An Analysis of Alternative Jet Fuel Supply for

Manassas Regional Airport

Final Report

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TABLE OF CONTENTS

1. TABLE OF FIGURES

2. EXECUTIVE SUMMARY

Manassas Regional Airport is owned by the City of Manassas and located in Prince William County, approximately 30 miles southwest from Washington DC. In 2012, it was the fourth busiest airport by operations in the Commonwealth of Virginia, averaging 237 operations a day. However, those operations are a function of aviation fuel, which is powered by petroleum that is cheap enough for those operations to be affordable. If petroleum prices were to increase too much and jet fuel prices were to get too expensive, the cost of flying could become too prohibitive to the flying customer, which risks putting every Manassas Regional Airport stakeholder, including the airport itself, out of business. If an alternative to conventional jet fuel could be developed, then the risk of unmanageable petroleum prices facing the aviation industry would be mitigated.

The purpose of this project was to determine the best way to bring bio-based alternative jet fuel to Manassas Regional Airport. If alternative jet fuel could provide assurance that fuel prices won't become too expensive or too volatile, than every fuel distribution stakeholder would have a financial interest in acquiring alternative jet fuel. Solving the problem requires an understanding of Manassas Regional Airport's operations, fuel distribution system, the motivation of Manassas Regional Airport fuel distribution stakeholders, existing alternative jet fuel suppliers that could serve Manassas Regional Airport, and the availability of bio-based alternative jet fuel feedstock in the region.

In 2012, the Airport Cooperative Research Program (ACRP), a collaborative aviation research initiative focused on improving airport competitiveness with innovative solutions, published a report titled, *ACRP 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting*. The report outlined a framework for evaluating the feasibility of introducing alternative jet fuels into an airport's jet fuel supply chain. This report, which served as the primary influence in the development of this team's approach to solving this problem, helped the team identify options to evaluate as well as the approach used to evaluate those options. The team identified three options for bringing bio-based alternative jet fuel to Manassas Regional Airport.

1. **Drop-in Biofuel Delivery.** This option simply involves purchasing bio-based alternative jet fuel from a biofuel supplier.
2. **On-Site Blending of biofuel.** This option involves purchasing both unblended biofuel and conventional jet fuel, and blending the two fuels at the airport. The blending is required in order for the fuel to satisfy chemical specifications of safe jet fuel.
3. **On-Site Production of biofuel.** This option involves constructing a biofuel production facility on airport property and producing alternative jet fuel at the airport.

The logistic feasibility of each option was determined by analyzing the how each option could be implemented. The financial viability of each option was evaluated by comparing each option's cost over a 20 year period to the airport's option of doing nothing, and continuing to use conventional jet fuel. Some of the costs associated with each option could be estimated and adjusted for expected inflation of the next 20 years, but some factors required the development of a sophisticated forecasting model to predict prices. Conventional jet fuel and soybean oil were the two components of the price of alternative jet fuel that required the sophisticated forecasts to estimate their price over a 20 year period. Using these forecasts as inputs, a comprehensive cost model was developed for evaluating each option.

While options 1 and 2 were deemed not logistically feasible in the near term, all three options are logistically feasible in the long term. However, all three options are too expensive. In fact, the break-even cost per gallon of jet fuel with any of the three options was estimated to be nearly twice that of conventional jet fuel. These results are summarized below.

Summary of the Analysis Results

Option	Logistically Feasible – Near Term	Logistically Feasible – Long Term	Change in Net Present Value over 20 years (in thousand dollars)	2013 Cost Estimates ($/gal)
"Do-Nothing" Option	Yes	Yes	$ 0	$ 3.89
1 – Drop-in Biofuel Delivery	No	Yes	$ (20,436)	$ 7.49
2 – On-site Blending of Biofuel	No	Yes	$ (20,710)	$ 7.20
3 – On-site Production of Biofuel	Yes	Yes	$ (21,235)	$ 9.35

There are, however, circumstances that could change that may lead to a situation where bio-based alternative jet fuel at Manassas Regional Airport becomes an economically viable reality. These specific circumstances are related to price divergence between biofuel feedstocks and jet fuel, regulatory incentives for biofuels, and technology improvements. These circumstances are studied in detail at the end of this report.

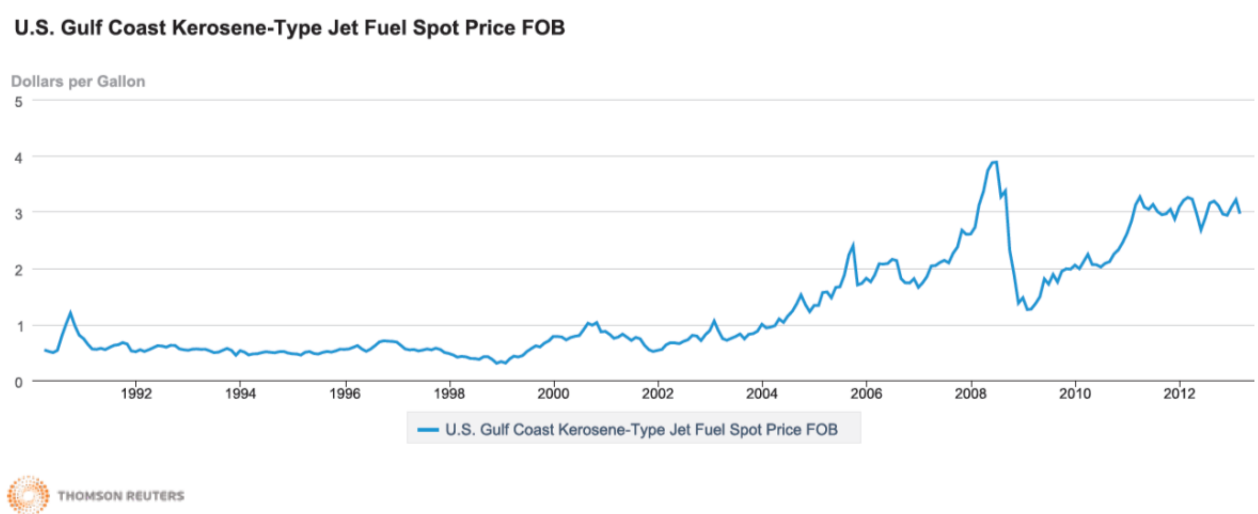
3. BACKGROUND

Aviation has a sustainability problem. Unlike other modes of transportation, the aviation industry is limited in the sources of power from which it can choose. To date, batteries big enough to power a commercial airplane are too heavy. Nuclear powered aircraft present unacceptable risk to the flying public. And solar power has not proven to be feasible for commercial operation. Because of these limitations, and the limited supply of petroleum on Earth, it is in the interest of the aviation industry to find alternative jet fuels.

Jet fuel is a common type of aviation fuel used to power gas turbines. There are many variations of jet fuel, but in the civilian aviation industry, three variations are used: Jet A, Jet A-1, and Jet B. While each of these three jet fuels is slightly different, they are similar in that all are derived from kerosene. Kerosene is a fuel oil that is made by distilling petroleum. And because petroleum is a non-renewable energy source for which there is a limited supply on Earth, there is a great interest within the aviation community to create jet fuel from synthetic kerosene, which is derived from non-petroleum sources. A jet fuel created from synthetic kerosene would be classified as an “alternative” jet fuel.

3.1. Financial Considerations

Biofuel offers the aviation industry the ability to diversity their fuel supply. As mentioned earlier jet fuel in use today is derived almost entirely from petroleum. Unfortunately, its supply is diminishing and its rising prices are highly volatile. This poses a concern for airlines since fuel prices represent around 30% of total operating expenses (AviationDB 2012). In 2013, jet fuel is predicted to be cost the aviation industry 216 billion dollars (IATA 2013). Rising fuel prices will continue to have a severe impact on airline’s profitability and has been the major cause of the upward trend in airfares



Sources: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPJK_PF4_RGC_DPG&f=M

Figure 1: Monthly U.S Gulf Coast Kerosene Price from January 1991 to February 2013. (Per Gallon)

Biofuels provide airlines with the opportunity to potentially reduce jet fuel prices along with their volatility by diversifying its supply and reducing the impact of potential carbon taxes. Airlines may also have the ability to enter into long-term supply contracts with potential producers to further decrease fuel price volatility.

However, while Biofuels have the potential to reduce airline costs by diversifying the market, they have a high startup cost. This is because the supply of feedstock is currently limited due to limited demand and the technologies needed to store, transport and turn feedstock into biofuel are cost intensive. It is expected that if biofuels where to become an alternative jet fuel then as time progresses feedstock supply and technology would improve to reduce costs.

3.2. Environmental Considerations

The aviation industry can potentially reduce its environmental footprint by using alternative jet fuel. While the hope is that bio-based alternative jet fuel will reduce greenhouse-gas (GHG) emissions, it's possible these emissions may increase when accounting for emissions during the entire lifecycle of alternative jet fuel, including production, distribution and combustion of the fuel. Analyzing emissions through the entire supply chain is known as life-cycle analysis, and is important to obtain an accurate estimation of the environmental impacts of an alternative jet fuel project.

A reduction in greenhouse gas emissions has an immediately favorable impact on an airport's operations. Airports must comply with National Ambient Air Quality Standards (NAAQS), which are Environmental Protection Agency (EPA) standards for air throughout the United States. Airport operations planning, including air traffic patterns, ground operations, and airport capacity, are all affected by NAAQS. A reduction in greenhouse gas emissions means an increase in flexibility of airport operations (FAA 2007).

3.3. Drop-in Alternative Jet Fuels

Alternative jet fuels are fuels derived from an energy source, or "feedstock," other than petroleum. These alternative sources can be non-petroleum fossil fuel feedstocks, such as coal or natural gas, and bio-based renewable feedstocks, such as plant or animal oils, crop residue and woody biomass. To create alternative jet fuel, synthetic kerosene would have to be created from these alternative feedstocks.

The biggest technical challenge in creating jet fuel from alternative feedstocks is that the alternative must be capable of replacing regular jet fuel without requiring new infrastructure. Infrastructure for aviation fuel includes everything from storage tanks and pipelines in the fuel supply chain to the fuel system that powers the engines on an aircraft. Requiring changes to existing aircraft fleets or fuel distribution networks would make alternative jet fuel practically infeasible. An alternative jet fuel capable of achieving this type of interoperability is known as a "drop-in" fuel (CAAFI 2013).

Drop-in alternative jet fuel must meet the same chemical specifications as conventional jet fuel. In the United States, the American Society for Testing and Materials (ATSM) has established these specifications for Jet A, which are described in ASTM Specification D1655 (EAA 2013). Alternative jet fuel is described in ASTM Specification D7566, which includes all requirements of D1655 and more. Currently, there are two accepted methods that have been developed for creating the synthetic kerosene, which precipitates the creation of alternative jet fuel.

Fischer-Tropsch (FT) – A chemical process used to convert natural gas, coal, and biomass into liquid fuel. When applied for aviation purposes, it can be used to create Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK), an alternative jet fuel that can be blended with conventional jet fuel to meet ATSM Specification D7566, the U.S. standard for alternative jet fuel (Renewable Jet Fuels 2013).

Hydroprocessing – A process of refining plant oils and animal fats into liquid fuels. When applied for aviation purposes, it can be used to create Hydroprocessed Esters and Fatty Acids (HEFA), also referred to as Hydroprocessed Renewable Jet (HRJ), an alternative jet fuel that can be blended with conventional jet fuel to meet ATSM Specification D7566, the U.S. standard for alternative jet fuel (Renewable Jet Fuels 2013).

3.4. Jet Fuel Supply Chain

While these methods can create fuel very close to reaching ATSM Specification D1655, neither method has been able to achieve the entire specification on its own. Instead, conventional jet fuel must be mixed with the alternative jet fuel to create a blended fuel that satisfies all requirements in ATSM Specification D7566. The fact that a stand-alone drop-in alternative jet fuel has yet to be invented is a key inhibitor to integrating alternative jet fuel into an airport's fuel supply chain. To date, the highest percentage of alternative jet fuel that has been approved in a blended fuel is 50% (ACRP 2012, Section 2.1).

Figure 2 below shows a conventional jet fuel supply chain. The fuel is made with petroleum-based kerosene at some offsite facility and transported to the airport fuel farm where it can be store nearly indefinitely.

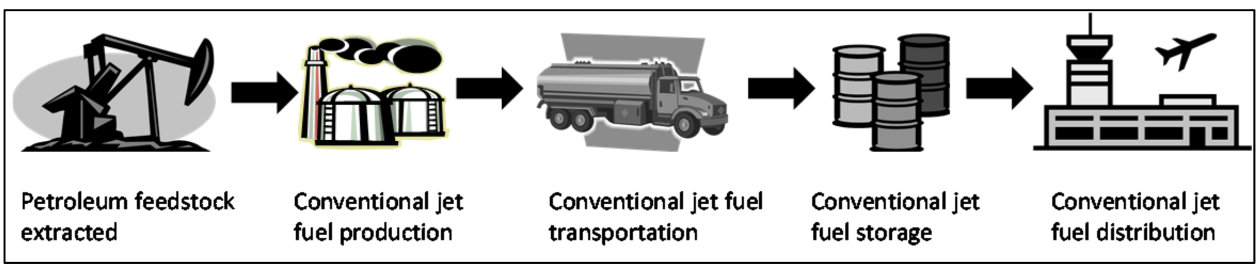


Figure 2. Conventional jet fuel supply chain from petroleum extraction to end user consumption.

Figure 3 shows how alternative jet fuel would be incorporated into the supply chain. Like jet fuel, the alternative fuel would be created at an offsite facility. But because it is not yet drop-in grade jet fuel, it must be transported using different infrastructure so as to not contaminate the conventional jet fuel. A blending facility must then be constructed near the airport fuel farm so the alternative and conventional fuels may be blended (While the blending does not have to occur at the airport fuel farm, it is a desirable location because it does not significantly disrupt the already existing conventional jet fuel supply chain and an airport is likely to already own the land where a blending facility would be built. Both of these aspects present significant cost savings (ACRP 2012, Section 5.2.2)).

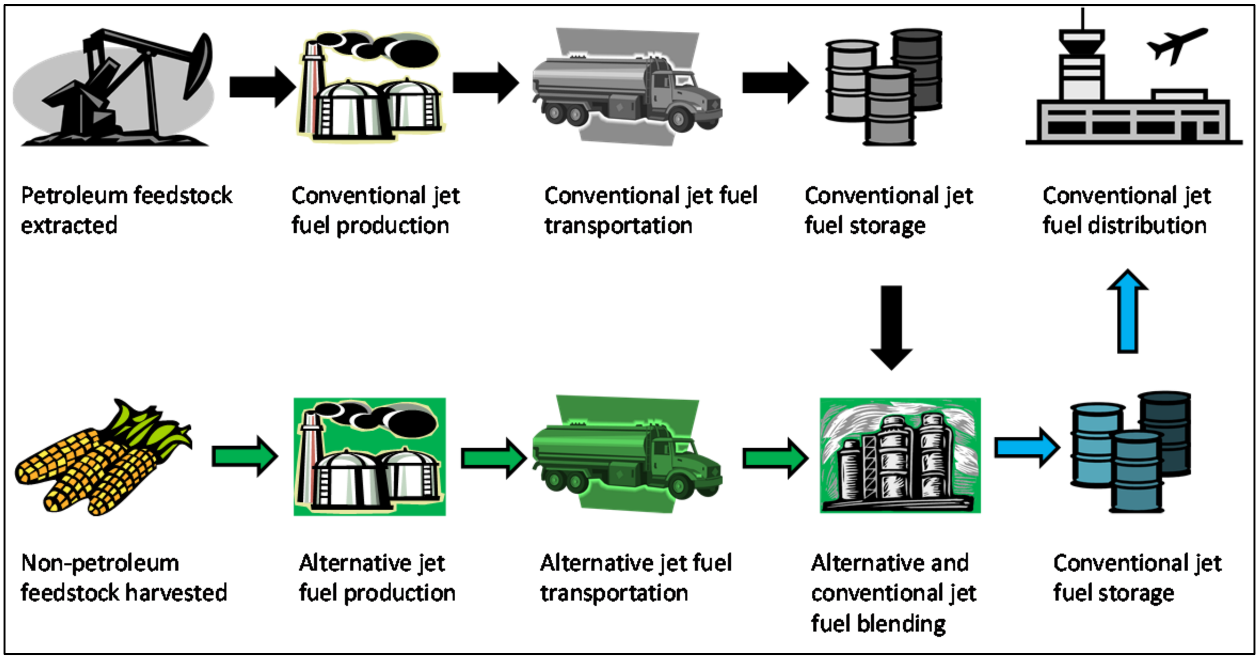


Figure 3. Bio-based alternative jet fuel supply chain from biomass extraction to end user consumption.

4. PROBLEM DESCRIPTION

The purpose of this project is to determine the best way to bring bio-based alternative jet fuel to Manassas Regional Airport. Solving the problem requires an understanding of Manassas Regional Airport's operations, fuel distribution system, the motivation of Manassas Regional Airport fuel distribution stakeholders, existing alternative jet fuel suppliers that could serve Manassas Regional Airport, and the availability of bio-based alternative jet fuel feedstock in the region. By studying these different characteristics and their interrelations, we can determine a financially viable solution for bringing bio-based alternative jet fuel to Manassas Regional Airport that is also logistically feasible.

