially heats the oil to the separation points of its different constituents; each constituent can be collected at its separation point (Ophardt 2003). Gasoline is the petrochemical of greatest demand, so special refinement processes are used to produce as much gas as possible (Ophardt 2003). A fully refined barrel of crude oil yields about twice as much gasoline as diesel fuel, the second highest yielding fuel (Figure 3) (EIA 2009a).

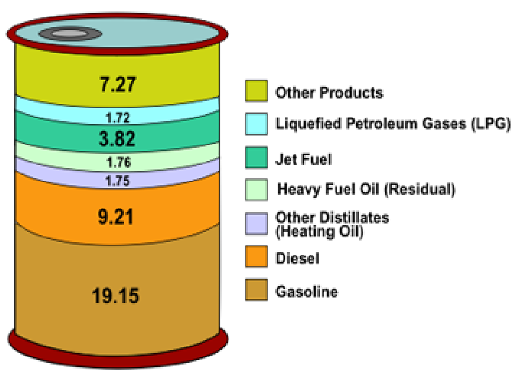

Figure 3: Crude oil allocation towards fuel production (EDinformatics 1999).

Gasoline as a Fuel:

Gasoline is currently the primary fuel source for automobiles (Dwyer 2006). This volatile mixture is traditionally derived from crude petroleum, a finite and polluting fossil fuel source; however, in recent decades concern about the finite and polluting nature of this fuel has increased (Ophardt 2003). As a result of the exploitation of a dwindling supply of petroleum, the cost of gasoline has been steadily rising. The convenience factor allows gasoline to maintain its stronghold as top transportation fuel, as widespread infrastructure and fueling stations have been available for decades.

The fluctuation in gasoline price per gallon can be attributed to the dynamics of supply and demand. Some sectors of American culture have had a renewed attraction to public transportation and reliance on personal mobility (walking and/or biking) which has shown a negligible reduction on the demand for gasoline (Root 1996). Unless a new, more reliable source of fuel becomes readily accessible to the public, there is little expectation for gasoline to show a significant drop in price (CBO 2008). Since gasoline is the primary fuel source in automobiles, this causes additional costs on the transportation sector.

The production processes and the vehicular combustion of gasoline emit harmful carbon emissions and other GHGs (methane, nitrous oxide, hydrofluorocarbons) (EPA 2005a, EPA 2009a,). Studies suggest that our climate change crisis has been directly linked to the rising output and accumulation of carbon dioxide (CO_2) in the atmosphere (IPCC 2005, UCSD 2002), suggesting that gasoline and other petroleum-based fuels contribute significantly to this escalating climate issue. This is an issue especially for the transportation sector, which is the second highest CO_2 producing sector, and the single largest consumer of petroleum (see Figure 4) (EPA 2009a).

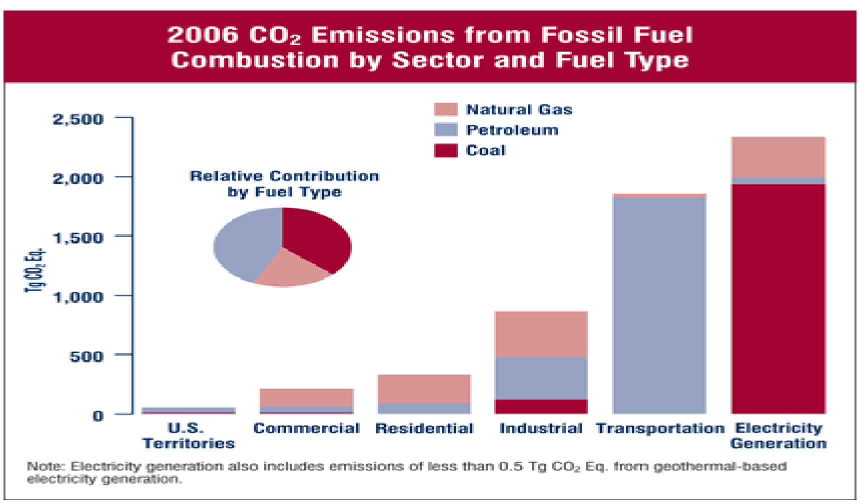

Figure 4: Emissions from fossil fuels consumed by various sectors (EPA 2009a).

In 2008 alone, the United States consumed an estimated 137.8 billion gallons of gasoline, the equivalent of approximately 377,534,246 gallons consumed per day (Naidenko 2009). According to rough calculations, that would mean Americans contribute around 3,349,696.14 metric tons of CO_2 emissions per day (EPA 2005a). As a result, the EPA has taken initiative to decrease CO_2 emissions, which includes an increased focus on areas with the worst smog and pollution levels (EPA 2009b). A 1995 amendment to the Clean Air Act requires such problematic localities (including Baltimore) to implement the use of reformulated gasoline (EPA 2009b). Reformulated gasoline contains oxygen-rich chemicals for cleaner burning (Gustafson 2008). The Maryland Clean Car Act of 2007 will also help curb CO_2 emissions, as Maryland will be adopting California's stricter emissions standards starting in 2011 (MDOE 2009). However, these are short-term solutions to a larger problem.

Gasoline is still the most widely available transportation fuel, and comparatively cheap relative to renewable sources of energy. Although U.S. crude oil production is expected to increase from 2009 to 2010 for the first time since 1991, the price at the pump is also expected to rise (EIA 2009d). This will likely cause increased interest in hybrid vehicles, and even conservative estimates are predicting hybrid sales to triple by 2015 (J.D. Power, 2008).

Diesel as a Fuel:

The diesel engine was invented in the 1890s by Rudolph Diesel. Before petroleum based diesel was developed, diesel engines ran on vegetable based oils. At the 1900's World's Fair, a diesel engine that ran on peanut oil was unveiled (PCBio 2009). However, once petroleum based diesel fuel was widely available and cheap, it became the choice fuel in diesel engines. T3his change in fuel allowed diesel engines to become very powerful and more efficient (PCBio 2009).

Over a century has passed since Rudolph Diesel's invention, and the diesel engine has been enhanced greatly during that time. Older diesel engines mixed fuel and air in a pre-combustion chamber before injecting the mixture into the cylinders, which resulted in low efficiency and high emissions (DOE 2003). Newer engine designs use computers to precisely time when the fuel is injected into the cylinder to optimize ignition (DOE 2003). This major improvement resulted in a more complete burning of the fuel; more power delivered, lowered emissions, and increased fuel economy (DOE 2003).

Both gasoline and non-vegetable diesel are petroleum-based fossil fuels, with their own inherent strengths and weaknesses. As a fuel, diesel is a more complex material, containing more carbon atoms, making it a heavier, denser fuel than gasoline (DOE 2009f). Diesel and gasoline also differ in that diesel has a higher boiling point and freezing point than gasoline (DOE 2009f). Arguably, the most important difference between gasoline and diesel fuels in regards to their functionality in engines is the combustion ratio at which they explode. Diesel fuel will self-ignite when it reaches a certain level of compression, eliminating the need for the spark needed in gasoline engines (DOE 2009f). Diesel also has a higher energy density than gasoline, containing about 155 MJ/gallon, compared with 132 MJ/gallon (Brain 2000c). It is important to note that in a modern diesel engine, the air is compressed and then the fuel is injected, making a higher compression ratio than what can be obtained in a gasoline engine (Brain 2000c). This is possible because diesel fuel has greater energy content relative to gasoline; the likelihood that diesel particles will react with the oxygen in the cylinder is also greater, which is why no spark is required (Brain 2000c).

Diesel and gasoline are both extracted from crude oil. However, the refining process used for crude oil yields approximately twice as much gasoline as it does diesel fuel (EIA 2009a). This makes diesel fuel less plentiful than gasoline (Figure 3). As demand for diesel increases, its costs have increased as well (EIA 2009a). In 2007, about 95.5% of the diesel used in the U.S. was refined in the U.S (Hofman 2003). Of the crude oil used, about 66% was imported (Hofman 2003).

The cost to the consumer for diesel fuel is generally higher than for gasoline. Part of the recent increase in the price of diesel can be attributed to the U.S. transition to ultra-low sulfur diesel (ULSD), which costs more to refine than low sulfur diesel (Cullen 2006). The main goals behind the transition to ULSD are to reduce sulfur emissions and to allow for better more advanced emissions control systems to function without being degraded by sulfur (EPA 2009b). ULSD contains about half the average sulfur content of gasoline: 15 parts per million (ppm) in diesel versus 30 ppm in gasoline (NPRA 2009). Diesel is in high demand in countries with rapidly developing infrastructure, like China and the U.S. In addition, diesel engines are substantially more powerful than gasoline, and generally about 30-35% more fuel efficient (FuelEconomy.gov 2009d).

The other costs associated with diesel fuels are the environmental impacts of its use and the comparative cost of engine maintenance. Environmentally, diesel has its ups and downs. Diesel releases more CO_2 per gallon of fuel consumed than gasoline (22.2 lbs/gal in diesel versus 19.4 lbs/gal in gasoline) (EPA 2005b). Therefore, although more CO_2 is released per gallon, the increased mileage efficiency of diesel results in less CO_2 released per mile traveled (EPA 2005c). Due to the higher cost of refinement for diesel, it has been suggested that even though it releases less CO_2 per mile, the amount of CO_2 actually created may be offset during its production (Monahan 2005).

Diesel engines outperform gasoline engines in terms of engine life and comparative cost of maintenance that is due to their lower running temperature and the greater lubricity of the fuel (Brain 2000c). Since diesel burns at a lower temperature than gasoline, engine wear is greatly reduced in a diesel engine. Conversely, replacement of fuel filters, gaskets, and certain other rubber components may occur more often when running a diesel/biodiesel mixture, than in a standard gasoline engine (Brain 2000c).

Diesel vehicles also can make use of hybrid technology. Hybrid diesels exist in two forms: the conventional type where the vehicle runs off either the diesel engine or electricity from a lithium ion battery or, vehicles with turbine driven diesel engines which charge a battery that runs the vehicle (Neuman 2007). Right now, diesel hybrids of the conventional (non-turbine) type are only found in buses, which offer about twice the fuel mileage or efficiency of diesel alone. The turbine-hybrid-diesels are cleaner and offer even better mileage. The New York City Transit Authority runs about 600 diesel/electric hybrids, and has been testing turbine diesel buses with the hopes of potentially purchasing more to use (Neuman 2007). Locally, MTA is already running 30 conventional hybrid buses and is expecting to be running about 600 by 2014 (MTA 2009).

Compressed Natural Gas/Liquid Natural Gas as a Fuel

Natural gas is not a single pure material; it is a mixture of gases and can be comprised of up to 90% methane (NaturalGas.org 2004a). The remaining portion of the gas is made up of many other hydrocarbons, including propane and butane. The geological conditions surrounding the formation of natural gas are very similar to that of oil. Over tens of thousands of years, decaying organic matter is squeezed beneath Earth's surface. The heat from inside Earth, along with the pressure from its surface, breaks down the carbons to form natural gas or oil. Natural gas and oil can form at the same location. The varying temperatures and pressures determine whether oil or natural gas is to be formed. The natural gas is trapped underground by an impermeable rock layer, thus "capping" the oil reservoir. The gas is then recovered from the earth by simply drilling through the impermeable rock layer and collecting it as it escapes through the fissure in the rock (NaturalGas.org 2004a).

