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Alternative Fuels For Ground Support Equipment

Samuel Enlof

ALTERNATIVE FUELS FOR GROUND SUPPORT EQUIPMENT

By

Samuel L. Enlöf

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(Advisor)

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Abstract

Airlines are in desperate need of reliable methods and materials to save and transform traditional ground operation fuel. This topic has taken precedence within the airline and aviation industries due to alarming product costs in accordance with the dilapidation of global and domestic economies. This is also in conjunction with similarly volatile geo-environmental atrocities being committed at an alarming rate-- often due to harsh chemicals and other pollutants evoked by the airline industry.

It is imperative to determine which alternative fuels are conducive to the modern airline industry. The advantages and disadvantages of each alternative fuel needs to be evaluated and analyzed; in addition to consideration of the monetary and environmental costs associated with the usage of alternative fuels for ground support equipment.

Chapter I: Introduction

The aviation industry in the U.S. grew by 3.8% in 2008-- which was less than expected (International Civil Aviation Organization, 2009). The International Civil Aviation Organization (ICAO) is expecting the industry to recover from the slow growth in late 2009, or early 2010, and continue to grow by approximately 5.5% within the next several years (International Civil Aviation Organization, 2009). With the current focus on global warming and the emission of green house gases, it is necessary for the airlines to begin assessing their options and what they can do to reduce their contributions to the problems. Many airlines are working on programs; to reduce their costs and also reducing the emissions produced. For example, Northwest Airlines has a program in place only allowing planes to taxi using one engine; turning on the second engine at the runway end (Northwest Airlines, 2007). There needs to be vigorous exploration regarding how to reduce the amount of green house gases emitted by the ground support equipment (GSE) considering most airlines do not have alternatives to traditional GSE. Airlines use ground support equipment continually, creating a large amount of green house gases.

In today's world, it is becoming imminent for airlines to create a brand different from others; and using alternative GSE would allow an airline to be identified as a "green" airline. Another reason why airlines need to find alternative means to run ground support equipment is due to the cost of fuel in today's aviation industry. The oil prices are currently volatile so that the airline

industry must find protection against the fluctuations to stay competitive (Northwest Airlines, 2008).

This study focuses on which GSE alternatives are available for U.S. airlines and which will be most feasible. This research will focus on the equipment that is currently available; the opportunities and challenges of using the GSE; the associated costs (capital, operational, environmental, health) of refitting current equipment compared to buying new equipment. The purpose of this study is to examine an alternative fuel that is both operational and cost beneficial to use.

Statement of Problem

The green house effect has been known to modern man since 1824, when a scientist names Joseph Fourier figured out that the Earth would be significantly cooler if we did not have an atmosphere (The National Geographic, 2007). It was not until 1895 that a Swedish scientist discovered that humans can influence the greenhouse effect by producing carbon dioxide that is a green house gas (GHG). Since then, we know more about this phenomenon and in today's society most individuals associate the green house effect with global warming and a changing climate.

It is commonly called the green house effect because the phenomenon is very similar to a green house used by humans to grow plants and crops. There are certain gases in the Earth's atmosphere which trap heat. The gases let in sun light which hits the Earth's surface; some of the sunlight is absorbed while some

of this heat is reflected back into the atmosphere. Some of this heat is “trapped” in the atmosphere; the amount of heat trapped depends on the amount of green house gases available in the atmosphere (The Climate Crisis, 2008). The higher the concentration and level of gases leads to increased heat warming the earth (The National Geographic, 2008).

The level of GHG has varied throughout the history of the earth. Different levels of GHG have lead to climate changes in previous eras, like the ice age but it has all been part of Earth’s natural cycle. For centuries green house gas emissions have been balanced out by green house gases that are normally absorbed, allowing our climate to remain relatively constant. Lately the amount of GHG has drastically increased in the Earth’s atmosphere; namely, carbon dioxide. We produce these gases by utilizing fossil fuels, like gas, coal, and oil. It is believed that these fuels produce a large amount of green house gases, in effect trapping more heat in the atmosphere than the Earth can absorb.

Due to a larger amount of GHG in the atmosphere, the Earth’s temperature is increasing at a much more rapid rate than it would be if it wasn’t for humans and the industrial revolution (The National Geographic, 2008). An even more rapid temperature increase will potentially create many negative effects including those catastrophic in nature. A temperature increase will lead to increasing sea levels because the ice sheets in and around the North Pole and Antarctica are already starting to melt (Ponce, 2007).

A temperature increase will also lead to more irregular and severe weather. Our weather patterns will be more extreme with heavy rains followed by

severe droughts. For example, it has been determined that the amount of category four and five hurricanes has more than doubled in the last 30 years (The Climate Crisis, 2007). Some researchers believe the Arctic Ocean could be ice-free by 2050, and more than 1 million species could be extinct by that same year (The Climate Crisis, 2007).

The airline industry is a contributor when it comes to the production of green house gases, especially carbon dioxide. In today's airline industry, almost all equipment burns oil in order to operate. The airline industry is expected to grow by a rate of 4-5 % in North America and Europe, while the market in Asia (especially China) is expected to grow at an almost explosive rate of 15-20%. With the airline industry already being a large contributor to the emission of green house gases, the expected industry growth will only exacerbate the dire state of the atmosphere and planet Earth.

Some airlines have developed programs called "carbon offset" programs. In these programs the airlines are not trying to reduce the amount of green house gases; instead they will fund projects like solar power (Scandinavian Airlines, 2008). By doing this, Scandinavian Airlines believe emissions will be offset. The problem is that even if the funding for projects help, it does not offset the emission already produced.

Scandinavian Airlines (SAS) is currently testing a system called the "green approach" on certain pre-determined routes. Instead of flying an approach in several different steps that requires a lot of different changes in the power settings (higher fuel burn); SAS is trying to fly their approaches using a low RPM

setting in a low slow descent instead of the step-down approach. They believe this will reduce the amount of fuel burned and the amount carbon dioxide emitted into the atmosphere (Scandinavian Airlines, 2007). The founder of Virgin Atlantic, Sir Richard Branson, has together with Al Gore created a program called the “Earth Challenge”. They offer an award of $25 million to the individual or group that comes up with a viable design on how to reduce green house gases (Virgin Earth, 2007).

Several North American airlines have also created programs which aim to reduce the amount of emissions and primarily reduce the cost of fuel. American Airlines has a program called the “Fuel Smart” program, where they try to conserve fuel by shutting down one engine while taxiing (American Airlines, 2007). Northwest Airlines (NWA) has a similar program where they try to save fuel by using only one engine while taxiing. NWA did also abolish their power out program in 2006 to increase fuel savings (Northwest Airlines, 2007). Instead of having aircrafts using reverse thrust to push out of the gate, Northwest Airlines made it a policy that all aircraft have to be pushed back from the gate using a pushback tractor (Northwest Airlines, 2007). Airlines have invested in new aircraft such as the Boeing 787, according to Boeing, is supposed to reduce the fuel burn by 27%.

Even though these programs help reduce green house gases, they are primarily created to save money and most of these programs are focused on how to reduce aircraft fuel burn. However, there is no focus on the equipment and infrastructure that support the aircraft. There are many thousands of belt loaders,

pushback tugs, air start units, etc. which burn fossil fuels in order to operate. NWA have two of their main hubs located in the upper Midwest; these hubs operate in too many cities with extremely cold temperatures during the winter months. A lot of the equipment used is being operated 24/7 during the winter months.