4.1. Manassas Regional Airport

Manassas Regional Airport (HEF) is owned by the City of Manassas and located in Prince William County, approximately 30 miles southwest from Washington DC. In 2012, it was the fourth busiest airport by operations in the Commonwealth of Virginia, averaging 237 operations a day (FAA 2013a).

In 2012, 2.35 million gallons of jet fuel were purchased by airport users from the Manassas Regional Airport fuel farm. Yearly fuel flowage from 2005-2012 for Manassas Regional Airport (Allabaugh 2013) is shown below in Table 1.

Table 1. Yearly fuel flowage at Manassas Regional Airport

Calendar Year	Jet Fuel (gal)
2005	2,475,867
2006	2,617,672
2007	2,361,741
2008	2,055,313
2009	2,073,920
2010	2,326,174
2011	2,279,535
2012	2,347,632

The fuel farm located at Manassas Regional Airport, known as the Central Fuel Farm, contains 112,000 gallons of jet fuel storage capacity and 45,000 gallons of aviation gasoline storage capacity. The Central Fuel Farm, in which all of the airport fuel supply is located, is comprised of a concrete access road, secondary containment basin, dike enclosed storage tank area, a 400-gallon passive oil/water separator, and a series of drainage structures to control the release of storm water and to prevent the release of a spill. Two Fixed Base Operators (FBOs) (APP Jet Center and Dulles Aviation, Inc.), two aircraft charter companies (Chantilly Air and FlightWorks, Inc.) and one airline operator (Metropolitan Aviation) own fuel storage tanks at the Central Fuel Farm. There are nine above-ground tanks, labeled 1-10 (with the number 4 omitted), at the Central Fuel Farm. These tanks are shown below in Figure 4.

Figure 4. The Central Fuel Farm at Manassas Regional Airport

4.2. Motivation of Fuel Distribution Stakeholders

Manassas Regional Airport makes money off the distribution of fuel at the airport by adding a surcharge to every gallon of fuel that flows out of the airport fuel farm (Berry 2013). The fuel distributor, which acts as an "airport gas station" for all airport users, makes money by purchasing fuel in large quantities at lower per gallon costs than it sells the fuel to airport users. Airport users make money by charging flying customers more than it actually costs to transport those customers. Since 30 % of the cost of flying comes from the cost of fuel (AviationDB 2012), any increase in fuel costs will directly increase the cost of flying in a significant way. If conventional jet fuel prices get too expensive or increase in volatility, the cost of flying could become too prohibitive to the flying customer, which risk putting every Manassas Regional Airport stakeholder out of business. If alternative jet fuel can provide assurance that fuel prices won't become too expensive or too volatile, than every fuel distribution stakeholder has a financial interest in acquiring alternative jet fuel.

Manassas Regional Airport also has an environmental interest in securing alternative jet fuel supply to the airport. Environmentally, the City of Manassas, which owns Manassas Regional Airport, has a responsibility to protect its residents from harmful environmental activity. As discussed in section 3, the use of bio-based alternative jet fuels offers an opportunity to decrease greenhouse-gas emissions.

Manassas Regional Airport is in the aviation business, not the fuel distribution business, however. And it is therefore necessary to view this problem from the perspective of the fuel distributor, which is in the position to choose the source of the jet fuel it distributes at the airport and the stakeholder that stands to gain or lose the most financially from any bio-based alternative jet fuel venture.

4.3. APP Jet Center

APP Jet Center is one of two fixed-based operators (FBO) at Manassas Regional Airport. It operates on-demand and charter flights under a Federal Aviation Administration (FAA) Code of Federal Regulations (CFR) Part 135 Certificate. It also provides airport services, including aviation gasoline and jet fuel distribution. It owns 40,000 gallons of jet fuel and 30,000 gallons of aviation gasoline capacity at the Manassas Regional Airport Fuel Farm.

For the purpose of this project, the analysis of the problem is studied from the perspective of APP Jet Center and whether the sale of bio-based alternative jet fuel is a logistically feasible and financially viable opportunity.

4.4. Alternative Jet Fuel Suppliers

The bio-based alternative fuel business has been around for a while. The first public demonstration of any bio-based fuel was at the 1900 World Fair, when the Otto Company ran a diesel engine on peanut oil (Pacific Biodiesel 2013). And in a 1912 speech, Rudolf Diesel, the inventor of the diesel engine, said, "the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time." (Center for Sustainability 2011)

While alternative jet fuel has not been around for as long as biodiesel fuel, alternative jet fuel made from coal has been used in South Africa for more than 20 years (ACRP 2012, Appendix B). Sasol, a South African chemical company, created jet fuel from synthetic kerosene, which blended 50-50 with conventional jet fuel, which was approved for use in 1998 (ACRP 2012, Appendix B). However, coal is a non-renewable energy source, and similar successes with bio-based alternative jet fuel do not exist.

Bio-based alternative jet fuel is in its infancy. Many airlines have conducted flight tests using bio-based alternative jet fuel. The first such flight test occurred in December 2008 when Air New Zealand flew a Boeing 747-300 aircraft on alternative jet fuel developed by UOP (formally Universal Oil Producers), a Honeywell company, derived from *Jatropha* (ACRP 2012, Appendix B), a plant. Then on November 7, 2011 the first commercial flight using bio-based alternative jet fuel was flown by United Airlines using fuel developed by Solazyme, derived from algae (Solazyme 2011).

4.5. Regional Feedstock Availability

Oils and fats that can be used to as feedstocks for bio-based alternative jet fuel include non-edible oils (e.g., *Camelina*, *Jatropha*, pennycress, algae), edible oils (e.g., soybean, canola, peanut), and animal fats (tallow) (ACRP 2012, Section 2.3). Energy crops, which are grown explicitly for use as an energy source, include crops such as switchgrass and corn stover. Unfortunately, since the bio-based alternative jet fuel is relatively new, many of these feedstocks are not available in commercial quantities, since demand for their cultivation has been low up until recently.

The only type of oil feedstock that is available in large enough quantities for feasible use as a biofuel feedstock are edible oils. Table 2 below shows the six most-produced edible oils in the world. Palm oil and palm kernel oil are not cultivated in the U.S. because their seeds require a tropical climate. Of the four remaining oils, only two are produced in the Commonwealth of Virginia. Because of transportation costs, limiting feedstock transport to locations in the surrounding region of Manassas Regional Airport makes sense. Since soybean oil is more widely available in Virginia and less expensive than peanut oil, as shown in in Table 2 and Figure 5, soybean oil was chosen as the feedstock for this analysis.

Table 2. Most produced edible oils by Worldwide Production (USDA 2013)

	Average Yield (gal/acre)	2012 World Production ('000 Metric Ton)	2012 US Production ('000 Metric Ton)	2012 Virginia Production ('000 Metric Ton)
Palm Oil	635	54,320.00	-	-
Soybean Oil	48	43,090.00	9,490.00	117.98
Rapeseed (Canola) Oil	127	23,910.00	600.00	-
Sunflower seed Oil	102	13,840.00	260.00	-
Palm Kernel Oil	612	6,250.00	-	-
Peanut Oil	113	5,320	120.00	18.00

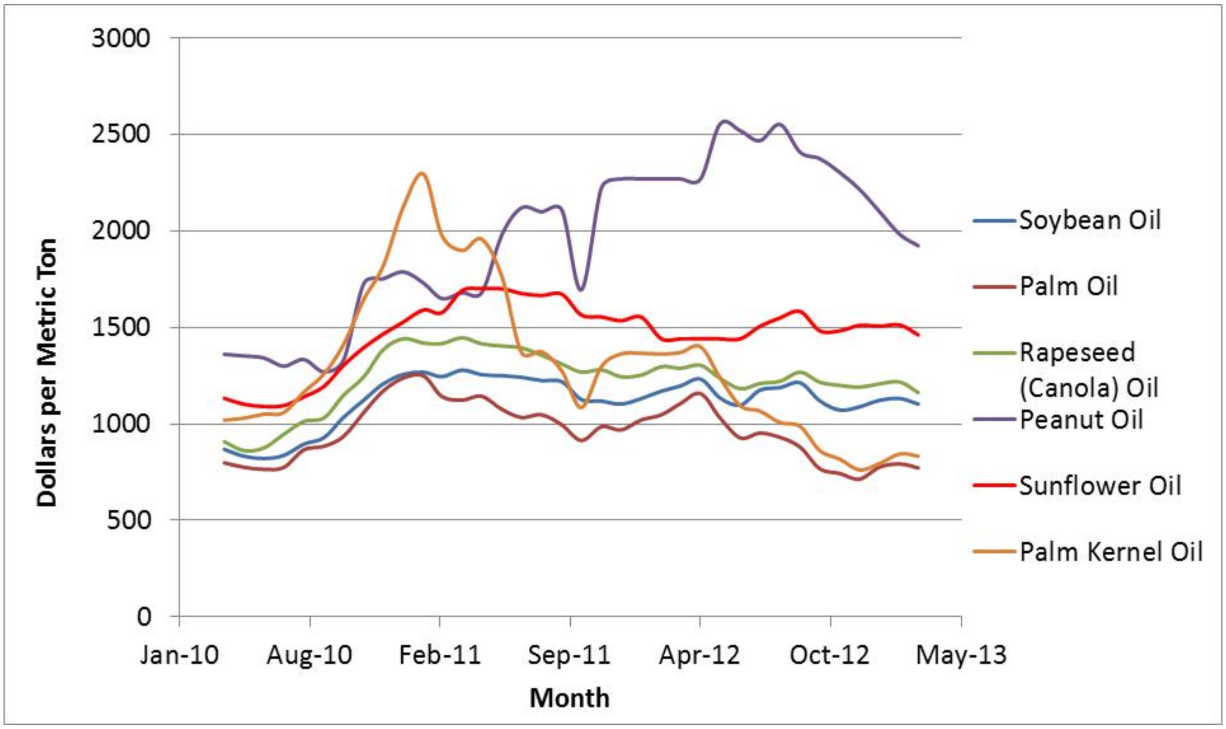


Figure 5. Monthly price per metric ton of edible oils (IndexMundi 2013).

It is worth pointing out that while soybean oil is the cheapest oil produced in the U.S., its average yield per acre is the lowest. All feedstocks are able to be grown in the Virginia climate, so if one were to select a feedstock dedicated for biofuel production, it may make sense to choose a higher yielding crop, such as rapeseed (canola) oil.

5. TECHNICAL APPROACH

The technical approach used to study this problem includes the identification of alternatives based on steps involved in the alternative jet fuel supply chain. Once the options are identified, economic and logistical analyses of the impact on APP Jet Center will be completed for each option. Of the logistically feasible options, the most economical option, which provides bio-based alternative drop-in jet fuel at the lowest cost, will be the preferred option. The lowest cost option is determined based on a price forecast of the variable costs combined with a cost model of the other parameters that make up the total cost of that option. And if the preferred option provides jet fuel at a lower cost than the "do nothing" option, then the team will recommend APP Jet Center move forward with implementation of that option.

In 2012, the Airport Cooperative Research Program (ACRP), a collaborative aviation research initiative focused on improving airport competitiveness with innovative solutions, published a report titled, *ACRP 60: Guidelines for Integrating Alternative Jet Fuel into the Airport Setting*. This report outlines a framework for evaluating the feasibility of introducing alternative jet fuels into an airport's jet fuel supply chain. This report served as the primary influence in the development of this team's approach to solving this problem. And it is the hope of this team that this project report will further enhance the understanding of integrating alternative jet fuel into an airport's supply chain.

5.1. Identifying Alternatives

From studying the process steps of the alternative jet fuel supply chain, implementation options can be identified by allowing APP Jet Center to take on a progressively larger share of the supply chain, one step at a time. Following this logic, there are three reasonable options from which to choose for integrating bio-based alternative jet fuel into the jet fuel supply chain at Manassas Regional Airport. These options are depicted in Figures 6, 7, and 8. Each option adds an additional step from the supply chain into Manassas Regional Airport operations, placing more control of the supply chain into the hands of the Manassas Regional Airport fuel distributor.

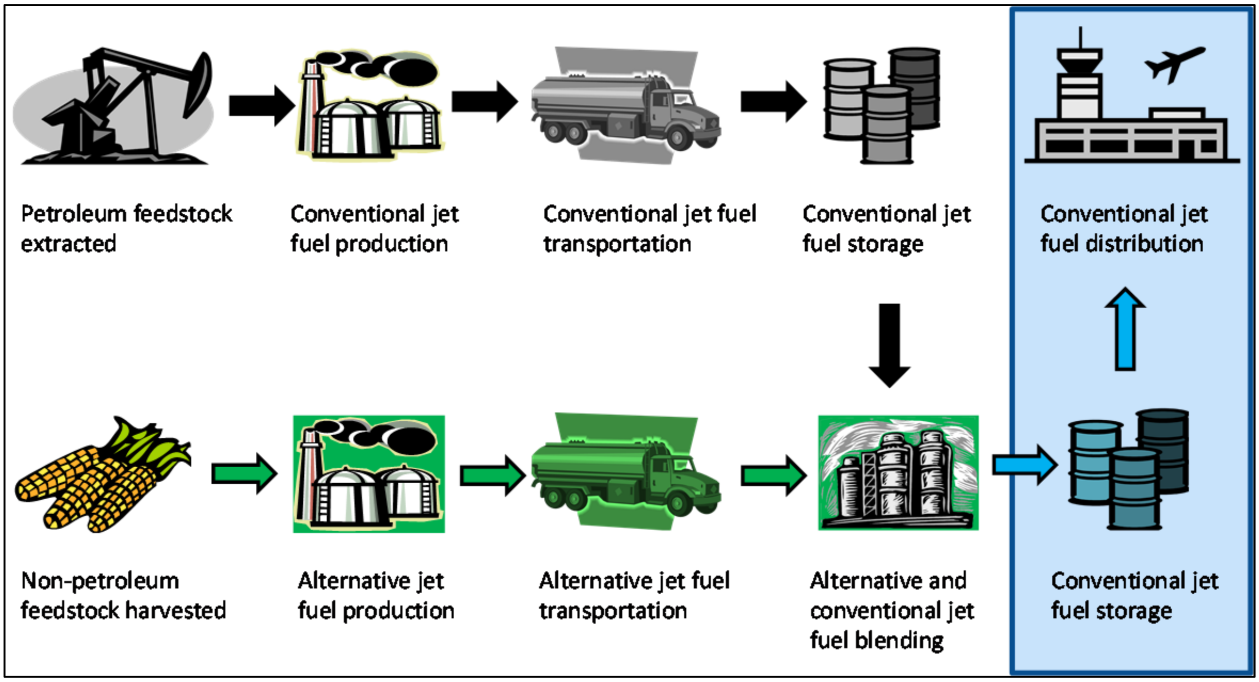


Figure 6. Option 1 – Drop-In Bio Fuel Delivery

Option 1, conceptually, is the simplest option to implement in that it merely involves ordering drop-in biojet fuel instead of conventional jet fuel. However, drop-in biojet fuel suppliers must be identified and the price per gallon of the biojet fuel must be compared with a gallon of jet fuel in order to understand the impact of this option.

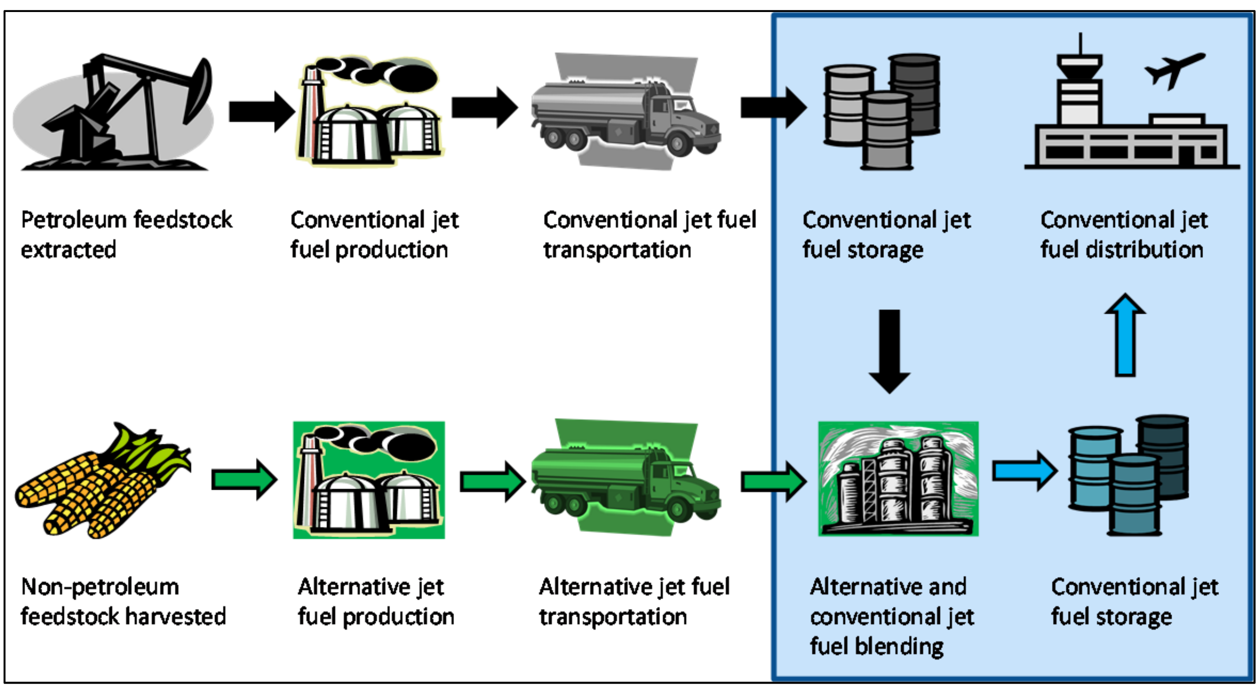


Figure 7. Option 2 – Onsite Bio Fuel Blending

Option 2 would require APP Jet Center to purchase both conventional jet fuel and bio-based alternative jet fuel and then blend the two fuels at the airport to meet ASTM Specification D7566. Like option 1, biojet fuel suppliers must be identified and the price of non-drop-in biojet fuel must be determined. The total cost associated with the blending operation can then be estimated on a per gallon basis and compared to the base case.