Natural gas was first used to heat homes in Britain in 1785 (Naturalgas.org 2004b). It was not until the 1920s that a pipeline structure was first considered for the U.S. There was a boom in natural gas infrastructure throughout the 1960s because of an increase in building technology during and after World War II (Naturalgas.org 2004b). Natural gas was first explored as an alternative fuel for vehicles during the gas crisis of the 1960s and 1970s, and the infrastructure for this fuel has been growing ever since. An increased demand for natural gas over the last 40 years has led to natural gas pipelines running underground throughout the country. Reservoirs deep inside Earth are still being found, which may lead to a further increase in infrastructure. As a motor fuel, natural gas can either be liquefied (LNG) or compressed (CNG) (IANGV 2007). LNG is created by cooling natural gas to a temperature of -260°F. It is the preferred form for storage and transport of natural gas; its volume is 600 times less than the gaseous form (EIA 2009c).

Currently, there are over eleven hundred CNG fueling stations around the country, but only half are available to the public (NGVA 2006). There are no CNG fueling stations near the University. The current price for one gallon of gas equivalent of CNG is around $2.20, but prices vary depending on location (NGVA 2006). Recently, the price of natural gas has been falling due to better technologies that make it easier to extract the gas (NGVA 2006). There are numerous pipelines that carry natural gas all over the country (EIA 2009b). Although there is currently only one CNG vehicle on the market, the Honda Civic, natural gas retrofits are becoming more readily available to the consumer.

Any vehicle can be retrofitted to run on CNG. When a vehicle runs on natural gas, there is no difference in the operation of the vehicle. Natural gas is a combustible fuel just as gasoline is; therefore, any vehicle can be retrofitted to run on natural gas as long as there is a retrofit ‘kit’ available for the vehicle in question. A vehicle can either be dedicated to natural gas or be “bi-fuel” and run off of both natural gas and regular gasoline. The warranty of vehicles is not affected as long as the retrofit is EPA approved (Transco Energy 2009). In order for a retrofit to be EPA approved, it must be completed by persons certified by the EPA to complete natural gas conversions (Transco Energy 2009). One six-cylinder conversion kit costs around $3,180, along with $2,200 for the gas tanks, and a $2,000 installation (CNGInterstate 2008). Thus far, there have been no reports of adverse effects on vehicles from retrofitting. In fact, the only additional maintenance on a retrofitted vehicle is replacing the fuel tanks which, on average, last 20 years (CNGInterstate 2008). In contrast to some expectations, the safety of the vehicle is not compromised through the retrofit installation (NGVA 2006). In fact, the CNG tanks that are installed are actually stronger and safer than regular gasoline tanks (NGVA 2006). In the event of an accident, there would not be an “explosion” of the tank; the natural gas would simply leak into the atmosphere. The DOE provides a list of many companies that perform certifications, retrofits, and installation of on-site CNG dispensing and storage units. Should Towson University wish to install CNG fueling infrastructure on campus, there is a natural gas pipeline that runs directly through the heart of Maryland, which is owned by the Transcontinental Gas Pipeline Company (EIA 2009b). This natural gas pipeline makes CNG a feasible alternative fuel source for the area. According to the EPA, there is a 70-90% reduction in particulate matter emissions and up to a 60% reduction in nitrogen oxide emission from natural gas fuel vehicles (EPA 2009d). This extreme reduction in emissions makes the CNG vehicle a very attractive option for a “green” fleet.

Recently, a very large natural gas reservoir has been discovered in the Marcellus Shale, a rock formation located around the Appalachian Mountains. This shale is located in Ohio, West Virginia, Pennsylvania, New York, Maryland, Kentucky, Tennessee, and Virginia (Geology.com 2009). Recent estimates suggest the reservoir holds around 500 trillion cubic feet of natural gas which would be enough to provide the entire U.S. with natural gas for about two years (Geology.com 2009). If this source of gas were to be tapped, it is in close proximity to the Baltimore area and could lead to extremely cheap prices of natural gas for the region from its limited transportation costs. The possibility of this future endeavor would obviously influence the decision of whether or not to consider natural gas vehicles. The potential environmental impact of extracting natural gas from the Marcellus Shale plays a factor in the decision of whether or not to extract. The extraction process consists of a technique called hydro-fracking, where highly pressurized water is injected and mixed with chemicals into the shale, allowing an easy outflow of gas (Mouawad 2009). This is a concern to people who live in the area of the Marcellus Shale because of groundwater contamination issues.

CNG has been a viable fuel source for years. Many city mass transit and heavy duty vehicles use CNG in preference to gasoline because of the lower emissions and longer engine life (CAI 2009). Adoption of an alternative fuel depends on the willingness to develop infrastructure and share costs. Infrastructure is needed if a type of fuel source is to become generally accepted. One excellent example is the local use of CNG by the Baltimore Gas and Electric (BGE) Company. They had invested and installed several filling stations around the Baltimore area to be used by their Fleet. Industrial development of infrastructure could have allowed local governments and businesses to piggy back off another company's stations, making CNG a more economical and environmentally friendly fuel choice. Unfortunately, BGE has phased out its use of CNG to fuel its vehicles, dismantling much of its fueling infrastructure because the anticipated interest from local and state agencies did not occur and the costs were more than they wanted to bear alone (Nichols and Aker 2009). This, in turn, has reduced the feasibility of CNG as a alternative fuel option for other governments and organizations in the Baltimore area. However, if infrastructure is already in place, CNG as a vehicle fuel is a very good alternative to conventional gasoline and diesel.

Filling stations for natural gas (both CNG and LNG) are very similar to conventional gasoline stations. The driver can just pull up to the station, connect the nozzle to the filling cap and refuel (IANGV 2008). From the consumer's perspective, CNG is currently not a viable option. Currently, a citizen cannot pull up to a gas station in the area and fill up their car with natural gas. Home fueling units are available, but this limits the range of the vehicle since it must return home to fuel (Consumer Energy Center 2009). These household units tie into the home's natural gas line used for heating and cooking, and compress it to be pumped into a vehicle. But even if a CNG fueled vehicle is still a good choice, another problem arises; the CNG Honda Civic is the only one vehicle available to consumers that runs on natural gas (DOE 2009g). Currently, this car is only available to California residents because the state has CNG infrastructure available to the public.

The current overall lack of infrastructure and vehicle availability makes the future for natural gas as a vehicle fuel bleak. At this point and time, it seems unlikely that it will become the next fuel for America. It seems natural gas will be only used by commercial and public transportation as a cleaner "quick fix" solution to the overuse of gasoline. However, if public demand grows leading to an increase in infrastructure, natural gas could prove to be a viable short term alternative.

Propane as a Fuel:

Propane, a by-product of oil refining and natural gas production, is a very economical and clean alternative fuel that can be used to power anything from vehicles to lawn mowers. Like any of the alternative fuels, there are plenty of benefits to switching from a conventional fuel to the alternative fuel, but there are also costs associated with switching. Propane is currently being used primarily by the petrochemical industry and for residential and commercial uses (DOE 2009h). Since propane is used as a heating fuel, the price of propane increases during the winter season and decreases during the summer, unless a set price is guaranteed. If no set price is guaranteed, propane can end up being more expensive than gasoline during the peak seasons. Propane is cheapest near a natural gas supply source; it is being used for transportation in states such as Texas, where natural gas is a major resource and therefore propane is available (DOE 2009h). One benefit of propane is that most of the propane currently used for transportation is produced in the U.S., thereby reducing our reliance on imported propane.

Propane is separated from methane (natural gas) and ethane by boiling the liquid components, turning them into gases (MD EA 2009). As the gases travel upwards, they are cooled. Depending on how quickly they revert to liquids, compounds can be separated based on their different characteristics (MD EA 2009).

Propane is listed as an alternative fuel under the EPAct of 1992 with more than 10 million propane fueled vehicles being used worldwide (DOE 2008d). Propane and gasoline fueled vehicles use a similar engine: a spark to ignite the gasoline or propane, which leads to combustion and power production (DOE 2008d). The majority of these vehicles are in Europe, where there are approximately seven million propane vehicles (DOE 2009h). Countries using the most vehicles running off propane include South Korea, Poland, Australia, and Russia (DOE 2009h). From 1997 to 2008, South Korea's propane vehicle fleet grew by 1.8 million, putting it at 2.2 million vehicles (DOE 2009h). When propane and gasoline are used in similar light-duty, bi-fuel vehicles, propane results in a 98% reduction in toxic emissions, which is one of the main incentives for propane vehicles (PERC 2008a).

Currently, there are no light-duty propane vehicles in production by manufacturers in the U.S.; however, Ford and GM offer propane vehicles in Europe and Australia (DOE 2009h). There are several companies that are able to convert vehicles to run off propane fuel in the U.S. Roush Industries is one such company and they currently convert F-150 pickups to dedicated propane use and are working on converting F-250 and 350s as well (PERC 2008b). One of the main drawbacks in the U.S. with propane is vehicle availability. A 'traditional' vehicle must be purchased, and then converted to propane. Conversions to propane in the U.S. have to meet EPA approval which requires a conversion by a licensed propane conversion technician (MD EA 2009). This also means that any mechanic who wants to work on the truck needs to be certified. These conversion and safety provisions increase the costs of owning a propane vehicle.

Propane has an additional benefit of a high octane rating of ranging from 104-112, an increase of about 17% from the normal gasoline octane rating of 87% (DOE 2008d). This combined with the fact that propane contains less contamination than gasoline and lower amounts of carbon, have been shown to double engine life relative to gasoline engines (DOE 2008d). Therefore, a major incentive for conversion is that the vehicle will not have to be replaced as quickly because the engine is able to last up to twice as long as a gasoline engine. This can help to offset the costs of converting a fleet, which can run from $4,000-12,000 per vehicle (DOE 2009h).

An example of a working propane fleet in the U.S. can be found in Texas, which will be adding 882 propane vehicles for schools (245 buses), state agencies, and local governments (637 light and medium duty vehicles) to their existing fleet (M. Williams 2009). This expansion comes as a result of being awarded a total of $50.4 million from the American Recovery and Reinvestment Act funding through the Department of Energy's Clean Cities grant program (M. Williams 2009). There are already more than 1750 propane school buses operating in Texas (M. Williams 2009). The Texas grant also includes almost $3 million towards building thirty-five propane refueling stations (M. Williams 2009).

In many parts of the country, including Maryland, the lack of propane refueling stations is a major drawback for propane use in vehicles. There are about 3,400 propane fueling stations in the U.S., most open for the public, but there are only 15 liquid petroleum gas (LPG) stations in Maryland (MD EA 2009). A LPG filling station can cost up to $25,000 for a basic filling station with a 500 gallon tank (DOE 2009h). A more sophisticated station with a 15,000 gallon tank costs around $175,000 (DOE 2009h).

Since there are so few filling stations in Maryland, propane would probably not be feasible in Towson University's Fleet unless it was used as a bi-fuel, because fill up would be off campus. However, the Fleet vehicles, such as trucks and vans, that are gasoline powered that are generally restricted to campus could be converted. This would increase the engine life, lower repair costs, and drastically lower harmful emissions.

FUEL SOURCE: BIOMASS FUELS

Corn-based Ethanol (Starch Ethanol)

All resources have a price, and corn-based ethanol is no exception. As a component of the most popular alternative fuel in the U.S., ethanol blended fuel is expensive in comparison to traditional gasoline. Assuming that corn prices are around $2.00 per bushel, E85 corn-based ethanol costs $1.00-1.06 (2005 dollars) per gallon to produce, compared to an average conventional gasoline price of $2.27 per gallon in 2005 (EIA 2007). Moreover, the farmers who are producing ethanol cannot afford to burn it to make it; therefore, energy from petroleum is not saved because it is used during the production of corn to produce ethanol (Segelken 2001). A liter of E85 has an energy equivalency of 0.80 liters of gasoline (Clean Air Trust, 2008). Thus, drivers using an ethanol and gas blend will pay more to fuel their car than they would if they were using a 100% gasoline in a conventional vehicle (Pollick 2009).