Purpose of the Study

The purpose of this study is to research the alternative ground support equipment that could be used by US airlines. This examination will break down the advantages and disadvantages with each alternative in relation to different route systems. The study will research the costs associated with the implementation of alternative ground support equipment. These costs will be both capital and operational, and perhaps most importantly, the benefit to the environment of not using alternative means of fuel. The results produced by this study will allow U.S. airlines to properly analyze the logistical and economical advantages/disadvantages with the usage of alternative ground support equipment.

Significance of the Study

Identifying the opportunities and challenges with the current alternatives will benefit to airlines as it will allow them to better understand which alternatives would be most advantageous for their individualized type of operation. The

results from this study may also be an additional resource for other aviation operators, like fixed base operators (FBO).

Results from this study can assist the GSE manufacturers to develop future alternative ground support equipment as this study will identify the variables that are important when creating reliable ground support equipment.

Finally, this study will aid the U.S. airlines in their process of saving fuel and reducing green house gas emissions. It will prove beneficial to Airlines by providing them with a cost analysis which will be specific to their company profile.

Research Questions

In an effort to reduce the money spent on fuel; and also in an effort to reduce the amount of greenhouse gases produced and emitted by ground support equipment within U.S. Airlines, this study will focus on identifying alternative means of ground support equipment. In this research study, the following questions will be addressed:

1. What are the alternatives to the equipment used today?
2. What are the advantages/disadvantages with the usage of alternative ground support equipment?
3. What are the costs (capital, operational, environmental, health) associated with the use of alternative ground support equipment?

Conceptual Framework

There are not very many models that have been created to research which types of fuel alternatives exist for GSE. Northwest Airlines has established an alliance with the School of Environmental Studies- they are working on a program that will be discussed in this study (Northwest Airlines, 2008). The environmental department within Northwest Airlines does have an ongoing process to study alternative types of fuels that could be used in GSE. This will also be considered within this investigation.

Southwest Airlines and the State of California have also worked on model regarding electrical driven ground support equipment. American Airlines and Air Canada have also done some research within this particular area of study (Ehman & Jones, 2006).

Operational Definitions

For this study the following definitions will be used:

Carbon Dioxide: Green house gas produced when burning fossil fuels, like gas, oil, and coal.

Electrical GSE: Runs on electricity, uses a battery that needs to be charged.

Ethanol: alternative fuel made from fermented crops. It can be added to fuel or it can be used separately with a specific engine.

Green Approach: New way of flying the final approach segment before landing where the aircraft maintains a slow constant descent down to the runway, instead of flying the approach- using several steps that cause a higher fuel burn.

Green House Gases: Gases that are naturally emitted and also emitted by man into the earth's atmosphere. Gases that will trap heat in the atmosphere- the more gases available in the atmosphere, the more gases will be trapped.

Global Warming: an increase of the earth's temperature by a few degrees resulting in an increase in the volume of water which contributes to sea-level rise

Ground Support Equipment (GSE): equipment used by airlines to serve their aircrafts. Some of this equipment involves but does not exclude: belt loaders, pushback tugs, and ground power units.

Hydrogen: chemical element that has the potential to be used as an alternative fuel for ground support equipment. Hydrogen is the most abundant element that currently exists on Earth.

Methanol: Methanol is made from natural gas, wood coal, and bio mass.

Natural Gas: Originates from the ground but it is also made from bio mass.

NWA Airport Operations Department: Department within Northwest Airlines that is responsible for the ground handling of all Northwest Airlines flights. This responsibility includes: luggage offload/on load, fueling, catering, check-in and boarding of passengers, and so on.

Propane or Liquefied Petroleum Gas (LPG): Alternative fuel used to heat homes, can also be used as a fuel for ground support equipment and other vehicles.

Assumptions

The following assumptions will be made within this study:

1. Global warming is a real phenomenon.

2. Alternative fuels that can be used for other vehicles outside the aviation industry, are also assumed to work for ground support equipment.
3. The cost of oil will continue to wreck havoc on airliners' financial performance due to the volatility and lack of control.
4. The alternative ground support equipment has to be able to operate continuously in all types of weather conditions.

Limitations

These are the limitation for this study:

1. This study will focus on the Ground Support Equipment for U.S Airlines.
2. The suggestions in this study will relate directly to U.S Airlines, the alternative fuels suggested to be used by U.S Airlines may not necessarily be suitable for other airlines.
3. There may be different types of Ground Support Equipment that work more effectively depending on the geographical location (heat/cold extremes.

Literature Review

The purpose of this literature review is to review and analyze literature previously published in this area. This literature review will be divided into four areas. The first category reviews literature that studies the concept of global

warming and also what effect the green house gases have on our atmosphere. The second category of the literature review will review material describing the alternative fuels and ground support equipment available.

In the third category of this literature review, material dealing with the advantages and disadvantages of these alternative fuels and GSE will be reviewed.

The fourth, and last category, will be reviewing literature that describes the different costs associated with the process of implementing alternative ground support equipment.

Global Warming and Green House Gases

The National Geographic explains how greenhouse gases are produced when burning fossil fuels like coal, gas, and oil. The National Geographic further explains how some green house gases (i.e. carbon dioxide CO2) trap more heat than other gases. Studies show that the flow of ice from glaciers in Greenland has more than doubled in the past decade (Krabill, et. al., 2004). The World Health Organization's research supports the ideas above by suggesting that the number of deaths due to global warming will double in the next 25 years- circa 300,000 deaths per year (World Health Organization, 2008).

A study conducted by Professor Miguel Ponce, at the San Diego State University, shows that about 75% of the annual increases in carbon dioxide in the atmosphere are due to the burning of fossil fuels (Ponce, 2007). The National Aeronautic and Space Administration (NASA), and James Hansen, explain how greenhouse gases reduce the heat radiation to space, which allows the earth to warm up. Hansen further explains how green- house gases are produced

differently and how various gases grow at different rates. The National Center of Atmospheric Research (NCAR) describes how they believe global warming affects our climate by claiming that the Arctic summer ice will have virtually disappeared by the year 2040 (NCAR,2008).

Jeff Kluger explains the carbon dioxide levels are increasing in earth's atmosphere and attests that we can feel the effects in temperature changes. Nineteen out of the 20 hottest years on record, occurred in the 1980s or later and the hottest year on record occurred in 2005 (Kluger, 2006).

An article in The New York Times states that by year 2100, it is expected for the sea level to rise between 7 and 23 inches (The New York Times, 2007).

The United States Environmental Protection Agency (EPA) describes four different types of greenhouse gases that exist in the atmosphere due to human inventions. The four different gases described by EPA are the following:

1. Carbon Dioxide enters the atmosphere when fossil fuels are burned (oil, natural gas, coal). Carbon dioxide is removed from the atmosphere when it is absorbed by plants and flowers.
2. Methane gas is produced by the production and transportation of coal, natural gas, livestock and other agricultural procedures.
3. Nitrous oxide is a gas that is emitted by agricultural and industrial procedures and activities.
4. Fluorinated Gases are several different green house gases emitted by industries. Sometimes referred to as "High Global Warming Potential

Gases” due their severe negative effect on global warming (EPA, 2008).

EPA further explains that the only greenhouse gas that naturally exists in earth’s atmosphere is carbon dioxide, while all others are produced by humans (EPA, 2008).

Alternative Fuels to be used for Ground Support Equipment

This research focuses on what the airlines can do to reduce their green house gas emissions produced by ground support equipment and. Most of the reviewed literature seems to focus on other industries outside the aviation industry. Although not specific to ground support equipment, these studies can still be used in reference as to what alternatives are available.