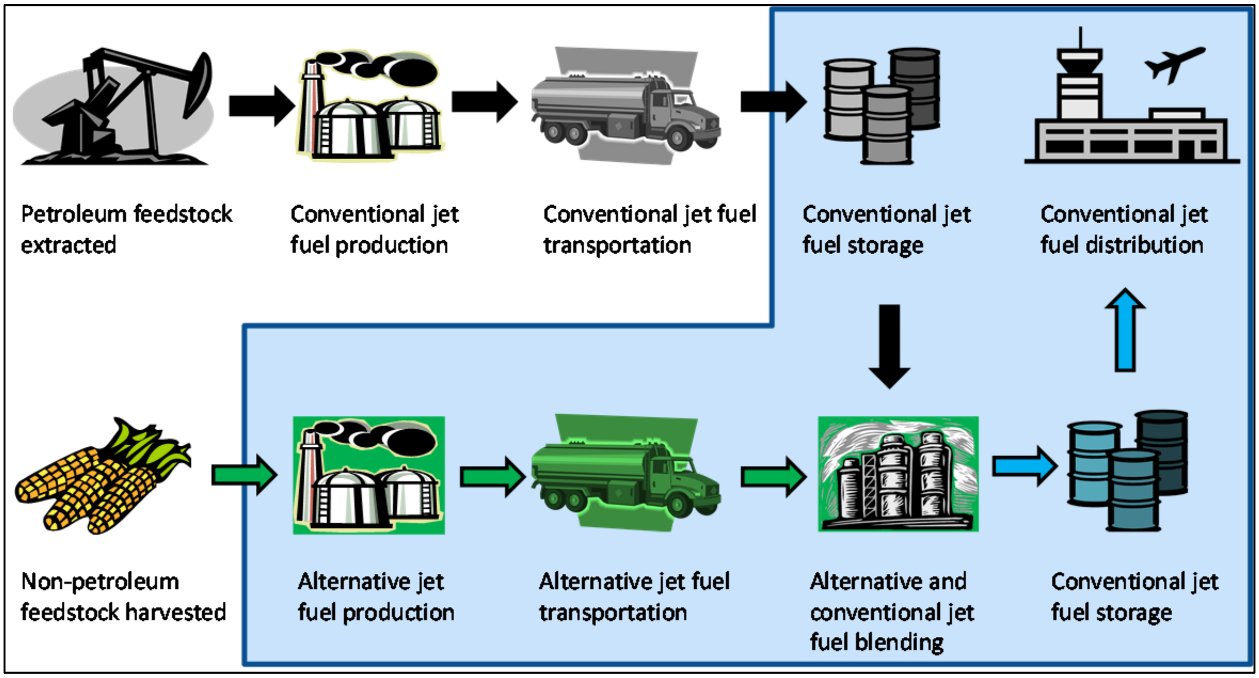


Figure 8. Option 3 – Onsite Bio Fuel Processing

Option 3 is a logistically complex solution for bringing bio-based alternative jet fuel to Manassas Regional Airport. However, since many of the steps associated with creating bio-based alternative jet fuel are performed by APP Jet Center in this option, there is a potential opportunity for savings by not paying other companies to profit from these steps. Additionally, if the biojet fuel suppliers in options 1 and 2 cannot be identified or do not exist, option 3 becomes the only logistically feasible option.

5.2. Logistical Analysis

Each alternative presents different logistical issues for consideration. The purpose of the logistical analysis is to determine exactly how the option would be implemented. Questions that must be answered as part of the logistical analysis include:

- What would the new fuel supply and distribution process look like and how would it change from today, specifically considering the transportation and storage of the fuel?
- What are the challenges to implementation and how would they be overcome?
- Who are the stakeholders involved?

5.3. Price Forecasting

The options were studied over a 20 year period. While many of the costs can be estimated and adjusted for expected inflation over the next 20 years, some factors affecting the cost of alternative jet fuel are constantly changing over time and cannot be estimated using such a trivial approach. Specifically, conventional jet fuel, which affects the cost of all three options as well as the base case, needs to be forecasted. Soybean oil, which affects all three options, also needs to be forecasted. We developed a price forecasting model for both conventional jet fuel and soybean oil. The price forecast is explained in detail in appendix A.

5.4. Cost Modeling

The cost model was developed to estimate the total cost of implementation for each option for bringing bio-based alternative jet fuel to Manassas Regional Airport under various economic conditions. Figure 9 describes the cost model used to analyze each option.

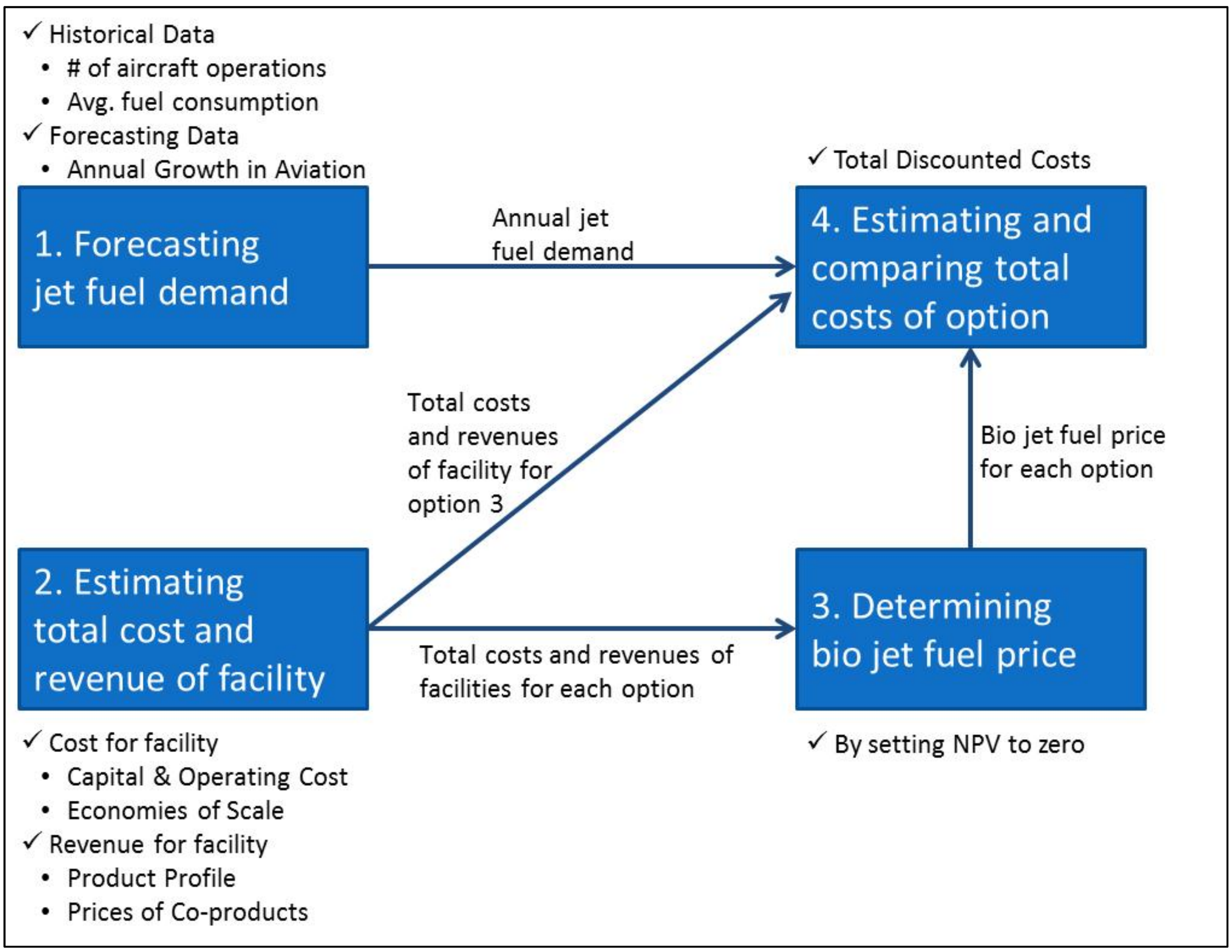


Figure 9. Cost Modeling

The cost model begins by forecasting jet fuel demand at Manassas airport. To forecast jet fuel demand, we used the number of aircraft operations and the average fuel consumption per operation from historical data at Manassas Regional Airport, and then increased the demand using the forecasted annual growth in aviation. The forecasted jet fuel demand is used to determine the size of producing facility for option 3 and calculate the total cost of each option for integrating bio jet fuel at Manassas airport.

The second step is to estimate total cost and revenue of new processing facilities. These estimates are used primarily to study option 3, for which APP Jet Center would incur these costs, but also for options 1 and 2 when actual costs are not available. The total cost for a new processing facility consists of capital expenses and operating expenses. Operating expenses include fixed and variable operating expenses. The cost model follows the work of Pearlson (Pearlson 2011), and, where needed, estimates refinery expenses using an economies of scale factor from the cost-curve method suggested by Gary and Handwerk (Gary and Handwerk 2001). The forecasted soybean oil price from section 5.3 is also used to estimate variable operating expenses. To estimate total revenues, the model uses Pearlson's (Pearlson 2011) product profiles of the processing facility and price projections of the co-products.

The next step in the model determines the prices of bio jet fuel for facilities with different production capacities. The product prices for facilities of different production capacity should be different because of economies of scale, which is that the total cost of a facility is not proportional to its capacity. The price of bio jet fuel for a facility with a certain capacity is found by setting the net present value to zero.

Finally, the total cost of each option is estimated and compared to determine the most economical option. All of the model's earlier calculations are combined with price forecasts from section 5.3 and integrated in this step. The comparison is performed with total discounted costs incurred in each option over a 20 year period. A screenshot of this cost model is shown in Appendix B.

6. ANALYSIS

Each option for bringing bio-based alternative jet fuel to Manassas Regional Airport was analyzed in detail, considering logistics of implementing each option and the relative cost of each option over a 20 year time frame (Gary and Handwerk 2001).

6.1. Assumptions

In order to estimate and compare total cost of each option for integrating bio-based alternative jet fuel at Manassas Regional Airport, several assumptions are made. Most of the assumptions are to estimate the cost of constructing a processing facility and the price of bio jet fuel, because both the facility and bio jet fuel are either proprietary or not advertised. The assumptions used in analyzing all of the options are shown in Table 3. As with the approach to the cost modeling, these assumptions are taken from Pearlson (Pearlson 2011).

Table 3. Cost Model Assumptions

Facility Size	(100 – 6500) BPD
Total Plant Investment	(calculated) $
Construction Period	3 years
% Spent in 1st Year	8%
% Spent in 2nd Year	60%
% Spent in 3rd Year	32%
Internal Rate of Return	15%
Cost Year for Analysis	2012
Duration for Analysis	20 years
Inflation	2%

The facility size will be decided by considering the forecasted demand of bio jet fuel for APP Jet Center, and based on the size-dependent investment cost of the facility, including capital expenses and operating expenses.

6.2. Jet Fuel Demand

Jet fuel demand at Manassas Regional Airport is estimated by using the forecasted number of aircraft operations in the future. There are several forecasts in the aviation industry, such as Boeing's 'Current Market Outlook', the 'Global Air Transport Outlook' from the International Civil Aviation Organization (ICAO), and 'FAA Aerospace Forecast.' Since Manassas Regional Airport is mainly dealing with General Aviation (GA) with over 85,000 annual aircraft operations, the FAA's 2.2% annual growth estimate (FAA 2011) is used to forecast the number of aircraft operations in the future. The estimated number of operations is converted to predicted jet fuel demand by multiplying by the average fuel consumption per operation in 2012, which is 54.3 gallons per 2 operations (Allabaugh 2013). Jet fuel demand for APP Jet Center is then derived by multiplying the total jet fuel demand at Manassas Regional Airport by the proportion of APP Jet Center's jet fuel storage capacity (40,000 gallons) to total capacity at Manassas

Regional Airport (112,000 gallons), which comes to 35.7%. Thus, jet fuel demand for APP Jet Center is written as below:

Jet Fuel Demand (i) = # of Ops (i) * 54.3 gal / 2 * 35.7%   (i = 2014, …, 2033)

Table 4. Jet Fuel Demand for APP Jet Center

Year	Total	2014	2015	2016	2017	2018	2023	2028	2033
# of Airport Operations	2,239,000	90,318	92,305	94,335	96,411	98,532	109,858	122,486	136,565
Jet Fuel Demand ('000 gallons)	21,699	875	895	914	934	955	1,065	1,187	1,324
Bio Jet Fuel (50:50) ('000 gallons)	10,849	438	447	457	467	478	532	594	662

Table 4 shows APP Jet Center's jet fuel demand and bio jet fuel demand over the next 20 years. These demand forecasts will be used to analyze all of the options studied in this report. The 2033 bio jet fuel estimate of 662,000 gallons serves as the minimum capacity of the processing facility that will be considered in this project.

6.3. Base Case – "Do Nothing" Option

An analysis of the "do-nothing" option was completed so each of the alternative jet fuel options could be compared against the impact of a decision not to implement any bio-based alternative jet fuel options.

6.3.1. Logistical Analysis

By regulation (Redden 2013a), APP Jet Center is only able to fill its tanks to 80% of capacity. For its two 20,000 gallon jet fuel tanks, this means each can only be filled with 16,000 gallons at a time, or 32,000 gallons total. Fuel deliveries are made by truck in 8,000 gallon intervals. Deliveries can be made the same day they are scheduled, and the delivery cost is minimal (Redden 2013a), so there is limited incentive for APP Jet Center to optimize its fuel inventory. Because of this, APP Jet Center can order fuel on an "as-needed" timeframe, which is generally three times per week (Redden 2013b).

6.3.2. Economic Analysis

The primary competitor to APP Jet Center is Dulles Aviation, Inc., the only other FBO at Manassas Regional Airport. APP Jet Center is constantly aware of the fuel price charge to airport users by Dulles Aviation, Inc., and ensures its fuel prices are competitive (Redden 2013a). Its fuel prices tend to track daily Kerosene prices within a few cents per gallon (AirNav 2013).

Currently, APP Jet Center orders conventional jet fuel from Eastern Aviation Fuels. The cost that APP Jet Center pays for a gallon of jet fuel includes Eastern Aviation's price for jet fuel, fixed freight rate cost, a Federal Excise Tax, an extended term and dealer link fee, and a Virginia Motor Fuel Tax. The price of jet fuel was forecasted using the method explained in the section 5.3 of this report. The other components of the total cost of jet fuel in 2013, obtained from APP Jet Center, were increased by an estimated inflation rate of 2% (Bureau of Labor Statistics 2013). Then, the total cost to APP Jet Center for fuel in each year was estimated by multiplying by jet fuel demand. As shown below in Table 5, total discounted cost for this "do-nothing" option is 28.6 million dollars over the 20 year period from 2014 to 2033. This cost represents the baseline cost against which all other options with be evaluated.

Table 5. Jet Fuel Price and Total Cost of "Do-Nothing" option

Year	Total	2014	2015	2016	2017	2018	2023	2028	2033
Conventional Jet Fuel Purchasing Price		4.038	4.156	4.369	4.576	4.814	6.024	7.238	8.456
Conventional Jet Fuel Price		3.670	3.781	3.986	4.185	4.416	5.584	6.752	7.920
Freight Rate Cost		0.053	0.054	0.055	0.056	0.057	0.063	0.070	0.077
Federal Excise Tax		0.249	0.254	0.259	0.264	0.269	0.297	0.328	0.363
Extended term and dealer link fee		0.015	0.016	0.016	0.016	0.017	0.018	0.020	0.022
Virginia Motor Fuel Tax		0.051	0.052	0.053	0.054	0.055	0.061	0.067	0.074
Annual Cash Flow ('000 dollars)	(137,461)	(3,535)	(3,718)	(3,995)	(4,276)	(4,598)	(6,414)	(8,593)	(11,194)
Net Present Value ('000 dollars)	(28,595)	(2,673)	(2,445)	(2,284)	(2,126)	(1,988)	(1,379)	(918)	(595)

6.4. Option 1 – Purchasing Drop-in Bio Fuel

Option 1, conceptually, is the simplest option to implement in that it merely involves ordering drop-in biojet fuel instead of conventional jet fuel. However, drop-in biojet fuel suppliers must be identified and the price per gallon of the biojet fuel must be compared with a gallon of jet fuel in order to understand the impact of this option.

6.4.1. Logistical Analysis

No additional fuel storage infrastructure would be required for this option. Because the fuel is "drop-in," it is able to be integrated into the existing fuel supply. APP Jet Center would merely fill its two 20,000 gallon jet fuel storage tanks with the alternative jet fuel instead of the conventional jet fuel.