The allocation of agricultural investments into corn-based ethanol production indirectly affects the overall cost of food, specifically livestock feed and production (EIA 2007). In order to meet the demand for corn-based ethanol, farmers will need a lot of land to grow corn. As more land is used to grow corn, farmland available for other food products will decrease resulting in an increase in food costs (Economist Newspaper 2007). Because corn in the U.S. is often used to feed livestock, meat prices are also expected to increase since corn is being diverted to be used for fuel instead of food (Segelken 2001).

Ethanol is a more sustainable resource than gasoline, but still detrimental to the environment. In areas which cannot depend on rain fed production, corn requires a lot of water to grow which can put a strain on the water supply (Segelken 2001). Irrigation used in corn agriculture depletes ground water faster than the natural recharge rate (Segelken 2001). Furthermore, areas with little agriculture are now starting to grow corn for ethanol production which may also put stress on the water supply (National Academies 2007).

Agricultural land used for corn production erodes land surfaces faster than it can repair itself; therefore, soil erosion is a harmful byproduct of the production of corn-based ethanol, causing an increase in nutrient and sediment pollution in waterways (National Academies 2007). Excess nutrient and sediment pollution from agricultural run-off can also lead to anoxic and anaerobic aquatic conditions, disrupting ecosystem interactions (Rayloff 2004).

In terms of total energy required and environmental costs of corn-based ethanol, it takes 70% more energy to produce ethanol from corn than is actually derived from burning the ethanol produced; thus, the overall energy input is greater than the energy output, leaving a net energy loss (Segelken 2001). The burning of coal, oil, and natural gas to harvest and distill corn would also contribute to air pollution (Knufken 2009).

Cellulosic Ethanol

Cellulosic ethanol is a type of biofuel derived from the fermentation of lignocellulosic material from plant matter. In most cases, highly productive plants such as switchgrass, *Panicum virgatum*, and *Miscanthus giganteus*, are selected for the production of cellulosic ethanol; however, wood chips and lawn clippings are also popular materials to use (DOE 2009i). Producing cellulosic ethanol costs about $1.80 per gallon gasoline equivalent (GGE) compared to E85 corn-based ethanol, which was produced in 2005 for about $1.00 per GGE (Energy and Climate 2009, EIA 2007). This alternative fuel will retail for $2.70 per GGE (Energy and Climate 2009). These prices have been adjusted to reflect the gasoline equivalent since one gallon of ethanol contains approximately two-thirds of the energy of a gallon of gasoline (EIA 2007).

Lignocellulosic materials such as switchgrass are much more efficient than corn in terms of the amount of energy that is returned per hectare (Biello 2008). A scientist working for the USDA agricultural research service reported that yields from switchgrass fields would deliver an average of 13.1 megajoules (MJ) of energy from ethanol for every 1 MJ of energy from petroleum consumed in the production and harvesting (Biello 2008).

Figure 5 shows retail fuel prices for gasoline and many alternative fuels over the past nine years. From the graph we see that corn based ethanol, in the form of E85, comes close to matching gasoline prices between December 2003 and April 2004, but never dropped below the price of gasoline. In fact, E85 seems to mainly follow the trends in gasoline prices at a slightly higher average price. This may be due to the fact that E85 is blended with gasoline and is therefore influenced by oil prices (Biello 2008). Cellulosic ethanol, which is not included in the figure, is produced solely from lignocellulosic materials and will not be influenced by fluctuating oil prices (Biello 2008).

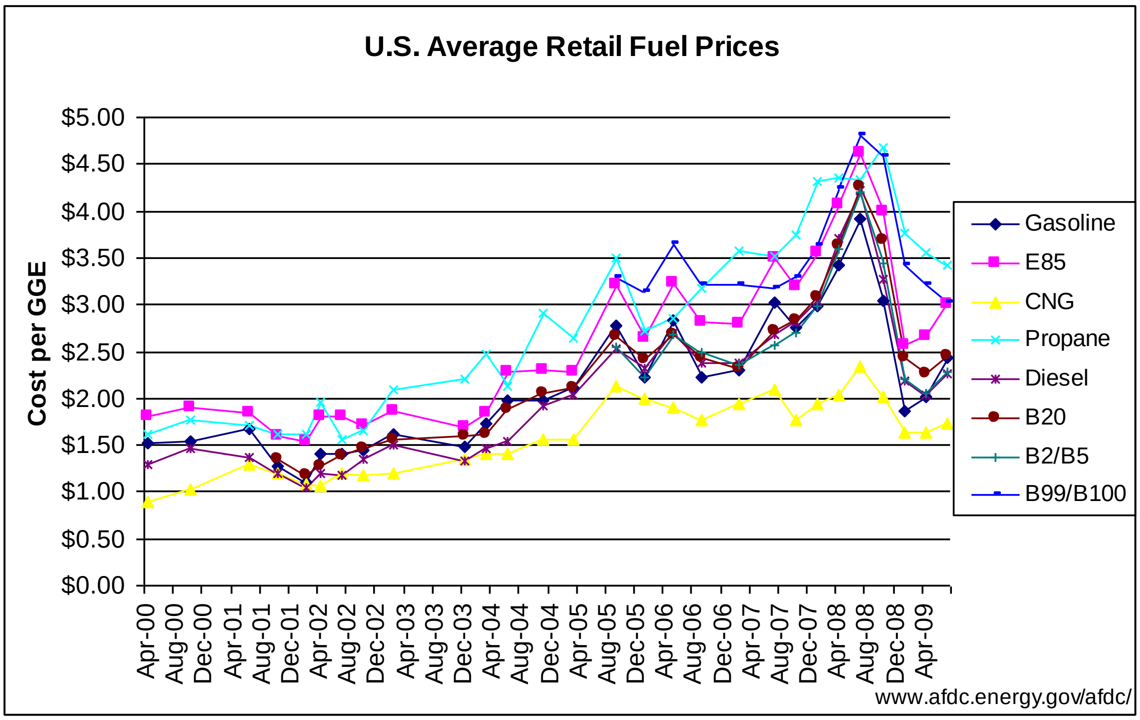

Figure 5: U.S. Average Retail Fuel Prices from April 2000 to April 2009 reported in gallons of gasoline equivalent. E=ethanol blend with the percent ethanol noted by the number, B= Bio-diesel/petroleum diesel mixtures with the percent biodiesel noted by the number (DOE 2009n).

There are two methods for the production of cellulosic ethanol (DOE 2009i). The first method involves pretreatment of the raw plant matter to remove the unnecessary components of the plant in order to speed up the hydrolysis of the cellulosic material. This is then followed by an acid hydrolysis to break the cellulosic material into sugars that is then fermented and distilled to produce alcohol (DOE 2009i). The second method involves partially combusting the raw material under controlled conditions to form a gas made up of carbon monoxide (CO), CO_2, and hydrogen (DOE 2009i). The gas is then fermented using either a catalytic reactor or a microorganism bacterium which "ingests" or "consumes" gases to produce ethanol and water (DOE 2009i).

The difficulty with cellulosic ethanol lies in the breaking down of the lignocellulosic materials into sugars (BlueFire Ethanol 2009). Lignocellulosic material is very resistant to decomposition and the extraction of the sugars may be challenging, which may lead to a longer processing time (BlueFire Ethanol 2009). More recently, however, concentrated acid hydrolysis technology is being used to convert cellulosic waste material to ethanol which will help speed up the production process while helping cities manage landfill waste (BlueFire Ethanol 2009). BlueFire, a company on the leading edge of this technology was recently awarded funding from DOE to construct a commercial scale cellulosic ethanol production facility. DOE is partially funding the construction of a total of six cellulosic bio-refineries which will be located on or near landfills in markets with the highest demand for ethanol, with efforts in reducing environmental and economic costs (BlueFire Ethanol 2009).

Cellulosic ethanol is one of the more attractive biofuels for several reasons. It is a more sustainable alternative to both conventional gasoline and corn-based ethanol (Biello 2008). The plant matter used to produce ethanol is abundant and renewable. The University of Maryland College Park has been investigating the possibility of utilizing switchgrass to create renewable energy systems for farms, with promising results thus far (Staver2009). Switchgrass is a common plant species used in the construction of riparian buffer zones due to its excellent ability to trap, store, and retain nitrogen (Staver 2009). Nitrogen is a fertilizer and byproduct of agricultural production that also has adverse affects on water quality in high concentrations (Biello 2008). These grasses can be harvested by cutting at ground level, and used to produce fuel for heating and maintaining the farm, ultimately reducing costs and increasing the sustainability of the farm while decreasing its impact on the environment (Staver 2009). Since the root system of switchgrass is extensive and the plants regenerate from the roots, the fields can continue to be harvested for 10-20 years once established (Staver 2009).

Cellulosic refineries can also help to manage overflowing landfills by using municipal waste as a source of cellulose (BlueFire Ethanol 2009). Cellulosic ethanol is also a very clean fuel in terms of the amount of carbon that is consumed versus the amount that is released. Switchgrass, for example, will store enough carbon in its root system to offset approximately 94% of the GHG emitted during production, harvesting, and consumption of the ethanol fuel produced from the harvested portion (Schmer et al. 2008). Figure 6 shows the percent displacement of GHG emissions per harvest year by replacing conventional gasoline with cellulosic ethanol made from switchgrass. Data was recorded from ten different switchgrass fields used for ethanol production. The minimum displacement of GHGs per field is shown by the gray bars, the average displacement per field is indicated by the light blue bars, and the maximum displacement is shown by the green bars. A displacement of 100% means that the switchgrass field is taking as much GHG from the atmosphere as it is contributing to it. If it's greater than 100%, it means that the field is taking more GHGs out of the atmosphere than it is contributing during both production and consumption. This percentage takes into account the amount of GHGs released to the atmosphere during the establishment process, harvesting the grasses, refining the grasses to a fuel, and consuming the fuel in an engine.

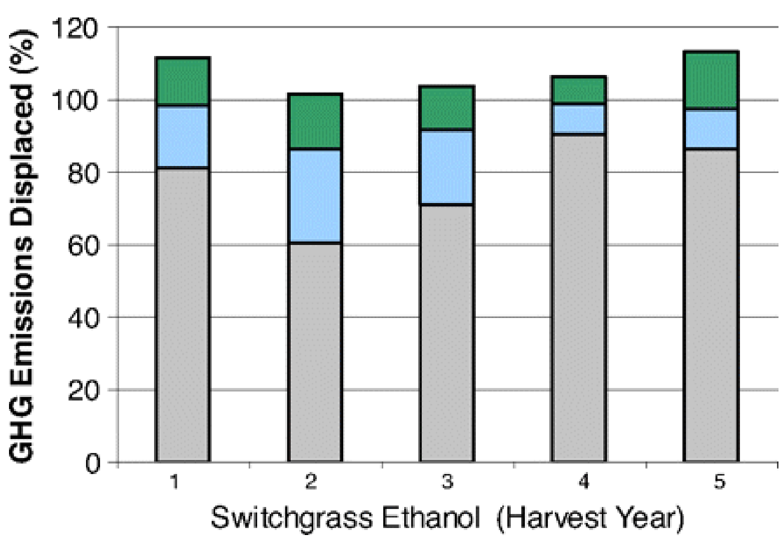

Figure 6: Estimated Percent Displacement of GHG Emissions by Replacing Conventional Gasoline with Cellulosic Ethanol from Switchgrass (Schner et al. 2009).