The EPA conducted a study where premature deaths due to air pollution, were compared with deaths due to car accidents. The study shows that approximately 60,000 people die prematurely due to air pollution; while approximately 40,000 annual deaths are due to traffic accidents (EPA, 2000). The Environmental Protection Agency describes the following five alternative fuels (EPA, 2000):

1. **Electricity**-electricity is quickly becoming an option. Improvements in technology have made electricity a viable option. Research conducted by EPA shows electricity as one of the best ways of reducing emissions produced by automobiles.
2. **Ethanol**-is a liquid alcohol that is a by-product of grains and agricultural waste.

3. **Methanol**-is a wood alcohol that is made from natural gas, wood coal, and also bio mass.
4. **Natural Gas**-originates from the ground but it is also produced by biomass
5. **Propane**-also called Liquefied Petroleum Gas (LPG), is a mixture of gases that is usually more widely available than the other alternatives.

There is also plenty of literature from GSE manufacturers that describe the different types of alternative equipment available. A company called eGSE America published a technical specification regarding one of their Electric Pushback Tractors (eGSEAmerica, 2005). In this technical specification, the company describes design requirements, performance requirements, operator considerations, and also maintenance requirements for one of their electrical driven pushback tugs.

The NWA Environmental department is also researching additional alternatives. According to Mr. Daniel Riebe, NWA Environmental Department, the state of California already has a plan in place for the requirements of the use of electrical GSE (NWA Environmental, 2008). The School of Environmental Issues in Minneapolis, conducted a study with wind power. It was found that one wind mill could provide enough energy needed for two normal houses in a year (School of Environmental Issues, 2008). A group of students from this school is currently researching if this could be used by NWA to power their GSE.

The U.S. Department of Energy has done several studies on alternative fuels to determine what is available and the advantages/disadvantage with each and every fuel type.

Advantages and Disadvantages with Alternative Fuel

Bio Fuels

There is plenty of literature which states that bio fuel consumption should be increased. President George W. Bush and his administration signed energy legislation in December 2007, stating that the annual usage of ethanol and other bio fuels should be 136 liters by 2022 (The Canadian Press, 2008). The government believes that ethanol is a product that will significantly reduce the amount of green house gas emissions, and is also a product that can be produced domestically without having to rely on the other countries- as opposed to oil.

Professor(s) David Pimentel and Tad Patzek, of Cornell University, conducted a study regarding the usage of ethanol as an alternative fuel. The purpose of this study was to analyze in detail the energy input-yield ratios when producing ethanol from corn, switch grass, and wood biomass. The study also researched the benefits of producing biodiesels from soya beans and sun flowers (Pimentel&Patzek, 2005). After the study had been completed and assessed, Pimentel and Patzek suggested that ethanol is not the most efficient sources of fuel when comparing the energy input with the energy output. When it comes to the production of ethanol using corn, it was determined that it requires 29% more

fossil energy than the fuel produced; switch grass requires 45% more fossil energy; while wood bio mass would require 57 percent more fossil energy than produced (Pimentel & Patzek, 2005). The researchers identified the following variables:

1. Only a very low fraction of the sunlight that reaches earth is actually absorbed by plants. Corn only captures 0.25% of all the sunlight.

2. When producing Ethanol, the carbohydrates are converted into Ethanol by using microbes that on average bring the concentration of Ethanol to 8% in a broth, with water making up the other 92%. To be able to remove the 8% of Ethanol, it takes a large amount of fossil fuels.

3. There are two problems with the production of biodiesel according to Pimentel&Patzek: the relatively low yield of oil crops, and also, the oil extraction process for all crops are highly energy intensive.

Most of the literature reviewed suggested that Methanol holds more disadvantages than advantages- it is suggesting that the availability of Methanol is very limited; it is highly corrosive and produce negative by-products (Ehman & Jones, 2006; and West, 2006).

Electrical-Driven Equipment

After reviewing literature regarding electrical driven equipment, most research suggests that the advantages outweigh the disadvantages. The Environmental Protection Agency (EPA) suggests that use of electrical cars is

quite possibly the best way of reducing the amount green house gases produced by traditional fossil fueled vehicles.

A study conducted by the California Environmental Protection Agency in 2005, researched how well electrical GSE would work at the Sacramento Airport (SMF). Southwest Airlines was provided with 12 electrical driven baggage tugs to compare these with the traditional tugs, driven by fossil fuels. The study concluded that there was a significant reduction in fossil fuel savings cost, approximately $1,277 in cost saving per tractor in one year (California Environmental Protection Agency, 2005). The study also showed a significant reduction in the amount of green house gases emitted into the atmosphere. The experiment at SMF proved that there was a reduction of 343 tons of Carbon Dioxide, 16 tons of HC, and also 7.4 tons of NOx.

According to EPA, electrical driven equipment does not require the same maintenance as vehicles driven by the traditional fossil fuels. In addition, electrical equipment does not have as many moving parts that could break compared to a fossil burning engine (EPA, 2002). Furthermore, the EPA claims that electrically driven equipment will reduce the US dependency on oil, and reduce noise pollution. Several other agencies and researchers, including government-based agencies, support these claims regarding electrical driven vehicles.

When it comes to the negative aspects using electrical GSE- most research conducted and literature reviewed agreed on the same points. A study by American Airlines and Air Canada (Ehman&Jones, 2006) suggests that there

could be infrastructural issues and additional ramp space required to accommodate electrical GSE (Ehman&Jones, 2006). Other literature reviewed suggests that another disadvantage with electrical equipment is the necessity of the battery needing to be charged. Another hindrance includes the battery needing to be replaced at a much lower mileage than normal engines (Lifeport Energy, 2007).

Hydrogen Driven Equipment

The magazine “Ground Support World Wide” discusses the advantages and disadvantages of using hydrogen as an alternative fuel for ground support equipment. Several studies have been done by civilian and military GSE manufactures on the usage of hydrogen as an alternative fuel. These studies have shown that hydrogen has the potential to emit less emission than any other alternative fuel and that it would be more reliable and efficient than electricity (Groundsupportworldwide, 2009).

Natural Gas/Propane Driven Equipment

A study conducted in 1990 by Horst Urbaniak, a GSE Technical Standards Manager for Air Canada, showed that Propane or LPG could be a great alternatives to the traditional fossil fuels used. For this study, Air Canada set a determined amount of variables which had to be followed in order to analyze what alternatives that would work for their equipment. These variables are the following:

1. Capital cost of alternative GSE, i.e. electrical, gasoline, diesel, or LPG powered GSE.

2. Operating cost of each fuel type
3. Maintenance cost of each alternative type
4. Cost of training mechanics for each GSE type
5. Emissions Reductions
6. Fuel must be able to last for 8 hrs before being refueled
7. Less than 1 year payback on investment

After a 5 year study the following results were obtained while using LPG powered equipment:

1. Fuel cost cut in half
2. Emissions reduced with 80% compared to equipment using fossil fuels
3. Oil change and maintenance cycles where extended
4. Equipment reliability improved
5. Maintenance cost reduced with 20%
6. Payback of refitting 150 pieces of equipment was 11 months (Urbaniak, 1990)

These findings are in conjunction with what the US Department of Energy has found during their research regarding propane. Propane or, LPG, is the most commonly used alternative of fuel in the US (Department of Energy, 2007). Furthermore, Department of Energy's research finds that propane has a higher density of energy compared to other alternatives; allowing equipment to run longer. Another important fact provided in their study concludes that propane tanks are 20 times more puncture resistant, and has the lowest ignition point among the alternative fuels (US Department of Energy, 2007). Both these studies

provide us with important variables that need to be considered when choosing an alternative fuel for airlines ground support equipment. An article posted in *LifePort Energy 2007* describes one of the major disadvantages of using propane has to do with the cost associated of refitting traditional vehicles in order to run per use of propane. In order to evaluate the pros and cons of the various fuel alternatives, American Airlines together with Air Canada conducted a research study. Natural Gas or Compressed Natural Gas (CNG) was determined to have lower emissions than gas but not lower than diesel (Ehman & Jones, 2006).