The fundamental challenge for APP Jet Center in implementing this option is there may not be an alternative fuel supplier from which APP Jet Center can order. As explained in section 4.5, there are few alternative jet fuel suppliers in the U.S., and it's likely the limited alternative jet fuel they produce will be purchased by entities other than APP Jet Center. This is in part because the market for bio-based alternative jet fuel is so new, and many companies remain in research and development, while working towards a viable solution for commercial production of bio-based alternative jet fuel.

One company that shows promise is Byogy Renewables, Inc. (Byogy Renewables 2009), which is a biofuel producer, headquartered in San Jose, California. The company claims it can supply bio based alternative jet fuel that can be used by any commercial or military jet turbine engine without changing any infrastructure. Using a proprietary refining process, Byogy can convert any source of bio ethanol into alternative jet fuel. The company also claims "since a conventional global ethanol industry already exists, Byogy has access to sufficient renewable bio ethanol feedstock to make its first billion gallons of renewable jet fuel by 2014 and perhaps earlier" (Byogy Renewables 2009).

Our research did not find any alternative jet fuel suppliers on the East coast. This means APP Jet Center will have to purchase its alternative jet fuel from distant locations and pay for its transport to Manassas Regional Airport. In the case of Byogy Renewables, located in San Jose, CA, the fuel would have to be transported nearly 3,000 miles (Google Maps 2013). Fortunately for APP Jet Center, Manassas Regional Airport is located just 0.9 miles from the Broad Run Airport Virginia Railway Express (VRE) train station (Google Maps 2013), which makes possible the ability to transport the alternative jet fuel from San Jose, CA to Manassas, VA by train, a much cheaper option that transportation by truck.

APP Jet Center's average daily fuel flowage is 2,400 gallons, and it has up to 32,000 gallons of usable storage capacity (Redden 2013a). On a reasonable busy day, if fuel flowage is double the daily average, and if it's unlikely there would be more than two days in a row with the busy fuel flowage, we can make some assumptions about the fuel inventory. Using these theoretical assumptions, APP Jet Center would need 9,600 gallons for a two day supply. And, since there are no more than two busiest days in a row, APP Jet Center would need no more than 12,000 gallons for a three day supply. APP Jet Center should be able to meet its jet fuel demand if it schedules a delivery of 16,000 gallons every 3-5 days.

6.4.2. Economic Analysis

Despite finding a potential supplier in Byogy Renewables, it's unclear if they'll actually be able to supply alternative jet fuel to Manassas Regional Airport, and even more unclear at what cost. Additionally, it's possible that many more suppliers will become available in the next few years, as it seems there are many companies are researching and developing alternative jet fuel production technology. So, it's useful to estimate what the cost might be for a supplier to produce alternative jet fuel, as a means to evaluate this option over a 20 year period, not just considering today's circumstances, which are likely to change.

Using the method laid out by Pearlson (Pearlson 2011), we estimated the price of drop-in bio jet fuel by assuming that bio jet fuel is produced on a commercially viable scale. The price of bio jet fuel was estimated in a similar manner to finding the gate cost for the distillate streams from Pearlson, but all types of costs were adjusted by Consumer Price Index (CPI) (Bureau of Labor Statistics 2013) to the costs in the year of 2012. The price of feedstock, for which we've chosen soybean oil in this case study, was estimated using the price forecasting method discussed in section 5.3.

Once the price of bio jet fuel was estimated, the price of drop-in bio jet fuel in a 50:50 blending case was calculated with the following equation.

$$\text{Drop-in Bio Fuel Price} = \{(\text{Bio Fuel Price} + \text{Conventional Fuel Price}) / 2\} * \text{Margin}$$

After determining our forecasted price of conventional jet fuel, we added a 15% premium to account for the producer's profit margin, which was estimated from the biodiesel industry profit margin, averaging between 10% and 20% (EIA 2012).

Table 6 shows the bio jet fuel price, drop-in bio jet fuel price, jet fuel cost, transportation cost, annual cash flow and the net present value of option 1. As mentioned above, the $8.95/gallon cost of bio jet fuel in 2012 was adjusted for inflation in the future. Based on the bio jet fuel price, drop-in bio jet fuel prices were derived from the assumed 50:50 blend. The total cost of option 1 consists of jet fuel cost and transportation cost, which was assumed to be from a bio jet fuel supplier is located in California, with the fuel transported by rail at a cost of 3.5 cents per ton-mile (AAR 2012). Annual costs were estimated to be 7.0 million dollars in 2014 to 17.4 million dollars in 2033. Total net present value of the option 1 is 49.0 million dollars.

Jet Fuel Cost= (Drop-in Bio Jet Fuel Price) * Jet Fuel Demand

Transportation Cost= {3.5(cents/ton-mile)*3000(mile)/303.77(gal/ton)} * Jet Fuel Demand

Table 6. Drop-in Bio Jet Fuel Price and Annual Cash Flow of Option 1

Year	Total	2014	2015	2016	2017	2018	2023	2028	2033
Bio Jet Fuel Price ($/gallon)	8.95 (2012 only)	9.32	9.50	9.69	9.89	10.08	11.13	12.29	13.57
Drop-in Bio Jet Fuel Price for Purchasing		7.68	7.85	8.09	8.32	8.57	9.86	11.23	12.67
Jet Fuel Cost ('000 dollars)	(222,255)	(6,721)	(7,026)	(7,393)	(7,770)	(8,181)	(10,504)	(13,331)	(16,765)
Transportation Cost ('000 dollars)	(9,428)	(309)	(322)	(335)	(350)	(365)	(449)	(552)	(680)
Annual Cash Flow ('000 dollars)	(231,683)	(7,030)	(7,348)	(7,728)	(8,120)	(8,545)	(10,953)	(13,884)	(17,445)
Net Present Value ('000 dollars)	(49,031)	(5,082)	(4,620)	(4,227)	(3,863)	(3,537)	(2,258)	(1,425)	(891)

6.5. Option 2 – On Site Blending of Bio Fuel

Option 2 would require APP Jet Center to purchase both conventional jet fuel and bio-based alternative jet fuel and then blend the two fuels at the airport to meet ASTM Specification D7566. Like option 1, biojet fuel suppliers must be identified and the price of non-drop-in biojet fuel must be determined. The total cost associated with the blending operation can then be estimated on a per gallon basis and compared to the base case.

6.5.1. Logistical Analysis

APP Jet Center conveniently has two storage tanks in the Manassas Regional Airport fuel farm. So in implementing option 2, one storage tank could be dedicated for blending the alternative jet fuel with conventional jet fuel, while the other tank would be used for distribution of the drop-in jet fuel. This is the preferred method for implementing this option, since it does not involve the construction of an additional blending tank, for which there's no room in the current Manassas Regional Airport fuel farm. Expansion of the existing fuel farm may not be approved by airport officials and would add to APP Jet Center's cost of implementing this option.

Like in Option 1, there are no alternative jet fuel suppliers from which APP Jet Center can order. Byogy Renewables, Inc., mentioned in the discussion of Option 1 for its advertised drop-in alternative jet fuel, appears to be a candidate for unblended alternative jet fuel as well. The company states that "the process [of producing bio-based alternative jet fuel] can be "tuned" to adjust the specific properties of the fuel to meet customers' individual requirements." So for this option, APP Jet Center would order unblended alternative jet fuel from Byogy Renewables.

As in option 1, APP Jet Center could take advantage of its proximity to the Broad Run Airport Virginia Railway Express (VRE) train station (Google Maps 2013), and have its alternative jet fuel transported by train from Byogy Renewables in San Jose, CA. Fuel deliveries would be made in 8,000 gallon quantities, which would be blended with 8,000 gallons of conventional fuel upon delivery, to make 16,000 gallons of a 50:50 blend of alternative jet fuel

Once the alternative jet fuel is blended, it would have to be tested for compliance to ASTM Specification D7566. As with the limited number of potential alternative jet fuel suppliers, there are very few laboratories currently capable of testing for D7566, which requires very specialized equipment (Miller 2013). While prices would vary, it is estimated this test could cost as much as $4,000 and could take weeks to receive results depending on where the laboratory is located (Miller 2013).

If APP Jet Center must wait a week to get the results back from its D7566 testing, this option is not logistically feasible to implement. Using the same theoretical daily demand variance from section 6.4.1, If APP Jet Center had 16,000 gallons of drop-in jet fuel in one tank at the time it performs the alternative jet fuel blending in the other tank, it would have approximately seven days before the first tank ran out of fuel (at an average rate of 2,400 gallons per day). However, if there was one busy day (4,800 gallons per day) in that week, APP could run out of fuel in as little as five days, at which time it would still be waiting on the test results. If D7566 testing took only 2 days, this option would become logistically feasible. This is a reasonable timeframe for conventional jet fuel (D1655) and biodiesel fuel (D6751), which can both be tested in less than 48 hours (Miller 2013) (Murphy's 2013).

6.5.2. Economic Analysis

The methodology used to estimates the total cost of option 2 is very similar to the method explained in section 6.4.2 for option 1. The difference is that for option 2, the conventional jet fuel and alternative jet fuel are bought separately and blended at the cost of APP. Thus the equation in section 6.4.2 is changed to the following:

Drop-in Bio Fuel Price= {(Bio Fuel Price * Margin) + Conventional Fuel Price} / 2

The bio fuel price, margin and conventional fuel price are the same as in option 1. We then accounted for the cost of blending and testing for ASTM Specification compliance (Estimated to be $4,000 per batch (Miller 2013)), as shown in Table 7.

Table 7. Non Drop-in Bio Jet Fuel Price and Annual Cash Flow of Option 2

Year	Total	2014	2015	2016	2017	2018	2023	2028	2033
Unblended Bio Jet Fuel Price ($/gallon)		10.71	10.93	11.15	11.37	11.60	12.80	14.13	15.61
Drop In Jet Fuel Price ($/gallon)		7.38	7.54	7.76	7.97	8.20	9.41	10.69	12.03
Conventional Jet Fuel Cost (‘000 $)	(68,730)	(1,767)	(1,859)	(1,998)	(2,138)	(2,299)	(3,207)	(4,296)	(5,597)
Unblended Bio Jet Fuel Cost (‘000 $)	(143,215)	(4,689)	(4,888)	(5,095)	(5,312)	(5,537)	(6,816)	(8,390)	(10,329)
Transportation Cost (‘000 $)	(4,714)	(154)	(161)	(168)	(175)	(182)	(224)	(276)	(340)
Blending Cost (‘000 $)	(5,425)	(219)	(224)	(229)	(234)	(239)	(266)	(297)	(331)
Annual Cash Flow (‘000 $)	(222,084)	(6,829)	(7,132)	(7,489)	(7,858)	(8,257)	(10,514)	(13,260)	(16,596)
Net Present Value (‘000 $)	(49,306)	(5,164)	(4,689)	(4,282)	(3,907)	(3,570)	(2,260)	(1,417)	(882)

As mentioned before, two types of jet fuels are brought separately to Manassas airport, so the cost of purchasing each type of jet fuel is estimated individually. The blending cost, $4,000, is incurred for every batch of alternative jet fuel that is blended, which in this case, is every 16,000 gallons of blended fuel. The transportation cost in this option is only half that of option 1 because only unblended bio jet fuel, which is half of total jet fuel demand, is brought from a supplier in West Coast. After all calculations, NPV of option 2 becomes 49.3 million dollars.

6.6. Option 3 – On Site Production of Bio Fuel

Option 3 is a logistically complex solution for bringing bio-based alternative jet fuel to Manassas Regional Airport. However, since many of the steps associated with creating bio-based alternative jet fuel are performed by APP Jet Center in this option, there is a potential opportunity for obtaining alternative jet fuel at a cheaper rate, since APP Jet Center is not paying other companies to profit from these steps. Additionally, since the biojet fuel suppliers in options 1 and 2 cannot be identified, option 3 becomes the only logistically feasible option in the near-term.

6.6.1. Logistical Analysis

If APP Jet Center is able to get permission from Manassas Regional Airport to build a processing facility on its existing airport property, it would allow APP Jet Center to purchase land already zone for industrial use (City of Manassas 2012), allow APP Jet Center to avoid costs of trucking its biofuel to the airport, and would allow APP Jet Center to continue to operate its business from its current location.

Finding Feedstocks

Before considering whether to construct a bio-based alternative jet fuel processing facility, it's important to understand whether enough feedstock would be available to APP Jet Center. For this project, we chose to study the implications of alternative jet fuel that is derived from soybean oil, since it is one of the more widely available alternative jet fuel feedstock options (USDA 2013).

In searching for feedstock availability, it's important that the feedstock be in close proximity to the production plant because the transportation cost of the feedstock has a significant influence on the economic viability of the alternative jet fuel (ACRP 2012). Therefore, our search for feedstock was limited to the Commonwealth of Virginia and the immediately surrounding areas.

The United States Department of Agriculture (USDA) continuously collects feedstock availability information and provides the public a means to sort through that information by geographical area. Using the USDA Web site (USDA 2013), we input our criteria for screening the feedstock in an inventory application and it shows that one of the most prevalent oilseeds in geographic areas close to Virginia State include soybeans, which confirms the feasibility of its use in this case study. Figure 10 shows the result of USDA inventory application.

Alternative Crops
Crop Type = Oil
State = Maryland, North Carolina, Pennsylvania, Virginia, West Virginia
5 records returned

Click on a crop below to learn about its culture and marketing in the state shown. State Cooperative Extension agents compiled most of the information presented in these links.

Crop Link	State	Crop Type
Peanut: Virginia Coop. Ext. Crop Pubs.	Virginia	Oil
Soybean: Virginia Coop. Ext. Crop Pubs.	Virginia	Oil
Soybean: Virginia Coop. Ext. Home Gardening	Virginia	Oil
Corn: West Virginia U. Coop. Ext. Field Crops	West Virginia	Oil
Soybean: West Virginia U. Coop. Ext. Field Crops	West Virginia	Oil

Figure 10. USDA Application Output for Alternative Oil Crops in Mid-Atlantic

After searching for soybean refineries in the screening area, one of the largest and more promising potential feedstock suppliers to APP Jet Center is Perdue Agribusiness (Perdue Agribusiness 2013). A subsidiary of Perdue Agribusiness is Perdue Oilseeds, which owns and operates a refinery located in Salisbury, MD, where it is less than three hours from Manassas Regional Airport (Google Maps 2013), and refines soybeans into soybean oil. In addition to serving major food manufacturers in several industry segments, Perdue Oilseeds also provides feedstock for many non-food applications, including the ethanol and biodiesel industries (Perdue Agribusiness 2013). Perdue Oilseeds transports its product by truck or rail, which would allow APP Jet Center flexibility in determining whether it has its feedstock delivered by rail, via the Broad Run Airport VRE train station, only 0.9 miles away (Google Maps 2013), or by truck, as is done with its conventional jet fuel deliveries from Eastern Aviation.

Siting the Production Facility

The Manassas Regional Airport fuel farm, known as the Central Fuel Farm, is located in the North Eastern corner of the airport property. The airport property and Central Fuel Farm are shown below in Figure 11. Logistically, it would make sense for Manassas to build a biofuel processing plant near the Central Fuel Farm to limit the amount of additional infrastructure required to transport to the biofuel from the processing facility to the fuel farm. The Central Fuel Farm is also conveniently and safely located in a corner of the airport property not near active runway and taxiway operations.

Figure 11. Manassas Regional Airport Property Line

To build the processing facility near the fuel farm requires finding available land, using Federal Aviation Administration (FAA) methods of calculating whether the new structure would interfere with airport operations, and then ensure the facility would meet any required environmental regulations.

It turns out there is an existing plot of land directly adjacent to the Central Fuel Farm, ideal proximity for the construction of a biofuel processing facility. Illustrations of one and five acre plots of land are shown in Figures 12, and 13, respectively. These illustrations are approximations of the land required for a biofuel processing plant.