Green Gasoline

In addition to E85 fuels, which still rely on conventional gasoline, recent research in alternative fuels has led to the development of a new liquid fuel that is "identical to standard gasoline" (NSF 2007). Green gasoline, as a biomass fuel, can be considered an alternative to both corn based ethanol and soy based biodiesel because it is not derived from human food based feedstocks (Hira & Guilherme de Oliveira 2009, NSF 2007). Green gasoline, also known as a bio-oil or bio-gasoline, is considered a second-generation biofuel (ethanol being a first generation biofuel) because it is produced sustainably from biomass feedstocks (Inderwildi & King 2009). It is derived from non-food sources and agricultural residues such as the leaves, stems and husks of crops, industrial and forestry byproducts such as wood chips, non-food plants, and grains like switchgrass (Inderwildi & King 2009, NSF 2007), municipal solid waste, animal waste and aquatic plants and algae (Demirbas et al. 2009, Asadullah et al. 2007).

Green gasoline has many advantages over other alternative fuels as a result of its ability to be directly integrated into existing infrastructure. Its chemical composition is so similar to that of petroleum based gasoline after the catalyzation process that this new fuel can easily replace conventional gasoline (Asadullah et al. 2007, NSF 2007). Such chemical similarities could result in an uncomplicated adaptation of existing refineries, pipelines, vehicle engines, and transportation methods (NSF 2007, Ong & Bhatia 2009). Major strides have been made in pyrolysis and catalytic cracking, the processes by which biomass is converted to a useable substrate for green gasoline production. Recent advances indicate only minor modifications may be necessary to implement the technology in current refinery processes (Ong & Bhatia 2009). Cost of modification to infrastructure and for mass production of the fuel is unknown because of this new technology. Likewise, current gasoline vehicle engine systems can also be utilized with green gasoline (Ong & Bhatia 2009). The benefit of being able to use current infrastructure is appealing and could allow for easy transition to this new fuel.

GHG emissions are reduced by an estimated 85% and energy input remains low in the processing of biomass hydrocarbons (Gevo, Inc. 2009). The low energy inputs required in the production of green gasoline results in a higher net BTU energy output content (95,000-112,000 BTU/gallon) than starch-based ethanol (E100) (76,000 BTU/gallon) (Gevo, Inc. 2009). Vehicles running on green gasoline will be more powerful than those that run on E85, a current issue with flex fuel vehicles. Green gasoline has significantly lower GHG emissions than conventional gasoline: 15,000 grams (g) CO_2/million BTU of fuel and 98,000 g CO_2/million BTU of fuel respectively (Gevo, Inc. 2009). Since green gasoline is derived from plant materials it is important to note that CO_2 is removed from the atmosphere as the plant is growing which will further impact calculated emissions.

It is important to note that the relatively new development of green gasoline means that the costs of production and distribution, once the technology is established, are not known. Gevo Inc. predicts that the production cost of green gasoline is expected to be slightly more expensive ($/gallon) than ethanol but less expensive than conventional gasoline (Gevo Inc.2009).

Not only can green gasoline be used in automotive vehicles, but studies suggest that it may also be used as an alternative to conventional jet fuels (Gevo, Inc. 2009). While experimenting with production and utilization of biomass hydrocarbons, Gevo Inc. has successfully synthesized and tested a jet fuel blend-stock (Gevo, Inc. 2009). This is a major advancement because most alternative fuels have not been found to be as powerful as conventional fuels (Ebert 2008). Since jets require high energy output from their fuel, the fact that green gasoline has the ability to be used as a jet fuel shows that it has as much power as conventional gasoline. Using green gasoline instead of jet fuel could have significant environmental benefits because of the fuel inefficiency of jet fuel. This offers a greater advantage for green gasoline and could benefit the advancement of green gasoline technology and implementation.

Green gasoline and biomass fuels in general could secure future energy independence (Demirbas et al. 2009, Ong & Bhatia 2009). While fossil fuel energy sources are non-renewable and rely on foreign markets, biomass is renewable and can be sustainably produced in local economies (Demirbas et al. 2009, Ong & Bhatia 2009). Likewise, global economies can benefit, especially countries that are developing may be able to build an economy based on green technologies through use and distribution of biomass fuels and feed stocks (Demirbas et al. 2009, Hira & Guilherme de Oliveira 2009). Turning biomass fuels into an industry could give developing countries a market in which they can sell renewable fuels.

There is debate as to whether or not using biomass will affect biodiversity. The use of biomass byproducts is beneficial from a human standpoint because it does not tap into our food sources; however, using waste material that would ordinarily be recycled through decomposition does disrupt nutrient cycles in nature (de Pous 2008). Intercepting natural recycling processes could disrupt carbon, nitrogen, and phosphorous inputs and outputs in ecosystems with unknown consequences from these disruptions (de Pous 2008).

Although current engine systems could accept green gasoline with no problem, conventional gasoline cannot be used simultaneously, which is unlike FFVs because they can use any acceptable blend at any time. A vehicle running on green gasoline or conventional gasoline would need its engine flushed before the other fuel type could be used (Hira & Guilherme de Oliveira 2009).

Advances are slow in developing and improving green gasoline production. Technological studies are still being done to find the best process for deriving fuels from biomass which means that the estimated time until the institution and utilization of green gasoline on the market could be another 5-10 years, if not more (NSF 2007, Regalbuto 2009). Green gasoline is a new technology which may be on the market in future years.

Biodiesel

Biodiesel is a renewable fuel made through a chemical process which converts plant and animal oil and fat into a usable fuel. Chemically, biodiesel is a methyl ester: a long, fatty acid chain with an alcohol attached (NBB 2009a). Transesterification of vegetable oil and methyl alcohol in the presence of a catalyst creates glycerol and a methyl ester (NBB 2009a). Methyl ester, or pure biodiesel, can be used in any diesel-fueled vehicle, or can be mixed with petroleum based diesel fuel to create a blended biodiesel fuel. A wide range of biodiesel fuel types are currently available and are named by the percent of biodiesel it contains. For instance B100 would be 100% biodiesel whereas B5 would only have 5% biodiesel and 95% petroleum diesel, a blending of fuels similar to the various ethanol and gasoline mixtures. In many climates it is advantageous to blend biodiesel because pure biodiesel will begin to thicken and gel around 30° F (Hofman 2003). By blending with petrol-diesel, the temperature at which gelling can occur drops because diesel fuel has a lower thickening/gelling temperature. This is beneficial because a blended fuel can be used in colder climates without running the risk of gelling. Also, to prevent gelling of biodiesel in cold temperatures, a fuel line heater can be added to the vehicle (Hofman 2003).

Biodiesel is a cleaner burning alternative fuel to petroleum based diesel fuel (PCBio 2009). It is refined from various vegetable oils and fats instead of crude oil, which may be able to help reduce the dependence on foreign crude oil (PCBio 2009). Biodiesel emits almost 80% less CO_2 than petroleum-based diesel and has no sulfur content, whereas even ULSD has 15 ppm sulfur (BBio 2009). Since biodiesel isn't produced in high quantities just yet, it is more expensive per gallon than petroleum-based diesel, but a change in demand and production could alter this; as more producers of biodiesel enter the market, competition will eventually lower prices (BBio 2009). Locally, the non-profit co-op Baltimore Biodiesel is selling their B75 for around $3.00 per gallon (BBio 2009).

There are no serious modifications needed to run a petroleum diesel engine on biodiesel, but it is suggested that fuel lines should be replaced when switching to a biodiesel mixture higher than B20. Biodiesel is a solvent that tends to break down the rubber fuel lines over time, so switching to fuel lines made of a synthetic material is suggested (Hofman 2003). Since biodiesel functions as a solvent, older vehicles may have to replace fuel seals and other rubber components that can also deteriorate (Blair 2009). Fuel filters may also need replacement soon after making the switch to biodiesel. As a solvent, biodiesel tends to clean out accumulated deposits from engine buildup. This can clog filters and cause poor engine performance (Blair 2009, Hofman 2003).

In 2006, San Francisco's Mayor Gavin Newsom directed City officials to increase their use of biodiesel fuel in the city's fleet (Lubinski 2008). San Francisco's Municipal Transportation Authority (MTA) has started to transition its entire fleet of diesel vehicles to run on B20. The city has performed small tests on 40 buses by using B20 for an extended period of time to make sure there were no problems with the fuel or the efficiency of the diesel engine (Lubinski 2008). After the test period showed no problems, the city began using B20 in 600 vehicles (Lubinski 2008).

Increasing the use of biodiesel has now become the better environmental and economical decision in some states. North Dakota uses about 165 million gallons of diesel fuel per year. Of those 165 million gallons, about 85 million gallons are used for farm equipment in crop production. In 2001, about 2.1 million acres of soybeans were produced in North Dakota, with an average yield of about 33 bushels per acre (Hofman 2003). Soybeans contain about 18% oil and the average oil production could be around 49 gallons per acre (Hofman 2003). If this oil were converted to biodiesel, more than 100 million gallons of fuel could be produced per year, 60% of the state's total consumption (Hofman 2003). Soybean based diesel fuel could be used to fuel all farm equipment in the state of North Dakota. Other oil crops grown in the state could be used to produce additional fuel. For every BTU of energy used to produce the soybean crop and process the oil, about 3.3 BTUs are produced as fuel (Hofman 2003).

Maryland Biodiesel opened a facility in Berlin in 2006, becoming the first biodiesel production facility in Maryland (MDBio 2006c). The facility produces 1,500 gallons of B100 per day and is currently working to meet the growing demand for biodiesel in Maryland (MDBio 2006c). The U.S. Department of Agriculture and Congressional Budget Office have confirmed the introduction of biofuel into federally mandated fleets as the cheapest method of compliance with current EPAct regulations (MDBio 2006a). Using 450 gallons of B100 per year results in earning one alternative vehicle credit (MDBio 2006a). B100 can also be used to fulfill up to 50% of the total AFV mandate that state fleets must meet each year (MDBio 2006a). However, the use of biodiesel under EPAct compliance credit is not limited to vehicles which weigh less than 8,500 pounds, so the fuel purchased may be used in the older or heavier machinery (MDBio 2006b).

FUEL SOURCES: HYDROGEN AND ELECTRIC

Hydrogen

Hydrogen has been explored in various ways for use as an alternative fuel in vehicles. According to the EPAct of 1992, hydrogen gas qualifies as an alternative fuel (EPAct 1992). There are two ways that hydrogen can power a car. The first way is through the use of a fuel cell vehicle, which produces electricity to run the motor of the car (EIA 2008). In this case, the vehicle is effectively an electric vehicle with hydrogen as the source of electricity. Alternatively, hydrogen gas can be used to fuel an internal combustion engine. As a fuel, hydrogen has many advantages for the environment when compared to other non-renewable fuels.

Hydrogen gas can be obtained from a variety of different hydrogen containing compounds. As the smallest and lightest element, once hydrogen gas is formed, it rises up into the atmosphere, leaving almost no pure hydrogen gas on Earth (EIA 2008). The environmental costs associated with the production of hydrogen gas vary, depending on the extraction source of the gas. In the most common method of extracting hydrogen gas, hydrogen containing compounds such as coal, petroleum or natural gas are put through a chemical process to extract the gas (EIA 2008, Larminie 2003). Currently, a majority of hydrogen gas in the United States is produced through steam reforming of natural gas (NREL 2009). Biomass can also be used as a source from which to extract hydrogen gas (EIA 2008). Biomass along with coal, petroleum, and natural gas, cause the hydrogen extraction process to produce more harmful emissions than using a renewable resource, such as water and producing hydrogen through electrolysis (Larminie 2003).