Cost of Alternative Fuels

In today's aviation industry, it is all about saving money wherever the airlines deem appropriate. Airlines will not start modifying their current ground support equipment fleet without first knowing the associated costs. Several pieces of the reviewed literature divide the costs into a variety of categories. The categories include capital costs, operational costs, and infrastructure cost. There are also other indirect costs- the cost to our environment and to the employees whom have to breathe in the emission produced.

Capital Costs.

The US Department of Energy conducted a study on costs associated with electrical ground support equipment. In the study they outline a High-Level cost analysis that is broken down into two different categories. These categories include:

1. Capital Cost, including the purchase price of new GSE, alterations that are required before the equipment can be used, cost of batteries, and also the cost of installing the proper charging stations.

2. This category includes GSE maintenance, charging infrastructure maintenance, and also fuel cost (Morrow, 2007; Hochard, 2007; Francfort, 2007). The literature further breaks the cost down into seven different cost categories when it comes to electrical equipment they are as follows:

- The price of purchasing the new GSE
- The price associated with the necessary GSE alterations
- Cost of battery charging system
- Cost to install the charging system
- Cost associated of the maintaining the necessary infrastructure
- GSE Maintenance cost
- Cost of fuel (electricity)

The literature regarding Air Canada's cost analysis suggested that the payback on the capital cost of refitting their conventional ground support equipment into propane driven equipments was met within a year (Urbaniak, 1990).

Operational Costs

An article in *HybridCar, 2006*, reviews the costs associated with the usage of Ethanol. The article suggests that Ethanol can be more expensive than fuel depending on where you live in the country. Ethanol is approximately 30% less expensive than gas in the Midwest; while it can be as much as 35% more expensive on the West coast (HybridCar, 2006). These variables have to be

taken into account by airline when deciding which fuels to use. Maybe ethanol can be cost beneficial in Midwest while it is better to use electricity on the West coast. Southwest Airlines together with the State of California, suggest that usage of one electrical pushback tug saved the company approximately $1,277 a year in fuel savings (California Environmental Protection Agency, 2005).

CHAPTER II: Population

The ideal survey population could be described as varied in regard to the wide-ranging research questions proposed within this study. The initial research question (What alternative ground support equipment exists in today's aviation industry) relates to the research and examination of ground support equipment manufacturers found within the US. The study would also address organizations and government departments such as the US Department of Energy and the Environmental Protection Agency. Additionally, US airlines would need to be considered in order to better understand which alternatives are available.

The second research question (What are the advantages/disadvantages with the different types of alternative ground support equipment) suggests the focus will be on surveying various types of ground support equipment manufacturers. These manufacturers would be able to provide this study with insight concerning the advantages and disadvantages related to a range of the types of equipment. Certain manufacturers could operate from a biased point of view concerning their own equipment- thus it could be hard to obtain objective information regarding the different types of equipment. The US Department of Energy will likely prove to provide un-biased data for the second research question.

Other airlines (Southwest Airlines, Air Canada, and American Airlines) have conducted studies to find the advantages/disadvantages associated with the use of assorted types of alternative ground support equipment. The study

would attempt to gather supplemental information from the aforementioned airlines.

The third query (What are the costs associated with the usage of alternative ground support equipment) will survey a combination of Northwest Airlines stations and GSE manufacturers. NWA stations will be able to provide the research study with information regarding the costs of operating traditional types of ground support equipment. Each NWA station would be able to provide information regarding the money spent on fossil fuels, in addition to the maintenance costs of upholding traditional GSE. The ground support equipment manufacturer would be able to provide this study with information regarding the capital and operational costs of purchasing the different types of alternative ground support equipment.

Sample

When conducting the survey of NWA stations, the researcher would work with the Northwest Airlines airport and customer service department to receive budget data.

This study attempts to identify ground support manufacturers that would prove able to answer questions regarding the advantages and disadvantages with the usage of alternative ground support equipment. The U.S. Department of Energy and the Environmental Protection Agency would assist in identification of which ground support equipment manufacturers to contact per use of a plethora of methods including internet accessibility.

Benchmarking other airlines will also be possible. Because the author of this study works for NWA as a station manager, it should not prove to be an advanced issue.

Study Design

A variety of NWA stations would be identified to be surveyed. Several NWA stations will be identified in varying geographical areas. Each of their budgets will be analyzed to determine capital and manpower spent on the maintenance and usage of ground support equipment that use traditional fuel. These costs would be analyzed and compared to the cost of purchasing and maintaining ground support equipment that utilizes alternative fuels. Similar questions would be asked to the manufacturers of alternative ground support equipment identifying the cost of purchasing/operating different types of ground support equipments. Identification of associated advantages and disadvantages will be considered.

Data Collection Methods/Procedures

The most time efficient manner of collecting necessary data would be per email and other programs associated with the internet. Data will be collected by sending emails to a range of ground support equipment manufacturers regarding the different types of alternative ground support equipment. Data will also be collected by researching information collected from the Environmental Protection Agency (EPA) and the U.S. Department of Energy regarding alternative fuels

available to the aviation industry. This data will be collected by researching the EPA and U.S. Department of Energy websites.

Budget data from NWA will be collected by contacting and establishing rapport with the manager responsible for budget related problems. This manager would be able to provide this research study with budget data for several different stations by sending a simple spreadsheet.

CHAPTER III: PRESENTATION OF THE DATA

The data used for this study was obtained from U.S. Department of Energy in accordance with the Energy Policy Act of 1992 have identified alternative fuels currently used commercially in the United States of America. The data obtained from the U.S. Department of Energy will be reliable and valid to use for this study. Financial data for the financial analysis will be provided directly from a major U.S. network carrier. The data from the network carrier is reported automatically and cannot be tampered with. In this study data in the following categories will be analyzed and reported: different types of alternative fuels, which ones would work, which would not, cost of utilizing alternative fuels, including maintenance costs, cost of purchasing fuels vs. traditional fuel.

Research Questions

The data collected in this research study has been collected to answer the following three questions:

1) What alternative fuels are currently available?
2) What are the advantages and disadvantages per use of alternative fuels?
3) What are the costs (capital, operational, environmental, health) associated with the use of alternative ground support equipment?

Data Related to Research Questions

Data concerning research questions 1 and 2 has been collected as a result of analyzing data from the U.S. Department of Energy and several GSE manufacturers. There are several alternative fuels currently available to airlines that lend to the reduction of costs and emissions. The issue concerning most airlines refers to the initial cost, reliability, and/or availability of such fuels. A growing number of operating airlines are looking into the option of using alternative fuels. The government can also help by offering tax incentives and ensuring more research is being conducted in order to further develop alternative fuels and valid reliability. Airport operators can also help airlines streamline the process by providing the necessary infrastructure, i.e. install electrical chargers conducive to charging electrical equipment on the jet ways. Airlines need to endorse the initiative for progressive methods because it would disregard the replacement of old equipment with diesel equipment, and aim to replace the old equipment with equipment that supports the utilization of alternative fuels. Figure 1 shows six alternative fuels that will be researched in this study.