Figure 12. One acre plot adjacent to the Central Fuel Farm

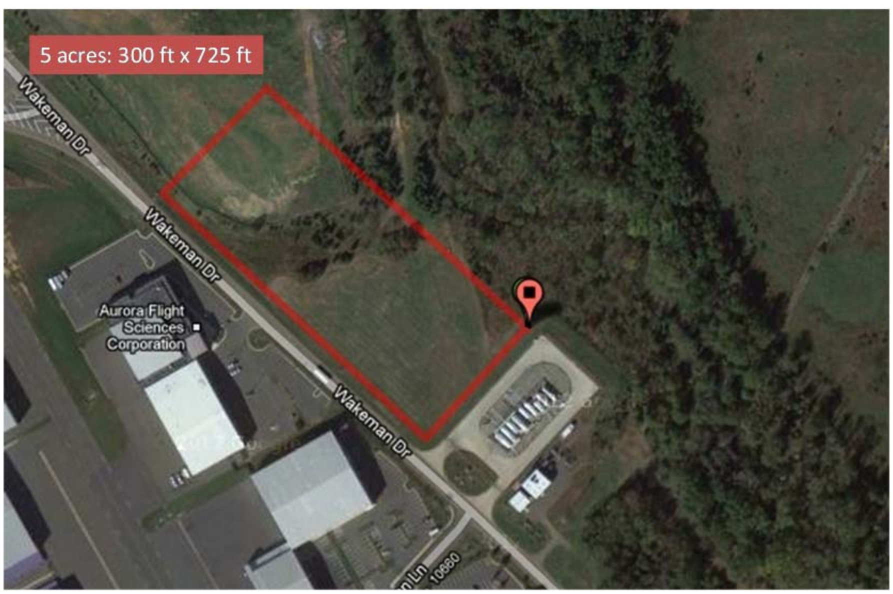
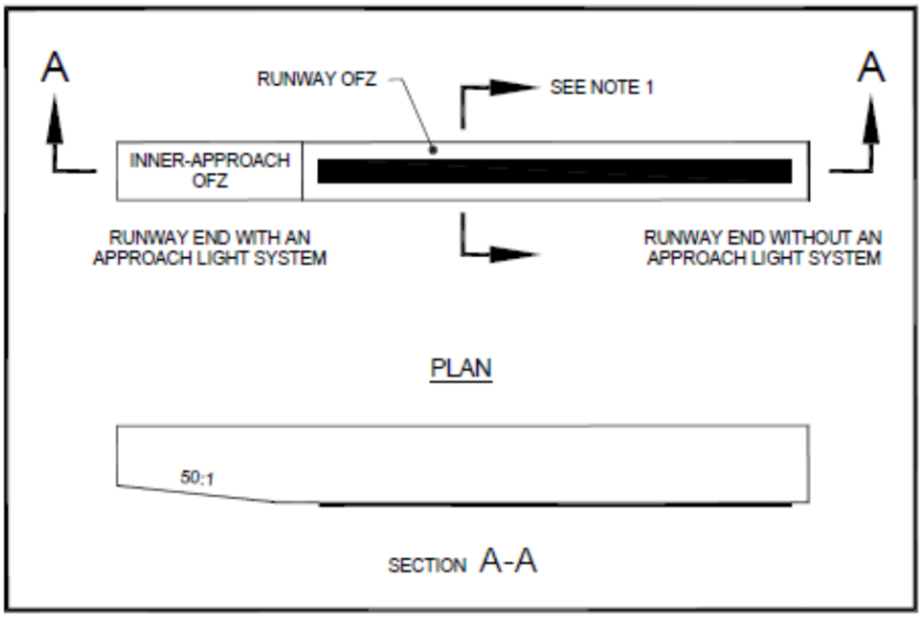


Figure 13. Five acre plot adjacent to the Central Fuel Farm

Obstacle Free Zone

Once the location for the processing facility is determined, APP Jet Center needs to ensure the facility would not interfere with airport operations. For this type of evaluation, there are two applicable safety zones, defined by the FAA, which need to be considered. The first of these two zones is the Obstacle Free Zone (OFZ). The OFZ is a surface surrounding the runway that must be kept clear during runway operations to ensure safety. The OFZ includes the Runway OFZ (ROFZ), and the inner-approach OFZ, depicted in figure 3-9 of FAA Advisory Circular (AC) 10/1300-13A, which is copied in Figure 14. The ROFZ is a volume of airspace centered above the runway centerline and the inner-approach OFZ is volume of airspace centered on the approach area. The size of these areas is a function of the aircraft using the runway. For faster approaches and larger aircraft, the dimensions of the OFZ get larger.



Note: 1. See Figure 3-13 for this view.

Figure 14. Obstacle Free Zone (OFZ)

For Runway 16L, the runway to which landing airplanes will come closest to the proposed location of the biofuel processing facility, the dimensions of the OFZ are shown in Table 8.

Table 8. Obstacle Free Zone Dimensions for Runway 16L

Item	Length
Runway Design	
Runway Length	6,200 ft.
Runway Width	100 ft.
Runway Obstacle Free Zone (ROFZ)	
Length	6,600 ft.
Width	250 ft.
Height	150 ft.
Inner-Approach OFZ	
Length (over ground)	2,600 ft.
Width	250 ft.
Height	150 ft.
Slope	1/50

Figure 15 shows the estimated OFZ over a satellite image of Manassas Regional Airport (Google Maps 2013). The inner-approach OFZ begins 200 feet from the runway threshold (where the ROFZ ends) and extends 200 feet beyond the last light unit for that runway's approach lighting system (ALS). The ALS for Runway 16L at KHEF is a Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights (MALSR) (FAA 2013b). A MALSR is a series of lights, spaced every 200 feet over a distance of 2,400 feet from the runway threshold, that act as a visual reference for pilots on final approach to a runway (FAA 2012). For Runway 16L, the MALSR extends to the opposite side of Observation Road, the road seen in Figure 15 on the approach end of 16L that runs perpendicular to the direction of 16L. At the edge of the inner-approach OFZ, the sloped floor of the zone reaches a height of 52 feet. From the figure, it is clear that the proposed 5 acre plot (the largest size plot of land considered) would not breach the protected limits of the OFZ.

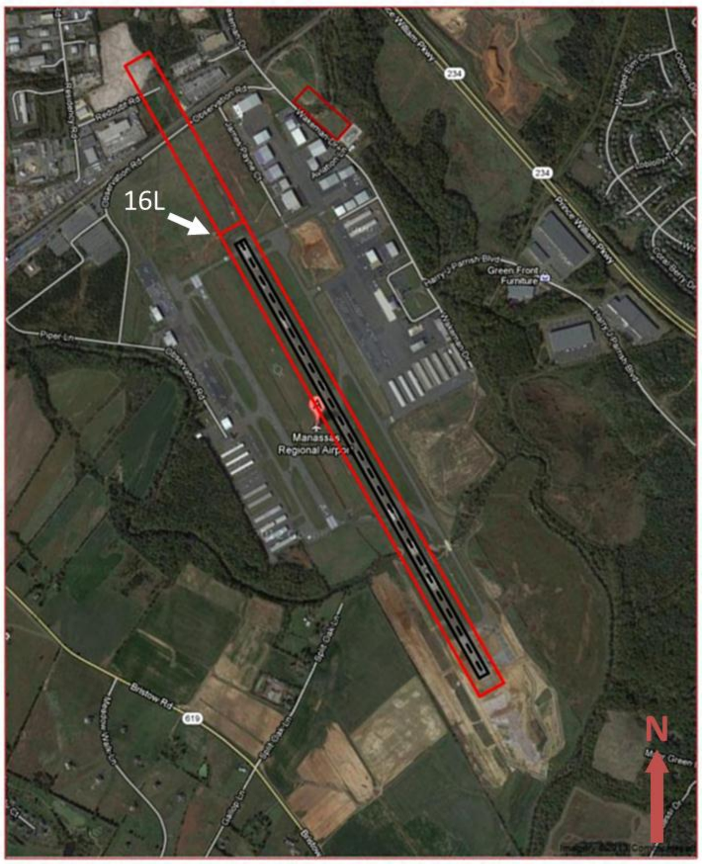
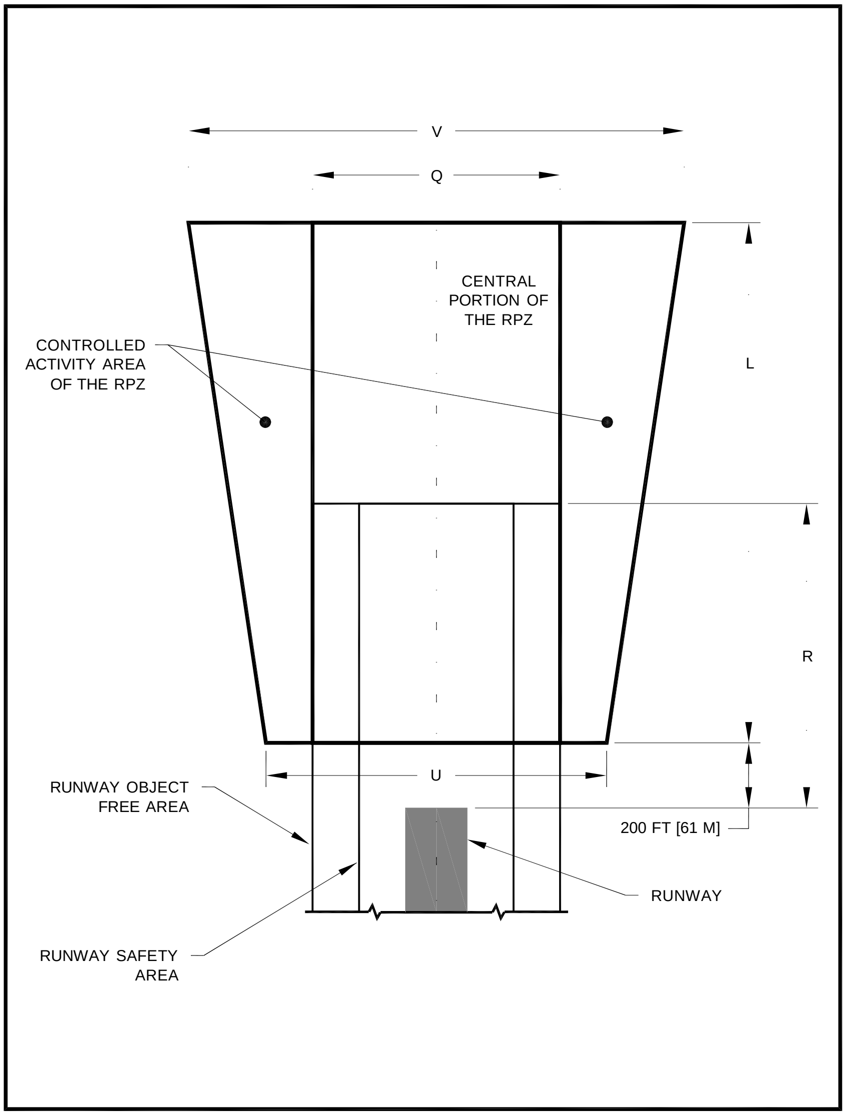


Figure 15. OFZ overlay on Runway 16L with 5 acre plot

Runway Protection Zone

The second safety zone that must be studied by APP Jet Center is the Runway Protection Zone (RPZ). The RPZ is meant to enhance the protection of people and property on the ground. The RPZ is trapezoidal in shape and centered about the extended runway centerline. The central portion of the RPZ extends from the beginning to the end of the RPZ, centered about the runway centerline with a width equal to the OFZ. The controlled activity area is the remaining area of the RPZ on either side of the central portion of the RPZ. Like the OFZ, the dimensions of these areas are a function of the aircraft using the runway. These areas and dimensions are illustrated in figure 3-16 of FAA AC 150/1300-13A, which is copied below in Figure 16.



Note: See Table 3-8 for dimensions U, V, L, R, and Q.

Figure 16. Runway Protection Zone (RPZ)

For Runway 16L, the runway to which landing airplanes will come closest to the proposed location of the biofuel processing facility, the dimensions of the RPZ are shown in Table 9.

Table 9. Runway Protection Zone Dimensions for Runway 16L

Item	Length
Runway Design	

Runway Length	6,200 ft.
Runway Width	100 ft.
Runway Object Free Area (ROFA)	
Length beyond runway end (R)	1000 ft.
Length prior to threshold (P)	600 ft.
Width (Q)	800 ft.
Approach Runway Protection Zone (RPZ)	
Length (L)	1,700 ft.
Inner width (U)	1,000 ft.
Outer Width (V)	1,510 ft.

Figure 17 shows the estimated RPZ over a satellite image of Manassas Regional Airport (Google Maps 2013). From the figure, it is clear that the proposed 5 acre plot (the largest size plot of land considered) would not exceed the protected limits of the runway protection zone.

Figure 17. RPZ overlay on Runway 16L with 5 acre plot

Environmental Assessment

Once the site of the processing facility has been located and its proximity to airport operations is determined to be safe, APP Jet Center must ensure it complies with applicable environmental regulations. The National Environmental Policy Act (NEPA), enacted in 1969, requires that certain federal projects must be studied for their environmental impact and allow for local and state government review of those impacts. According to FAA Order 1050.1E, *Environmental Impacts: Policies and Procedures*, a biofuel processing facility construction project on airport property is required to comply with NEPA requirements. For this project, the Commonwealth of Virginia's Department of

Environmental Quality (DEQ) is the state authority, and the Federal Aviation Administration's (FAA) Office of Airports (ARP) is the federal authority for reviewing the project's environmental impact, and ensuring it complies with NEPA requirements. The coordination between the FAA and DEQ is shown below in Figure 18 (DEQ 2012).

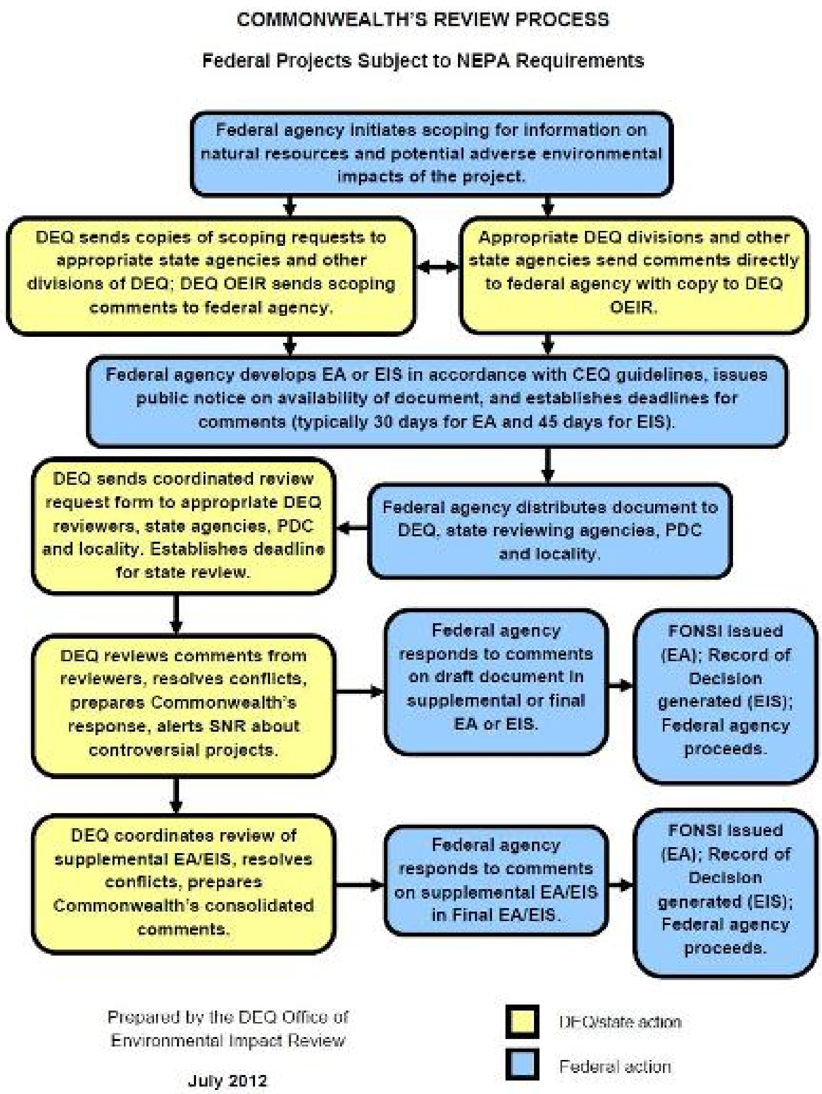


Figure 18. Virginia's review process for federal projects subject to NEPA requirements

The FAA official responsible for the approval of the project will determine the environmental review the project requires. There are three types of NEPA reviews that may be required for the project:

1. **Categorical Exclusion.** Projects (actions) that are categorically excluded do not require an Environmental Assessment (EA) or and Environmental Impact Statement (EIS). They represent actions that the FAA has found, based on past experience with similar actions, do not normally require an EA or EIS because they do not individually or cumulatively have a significant effect on the human environment. (FAA Order 1050.1E, Paragraph 303a)

2. **Environmental Assessment (EA).** If the responsible FAA official determines the project cannot be categorically excluded, then an EA must be prepared. The EA is used to describe the anticipated impacts of a proposed action and its alternatives to determine if the impact will be significant. If the project is found to introduce no significant impact on the environment, the project can move forward as planned. (FAA Order 1050.1E, Paragraph 404a)
3. **Environmental Impact Statement (EIS).** If the responsible FAA official determines the project may have a significant on the environment based on the EA or past experience with similar projects, then an EIS is required. The EIS is a more detailed description of the potential environmental impacts of the project and its alternatives (impact categories are outlined in Table 10), including a no action alternative, as well as methods to mitigate the severity of the impact. With the issuance of an EIS, local residents, communities and governments can understand the impacts of a proposed project and have an opportunity to comment. (FAA Order 1050.1E, Paragraph 500a)

Table 10. Potential Impact Categories for Environmental Impact Analysis

Environmental Impact Category	**Applicable to KHEF**
Coastal Resources	No
Compatible Land Use	Yes
Construction Impacts	Yes
Department of Transportation Act: Sec 4(f)	Yes
Farmlands	No
Fish, Wildlife, and Plants	Yes
Floodplains	No
Hazardous Materials, Pollution Prevention, and Solid Waste	Yes
Historical, Architectural, Archeological and Cultural Resources	No
Light Emissions and Visual Impacts	No
Natural Resources and Energy Supply	Yes
Noise	Yes
Secondary Impacts	Yes
Socioeconomic Impacts, Environmental Justice, and Children's Environmental Health and Safety Risks	Yes
Water Quality	Probable*
Wetlands	Probable**
Wild and Scenic Rivers	Yes

*Broad Run flows through airport property to a Northern Virginia water supply

**Delineation determination would be made by local district office of the Army Corps of Engineers or wetland delineation specialist (FAA Order 1050.1E, Appendix A, Paragraph 18.2c)

It's likely that based on the size of the biofuel processing facility and the chemical processes involved in producing biofuel, this project would require a full EIS before getting FAA and DEQ approval. Some potentially applicable impact categories are described in Table 10. Since the EIS will open the project up for public comment, strategies would have to be developed by APP Jet Center and Manassas Regional Airport officials to mitigate any negative environmental impacts to the local residents, on top of concerns from the Virginia DEQ and the FAA.