Electrolysis creates hydrogen gas by running an electrical current through water to split the hydrogen and oxygen atoms (NREL 2009). The electrolysis of water could be used to form hydrogen gas with few emissions, assuming the electricity supplied for electrolysis is derived from renewable sources (EIA 2008). However, due to the large proportion of electricity generated from coal power plants in the US, electrolysis from conventional grid-based electricity would be the least carbon-neutral extraction method (EIA 2008).

In a hydrogen fuel cell car, hydrogen, as either a compressed gas or liquid, is fueled into a car's fuel tank and then enters a PEM fuel cell, where it undergoes an electrochemical reaction with oxygen to produce electricity (EIA 2008). The hydrogen gas enters through an anode, often made out of platinum metal, where it is then ionized (DOE 2009j). Through ionization, the hydrogen gas is spilt into positive ions and negative ions (electrons). The positive ions go through the PEM, but the electrons are forced to go through a circuit around the membrane, which in turn creates the electricity (DOE 2009j). Oxygen (from the air) enters through the opposite side of the fuel cell, where it passes through a cathode creating oxygen ions (DOE 2009j). These oxygen ions react with the hydrogen ions to create water vapor and heat (EIA 2008). The water vapor leaves the car through the exhaust (Larminie 2003).

In an internal combustion engine run by hydrogen fuel, either hydrogen gas or liquid is fueled to the engine. Once the hydrogen enters the engine's cylinder, it is ignited and goes through a combustion reaction with oxygen (DOE 2001). Hydrogen has a low ignition energy, or high range of flammability, and therefore hydrogen fueled engines often have pre-ignition problems (DOE 2001). Pre-ignition in a hydrogen engine occurs when the hydrogen fuel ignites before the spark ignites it (DOE 2001). Hydrogen fuel also has low energy density; therefore, the energy output of the engine is lower than that of a regular gasoline engine. However, the hydrogen vehicle produces a lower amount of nitrogen oxide emissions (DOE 2001).

There is a lack of infrastructure for hydrogen gas in the United States. The availability of hydrogen gas is fairly low in comparison to other alternative fuels, such as natural gas, both at the pump and through the hydrogen pipeline (EIA 2008). Currently, natural gas has 295,000 miles of transmission lines and about 1.9 million miles of distribution lines, compared to a little over 1,200 miles of hydrogen gas pipelines, a majority of which are concentrated in Texas and Louisiana (EIA 2008). Another complication regarding the availability of hydrogen is the challenge of transporting the fuel. To ship by truck, railcar, or barge, hydrogen has to be either in the form of a compressed gas or liquid. Oftentimes, transporting the hydrogen from place to place can cost more than the actual price of the hydrogen fuel (EIA 2008). Around the Baltimore area, the closest hydrogen fueling station is in Washington DC. To have the only fueling station over 40 miles away causes use of hydrogen gas to be inefficient, costly and impractical for use in a vehicle. Currently hydrogen gas is also costly to purchase for the consumer. At a price of $2.00 for a gallon of gas, a gallon gas equivalent (gge) of hydrogen gas would cost $4.80 (DOE 2009a). However, the United States Department of Energy's Hydrogen Program has a projected goal of lowering the cost of hydrogen gas to \$2.00-\$3.00/gge by 2015, making it competitive with gasoline (CaFCP 2009).

All things considered, the future of hydrogen as a fuel source appears viable. It has the potential to be both clean and renewable, two characteristics that make it very attractive for everyone. Although the technology is not presently advanced, it is likely that the use of this fuel will only grow with time.

Electricity

Electric vehicles (EV), which qualify as an alternative fuel under EPAct, have a lot of potential as an alternative fuel vehicle (EPAct 1992). Although EV's are often titled "zero emission vehicles," a majority of the electricity that would power these vehicles in the Baltimore region is derived from coal power plants. Electricity would have to come from renewable resources for it to be a true "zero emission" alternative. In order to make EV's a viable alternative to gasoline engines, a change in infrastructure would be necessary to support a transition from gasoline to electric fueled vehicles. EV's in their current state are not able to compete with their gasoline competitors due to their limited range and the long charge times. Depending on the type of battery found in the EV, a full recharge may take anywhere from four to eight hours (CA ARB 2003). Because an EV's battery must be recharged or replaced upon running out of energy, the main concern with electric vehicles is related to problems of where and how to charge the vehicles.

EV's can be charged at any home outlet, but due to their limited range, public charging stations or drive through battery exchange stations would also be necessary for EVs to be a viable and reliable form of transportation. In only a few minutes time, public charging stations could provide EVs with a substantial amount of additional range, depending on the amount of voltage available and the capabilities of the battery (Greenemeier 2009). A public charging station would look similar to a gas station, but each kiosk would produce between 400 and 600 volts, compared to the 120 volts of standard US electrical outlets (Greenemeier 2009). It would cost approximately \$10,000 total for both the research and installation of each public charging station (MGE 2009). The research will make sure that the technology is "safe, reliable, affordable and environmentally responsible" (MGE 2009).

With a battery exchange station, on the other hand, a mechanical arm would go under the vehicle and switch out the old battery for a new, fully charged battery (Greenemeier 2009). It is estimated that a battery exchange station would cost approximately $500,000 to build. Additional costs would be involved in housing for all of the batteries, the batteries themselves, and the recharging of used batteries that would be needed to fit every make and model of electric vehicle (Vlasic 2009). Optimally, batteries would be owned and leased by exchange companies. A service like this would effectively spread the cost of the battery out over the vehicle's lifetime, rather than forcing the consumer to purchase the battery up front. Currently, it is unclear who will end up paying for the new infrastructure, which is a main hurdle for the transition toward any alternative fuel source (Greenemeier 2009).

To fully understand the differences in efficiency between a gasoline engine and an electric car, one must consider the efficiency with which chemical energy is converted into useful *work*; in this case, the turning of the car's wheels. Although gasoline has a relatively high energy density, internal combustion engines are quite inefficient at converting the chemical energy of the fuel into work. Even in modern combustion engines, energy losses from heat, friction, and idling result in conversion efficiencies of roughly 15% (FuelEconomy.gov 2009b). That is to say, of the 33.70 KWh (kilowatt hours) of available energy stored within one gallon of regular gasoline, only 5.06 KWh are transferred to the wheels (FuelEconomy.gov 2009b). Table 3 is a comparison of gasoline and electric vehicles:

Table 3: Comparison of Gasoline and EV Properties, Information Coming From a Range of Sources.

	Gasoline	Electric
Vehicle	09' Honda Civic	99' GM EV1
Energy Consumed/mile	.0345 gal/mile[1,3]	168 Wh/mile[2]
CO_2 Released/mile	0.68 lbs[3]	0.34 lbs[4,5]
GGE	$1.63-$4.06[6]	$0.75 [4,7]

1 based on 29mpg
2 (U.S DOE, 1999)
3 (FuelEconomy.gov-a, 2009)
4 (Eaves, 2004) 218 Wh (168Wh @ 77% well to wheel efficiency) x 1.55 lbs CO_2/kWh
5 (assumes 25% carbon neutral energy, 75% coal energy)
6 (EIA 2009k) based on 2 year price range (October 07'-09')
7 Based on energy needed to travel 29 miles @ 11.8 cents/kWh

Whether or not EV technology is mature enough for large scale production is debatable. The typical primary family car in America is expected to have both the capability to travel long distances and to refuel quickly. Therefore, most current electric vehicles will not 'satisfy' a typical American family. However, the couple hundred mile limited range of an EV built with currently available technology could satisfy the demands of a university fleet. Batteries remain prohibitively expensive for auto manufacturers, but some of these costs would be recovered by the consumer through reduced energy rates vs. gasoline costs (Table 3). Additionally, the electric motor's minimal maintenance costs when compared to a gasoline engine would further enhance savings. However, presently no auto manufacturer is willing to produce EV's on a large enough scale to make their purchase price remotely competitive with gasoline fueled autos.

The Electric Vehicle Paradigm

Electricity can be generated by a range of different fuels, most of which emit carbon dioxide; Figure 7 displays the most significant sources of electricity production in the US. Much like hydrogen vehicles, because EVs do not have measurable emissions themselves, it might appear as if they have no direct impact on the composition of the atmosphere. The environmental impact of the vehicle's use ultimately depends on the impact of the source of electricity, and therefore, when selecting a power source for an EV, it may seem logical to choose one of the options with the fewest carbon dioxide emissions associated with it. However, there are certain logistical and environmental issues that are involved that may complicate such a decision. Renewable fuel sources are very appealing due to their lack of emissions (EIA 2009e). However, there are other environmental impacts that need to be explored before a choice is made (EIA 2009e). Environmental impacts come in a variety of forms; some, such as greenhouse gas emissions, are more direct, while others come in the form of reduction of ecosystem services, which are very hard to evaluate economically and therefore are included in the economic equations (EIA 2009e).

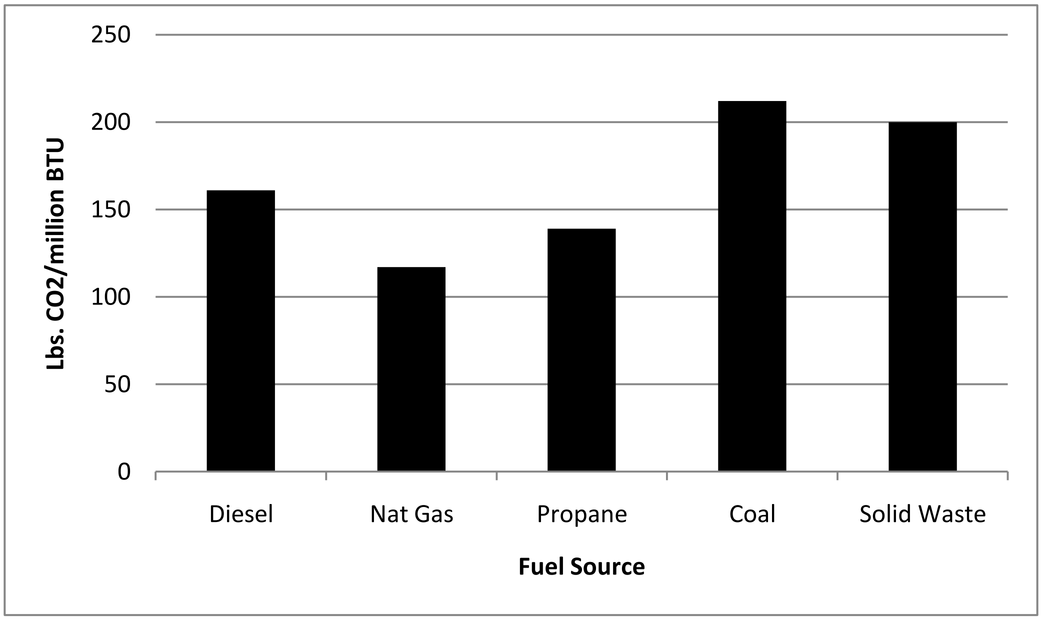

Figure 7: CO_2 (lbs.)/million BTU generated from different fuel sources (EIA 2009f).