Figure 1. Alternative Fuels

Alternative Fuels
Bio diesel
Electricity
Ethanol
Natural Gas
Propane
Hydrogen

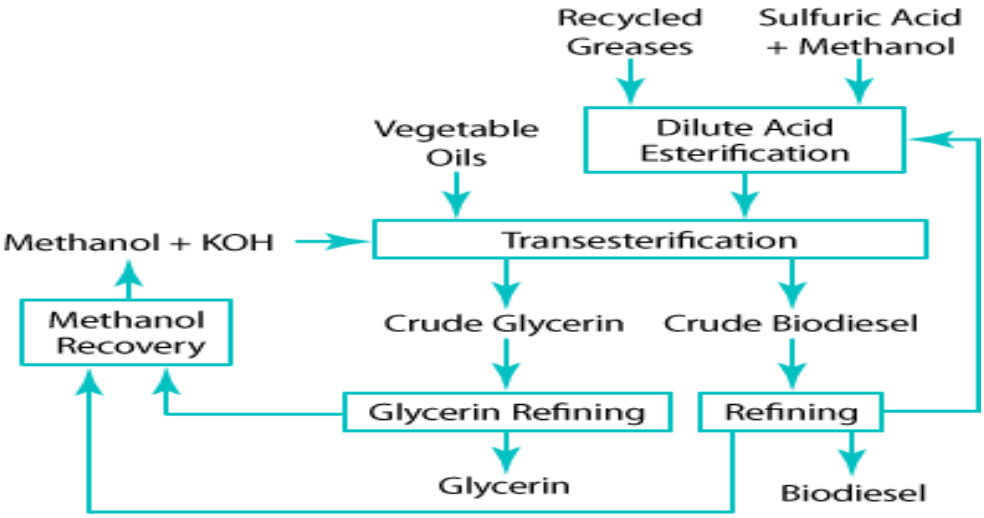
Source: (U.S. Department of Energy)

Each one of these will be analyzed to better understand the associated advantages and disadvantages. Further speculation relates to how they could be utilized within the airline industry.

Biodiesel

Biodiesel is an alternative fuel that is produced from new or used vegetable oils and animal fat. Oils and fats are combined with a type of alcohol substance to create biodiesel (U.S. Department of Energy, 2009). Technology is used to remove water and contaminants from the oils and fats prior to mixing it with alcohol (methanol is most commonly used in the U.S.). The process of producing (figure 2) biodiesel may seem simple but it takes modern technology to obtain the appropriate mixture that will function properly in a modern diesel engine. The biodiesel market in the U.S. is relatively small but it is growing and in 2007, production reached 490 million gallons. Biodiesel makes up approximately 5% of all diesels currently used, and around half of the production of biodiesel is produced by companies that already produce vegetable oils and animal fats (US Department of Energy, 2009). The other half that is produced comes from any fat or oil feedstock and cooking grease. The most common vegetable oil used in the U.S. is associated with soy oils.

Figure 2. Schematic of Bio diesel Production



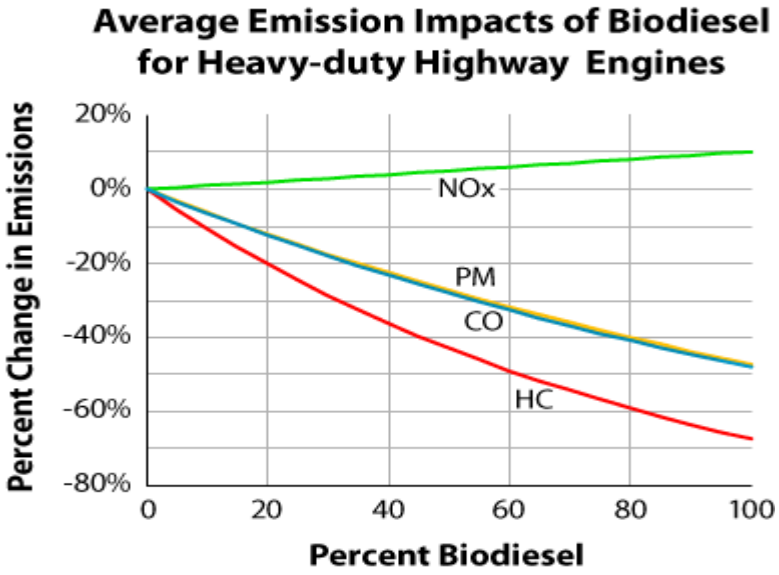
Source: (U.S. Department of Energy)

Biodiesel is most commonly used after blending it with regular, petroleum based diesel. Commonly used mixtures utilized commercially are referred to as, B-2 and B-5. B-2 suggests that there is a mixture of 2% biodiesel with 98% petroleum- based diesel. A B-5 mixture suggests that there is a mix of 5% biodiesel and 95% petroleum based diesel (US Department of Energy, 2009). Research suggests that it is becoming increasingly common to find a B-20 mixture (20% biodiesel). Additional benefits include usage or ownership of vehicles compatible with a B-20 mixture qualify for tax credits. Even though it is used in small quantities, a B-2 or B-5 mixture still have positive effects on air quality. Research has shown that using 100 gallons of B-5 will have the same effect on air quality as using 25 gallons of B-20 or 5 gallons of B-100 (Alternative Fuels & Advanced Vehicles Data Center, 2009).

In 2000, biodiesel became the only alternative fuel that was able to successfully complete the EPA tire I and tire II test under the Clean Air Act and it has been determined that the production and usage of biodiesel resulted in a 78.5% reduction of carbon dioxide emissions (US Department of Energy, 2009).

Biodiesel will not only reduce the amount of carbon dioxide produced but it will also reduce the carbon monoxide, hydrocarbons, and particulate matter. The reduction of emission depends on the mixture of biodiesel with petroleum- based diesel. The largest reduction in emissions would be produced by using B-100 but a B-20 mixture has also been determined to reduce CO emission by 11% and hydrocarbons by 21% (US Department of Energy). Figure 3 shows a graph that depicts the emission reductions per usage of a B-20 mixture. Using a B-20 mixture has been determined to reduce carbon dioxide emissions up to 15%.

Figure 3. Effect of Biodiesel mixture on emissions



Source: (U.S. Department of Energy)

Figure 4 describes the various pros and cons of using biodiesel. As described above, the usage of biodiesel will reduce the emissions of green house gases that are produced by using traditional petroleum-based diesel fuels. Advantages include the following: Biodiesel has a positive energy balance, meaning that that for every unit of energy used to produce a gallon of biodiesel, 3.24 units of energy is gained (Bio diesel board, 2009). Biodiesel can be used in traditional diesel combustion engines without any modifications having to be made to the engines. Biodiesel is also non-toxic which will cause less damage if released into the environment. This is an advantage for airlines considering fuel spills a fairly common occurrence. Furthermore, figure 4 also shows us that the advantages of using biodiesel points toward the fact that it can be produced by using existing production- meaning that it already exists in the U.S. Disadvantages include: Data shows that the properties of biodiesel are not much different than petroleum-based diesel. Data suggests (as depicted in figure 4) that glycerin is a byproduct of biodiesel and is found to be more available in certain regional areas. Most biodiesel production plants are located in the Midwest region and another disadvantage in conjunction with biodiesel is that it can only be used for diesel engines. Many of the vehicles currently used in today's aviation industry use gasoline that would not be able to accommodate biodiesel without major modifications.