A major environmental concern specific to the construction of a biofuel processing facility at Manassas Regional Airport is whether the water supply to Northern Virginia residents could be impacted by pollutants from the construction or operation of the processing facility. Broad Run, a creek that creates some of the airport property line as well as runs beneath runway 16L/34R, flows into the Occoquan Reservoir, a drinking water supply for more than one million people (PWCA 2013). Broad Run is depicted in blue on the map of Manassas Regional Airport in Figure 19 below.

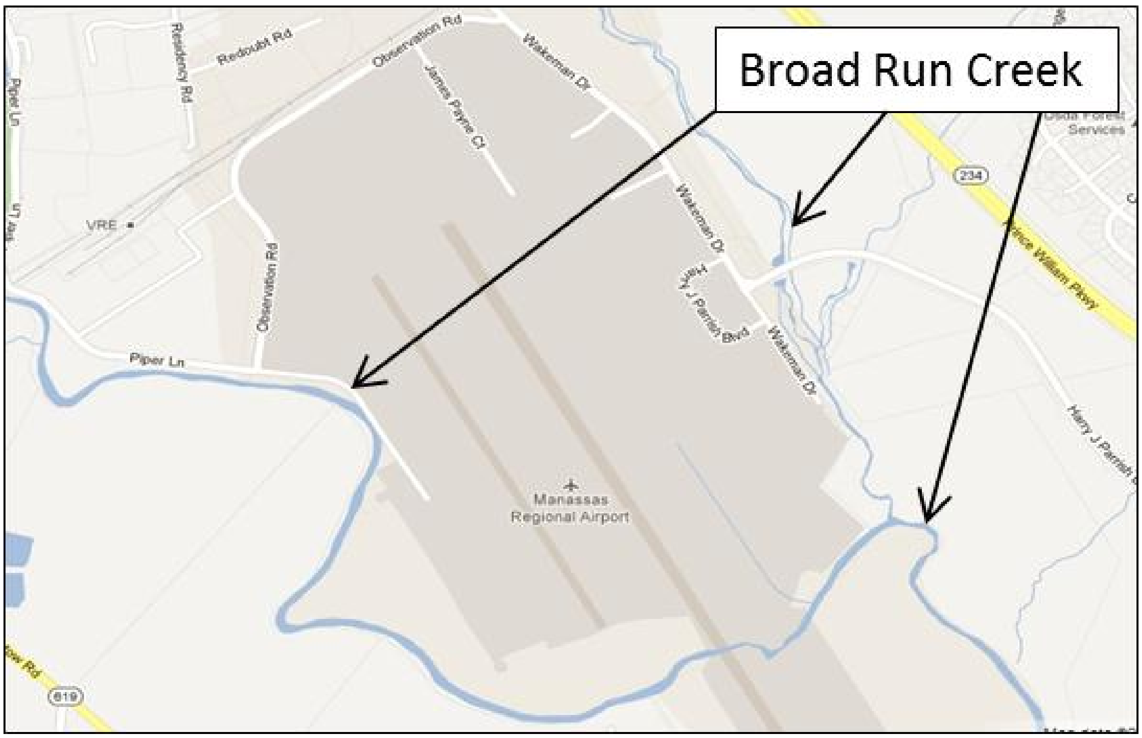


Figure 19. Map of KHEF depicting Broad Run creek (Google Maps 2013)

6.6.2. Economic Analysis

A biofuel processing facility would likely require 1-5 acres. Figure 20 below shows three properties within a mile of Manassas Region Airport that are currently for sale and within the boundary limits of the City of Manassas. While each property varies in terms of property layout, zoning and development, they can be used to project a realistic property cost of a 1-5 acre plot of land for a biofuel processing facility.

Figure 20. Properties for Sale near Manassas Regional Airport (Redfin 2013)

Table 11 includes listing information for the three properties shown in Figure 20. The biofuel processing facility would need to be zoned for industrial use. Raw (unzoned) land could be purchased with the intent requesting a zoning change, but there would be an inherent risk on whether the city of Manassas would approve the zoning change. Comparing the two properties zoned for industrial use shows that a developed property with utilities (sewage, electrical, etc.) infrastructure already in place, adds about $150,000 per acre value to the property.

Table 11. Properties for Sale near Manassas Regional Airport

Property	Size (Acres)	List Price ($)	Per Acre Cost	Zoning
10560 Redoubt Ln	7.08	$1,464,922	$206,910	Zoned – light industrial use
10214 Piper Ln	1.77	$235,000	$132,768	Raw Land
10669 Wakeman Ct	1.50	$550,000	$366,667	Zoned – light industrial use; Utilities

The estimated cost of purchasing land for a 1-5 acre biofuel processing facility is shown in Table 12.

Table 12. Estimated cost of property purchase for biofuel processing facility

Property Size	Raw Land	Zoned	Zoned and Developed
1 Acre	$133,000	$207,000	$367,000
5 Acres	$665,000	$1,035,000	$1,835,000

The size of a biofuel processing facility needs to be large enough to produce the amount of bio jet fuel required by APP Jet Center through the end of analysis period, 2033, because once the facility is built, expansion of the facility would be difficult and expensive. Based on the demand estimated before in section 6.2, 662,000 gallons of bio jet fuel would be consumed in 2033. So the facility should have a production capacity of at least 662,000 gallons of bio jet fuel. The biofuel processing facility, however, produces not only bio jet fuel but also bio diesel, LPG, Propane, and several other distillates. Table 13 shows products that are outputs of the alternative jet fuel production process (Pearlson 2011). After considering the demand of bio jet fuel and other product outputs of the facility, an appropriate size for a biofuel facility to satisfy APP Jet Center's needs is one with a capacity of 100 barrels per day, which equates to 1.5 million gallons per year. Because this would be a smaller facility (ACRP 2012), it's likely a 1 acre (zoned but not developed) plot at a cost of $200,000 would be sufficient land for this facility. We assumed that the facility is operated according to the maximum jet fuel case because the primary purpose of the facility is to provide bio jet fuel to Manassas airport.

Table 13. Product Profile of Biofuel Facility (Pearlson 2011)

Product Profiles (%)	Maximum Distillate	Maximum Jet
Soybean Oil	100.0	100.0
Hydrogen	2.7	4.0
Total In	102.7	104.0
Water	8.7	8.7
Carbon Dioxide	5.5	5.4
Propane	4.2	4.2
LPG	1.6	6.0
Naphtha	1.8	7.0
Jet	12.8	49.4
Diesel	68.1	23.3
Total Out	102.7	104.0

The costs of the processing facility can be estimated based on the size. The total cost consists of capital expenses and both fixed and variable operating expenses. These are estimated using the method proposed by Pearlson (Pearlson 2011). These cost estimates are adjusted by an economy of scale factor because capital costs are not linearly proportional to the size of the plant (Gary and Handwerk 2001). The equation of economies of scale conducted is like below.

$$\frac{\text{Plant A cost}}{\text{Plant B cost}} = \left(\frac{\text{Plant A capacity}}{\text{Plant B capacity}}\right)^{X}$$

This formula is commonly used in the refining industry, but it depends on the cost exponent (X) that varies with capacity. While variations in the cost exponent range from about 0.5 for small capacity units up to almost 1.0 for very large units (Gary and Handwerk 2001), the exponent of 0.5 was chosen for the 100 BPD facility. Table 14 shows the cost data used to estimate total costs of the facility in both this project and by Pearlson. Since Pearlson's estimates in Table 14 are in 2010 dollars, adjustments to the cost in 2012 were made using Consumer Price Index (CPI) (Bureau of Labor Statistics 2013) data.

Table 14. Expenses for the facility

	This Project	Pearlson
Size of facility (BPD)	100	4000
Size of facility (GPY)	1,533,000	61,320,000
Capital Investment (cents/gallon)	94	15
Total Capital Cost	$ 21.6 million	$ 140 million
Fixed Operating Cost (cents/gallon)	98	16
Annual Fixed Operating Cost	$ 1.5 million	$ 9.8 million
Variable Operating Cost (cents/gallon)	31	31

An important component of to this analysis is the sales revenue of co-products (outputs other than jet fuel). As described above in maximizing jet fuel output, half the product output from the processing facility is something other than jet fuel. To estimate the revenue that can be obtained from selling these other co-products, the prices of co-products are needed. We obtained these prices from their average 2012 price on commodity exchanges (Index Mundi 2013). To simplify the calculation, we assume that all of co-products produced by APP Jet Center's facility are sold at their average price, adjusted for inflation. This additional estimated revenue helps in reducing the impact of the capital investment of the new processing facility on APP Jet Center's total cost.

Table 15. Cash Flow of Option 3

	Total	2014	2015	2016	2017	2018	2023	2028	2033
Total Cost ('000 dollars)	(331,041)	(4,399)	(16,687)	(11,777)	(12,019)	(12,575)	(15,735)	(19,608)	(23,967)
Capital Investment	(21,615)	(865)	(12,969)	(7,782)	-	-	-	-	-
Fixed Operating Cost	(34,950)	-	-	-	(1,746)	(1,781)	(1,967)	(2,171)	(2,398)
Variable Operating Cost	(200,122)	-	-	-	(8,134)	(8,495)	(10,561)	(13,140)	(15,973)
Conventional Jet Fuel Cost	(74,354)	(3,535)	(3,718)	(3,995)	(2,138)	(2,299)	(3,207)	(4,296)	(5,597)
Revenue ('000 dollars)	113,107	-	-	-	7,220	7,196	6,954	6,458	5,628
Annual Cash Flow ('000 dollars)	(217,934)	(4,399)	(16,687)	(11,777)	(4,799)	(5,379)	(8,781)	(13,150)	(18,339)
Net Present Value ('000 dollars)	(49,830)	(3,327)	(10,972)	(6,733)	(2,386)	(2,326)	(1,887)	(1,405)	(974)

As shown in Table 15, option 3 has conventional jet fuel cost for the first three years, while APP Jet Center constructs the facility and ramps up operation, during which time it will have to continue to purchase and sell conventional jet fuel. In Option 3, much more money is spent up front but there is additional revenue that can be made from the sale of co-products. The NPV of option 3 becomes approximately 49.8 million dollars of costs.

7. RESULTS

The results of the analysis indicate APP Jet Center is better off financially if it avoids any of the options for bringing bio-based alternative jet fuel to Manassas Regional Airport. These summarized results are shown below in Table 16 and Table 17.

Table 16. Net Present Value of Each Option over a 20 year Period

Option	Total	2014	2015	2016	2017	2018	2023	2028	2033
"Do-Nothing" Option	(28,595)	(2,673)	(2,445)	(2,284)	(2,126)	(1,988)	(1,379)	(918)	(595)
1 – Drop-in Biofuel Delivery	(49,031)	(5,082)	(4,620)	(4,227)	(3,863)	(3,537)	(2,258)	(1,425)	(891)
2 – On-site Blending of Biofuel	(49,306)	(5,164)	(4,689)	(4,282)	(3,907)	(3,570)	(2,260)	(1,417)	(882)
3 – On-site Production of Biofuel	(49,830)	(3,327)	(10,972)	(6,733)	(2,386)	(2,326)	(1,887)	(1,405)	(974)

Table 17. Results of Analysis

Option	Logistically Feasible – Near Term	Logistically Feasible – Long Term	Change in Net Present Value over 20 years (in thousand dollars)	2013 Estimates ($/gal)
"Do-Nothing" Option	Yes	Yes	$ 0	$ 3.89
1 – Drop-in Biofuel Delivery	No	Yes	$ (20,436)	$ 7.49
2 – On-site Blending of Biofuel	No	Yes	$ (20,710)	$ 7.20
3 – On-site Production of Biofuel	Yes	Yes	$ (21,235)	$ 9.35

While it's not recommended APP Jet Center pursue bio-based alternative jet fuel in the near term, it's important to monitor certain circumstances that, if changed, would make alternative jet fuel at Manassas Regional Airport an economically viable reality. These circumstances are outline below.

8. SENSITIVITY ANALYSIS

In this section, several different scenarios are studied to understand what circumstances would be required to make bio-based alternative jet fuel at Manassas Regional Airport an economically viable reality.

8.1. Price Divergence

To see what conditions make bringing bio jet fuel to Manassas airport feasible, sensitivity analyses were conducted. The first element to affect the feasibility was the price of conventional jet fuel. The base price of conventional jet fuel is the price forecasted in this project, and its effect on the sensitivity of this analysis was observed by decreasing the price of conventional jet fuel in 10% increments while all other factors remain the same. When the Net Present Value (NPV) cost of any of the three options is less than the "do-nothing" option, bringing bio jet fuel is economically viable. As shown in Table 18, when the price of conventional jet fuel increases by 160%, NPV cost of option 2, on-site blending, is less than the "do-nothing" option. Thus, integrating bio jet fuel becomes a reasonable option, financially.

Table 18. Net Present Value of options by increased conventional jet fuel price

Increase	Option 0 (Base)	Option 1 ('000 dollars)	Option 2 ('000 dollars)	Option 3 ('000 dollars)
30%	0	(17,075)	(16,757)	(18,292)
50%	0	(14,835)	(14,121)	(16,330)
100%	0	(9,234)	(7,532)	(11,425)
160%	0	(2,514)	**375**	(5,539)

The second variable factor affecting financial viability is the price of the alternative jet fuel feedstock, which is soybean oil. The base price of soybean oil is the price forecasted in this project, and its effect on the sensitivity of this analysis was observed by decreasing the soybean oil price in 10% increments while all other factors remaining the same. When the price of soybean oil deceases by 70%, option 1 and option 2 both become more cost effective than the base case. Option 1 is the most cost-effective in terms of NPV. APP Jet Center can spend the least amount of money by buying drop-in bio jet fuel if the price of soybean oil decreases by at least 70%. These results are shown in Table 19.

Table 19. Net Present Value of options by decreased soybean oil price

Decrease	Option 0 (Base)	Option 1 ('000 dollars)	Option 2 ('000 dollars)	Option 3 ('000 dollars)
10%	0	(16,441)	(16,715)	(18,831)
30%	0	(9,646)	(9,920)	(14,024)
50%	0	(4,217)	(4,491)	(9,216)
70%	0	**1,212**	**938**	(4,409)

The next price divergence case to consider is with simultaneous changes to both conventional jet fuel and soybean oil prices. These results are shown in Table 20. When the price conventional jet fuel increases by 50% and the price of soybean oil price by 50%, then both option 1 and 2 become financially viable. For option 3 to become a cost effective alternative, the price of conventional just fuel would need to increase 100% while the price of soybean oil simultaneously decreases 50%.

Table 20. Net Present Value of options by changes in both conventional jet fuel and soybean oil price

Increase Conventional Jet Fuel	Decrease Soybean Oil	Option 0 (Base)	Option 1 ('000 dollars)	Option 2 ('000 dollars)	Option 3 ('000 dollars)
10%	10%	0	(15,321)	(15,398)	(17,850)
30%	30%	0	(6,286)	(5,967)	(11,081)
50%	50%	0	**1,384**	**2,098**	(4,312)
100%	50%	0	**6,984**	**8,687**	**593**

The final case studied is that of the alternative jet fuel feedstock whose price is not volatile. For this case, we studied an imaginary feedstock that begins 2013 at the same price of soybean oil, but increases in price only due to inflation of 2% (Bureau of Labor Statistics 2013). If such a feedstock were to become available, it would likely be a non-edible feedstock whose price is more stable because there is no competition for its use in the world's food supply. This example is laid out in Table 21. While the results clearly show this case would make all three options less expensive than the predicted results in Table 16, this type of price behavior would not be enough on its own to make any option more cost effective than the base case.

Table 21. Net Present Value of Each Option over a 20 year Period with a Less Volatile Feedstock

Option	Total	2014	2015	2016	2017	2018	2023	2028	2033
"Do-Nothing" Option	(28,595)	(2,673)	(2,445)	(2,284)	(2,126)	(1,988)	(1,379)	(918)	(595)
1 – Drop-in Biofuel Delivery	(40,318)	(4,134)	(3,760)	(3,448)	(3,157)	(2,897)	(1,866)	(1,185)	(744)
2 – On-site Blending of Biofuel	(40,592)	(4,216)	(3,830)	(3,503)	(3,201)	(2,930)	(1,868)	(1,177)	(735)
3 – On-site Production of Biofuel	(44,761)	(3,327)	(10,972)	(6,733)	(2,374)	(2,217)	(1,538)	(1,033)	(679)

8.2. Technology Improvements

Feedstocks

One of the primary barriers to implementation that APP Jet Center faces is that the technology of bio-based alternative jet fuel is so new, that, as explained in the logistical analysis of each option in Section 6, the commercial availability of bio-based alternative jet fuel is almost non-existent.