Coal Power

In the United States, 54% of the electricity produced is derived from burning coal (UoCS 2009a). Burning coal emits roughly 212 lbs of CO_2 to produce one million BTU (British thermal units), making it the leading carbon dioxide emitter per unit of electricity produced (Figure 7) (EIA 2009f). The average US coal fired power plant will emit 3,700,000 tons of CO_2 per year, which is the equivalent to cutting down 161 million trees (UoCS 2009b).

Non-Carbon Emissions: Each year, the average coal plant will also emit 10,000 tons of sulfur dioxide (SO_2) (UoCS 2009b). SO_2 causes acid rain, which damages both natural and human environments (UoCS 2009b). SO_2 contributes to respiratory illnesses and is capable of being transported long distances (EPA 2009e). Additionally, the average US coal power plant emits as much of nitrogen oxide, another gas which causes respiratory illness, as half a million late-model cars (UoCS 2009b).

Mercury, arsenic, lead, cadmium and trace amounts of uranium are also emitted by coal power plants (UoCS 2009b). A coal plant generates an average of 170 tons of mercury each year. Comparatively, 1/70th of a teaspoon of mercury in a 25 acre lake is enough to make fish unsafe to eat (UoCS 2009b). The average coal power plant also produces 225 pounds of arsenic which can travel vast distances through the air before depositing in nearby ponds and streams (UoCS 2009b). The EPA has set the standard for arsenic in drinking water at 10 parts per billion to protect humans from cancer (EPA 2006).

Extraction and Transportation: Mountain top removal strips 60 percent of US coal from the surface (UoCS 2009c). The process of mountain top removal involves soils from mountain tops being removed to uncover coal. The subsequent waste soils are then dumped into the valleys below, literally filling the valleys and streams to the brim (McQuaid 2009). The EPA estimates that an area the size of Delaware will have been deforested and 1,200 miles of stream destroyed by 2013 due to mountaintop removal in the Appalachian Mountains (McQuaid 2009).

After extraction, the coal must then be transported to the power plants. Locomotive transportation of coal is responsible for nearly 1 million tons of nitrogen oxide and 52,000 tons of particulates each year (UoCS 2009c). Coal is typically stored at power plants in uncovered piles, allowing lung-irritating particulates to be blown onto nearby houses and lawns (UoCS 2009c). In addition, runoff from coal storage leads to acid leaching in waterways surrounding coal power plants (Cook & Fritz 2002). Acid leaching is detrimental to streams because it changes the water chemistry by increasing aluminum concentrations to levels where aluminum becomes toxic to stream biota (Likens 2007).

Hydropower

Hydropower is the most commonly used renewable energy source in the world (SPE 2009). It is responsible for producing 6% of the world's energy. In the US, hydropower is the single largest source of electricity from a renewable energy source (SPE 2009). Hydropower is electrical power generated through the movement of water (SPE 2009). It is captured from waterfalls, river currents, and waterways (SPE 2009). In hydro-electric dams, water is directed through a pipe (penstock), where the force and pressure exerted by the water pushes the blades of a turbine, spinning a generator (EIA 2009g). The electricity from the generator may then be transmitted through long distance power lines for public use in distant areas (EIA 2009g). Other methods of harnessing hydropower include the use of the force of river currents (water diverted to canals or pipes), tidal fences (vertical axis underwater turbines), and waves (focusing waves into narrow channel) to run the turbines (SPE 2009).

Hydropower is considered a very clean power source (EIA 2009g). The major benefits of using this clean energy are its reliability, its ability to create large amounts of energy, and the output of energy can be easily regulated to meet immediate demand (SPE 2009). However, it does have a wide variety of externalities that result from its use (EIA 2009g). Ecosystems and land use are two of the most significant factors that are affected by hydroelectric dams (EIA 2009g). Since waterways often have to be diverted to capture the energy contained in the water, natural systems that depend on these waterways can be highly impacted. Ecosystems can be affected in many ways including disruption of fish migration, habitat loss for plants and animals, and altered physical conditions (EIA 2009g). Fish are some of the most impacted organisms. Fish migrations are often associated with breeding activity and therefore disruption can reduce the size and health of the populations dramatically (EIA 2009g). Organisms which depend on healthy fish stocks, predatory birds for example, are also consequently disturbed. Structures such as fish ladders are now being used to counteract some of the negative impacts of hydroelectric power systems on river and stream ecology (EIA 2009g). Another area that is affected by hydropower is human land use, which involves potential relocation of homeowners in regions which are lost due to flooding from the construction of new dams (EIA 2009g.

Hydropower is also a more costly source of electricity than coal, but if produced on a local scale it is cheaper (EIA 2009g). However, seasonal fluctuations in stream flow make small scale generation (micro hydropower) far less reliable (EIA 2009g). The future of hydropower is still under development.

New innovations for harnessing the energy of moving water are mainly focused on tidal energy and hydroelectric dams with lower environmental impacts (EIA 2009g).

Wind Power

Wind energy is a modified version of solar energy (AWEA 2009). Differential heating from the sun causes changes in the pressure gradient force in the atmosphere, resulting in wind (AWEA 2009). Similar to hydropower, the kinetic energy from the motion of the air spins the turbines, generating electricity. Horizontal-axis or propeller-style turbines are the most conventional wind turbine configuration (AWEA 2009). The size of the turbines correlates to the amount of wind energy available to be harnessed, with larger turbines being capable of capturing a greater amount of wind energy (AWEA 2009). Commercial wind farms generally consider an average wind speed of thirteen miles per hour to be the minimum amount of energy required for a profitable industry (AWEA 2009).

Wind energy is another clean renewable energy source, but nonetheless, comes with environmental costs. Wind farms require a large amount of land including a five acre safety zone surrounding turbines, a treeless area of thirty acres, along with roads and transmission lines for the maintenance of a wind farm (Biofuelswatch.com 2009). Large scale commercial wind farms can thus increase deforestation, soil erosion, and runoff pollution from access roads. Wind turbines can also negatively affect avian migrations (EIA 2009h). The wind does not always blow at a consistent rate, making wind power less dependable than many other electrical sources (Biofuelswatch.com 2009). Noise pollution created from the spinning turbines and turbine aesthetics are also disadvantages of wind energy (Biofuelswatch.com 2009). Wind energy is also currently expensive compared to the use of fossil fuels (Biofuelswatch.com 2009).

The future of wind energy will depend mainly on the current use of fossil fuels for electricity. As fossil fuel sources become scarce or incur price increases, wind energy will become a front runner of clean renewable energy.

Solar Power

Solar power currently accounts for less than 1% of the electricity produced in the US (Galbraith 2009). The two major methods of generating electricity through solar power are concentrating solar power (DOE 2008e) and photovoltaic cells (PVC's) (DOE 2006). Currently, the cost of electricity from solar power is expensive, with electric from PVC's costing four times as much as electricity generated from coal (Galbraith 2009).

Concentrating Solar Power: The concentrating solar power method of producing electricity uses mirrors to reflect sunlight onto a central receiver (see figure 8) (DOE 2008e). These receivers then turn the light energy into heat which can be used to produce steam or run a heat engine to drive generators (DOE 2008e). Once steam is produced, the system is similar to any system that uses energy to produce steam. Concentrating solar power systems can be affected by a lack of sunlight but can be combined with thermal storage systems to remain productive during cloudy days (DOE 2008f). This reliance on the sun makes the southwestern United States and other sunbelt areas worldwide attractive locations to place concentrating solar power systems, where they are able to achieve some of the world's highest solar-to-electric efficiencies (DOE 2008f).

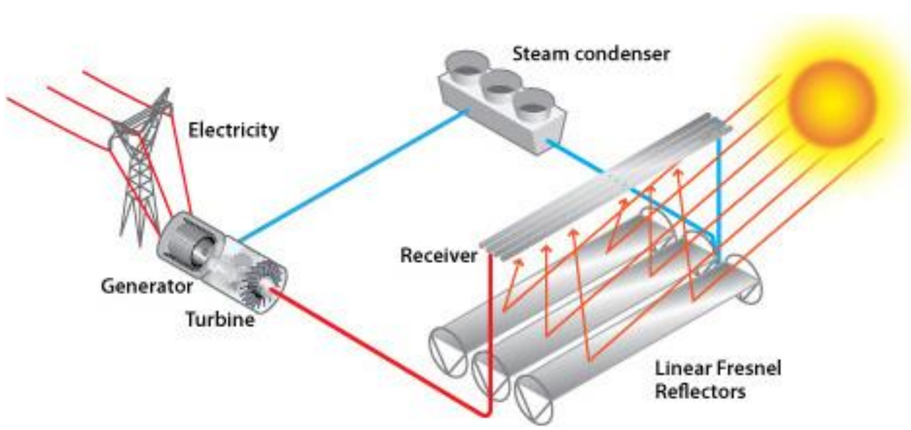

Figure 8: Concentrating solar power systems using reflectors to concentrate solar energy onto a receiver. This energy is then used to turn liquid into steam which drives a generator for creating electricity (DOE 2008g).

Proper management of concentrating solar power systems is necessary in order to minimize their environmental impact. The concentrated rays of sunlight can kill birds and insects if they fly in the path of the concentrated rays found between the mirrors and the receiver (EIA 2009i). Some of the fluids used to transfer heat are potentially hazardous to the environment and require proper disposal (EIA 2009i). Additionally, concentrating solar power systems require two times the amount of water as a coal or nuclear plant (Glennon 2009). Concentrating solar power systems are most effective in southwestern states where water is scarce and the surrounding habitats are sensitive to the little amounts of water available; this amplifies the environmental effects of solar power systems' use of water (Glennon 2009). The amount of water used could be reduced by 80-90% by using air-cooling techniques. However, this process would reduce the thermal efficiency of the systems (Glennon 2009).

Photovoltaic Cells (PVCs): PVC's use the sun to excite electrons into a direct current flow (see figure 9) (FSEC 2007a). Because the electrical grid uses an alternating current, electricity from photovoltaic arrays must be passed through a power inverter in order to be used on a grid (FSEC 2007b). Much like concentrating solar power systems, the functionality of PVC's depends on the availability of solar rays. In order to remain useful overnight or during cloudy conditions, batteries are usually used with photovoltaic arrays that store extra energy produced during the day for use during these adverse conditions (FSEC 2007c).

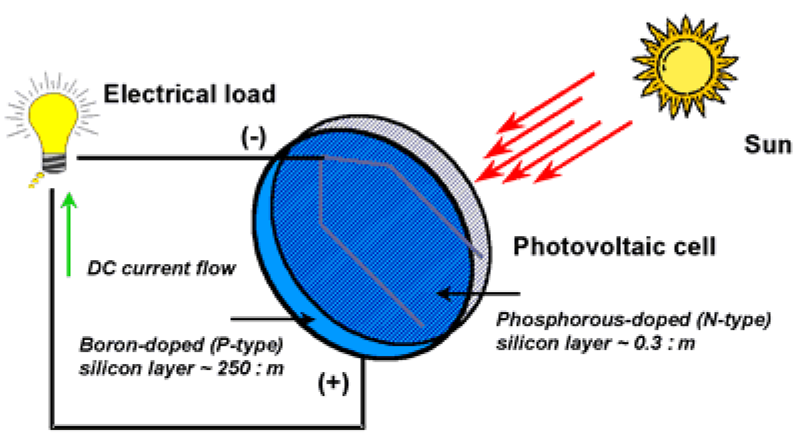

Figure 9: Sunlight excites electrons in a photovoltaic cell to create a current (FSEC 2007a).