Figure 4. Advantages & Disadvantages of using Biodiesel for GSE

Advantages	Disadvantages
Emission reductions	Potential market saturation of glycerin
Positive Energy Balance	Regional Availability
Easy to produce	Only for Diesel Vehicles
Non-toxic	Not efficient in cold weather
Modifications to traditional diesel engines not necessary	
Can be used for moderate to heavy equipment	

Source: (U.S. Department of Energy)

As previously stated, biodiesel could be used for heavy duty vehicles such as ground support equipment used in the airline industry. Conventional diesel combustion engines do not have to be modified to accommodate biodiesel as long as the biodiesel meets the standards set up by the Department of Energy. Because no modifications have to made to the traditional diesel engine, GSE currently used by airlines can be utilized without a modification cost.

The Miami International Airport is currently working on a project that entails a modification of an unspecified number of ground support equipment units to use biodiesel instead of traditional diesel (GroundSupportWorldwide, 2009). The Miami International Airport expects this project to cost nearly $54,000 due to modifications of the current distribution system i.e. within the current

system of distribution; fuel storage and fuel tanks require modernization (GroundSupportWorldwide, 2009).

Biodiesel would be distributed the same way as traditional diesel, i.e. by train, truck, or barge. While most airlines currently have vendors that provide them with fueling stations for a fee, it would be necessary to install and construct an airport fueling station that is able to accommodate biodiesel. Maintenance costs would not change since the same engines are being used. Mechanics that currently work on traditional GSE might need to attend extra training regarding how biodiesel works but it would not be a major cost and most of it could be done locally.

The operating cost for biodiesel would vary depending on the mixture of biodiesel. Figure 5 shows the average costs of the different fuels. As shown in figure 5, traditional diesel fuel is generally less expensive to operate than biodiesel. A large spoke station like IND, spent $330,863 on ground fuel in 2008 (Northwest Airlines, 2009). Using biodiesel, this cost would increase with a gallon of biodiesel being more expensive than traditional diesel. As shown in figure 5, a gallon of B99-B100, would almost be a $1 more than traditional diesel, a significant increase.

Figure 5. Average price of Biodiesel

Fuel Type	Average Nationwide $
Diesel	$2.44
Biodiesel (B20)	$2.67
Biodiesel (B2-B5)	$2.45
Biodiesel (B99-B100)	$3.47

Source: (U.S. Department of Energy, 2009)

Electricity

Electricity can also be used to power vehicles. It uses a battery that is powered by the electricity grid. The electricity produced is stored by using a battery. The battery will be depleted after it has been used, which means it will need to be plugged into a charging station. There are two different choices of electrical equipment in use, one that has onboard chargers and another that uses outside chargers. A positive by produce of electric vehicles is the fact that they do not produce any emissions whatsoever. The only emissions produced are emissions that are created during the production of electricity.

Research conducted by the New York Power Authority, determined that a single tug emits 54 tons of greenhouse gases and around 3, 248 gallons of diesel in a year. The study further illustrated that an electrical tug can reduce these emissions by 90 percent (Ground Support Worldwide, 2009). Electric vehicles can be used both for light duty and heavy duty vehicles but is mostly used for heavy duty equipment. Several airports and airlines are currently using electrical ground support equipment. For example, Southwest Airlines use electric tugs in

some of their stations. Figure 6 shows the various advantages and disadvantages associated with electrically powered aircraft. Research has shown that the usage of electric vehicles could reduce the amount of greenhouse gases by 6.12 billion tons (Electric Power Research Institute and National Resources Defense Council, 2007).

As shown in figure 6, the disadvantage of utilizing electricity would be the associated cost of converting traditional ground support equipment to electric capable. There is also a disadvantage with the limited battery life and the associated charging times. Charlotte of America, a company working improving electrical GSE, is currently working on new batteries that will increase its life span and also decrease the maintenance cost of electrical vehicles (GroundSupportWorld, 2009).

Figure 6. Advantages & Disadvantages of Electricity

Advantages	**Disadvantages**
Zero Emission	High cost to convert
Great availability	Infrastructural changes
Cheap to operate	Higher Maintenance Cost
Can be used for moderate to heavy equipment	Battery life/charge times

Source: (U.S. Department of Energy)

The data depicted in Figure 7 shows the associated cost of converting traditional gas/driven vehicles into electrical. As the data implies, the process is quite expensive. Direct current (DC) electrical equipment is less expensive than

alternate driven (AC) current. DC installations also tend to be a simplified system that is easier to install. Included in the cost of replacing “parts” is the cost of necessary infrastructure, i.e. charging stations. Batteries will need to be replaced on a regular basis depending on associated wear and tear. The typical rate indicates that a battery needs to be replaced every 20,000 miles.

A company called Electric Transportation Engineering is currently working on new technology that would reduce the infrastructural costs of electrical GSE. The company is currently working on a project that suggests an airline can use the ground power available on the jet ways to also charge electrical equipment. They anticipate new technologies will reduce the charge times.

Figure 7. Cost of Converting to an Electrical Vehicle

Supplies	**DC**	**AC**
Parts	$6,000-10,000	$10,000 and above
Batteries	$1,000-2,000	$2,000 and above
Labor	$ 3,500-8,000	$3,500-8,000

Source: (U.S. Department of Energy)

A new diesel tug can be purchased for around $ 260,000, a DC driven tug around $290,000, while an AC driven tug costs $321,000. The total cost of purchasing an AC tug with the necessary battery and charger would be $428,500, while a DC tug is slightly more expensive at $437,500. The cost of diesel tug is still $260,000 (Ground Support Worldwide, 2009). The initial investment cost is higher for electrical equipment but the long term expense is actually less for electrical equipment. A study by Jeff Bowles at the Junghenrich Lift Truck Corp, shows that the total yearly hourly operating cost per tug is less

for an electrical tug ($1.48) than a diesel tug ($4.93) (Ground Support Worldwide, 2009).

A study at the Sacramento International Airport reports they transformed 20 belt loaders from gasoline to electricity; the airlines saved $10,000 per vehicle (Ground Support World Wide, 209). Part of the cost can be offset by the relatively lower operating costs when operating an electrically driven aircraft compared to a gasoline/diesel driven vehicle. Even though AC drive vehicles are more expensive to convert, they do have a lower operating cost.

The data represented in Figure 8, compares the operating cost of a traditional vehicle compared to DC and AC driven aircraft. The data shows the operating cost of an AC vehicle to be one-fourth of the cost for a vehicle using traditional fuel. That would mean a NWA station like IND which spends approximately $330,863 a year in fuel-- could save up to $263,147 a year. Studies conducted by Department of Energy, has shown that utilizing electricity is cheaper in the long run especially when the cost of fuel goes up. Electric vehicles are also reportedly cheaper to maintain (Groundsupportworldwide, 2009).

Figure 8. Operating Cost

Type	**Per Mile**	**Cost (per/mile)**
DC	0.4 (kWh)	$0.05
AC	0.1774 (kWh)	$0.03
Gasoline	$3 gallon	$0.12

Source :(U.S. Department of Energy, 2009)

Ethanol

Ethanol is a renewable fuel produced from various plant materials that are similar to the chemical compound as alcoholic beverages. Ethanol is produced by using starch and sugar based feedstock. For example, corn is commonly used in the United States while sugar cane is used in Latin American regions. Ethanol can also be produced by using grass, wood, crops, and old newspapers or paper products. The production of ethanol using this type of material is more complicated than using grains or sugar cane.

Ethanol can be used in ground support equipment by mixing it with traditional gasoline or it can be used in its pure form. The most common mix is 10-15% of ethanol with 85-90% traditional diesel (U.S. Department of Energy, 2009).

For engines with a high compression rate, ethanol is the ultimate fuel to achieve additional performance.