The most readily available feedstocks for bio-based alternative jet fuel are edible oils, such as soybean oil, since they come from crops that are already cultivated for consumption. Using these mass-produced feedstocks is a convenient source of oil for bio-based alternative jet fuel to producers. But like aviation, other modes of transportation can use those same edible feedstocks for biofuel production, further increasing its demand. And with competition high for those edible feedstocks, the price of those feedstocks is also high. In 2012, soybean prices reached all-time highs of $600 per metric ton, doubling in price from five years earlier (Alpert 2012) in part because of their increased use in the production of biofuel. According to a study supported by both the FAA and NASA, the most significant challenge in developing alternative jet fuels lies in the development and commercialization of next generation biomass feedstocks that do not face such competition as a food source (PARTNER 2010).

While Table 21 showed a feedstock similarly priced to soybean oil whose price changes are less volatile could make bio-base alternative jet fuel less expensive, its initial high cost in comparison to conventional jet fuel keeps it from making alternative jet fuel cost effective. Instead, a lower cost feedstock is needed. Many companies are researching what are called “next generation” or “second generation” feedstocks that many people hope could provide this type of low cost potential.

Algae is an example of a next generation biomass feedstock. Algae can grow 20-30 times faster than food crops (McDill 2009) and can produce 300 times more oil per unit area than soybeans (Chisti 2007). In 2010, The Defense Advanced Research Project Agency (DARPA) announced it had extracted oil from algae at a cost of $2 per gallon and planned to be able to refine that oil into jet fuel at a total cost of less than $3 per gallon. And Barbara McQuiston, special assistant for energy at DARPA, projects oil from algae may be “headed towards $1 per gallon” (Goldenberg 2010).

Because algae can be cultivated on land not suitable for growing many edible crops, the impact on its lifecycle greenhouse gas emissions is minimal from land-use change. Land-use change refers to the fact that when farm land is used to create feedstock used from biofuel instead of consumption, land elsewhere in the world must be turned into farmland to make up for the loss is food production capacity. Bio-based alternative jet fuel made from soybean oil emits GHG emissions of between 0.4 and 0.8 times that of conventional jet fuel. But after accounting for land-use change emissions, the life-cycle GHG emissions can be as much as 8 times that of conventional jet fuel (PARTNER 2009). Since algae can result in a decrease in lifecycle GHG emissions when compared to conventional jet fuel (PARTNER 2009), it becomes desirable from an environmental perspective.

If algae can be successfully cultivated on a commercial scale, it could provide oil to biofuel producers with a cleaner, cheaper and much less volatile price than from edible feedstocks. Unfortunately, commercially available algae does not appear to be a reality in the near future. In March 2013, Exxon Mobil Corporation Chairman and CEO, Rex Tillerson, said that despite his company’s $600 million investment into creating fuel from algae, technological limitations suggest biofuel commercially produced from algae is “probably further” than 25 years away from being a reality (Carroll 2013).

ASTM D7566 Testing

As mentioned in the logistical analysis of option 2 (6.5.1), there a few laboratories with the specialized equipment and expertise to test for D7566, the ASTM specification for alternative jet fuel. In fact, the specification was only updated to allow bio-based alternative jet fuel in July 2011 (ASTM 2011). The ASTM specification for Biodiesel (ASTM D6751) has been around 10 years longer, since December 2001 (Renewable Energy Institute 2005). There are many laboratories capable of testing the biodiesel specification for around $1,000 (Murphy's 2013) in less than two days (Miller 2013) (Murphy's 2013). If biojet fuel testing decreases from $4,000 to $1,000, the $3,000 savings on a batch of 16,000 gallons would decrease the cost of alternative jet fuel in option 2 by **$0.19 per gallon**.

8.3. Impacts of Regulatory Incentives for Alternative Fuels

The final circumstance that APP Jet Center and Manassas Regional Airport should monitor is State and Federal regulatory incentives. There are a number of regulatory incentives that have already been enacted or considered for enactment by the U.S. Federal Government and the Commonwealth of Virginia to encourage the production of biofuel. While governments can alter such policies at any time, it appears governments, both domestic and international, are committed to encouraging and incentivizing biofuels. Some examples include:

- In 1997, an international treaty known as the Kyoto Protocol was signed and became effective in 2005. The treaty establishes legally binding maximums for GHG emissions that countries must meet (United Nations 2013). Because aviation contributes about 2% of U.S. GHG emissions (C2ES 2013), reducing aviation related GHG emissions will play a role in ensuring the U.S. complies with the Kyoto Protocol.
- In 2005, Congress established the Renewable Fuel Standard (RFS), which mandated certain amounts of biofuel be introduced into the U.S. transportation fuel supply. It requires that the 9 billion gallons of renewable fuel produced in 2008 be increased to 36 billion gallons by 2022 (EPA 2013).
- In 2010, the Commonwealth of Virginia established requirements that Commonwealth agencies and institutions must procure diesel fuel containing at least 2% biodiesel (DOE 2013). The biodiesel industry is more established than bio-based alternative jet fuel, but as alternative jet fuel becomes available, this biofuel blending requirement may be expanded.

Potential Policy Relevant to Option 1 – Up to $0.50 per gallon

There are no current federal or state incentives available to APP Jet Center if it implements Option 1, which involves just the purchase and resale of bio-based alternative drop-in jet fuel. However, if incentives applicable to other biofuels are adopted for alternative jet fuel, APP Jet Center would be eligible for the following tax credit, worth $0.50 per gallon:

> **Alternative Fuel Excise Tax Credit** - The Federal Government offers a tax incentive for alternative fuel sold for use or used as a fuel to operate a motor vehicle. The $0.50 per gallon tax credit is available for alternative fuels derived from non-petroleum fossil fuel feedstocks and a select group of fuels made from renewable feedstocks, such as ethanol and butane, but not including jet fuel. This tax credit cannot be combined with other biofuel tax credits for the same

gallon of fuel. Expiration date: 12/31/2013 (Public Law 112-240 and 26 U.S. Code 6426) (DOE 2013).

Potential value to APP Jet Center: $0.50 /gal

Potential Policy Relevant to Option 2 – Up to $1.00 per gallon

There are no current federal or state incentives available to APP Jet Center if it implements Option 2, which involves both the blending and sale of bio-based alternative jet fuel. However, if incentives applicable to other biofuels are adopted for alternative jet fuel, APP Jet Center would be eligible for the following tax credits in addition to the potential incentives for Option 1, worth up to a combined total of $1.00 per gallon:

Alternative Fuel Mixture Excise Tax Credit – The Federal Government offers a tax incentive to an alternative fuel blender on the sale or use of a blended alternative fuel. The $0.50 per gallon tax credit is available for alternative fuels derived from non-petroleum fossil fuel feedstocks and a select group of fuels made from renewable feedstocks, such as ethanol and butane, but not including jet fuel. This tax credit cannot be combined with other biofuel tax credits for the same gallon of fuel. Expiration date: 12/31/2013 (Public Law 112-240 and 26 U.S. Code 6426) (DOE 2013).

Potential value to APP Jet Center: $0.50 /gal

Biodiesel Mixture Excise Tax Credit – The Federal Government offers a tax incentive to a biodiesel fuel blender on the sale or use of biodiesel or a mixture of biodiesel and conventional diesel. The $1.00 per gallon tax credit is available for qualifying renewal diesel, as defined by the U.S. Environmental Protection Agency (EPA), including pure biodiesel, agri-biodiesel and renewable diesel blended with conventional diesel. Expiration date: 12/31/2013 (Public Law 112-240 and 26 U.S. Code 6426) (DOE 2013).

Potential value to APP Jet Center: $1.00 /gal

Policy Relevant to Option 3 – Up to $1.59 per gallon

There are both federal and state incentives available to APP Jet Center if it implements Option 3, which involves the production, blending, and sale of bio-based alternative jet fuel. These existing incentives, all in the form of competitive research grants, are outlined below. The grants could be worth up to $1.59 per gallon.

Biomass Research and Development Initiative – Through the U.S. Department of Agriculture's (USDA) National Institute of Food and Agriculture (NIFA) and the U.S. Department of Energy (DOE) Office of Biomass Programs, the Federal Government provides grant funding for projects addressing research, development, and demonstration of biofuels and bio-based projects and the methods, practices, and technologies for their production. As a private sector entity, APP Jet Center would be eligible to apply for the competitive award, to which DOE and NIFA expect to give between five to eight applicants with anticipated award amounts of $3 million to $7 million per award (NIFA 2011). Expiration date: 12/31/13 (Public Law 112-240 and 7 U.S. Code 8108) (DOE 2013).

Potential value to APP Jet Center: $0.65 /gal

Advanced Energy Research Project Grant – Through the Advanced Research Projects Agency - Energy (ARPA-E), part of DOE, was provides grant funding to develop transformational technologies that reduce U.S. dependence on foreign energy imports and reduce U.S. energy related emissions, The ARPA-E focus includes vehicle technologies, biomass energy, and energy storage. Funding award amounts vary, but typically range from $250,000 to $10 million (DOE 2013) (ARPA-E 2013).

Potential value to APP Jet Center: $0.92 /gal

Agriculture and Forestry Biofuel Production Grant – Through the Agriculture and Forestry Industries Development Fund, the Commonwealth of Virginia provides grants to promote and develop the agriculture and forestry industry, including the creation of qualified biofuel production facilities. Individual grants awarded to successful applicants can be up to $250,000 or 25% of capital expenditures, whichever is lower (Virginia Code 3.2-304) (DOE 2013).

Potential value to APP Jet Center: $0.02 /gal

Potential Policy Relevant to Option 3 – Up to $2.70 per gallon

In addition to the existing incentives outlined above, if incentives applicable to other biofuels, including recently expired incentives, are adopted for alternative jet fuel, APP Jet Center would be eligible for the following tax credits, which could be worth up to $1.25 per gallon. Additionally, if alternative jet fuel behaves similarly to biodiesel in the EPA's Renewable Fuel Standard becomes effective for alternative jet fuel, the value of the emission savings in a gallon of bio-based alternative jet fuel could be as much as $1.45 per gallon.

Renewable Fuel Standard (RFS) Program – Each year as part of the RFS Program, the EPA determines the Renewable Volume Obligation (RVO) for parties required to participate. Participants include any party that produces gasoline for use in the United States, including refiners, importers, and blenders. In order to track its use, renewable fuel is tagged with a Renewable Identification Number (RIN). Assigned RINs are transferred when ownership of a batch of fuel occurs, but not when fuel only changes custody. A trading program is set up so that parties unable to meet RVO requirements on their own may purchase excess RINs from other parties. Like any free market, the price of RINs varies throughout the year, but in 2011-2012, biodiesel RINs averaged $1.45 per gallon (Wagner 2011). Alternative jet fuel is not currently included in the RFS program. And while it's extremely difficult to predict what future RIN prices might be if jet fuel were included, a comparison to the RIN market for biodiesel makes for a reasonable estimate (42 U.S. Code 7545(o) and 40 CFR 80.1100-80.1167) (DOE 2013).

Potential value to APP Jet Center: $1.45 /gal

Second Generation Biofuel Producer Tax Credit – The Federal Government offers a tax incentive to a second generation biofuel producer on the sale or use of its biofuel. The $1.01 per gallon tax credit is available only for second generation biofuel, as defined by the U.S. Environmental Protection Agency, which is fuel produced from algae, cyanobacteria or lemma. The case study in this report studied the effects of soybean oil as APP Jet Center's feedstock, which disqualifies it for this incentive as the law is written today. Expiration Date: 12/31/13 (Public Law 112-240 and 26 U.S. Code 40) (DOE 2013).

Potential value to APP Jet Center: $1.01 /gal

Small Agri-Biodiesel Producer Tax Credit (Expired) – The Federal Government offers a tax incentive to a small agri-biodiesel producer on the sale or use of its biofuel. The $0.10 per gallon tax credit is available for agri-biodiesel, which is diesel fuel derived only from virgin oils and animal fats, that is made by a small producer, with no more than 60 million gallons of yearly production capacity. The case study in this report shows APP Jet Center would qualify as a small producer. Expiration date: 12/31/2011 (Public Law 111-312, Section 701; and 26 U.S. Code 40A) (DOE 2013).

Potential value to APP Jet Center: $0.10 /gal

Small Ethanol Producer Tax Credit (Expired) – The Federal Government offers a tax incentive to a small ethanol producer on the sale or use of its biofuel. The $0.10 per gallon tax credit is available for ethanol that is made by a small producer, with no more than 60 million gallons of yearly production capacity. The case study in this report shows APP Jet Center would qualify as a small producer. Expiration date: 12/31/2011 (Public Law 111-312, Section 708; and 26 U.S. Code 40) (DOE 2013).

Potential value to APP Jet Center: $0.10 /gal

Biodiesel Production Tax Credit – The Commonwealth of Virginia offers a tax incentive to biodiesel producers who generate up to two million gallons of biodiesel per year. The $0.01 per gallon tax credit is available to qualified producers certified by the Virginia Department of Mines, Minerals and Energy, and may not exceed $5,000 in a year. Currently, a producer is only eligible for the credit in the first three years of production (Reference Virginia Code 58.1-439.12:02) (DOE 2013).

Potential value to APP Jet Center: $0.01 /gal

Biofuels Production Grant – Through the Biofuels Production Incentive Grant Program, the Commonwealth of Virginia provides grants to producers of advanced biofuels derived from renewable biomass or algae. The $0.125 per gallon tax credit is available for every gallon of biofuel sold. Non-advanced biofuels, including biodiesel and ethanol, are eligible for a tax credit of $0.10 per gallon of biofuel sold in the commonwealth. The program is limited to those who produce at least one million gallons of biofuel a year, and a producer is currently only eligible for six years of grants. Expiration date: 6/30/17 (Virginia Code 45.1-393 and 45.1-394) (DOE 2013).

Potential value to APP Jet Center: $0.125 /gal

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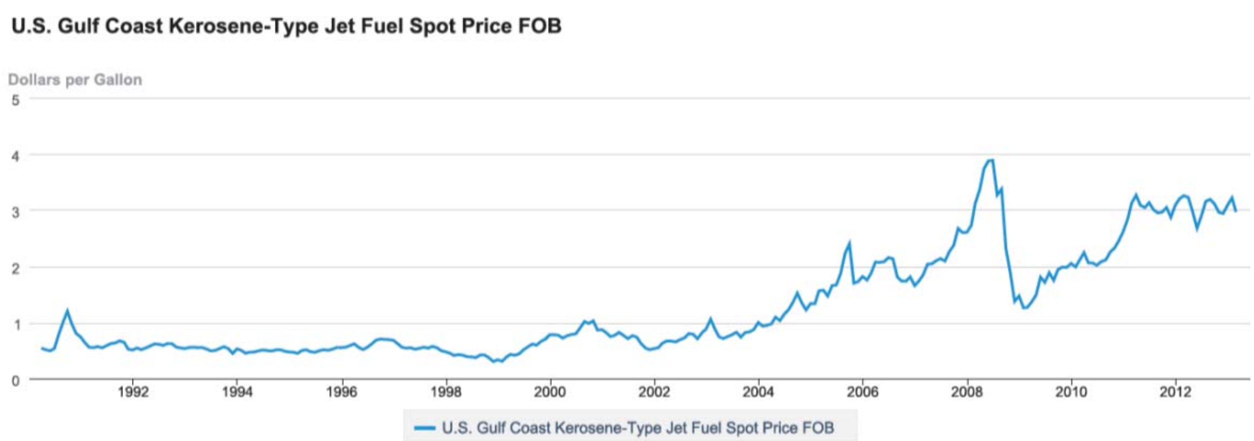
APPENDIX A – PRICE FORECASTING

Section1: Forecasting APP's Future Jet A Prices

Section 1.1: Data

Fuel Supply to APP comes from Eastern Aviation Fuel, which is the largest distributor of aviation fuel products in the Eastern United States. APP was kind enough to provide per gallon Jet A costs for the weeks of DEC 25, 2012 – DEC 31, 2012 and Feb 4, 2013 – Feb 8 2013. At the request of APP those costs will not be given in the report. However, for the given weeks stated above, APP's Jet A fuel costs closely followed U.S Gulf Coast kerosene prices and only differed by at most 4 cents. Thus, to forecast APP's future per gallon Jet A fuel costs, per gallon kerosene prices were forecasted with the assumption that Jet A prices are equivalent to U.S Gulf Coast kerosene prices.

Monthly, U.S Gulf Coast kerosene pricing data was obtained from EIA for a span 22 years from January 1991 to February 2013. Figure 1A gives a plot of the data.



THOMSON REUTERS

Sources: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPJK_PF4_RGC_DPG&f=M

Figure 1A: Monthly U.S Gulf Coast Kerosene Price from January 1991 to February 2013. (Per Gallon)

Section 1.2: Methodology

All statistical analyses were done in R using the "astsa" package and "forecast" package.
To forecast future fuel prices, kerosene pricing data was fitted to a Box Jenkins forecasting model. From Figure 1A it is obvious that the behavior of fuel prices from 2004 to 2013 is radically different from prices seen in 1991 to 2003. Also, because of increasing global oil demand and decreasing supply we assume that fuel prices will never behave as they did in the 90s. Hence, the forecasting model used in the report disregards data points collected prior to December 1, 2003.