PVC's use almost no water, giving them an environmental advantage over concentrating solar power systems (Glennon 2009). However, solvents, alcohols, and other toxic materials are used in the manufacturing process of photovoltaic cells, producing small amounts of waste materials (EIA 2009i). PVC's require 8-12 square meters of surface area per kilowatt when installed in the most efficient array, making surface area availability a limiting factor for PVC's (FSEC 2007d).

Nuclear Power

Nuclear energy is produced through the nuclear fission, or splitting, of an atom to produce steam from heat (Alternate Energy Sources N.D,.U.S. NRC 2009). Uranium is a viable choice for fuel because it is a heavier atom, making it easier to split (U.S. NRC 2009). Uranium is commonly found in rocks and is mined in the western US and many other locations around the world (EIA 2009j). Approximately one-fifth of the electricity in the US is generated from nuclear power and most of that uranium is imported (EIA 2009j). The type of uranium that is used in the fission process is U-235 and is relatively rare, with an estimated global supply to meet the world's demands for approximately eighty years (EIA 2009j; WNA 2009b). The total cost of producing nuclear electricity from nuclear power is half a cent per kilowatt hour (WNA 2009c). Unfortunately, the estimated eighty year time frame of U-235 availability suggests that nuclear energy will not remain a long-term energy source.

In the 1950s, Ford had designed a nuclear-powered automobile which housed very small, safe, light, and portable reactors (Silverman 2008). The back of the car contained a power capsule, which would need to be replaced or refueled at a charging station after approximately 5,000 miles of driving (Silverman 2008). Even though this car was never put into production, the idea of nuclear-powered cars may still be considered viable (Silverman 2008).

There are several advantages and disadvantages associated with direct nuclear-powered cars. The advantages include a relatively inexpensive and easy to transport fuel, waste is condensed, there are no emissions of GHG's, and a large amount of energy can be produced from the small amount of uranium (Nuclear Tourist 2009). Since nuclear power is used for a large proportion of electricity already, it has been well researched and has a life cycle that can be full circle if the fuel is reprocessed (see Figure 10) (Nuclear Tourist 2009). The disadvantages include the fact that uranium is non-renewable, has a slow geologic formation process, waste materials produced need a long-term storage location (the radioactive waste is highly toxic), and has a high cost to the public resulting from emergencies, security, storage systems, and radioactive waste (Nuclear Tourist 2009).

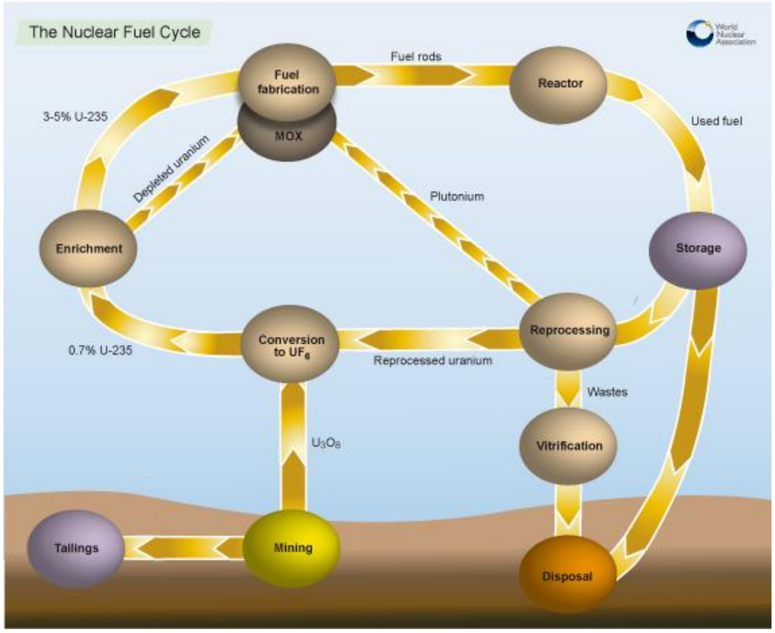

Figure 10: Nuclear fuel cycle: the life cycle of uranium used as fuel (WNA 2009a). The cycle starts with mining and ends with disposal; reprocessing used fuel is also an option with nuclear energy (WNA 2009a).

There are several laws and policies in place for the use of nuclear power. These laws pertain mostly to nuclear weapons, but there are a few that can also relate to nuclear energy for cars as well. First, the Atomic Energy Act of 1954 and the National Environmental Policy Act (NEPA) declares that nuclear energy is fine, as long as it helps humankind become more advanced (Nuclear Power Now N.D.). Second, the Nuclear Waste Policy Act of 1982 declares the Federal government is to take "responsibility to provide a place for the permanent disposal of high-level radioactive waste and spent nuclear fuel" (Nuclear Power Now N.D.). The Low-Level Radioactive Waste Policy Amendments Act of 1985, "gives states the responsibility to dispose of low-level radioactive waste" (Nuclear Power Now N.D.). Lastly, the Uranium Mill Tailings Radiation Control Act of 1978 launched programs under the Nuclear Regulatory Commission (NRC) which were formed to help control the amount of radon that may be released into the environment (Nuclear Power Now N.D.).

Even if nuclear power isn't utilized to fuel a car directly, there are other possibilities for its uses, including an energy source for the electrolysis of water to form hydrogen gas (Silverman 2008).

Likewise, because nuclear power produces a marginal amount of CO_2, it could also be used to create electricity to charge batteries for electric cars (Silverman 2008).

Alternative Electric Fuels – A Summary

Rule et al. (2009) conducted a lifecycle CO_2 analysis of alternative energy sources in order to compare the emissions of geothermal, hydroelectric, tidal, and wind energy. Lifecycle CO_2 emissions are expressed in grams CO_2/kWh and include energy from construction, regular maintenance and decommissioning of the plant. Production of concrete for hydroelectric dams, for example, can require enormous amounts of energy. At 1.8g CO_2/kWh, tidal generation proved to have the lowest CO_2 emissions, followed by wind power at 3.0g CO_2/kWh (Rule et al.t2009). Hydroelectric plants were found to have 4.6g CO_2 and geothermal, 5.6g CO_2/kWh. When compared to energy derived from coal, which emits roughly 1,100g CO_2/kWh, the emissions from each of these alternative energy sources are negligible (EIA 2009f).

In terms of available electricity sources, the Energy Information Administration (EIA) publishes the "Electric Power Monthly." In this document, the EIA reports their most recent energy data including preliminary sets of figures that are not complete yet. Also included are the price and usage trends. This publication could be a very useful tool when purchasing and/or using electric vehicles by providing the most up-to-date electricity data because it gives the fleet manager an up to date status report on many aspects of electricity sales and generation. The report can be found online at the EIA's website: http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html.

CHALLENGES FOR THE TU FLEET

As Towson University attempts to meet the goals of the President's Commitment and other federal requirements, the University faces a range of challenges. As part of EPAct compliance we are required to have seventy-five percent of vehicles purchased in a given year be "alternatively fueled." The

University vehicles purchased must be environmentally friendly, but they also must remain economically feasible. Hindering Towson University's efforts is the fact that gasoline/electric hybrid vehicles are not considered to be "alternative fuel vehicles" according to the EPAct of 1992 thereby removing one of the most successful vehicular options to reduce GHG emissions. This leaves options including electric, ethanol, compressed natural gas, propane, flex-fuel, and biomass fueled vehicles. However, many of these options simply cannot be adapted to campus use because these types of alternative vehicles do not produce the power needed for some campus uses such as plowing snow and hauling stone or mulch. On the other hand, hybrid vehicles can be much more powerful then the aforementioned vehicles, accommodating more campus transportation activities.

Further reducing the University's options is the fuel infrastructure itself. CNG vehicles can also attain the power needed for campus use but there are no natural gas pumping stations in the immediate area and installation of such stations is a very expensive endeavor. Any hope of an increase in local infrastructure was lost when BGE decided to move away from CNG in their fleet leading to a dismantling of stations they had in the area. Converting vehicles to natural gas or using biodiesel in diesel vehicles can be explored as an option to green Towson's Fleet. However in many cases these options will void any remaining warranties on the vehicles and State policy prohibits any repair or work done on a vehicle that voids the warranty. Electric vehicles would be a viable option for the Fleet however the more viable electric vehicles can be quite expensive. Many of the affordable electric vehicles that can be purchased are not intended for highway use and are considered low-speed vehicles. These vehicles do not have enough power to replace the heavy-duty vehicles on campus and with a 30 mph maximum speed could only be used for travel on the internal sections of campus.

Flex fuel vehicles, which can use E85 fuel can be purchased though the state contracts; however, there is no current local infrastructure for E85 availability and distribution. FFV's can be purchased and theses purchases helps us comply with the seventy-five percent alternative fuel mandate, but since there are no local facilities to fuel these vehicles with E85, they would run on regular gasoline and not aid in "greening" the Fleet.

In our current economy, there is not much of a demand for AFVs. Without demand, car manufacturers will not provide a supply of these vehicles thus making it impossible to add additional alternative vehicle options to the State contract. The low number of AFV's being distributed and used means there is no need to grow the infrastructure to transport and distribute fuels for these vehicles. Without a public infrastructure, the only way to maintain an alternative fueled fleet is to create a private infrastructure. This would be much too expensive for the University alone. Therefore, regional cooperation with other state agencies or county agencies would be needed to successfully incorporate AFVs into the Fleet. Nevertheless, the University must deal with these challenges in their efforts to create an environmentally friendly Fleet.

THE PLAN

Given the current state of the Towson University Fleet and the current desire to make improvements in the absence of unlimited budgets, it is important to view solutions on a temporal scale. The following short term recommendations will allow the Fleet to address, implement and transition to an increased efficiency, using low cost solutions. Recommendations for the long term will not only benefit the Fleet, but also help the University meet the goals of the President's Commitment and TU's Carbon Action Plan of overall carbon neutrality. It is important to note that these long term recommendations do require more planning and funding.

Short Term Recommendations

The Towson University Fleet can make minor, cost-effective changes that can be implemented now. These recommendations include driver education, reducing excess loads per vehicle, general and proactive maintenance, and energy-efficient vehicle-to-task assignments.

Driver Education Programs: Fuel-smart educational programs and their promise of increased sustainability are quickly becoming a more prevalent aspect of fleet management. Studies show drivers who are more aware of strategies that can increase their fuel efficiency save about 20-30% on gas (Sustainable Community Enterprises 2009). Estimated cost savings come to about $500 per driver (Sustainable Community Enterprises 2009). Fleets that have incorporated educational courses have reported that the implementation of fuel-efficient driving technique programs reduce wear on vehicles (Sustainable Community Enterprises 2009). Although this type of educational program appears costly, long-term gains such as improved safety, reduced maintenance needs, and reduced gas expenses make them worthwhile. Collaborating with local fleet operations, such as Baltimore County, might provide for an effective exchange of information, ideas, past successes, and future plans. Robert Majewski (2009), from Baltimore County Office of Budget and Finance, Vehicles Operations and Maintenance, presented to us the components of a newly incorporated fuel-smart education program recently adopted by the County. Some of these fuel-smart ideas and our findings relative to the anticipated savings from these actions include:

- Avoid idling vehicles for extended time periods – studies have shown that idling vehicles for an hour consumes the equivalent of a gallon of gas (LiveViewGPS 2009)
- Reduce speeds – drivers could save up to 14% on gas expenses simply by lowering their speeds (LiveViewGPS 2009)
- Avoid rapid starts and stops
- Route Optimization – reducing the miles driven by a fraction can accumulate savings on gas expense and increase net profits (LiveViewGPS 2009)
- Minimize weight and heavy loads in vehicles

Maximize Fuel Efficiency: By reducing a vehicle's weight by 10%, fuel efficiency may increase by 4-8% and reduce the amount of strain on the engine (InterAcademy Council 2009). Vehicles get more miles per gallon of gasoline without added weight producing drag (InterAcademy Council 2009). Replacing heavy cargo structures with lighter-weight materials will lighten a vehicle load. For example, the Dodge Sprinter vehicles in Towson University's maintenance Fleet carry heavy workbenches; these structures could be replaced with lighter materials. Some light-weight materials include high-strength steel, aluminum, magnesium and fiber-reinforced plastics (InterAcademy Council 2009).