Ethanol is a renewable fuel that can be used to operate ground support equipment. Figure 9 shows the advantages and disadvantages of using ethanol as fuel for ground support equipment. For example, one of the advantages of using ethanol is that it can easily be produced domestically and it would reduce the U.S. dependency on foreign oil. Some researchers claim one of the disadvantages in using ethanol is that it has a negative energy balance, i.e. more energy goes into producing it than it delivers as a fuel. The U.S. Department of Energy claims that ethanol has a positive energy balance because most studies

forget to take into account the energy contained in the co-products (US Department of Energy, 2009).

There are also claims that the production of ethanol would lead to corn deficit but due to the fact that ethanol can also be produced from other materials, this would not likely be the case. Research has shown that the use of corn-based ethanol could reduce greenhouse gas emissions with as much as 52% compared to petroleum-based fuel (US Department of Energy, 2009). Ethanol does produce carbon dioxide (which is a greenhouse gas) but studies conducted by the US Department of Energy have shown that these emissions are balanced out by the carbon dioxide absorbed by the crops when they grow.

Currently, there are no airlines in the US that are using ethanol for their ground support equipment.

Figure 9. Advantages & Disadvantages of Ethanol

Advantages	**Disadvantages**
Reduced reliance of foreign energy	Negative energy balance
Reduced green house gas emissions	Can lead to a lower fuel economy & damage engine
Economic opportunities for domestic rural areas	Emit carbon dioxide
Small cost to convert vehicles	Water collecting-rust forming

Source: (U.S. Department of Energy)

Traditional ground support equipment would have to be converted to accept Ethanol. There are conversion kits available to purchase, for $100-700 depending on the vehicle (EPA, 2009). Larger vehicles are most costly. A

conversion kit would have to be approved by the Environmental Protection Agency.

The cost per gallon of Ethanol is $1.81 (as of January 2009), which is almost a dollar less than the cost of gasoline/diesel. Ethanol is usually more expensive when it comes to an energy equivalent basis. When compared on an energy equivalent basis (ethanol has 27% less energy per gallon), the price of Ethanol is usually more than the cost of a gallon of gasoline/diesel (US Department of Energy, 2009). Data from the U.S. Department of Energy show Ethanol at a price of $2.56 based on the energy content. There is also a cost associated in converting current fuel stations to accommodate ethanol as shown in figure 10.

Figure 10. Ethanol Fuel Station Cost

Item	**Cost**
New Tank	$60,000
Converting Existing tank	$20,000
Annual maintenance/operating cost	$2,000

Source: (U.S. Department of Energy, 2009)

Natural Gas

Natural gas is another alternative fuel that is currently being used. Many U.S. airports use natural gas as an alternative to power buses and vans. Airlines, like Northwest Airlines have also utilized natural gas for some of their light ground support equipment (Northwest Airlines, 2009). There is natural gas vehicles designed to operate on natural gas. Most alternative fuels there are also

bio-fuel vehicles that will have two separate fuel tanks-- one for natural gas while the other one will be used for traditional fuel. Natural gas can either be produced by compressed gas or liquefied gas and, in accordance with the Energy Policy Act of 1992, it will qualify for tax credits. Today, natural gas can be used for light-duty-vehicle and heavy-duty-vehicles. The ground handling company, Swissport, currently uses natural gas and propane for their fleet of belt loaders and tugs in the state of California but have plans to transfer all of them to electrical.

As shown in Figure 11, the advantages of using natural gas as fuel suggest that it is a very clean burning fuel that drastically reduces the amount of greenhouse gases. The U.S. Environmental Protection Agency has called natural gas the cleanest fuel currently available (US Department of Energy, 2009). A disadvantage of using natural gas is that it does have a short range due to lower energy content, and adding additional fuel tanks will increase the weight of the vehicle. Adding the fuel tank also decreases the space available inside the vehicle.

Figure 11 also shows that natural gas is not a renewable energy resource and that we one day will run out. Also, data from the U.S. Department of Energy Shows that some other issues experienced with natural gas is storage, fueling, station sitting, training, and facilities (US Department of Energy, 2009). Some of the skeptics claim that natural gas has less torque than any pure diesel engine-- which could be an issue for GSE since they need a lot of torque for their push back. Another disadvantage with natural gas is that used by alone, it is mostly

methane which is classified as a greenhouse gas, and in the instance of a major leak would increase the amount of greenhouse gases in the atmosphere.

Figure 11. Advantages & Disadvantages of Natural Gas

Advantages	**Disadvantages**
Reduced green house emissions	Not a renewable resource
Easy to transport	Limited driving range
Infrastructure exists	Storage of fuel cylinder
Produced domestically	Less torque

Source :(U.S. Department of Energy)

The price of a gallon of natural gas is currently $1.64 a gallon, compared to $2.27 for a gallon of diesel) as of April 2009-US Department of Energy, 2009).

Auto manufacturers will charge around $1,500-6,000 for a light duty vehicle; while a heavy duty vehicle like a bus can cost as much as $320,000 (TUGtidbits, 2004). A regular diesel-driven tow tractor costs around $260,000. There are currently several ground support equipment manufacturers that sell tow tractors utilizing natural gas.

Studies conducted by gas companies in Texas have also determined that the cost of converting an E-450 shuttle van to run on natural gas would cost between $18,500-22,500 (Istockanalyst, 2008). Part of this cost could be offset by tax incentives in certain States. A study conducted by a coal company in Texas (Pioneer Natural Resources), analyzed the cost of converting twenty-five of their Ford 250 vehicles to run on natural gas. The results showed that it would cost around $12,000 per vehicle and that an inexpensive fuel station would cost $50,000 and up towards $500,000 (Istockanalyst, 2008).

Propane

Propane is a liquefied petroleum gas that can be used as a fuel for light and heavy duty vehicles. It is produced as a by-product of the production of oil and natural gas. Propane is stored under pressure with no color or smell. After the pressure is released, Propane vaporizes and turns and can be used for combustion. According to data from the U.S. Department of Energy, two percent of the energy currently used in the U.S. is from propane (US Department of Energy, 2009). Propane is a commonly used energy source for vehicles after gasoline and diesel. Propane would be stored under high pressure in a storage tank and according to the US Department of Energy, a gallon of propane consists of 25% less energy than a gallon of gasoline (US Department of Energy, 2009).

Figure 12 shows the advantages and disadvantage associated with the usage of propane. One of the obvious advantages is that it drastically reduced the amount of greenhouse gas emissions. Data from the U.S. Department of Energy shows that carbon monoxide emissions are reduced by 20-40% and particulate matter by 80%. Methane emissions actually increase by 10% when using propane (U.S. Department of Energy, 2009). Another advantage with propane is that it has a high energy density and can run longer on one tank. Propane is also ideal for low-power settings. A study conducted by Air Canada Ground Handling Services in 2005 and 2006, showed that propane driven ground support equipment saved 42% in fuel costs and reduced greenhouse gas emissions by 34% (Air Canada, 2009). The study conducted by Air Canada

maintains that the payback of refitting 150 pieces of equipment took place within 11 months.

Figure 12. Advantages & Disadvantages of Propane

Advantages	**Disadvantages**
Higher energy density	Increased fuel consumption
Reduce greenhouse gas emissions	High fuel prices
Reduce Foreign Oil Dependency	Non renewable fuel source
Low flammable point (very safe)	Decreased energy consumption

Source :(US Department of Energy, 2009)

The cost of converting a vehicle using gasoline into propane, costs between $ 4,000-12,000 (U.S. Department of Energy). The base price for a 2006 Chevrolet Silverado was $26,395. Converting this vehicle to use propane would cost $850 for an alternative fuel conversion and $9,950 for the propane conversion (Alternativefuel, 2009). The cost of a gallon of propane is currently more expensive than gasoline and diesel.

The latest report from the U.S. Department of Energy shows the national average (per gallon) of gasoline as $2.02, diesel as $2.27, and propane as $2.58 (US Department of Energy, 2009). The price paid per unit of energy content is $2.02, diesel $2.04, and propane at $3.58 (US Department of Energy, 2009). A vehicle that is being converted from gasoline/diesel to propane needs to be certified by the Environmental Protection Agency and the inspection has to be completed by a certified technician. The payback on the investment will all

depend on the number of miles the vehicle is proposed to travel within a year, the fuel economy of the original vehicle, the cost of the conversion. After the conversion has been completed it is important to remember that the weight of the vehicle will increase due to the propane tank that will be installed. This will, in turn, increase the fuel consumption of the vehicle.

Hydrogen

The sixth, and last alternative fuel considered, is hydrogen. Hydrogen holds a great potential future as an alternative fuel. Hydrogen is the most common element on earth and it exists in combination with other elements, (i.e. oil). In order to use hydrogen as a fuel it needs to be removed from other elements-- the most common method to complete this task is to combine steam, heat, and natural gas.

Due to its energy density, hydrogen has to be liquefied or compressed when stored, and can be used as a fuel either by using it in fuel cells, or by using it in a regular combustion engine. Hydrogen has yet to be used in vehicles but the U.S. Department of Energy has set a goal to start the use of hydrogen as an alternative fuel by 2015 (US Department of Energy, 2009). Hydrogen is produced very near to the site it is used and there is currently no infrastructure in place. When hydrogen becomes available as an alternate fuel for vehicles it will become the cleanest fuel available and it will be able to be produced from renewable energy sources such as solar and wind power.

Both civilian and military ground support equipment manufacturers are currently in the process of developing GSE that run on hydrogen. Fuel cells are being developed to be used on tow tractors and research has shown that a hydrogen fueled vehicle will always be fully charged and not have a performance drop at the end of the shift—which can happen with an electrically driven tow tractor. Refueling a tow tractor using hydrogen is also much more efficient than having to recharge a battery.

The Ford Motor company has developed a 4.6 liter hydrogen combustion engine that is being used by ground support manufacturers to develop an engine for GSE. The engine developed by the Ford company produces almost zero emissions and requires very little training (Ford Company, 2009).

Chapter V: Recommendation and Discussions

Recommendation

This research paper studied the various alternative fuels currently available (bio, eth, prop, ng, el, hy) their advantages/disadvantages, associated costs, and availability of the fuels that could be used by a U.S. airline.

The fuel to be used for a U.S. airline has to be reliable, as well as able to save airlines money in the long run. In today's economic downturn, airlines are not going to invest money on new equipment unless it can be determined that, the equipment is reliable, readily available, affordable, and it is compliant with the environment.

Biodiesel would allow an airline to reduce the emissions produced by traditional ground support equipment and no modifications would have to be made to current equipment but research suggests it would not be feasible to use biodiesel. A gallon of biodiesel is almost a $1 more than regular diesel, and it is not very likely that an airline would pay the extra money, even if it would reduce greenhouse gas emissions.

Electrically-driven ground support equipment produces almost zero green house gas emissions and it is already used by airlines. The only issue with electrical drive GSE is that it has to be charged and will lose some power towards the end of the battery's life cycle. The other issue with electricity is that an electric tug would cost approximately $150,000 more than a diesel tug to purchase an electrical tow tractor with the entire necessary infrastructure. A study conducted by the Junghenrich Lift Truck Corporation indicates that long

term costs of electricity are less than the cost of traditional fuels. Additionally, a study at the Sacramento International Airport contended that the operating cost is less for an electrical vehicle compared to traditionally powered equipment. The airline involved in the study saved $10,000 per vehicle by lowering of the operating costs. The study maintained that electrically driven vehicles are very reliable and as previously stated; an airline like Northwest Airlines could save $330,863 on an annual basis by using electrical GSE; in addition to possibly reducing the emissions by as much as 90%.

Ethanol is a fuel that is currently cheaper to purchase than traditional diesel. The concern regarding ethanol is that it has a negative energy balance. Some studies also show that ethanol usage will increase the carbon dioxide emission in the atmosphere. Another reason ethanol would not be the most feasible fuel for an airline, is that it collects water that leads to corrosion. GSE used by airlines will be used in all types of weather and must be able to withstand associated weather elements.

Natural gas a major disadvantage-- it is not renewable natural resources. A gallon of natural gas is almost $1 cheaper than a gallon of traditional diesel but if an airline is going to invest money on an alternative fuel it should be something that is both economical and environmentally feasible in the long run.

A study conducted by Air Canada Ground Handling Services, showed that propane-driven ground support equipment saved 42% in fuel costs and reduced greenhouse gas emissions by 34% (Air Canada, 2009). Although propane

allowed Air Canada to reduce their fuel costs, it would not be a feasible alternative fuel in the long run since it is not a renewable natural resource.

Hydrogen is a new alternative fuel that currently does not currently exist as a fuel for any vehicle but there is great potential. Hydrogen would be able to be produced from renewable sources of energy such as solar and wind power. Additionally, it would become the cleanest fuel available. The military has conducted several studies that show hydrogen will also be cheap to operate. At this time there are no estimates on how much it will cost to convert or purchase GSE using hydrogen. Considering the fact that it is going to emit no emissions and can be produced through renewable resources-- it has great potential.

Discussion of Results

There are several alternative fuels that are currently available to an airline that can reduce costs and emissions. Electricity is currently the alternative fuel with the greatest potential since it can reduce costs for an airline, and at the same time, reduce emissions. The study suggests that an airline can save up to $330,863 a year in fuel costs at Northwest Airlines stations that are similar in size to its Indianapolis station. Additionally, electricity can reduce emissions by as much as 90%. Advantages point towards its availability and user friendliness.

The issue concerning most airlines is the initial cost, reliability and/or availability of such fuels. The initial cost would be high for an airline that wants to use electricity but studies have shown this money can be made up in the long run due to lower operating costs. A study done by the Junghenrich Lift Truck

Corporation shows that the hourly operating cost for an electrical tug is $1.48 compared to $4.93 for a diesel tug. Propane is another alternative fuel that is currently used by airport operators; but because it is not a renewable energy source, it would not be an alternative fuel recommended for airlines.

The price of oil is very volatile and creates financial chaos within the airline industry, Airlines are already starting to conduct research in order to determine which alternative fuels would work for specific route structures. For example, Southwest Airlines have converted several tugs that use traditional fuels into electric tugs. The incentive for other airlines to follow will be rising fuel costs. A growing number of airlines are looking into the option of using alternative fuels. The government can also help by offering tax incentives and ensuring that more research is being conducted in order to further develop alternative fuels and its respective reliability. An example of one researchable alternative fuel that has great potential is hydrogen. Hydrogen is extremely clean and is a renewable energy source. The government, together with the private sector, needs to keep developing reliable engines that utilize hydrogen. The hydrogen infrastructure also needs to be researched and strengthened in order to properly understand the great potential of its use as an appropriate source of energy.

Airport operators can also help airlines make the transition process easier by providing the necessary infrastructure, i.e. install electrical chargers on the jet ways that are conducive to charging electrical equipment. Airlines need to endorse the initiative for progressive methods which disregards the replacement

of old equipment with diesel equipment; rather it should aim to replace the old equipment with new equipment that supports the utilization of alternative fuels.

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