Installing devices such as an Auto Meter will allow drivers to directly monitor their fuel and driving performance. The Auto Meter is a relatively recent product designed for the average driver seeking to reduce gas consumption and related expenses (Work Truck 2009). The meter is a visual, quantitative gauge that measures fuel economy based on driving style (Work Truck 2009). It is a relatively easy system to install with straightforward gauges to read (Work Truck 2009). The meter (see Figure 11) displays both a real-time fuel consumption (miles per gallon) gauge and a color-coded eco-graph, coded in red, yellow, and green (green being most fuel efficient) (Work Truck 2009). Reported claims of a 37% savings on fuel expense with a heightened awareness in personal fuel economy have been made (Work Truck 2009).

Figure 11: Auto Meter 9100 Model *Fuel Economy Meter* (Work Truck 2009).

General and Proactive Maintenance and Measures: General maintenance considerations for better fuel efficiency include routine tire checks (i.e., pressure and tread-wear), oil changes, no-leak fuel system, and routine engine care. The air pressure in a tire is crucial to a vehicle's fuel performance (BuyingAdvice 2009). Recommended tire pressure may differ from vehicle to vehicle depending on the make and model; this number is listed in the owner's manual. Adjusting a vehicle to its optimal tire pressure regularly can save the driver up to 10% on fuel expenses (BuyingAdvice 2009). Gas mileage can be improved by ratio of 0.3% per accurate pounds per square inch (psi) for each vehicle to be closer to its optimal tire pressure (USDE 2009). Routine oil changes can directly affect the need for and frequency of routine engine care (AA1Car 2009). Oil loses its viscosity over extended use which results in oil sludge and potential engine-damage (AA1Car 2009). However, the interval between needed oil changes is variable depending on the oil type, fuel type, driving style, distance, and frequency of vehicle use.

An energy-efficient vehicle-to-task assignment program would help establish a more synchronous fleet operation. Having large, heavy-powered vehicles assigned only for heavy-duty loads, or carpooling to maintenance tasks at common locations will reduce fuel consumption, vehicle emissions, and traffic. Also, rotating vehicle usage within the Fleet can increase vehicle life expectancy. Simple, non-labor intensive tasks (i.e. routine building inspections) should avoid the use of a larger, heavy-duty vehicle when a smaller, four-cylinder vehicle would be adequate.

Long Term Recommendations

Over the course of the next decade vehicle technologies will continue to improve, fuel options are going to increase, and changes in policy will occur. The ability of the Towson University Fleet to become more sustainable and efficient over the long run must rely upon these technological advancements, and how these advancements and potential policy changes shape the vehicle and fuel markets.

Diesel and Biodiesel: Diesel and biodiesel are currently the most viable alternative fuel sources on the market. Their current availability in the automobile industry, accessibility to the public sector, and their environmental benefit (cleaner more efficient burning), make them our top choice for moving Towson University's Fleet toward a greener future. Biodiesel is a clean burning alternative fuel to petroleum based diesel fuel (PC. Bio. 2009). Although slight modifications may be necessary for a vehicle to be able to operate on biodiesel, as mentioned earlier, we believe the benefits outweigh the costs when the switch is made to this fuel.

Biodiesel can be purchased through DGS contracts and fuel tanks could be kept on campus to refill Fleet vehicles. Many of the heavy duty campus vehicles may not be traveling great distances, so having a filling station on campus would decrease fuel usage. If a vehicle were off campus and running out of biodiesel, it would still have the ability to be refilled with ULSD to make it back to campus; diesel engines have the capability to run on both petroleum based diesel and biodiesel (NBB 2009a). As biodiesel becomes more accessible, there is a possibility that surrounding counties may follow and install the biodiesel-pumping infrastructure at their filling stations. Having biodiesel pumps available off campus will increase the range of campus vehicles that run on biodiesel fuel.

Electric Vehicles: Future solutions also lie in electric vehicles. There are several advantages of electric vehicles that will meet the needs of the Fleet and reduce heavy-duty vehicular traffic on campus. First, electric vehicles have no direct measurable emissions, which would be a major asset to the campus and the environment (Fuller 2009). Although fuels are still being burned in plants in order to power the grid, there is greater efficiency in large-scale plant-production of energy versus energy production at an individual level from car engines (Nichols and Akers 2009). Electric vehicles will minimize the number of point source polluters and make the transition to alternatively powered plants more environmentally effective. Second, electric vehicles tend to be lighter and smaller than their fossil fuel powered counterparts, decreasing long term damage to the brick walkways that are a major component of Towson University's campus.

A third benefit of electric vehicles is the ready-to-go infrastructure which makes them easy to charge. It may not be necessary to install charging stations on campus if Fleet vehicles draw their power from normal electrical outlets during off-peak hours (Greenemeier 2009). By keeping an extension cord in the vehicle, drivers can also charge their vehicles at standard electrical outlets when necessary (Greenemeier 2009). Transitioning to electric vehicles may not be the solution to the problem, but they hold the highest future potential to help Towson University achieve their goals concerning the fleet and cleaning the environment.

A few electric vehicles have been successfully used by Towson University's Fleet, on a trial basis, for on-campus activities only. Future advancements in technology could potentially allow for electric vehicles to be used in more activities. Electric trucks would also be extremely valuable to the Fleet as they would be light enough to be driven through the brick campus walkways and be functional enough to transport the needed tools and supplies to complete tasks. The price of the vehicles seems to be one of the major concerns with these vehicles. However, a decrease in price may occur as the demand for the electric vehicles increases and public perception of the electric vehicle improves. This may make electric vehicles a logical choice for servicing the future Towson University campus.

Other campuses throughout the country have utilized electric vehicles for on-campus tasks, and can be used as a precedent for how Towson University could use electric vehicles. For example, in their effort to "go green," Iowa State University purchased four electric vehicles in the Fall of 2008: two cars and two trucks (Krapfl 2009). These vehicles max out at 25 mph and are limited to travel kept on and around the campus (Krapfl 2009). However, the staff assigned to the vehicles finds their electric vehicles to be useful (Krapfl 2009). When speaking in reference to using these electric powered vehicles, Bob Currie, the Assistant Director of Facilities Services at Iowa State, states "they've been well received by people. For a bulk of what they do, the vehicles are a good substitute" (Krapfl 2009). The two trucks are open-backed and are used by various departments, such as the carpentry and grounds crews, for transporting supplies and tools around the campus (Krapfl 2009).

The Iowa State Facilities and Planning Management tested and tracked the electricity used, and the amount of money spent on that electricity, to keep the vehicles charged (Krapfl 2009). Their results showed that although the initial cost of the vehicles was pricy, at $17,000-21,000 each, the amount saved in gas could make up for the vehicle price in a matter of a few years (Krapfl 2009). The University estimated that it costs about $0.13 per day to keep a vehicle charged while each gas powered vehicle uses an average of $3.49 of fuel each day (Krapfl 2009)

Continued Monitoring of Alternative Fuel Advancements: We also recommend that a staff position be created to research the viability and accessibility of fuel types that may become available in the future. There are many known and unknown possibilities regarding alternative fuel development which is why it may be necessary to have a dedicated team available to continue researching the cleanest and most efficient fuels, as well as policies that may affect the Towson University Fleet. One of the most beneficial ways to put a team together would be to collaborate with Towson's Environmental Science and Studies (ESS) program. Creating an internship position where a couple students could research and report on continuing technologies, efforts by other fleets, advancements, and policies which could affect the long-term goals and benefit the Fleet, ESS, and ESS students. Internship credits and the possibility of a reasonable wage will provide incentive for students to work directly with Towson University's Fleet managers.

Fuel types such as hydrogen have the potential to offer clean and renewable transportation, if the electricity used to create the hydrogen is from a renewable source. Propane and CNG also hold potential, but would require large-scale infrastructure changes that are not within Towson University's budget, and as mentioned earlier, their implementation could raise additional concerns. Continue to watch for ethanol improvements. Ethanol derived from lignocellulosic plant matter will allow for higher energy production per hectare than can be obtained from corn based ethanol. Other advancements in biofuels such as algal created fuel and green gasoline should also be monitored. They show promise and could prove to be viable long term options. It will be vital to keep a close watch on local government and the public perception of these fuel types. Without the support of those two groups, it may not be realistic for Towson University to install new infrastructure.

Capitalize on Policy Options: Alternative fuel vehicle purchasing requirements is a major determinate in regulating the options available to the Fleet. Towson University is a part of the University of Maryland Fleet System and reports all of its vehicle purchase information back to this agency (L. Williams 2009). Therefore, the system as a whole, not just each individual college/university, is responsible for meeting the alternative fuel vehicle purchase requirements. As a result, Towson University can not apply to meet the vehicle purchase standards through the alternative compliance option unless the University of Maryland Fleet agency chooses to use this method. However, if the alternative compliance option were to be made available to Towson University it may be able to benefit the University and their Fleet.

The Alternative Compliance option is based on reducing petroleum usage rather than purchasing alternatively fueled vehicles (EPAct 2005). This petroleum reduction can be based on a number of different methods and factors, one of which is the use of biodiesel blends that are above the requirements of state law (DOE 2009l). In the state of Maryland this would include biodiesel blends of at least B5 (DOE 2009m). Towson University would also be able to purchase and use hybrid vehicles for their Fleet if the alternative compliance were to become an option. Credit for petroleum reduction can also be obtained by the use of alternative fuels in vehicles that are considered to be exempt by the EPAct of 1992 (DOE 2009m). This would allow the entire Towson University Fleet to ensure that the current EPAct standards are met. However, until the State adopts the alternative compliance method in their version of the EPAct of 1992 standards, the University must continue to purchase 75 percent alternatively fueled vehicles each year (DBM 2005).

There are other options that still exist in terms of meeting the standard compliance. The most efficient and beneficial to the University would be the use of a biodiesel blend of B20. The use of B20 is still covered by most manufacturer warranties (NBB 2009b) and is the minimum blend required to obtain credits for compliance (DOE 2009m). For older vehicles in the Fleet that are out of warranty, it may be possible to use a higher concentration of biodiesel to obtain more credit. The standard compliance method allows for up to 50% of the EPAct requirements to be met by using biodiesel fuel in a fleet's medium and heavy duty vehicles (DOE 2009m). For every 2,250 gallons of B20 that is used in the medium and heavy duty vehicles of a fleet, one credit will be gained, which is equivalent to the purchase of one alternatively fueled vehicle (DOE 2009m). For example, if Towson University were to purchase 16 vehicles in a year, at least 12 of these vehicles would need to be alternatively fueled. However, if the

University were to use B20 in their non-light duty vehicles, then up to six of the 12 alternative fuel vehicles that would need to be purchased could be covered by the use of biodiesel. Once Towson University purchases or gains credit for the 12 light duty vehicles, any alternatively fueled medium or heavy duty vehicles they purchase could then provide credits for alternatively fueled light duty vehicle purchases in future years.

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