The simplified form of the Box Jenkins Autoregressive model, denoted as ARMA(P,Q), used to forecast kerosene prices in the report is defined as follows:
A time series x_t for $t \epsilon \mathbb{N}$ is said to be ARMA(p,q) if x_t is weakly stationary and

Equation 1

$$x_t = \alpha + \phi_1 x_{t-1} + \phi_1 x_{t-2} + \ldots + \phi_1 x_{t-p} + \omega_t + \theta_1 \omega_{t-1} + \theta_1 \omega_{t-2} + \ldots + \theta_q \omega_{q-1}$$

where $\phi_p, \theta_q \neq 0$ and $\omega_t \overset{iid}{\sim} norm(0, \sigma_\omega^2)$, $\sigma_\omega^2 > 0$.

Section 1.3: Model Selection

In order to choose an appropriate model to forecast kerosene prices using data from December 1, 2003 to February 1, 2013, exploratory data analysis was performed by constructing autocorrelation plot ranging from lags 1 to 20 months.

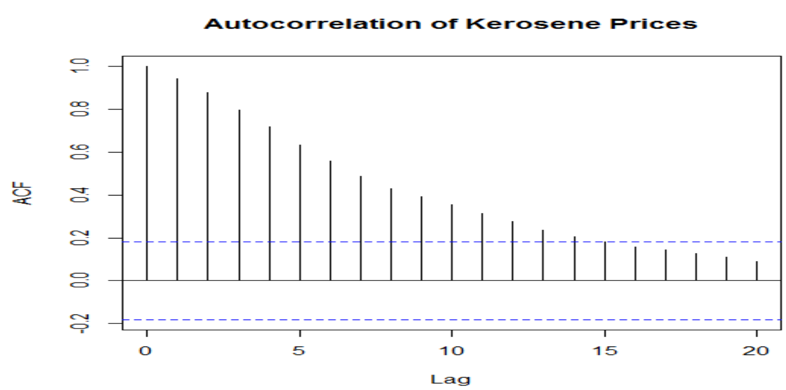


Figure 1B: Sample autocorrelation of kerosene data at lags 1 to 20 months

From Figure 1B it is clear that there exists an upper trend in kerosene prices. Thus, in order to fit a box-Jenkins forecasting model, which assumes a weakly stationary time series, the kerosene pricing data was differenced with lag 1. This means that monthly data points were subtracted from one another to examine the changes in kerosene prices from one month to the next. A new autocorrelation plot and partial autocorrelation plot were created to examine the transformed data.

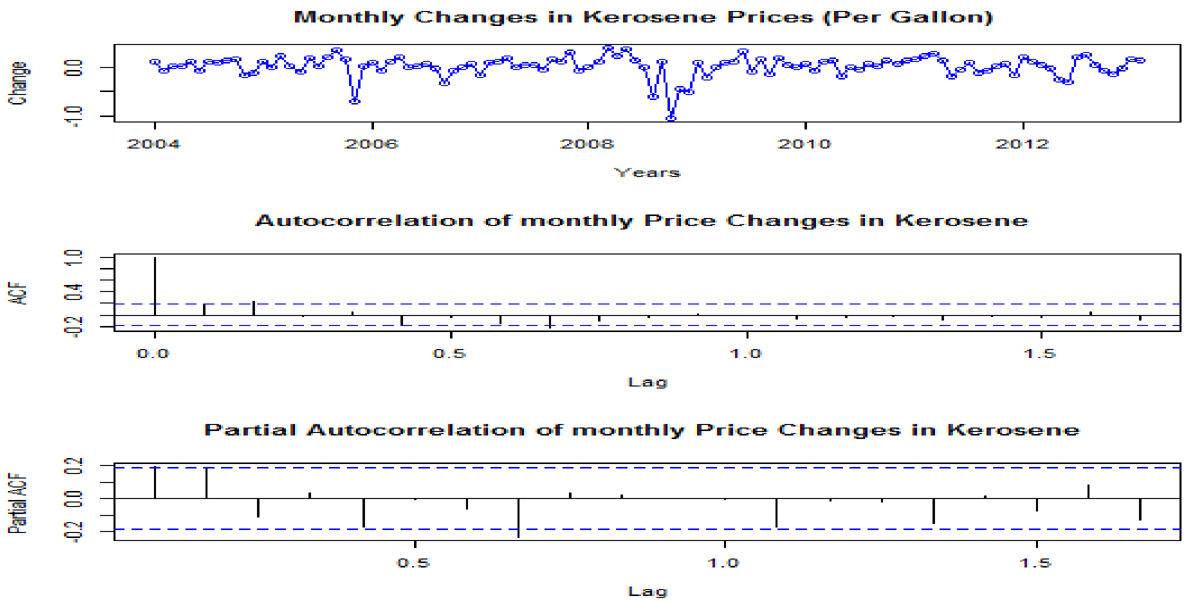


Figure 1C: The top figure is the difference in per gallon kerosene prices between consecutive months. The middle plot is the sample autocorrelation of monthly price changes in kerosene at lags 1 to 20. The bottom plot is the sample partial autocorrelation of monthly Kerosene price changes at lags 1 to 20.

Figure 1C supports the use of an ARMA(p,q) where p,q ∈ ℕ to forecast monthly changes in fuel prices. The first plot in Figure 1C shows that an upper (lower) trend in the transformed dataset does not exist, evidence that monthly changes in kerosene prices are weakly stationary. The autocorrelation function cuts off after lag 2 and the partial autocorrelation function tails off. Hence, the plots given in Figure 1C suggest that an ARMA(0,2) would be best suited to fit the transformed dataset.

In order to fit the untransformed dataset using the information above, the original data was fitted to an integrated autoregressive moving average model denote as ARIMA(p,d,q), a generalization of the ARMA model defined earlier. The ARIMA model is similar to the ARMA model defined above but instead of fitting the data directly the ARIMA model fits to a differenced data set of degree d. ARIMA model for a given non-stationary time series Y_t is defined as follows:

Equation 2

$$\phi(B)(1-B)^d\, Y_t = \alpha + \theta(B)\omega_t$$

where B is the difference operator

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p$$

$$\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \ldots + \theta_q B^q$$

$$\alpha = \mu(1 - \phi_1 - \phi_2 - \ldots - \phi_p)$$

$E[B^d(Y_t)] = \mu$

$\phi_p, \theta_q \neq 0$ and $\omega_t \overset{iid}{\sim} norm(0, \sigma_\omega^2), \ \sigma_\omega^2 > 0.$

Fitting an ARIMA(0,1,2) model results in the following model

Equation 3

$$Y_t = Y_{t-1} + \omega_t + \underset{(0.0951)}{0.1780} \ \widehat{\omega_{t-1}} + \underset{(0.0834)}{0.2045} \ \widehat{\omega_{t-1}}$$

Equation 3 gives parameter estimates and their standard errors below in parenthesis for the fitted ARIMA(0,1,2). In the equation Y_t = per gallon kerosene prices at time t. Notice, that the model does not fit a constant term. This is because it is assumed that once differencing has taken place, any term in the time series is assumed to be zero, meaning the constant term is assumed to be zero. (For a detailed explanation on how the estimates were calculated, see *Time Series Analysis with it Applications*, by Robert H. Shumway and David S. Stoffer section 2.6)

To test the adequacy of the model, residuals were plotted against time, residual quintiles were plotted against normal quintiles, residual partial autocorrelation and autocorrelation plots were created, and a Shapiro-Wilk test was performed on the residuals to test the ARIMA's normality assumptions.

The Shapiro-Wilk test for normality tests whether a random sample $x_1, x_2, \ldots x_n$ comes from a normal distribution. The null hypothesis for the test is that the data comes from a normal distribution. The test statistics is defined as follows

$$W = \frac{(\sum_{i=1}^{n} a_i \, x_{(i)})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

(where the $x_{(i)}$ are the ordered sample values ($x_{(1)}$being the smallest) and the a_i are the constants generated from the mean, variance and covariance of the ordered statistics of a sample size, n, from a normal distribution).

Small values of the test statistics W suggest departures from normality. P-values from the Shapiro-Wilk test are obtained through Monte Carlo simulation (For computational and theoretical underpinnings, see Shapiro, S. S.; Wilk, M. B. 1965).

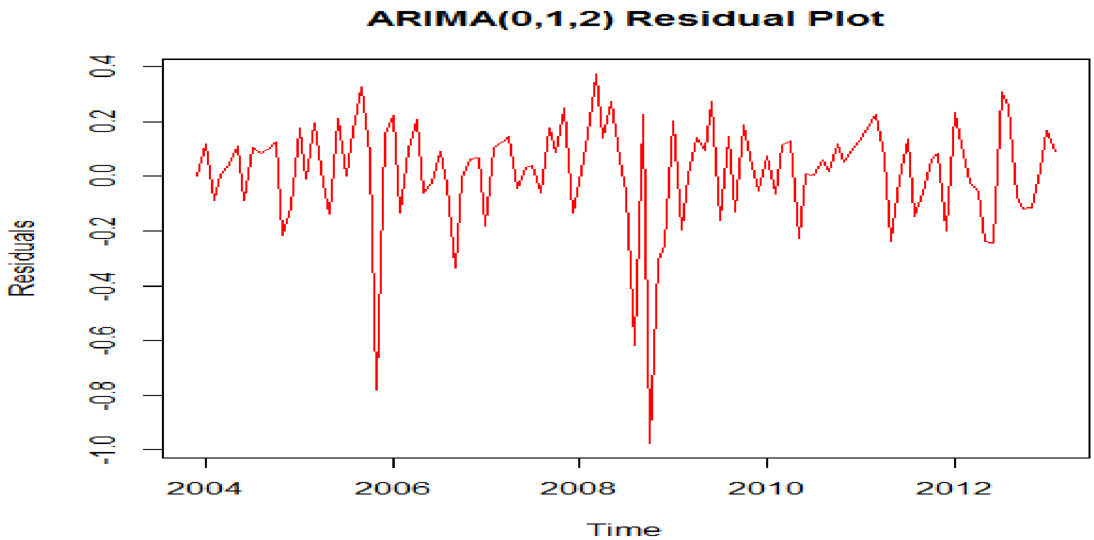


Figure 1D: ARIMA(0,1,2) residuals plotted against time.

It is clear from the residual plot above the model suffers heteroskedasticity, which means the behavior of the residuals depends on time. The residuals behave differently between the years 2008 and 2009 compared to other years. Furthermore, the mean of the residual is approximately equal to -0.0077, which is not zero. Clearly, the ARIMA model assumption that $\omega_t \overset{iid}{\sim} norm(0, \sigma_\omega^2),\ \ \sigma_\omega^2 > 0$ is severely violated. The Shapiro-Wilk test gives P-value = 1.149×10^{-09}, which clearly rejects the null hypothesis at the .05 level. These violations of normality and homoscedasticity are due to the high volatility of kerosene prices in 2008 due to the financial crises. This problem will be further explored and addressed later in the paper.

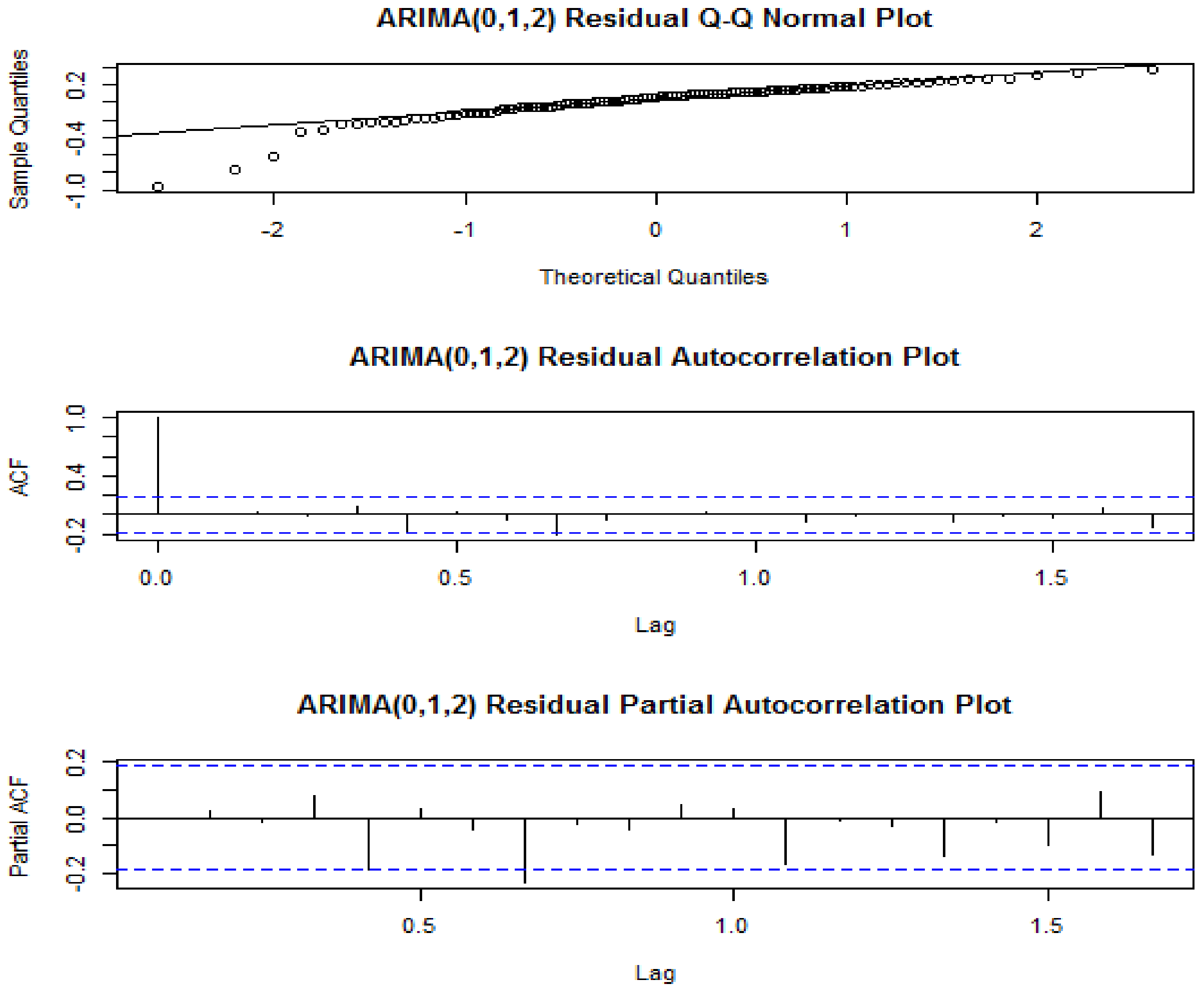


Figure 1E: The top figure is the residual Q-Q normal plot. The middle plot is the residual autocorrelation plot. The bottom plot is the residual partial autocorrelation plot.

The residual autocorrelation plot seems to have a pattern that repeats after certain lags given evidence that perhaps a model that takes into account seasonality would better fit the data, albeit this pattern is hardly noticeable. However, it is common knowledge that certain pricing behavior of goods repeats every year. For example, gasoline prices can be expected to increase every summer due to increases in demand. To further explore the possibility that a model taking into account seasonality will better fit the data, the ARIMA model described earlier was expanded to consider seasonality effects. Hence, the data was fitted to a more general form of an ARIMA model called a Seasonal Multiplicative ARIMA model (SARIMA).

The SARIMA model assumes that for a given non-stationary time series Y_t

Equation 4

$$\Phi_P(B^s)\phi(B)(1-B)^d(1-B^s)^D\, Y_t = \alpha + \Theta_Q(B^s)\,\theta(B)\omega_t$$

where B is the difference operator

$$\phi(B) = 1 - \phi_1 B \quad - \phi_2 B^2 - \ldots - \phi_p B^p$$

$$\theta(B) = 1 + \theta_1 B \quad + \theta_2 B^2 + \ldots + \theta_q B^q$$

$$\Phi_p(B^s) = 1 - \Phi_1 B^s - \Phi_2 B^{2s} - \ldots - \Phi_P B^{Ps}$$

$$\Theta_Q(B^s) = 1 + \Theta_1 B^s + \Theta_2 B^{2s} + \ldots + \Theta_Q B^{Qs}$$

$$E[B^d(Y_t)] = \mu$$

$$\Theta_Q, \Phi_P, \phi_p, \theta_q \neq 0 \text{ and } \omega_t \overset{iid}{\sim} norm(0, \sigma_\omega^2),\ \ \sigma_\omega^2 > 0.$$

The model above is denoted by ARIMA(p,d,q)X(P,D,Q)

Various SARIMA models where fitted to the data to explore which model would fit best. Each model was compared using the following criterions

Akaike information criterion (AIC): Let $\widehat{\sigma_k^2}$ be the maximum likelihood estimator for the variance of a model with k parameters and n observations. Then

$$\text{AIC} = \ln \widehat{\sigma_k^2} + \frac{2k}{n}.$$

The value of k that results in the minimum AIC is considered the best model. The intuition follows that a criterion whose goal is to only minimize $\widehat{\sigma_k^2}$ would be reasonable but as one increases the number of parameters in a model, then it is given that $\widehat{\sigma_k^2}$ will decreases and the criterion will not penalize for over fitting the data. The AIC takes into account over fitting the data with the term $\frac{2k}{n}$. (For theoretical development, see Akaike (1974))

Akaike information criterion corrected (AICc):

A corrected form of the AIC based on small sample distribution results in the Akaike information criterion corrected (AICc), which has the form

$$\text{AICc} = ln\ \widehat{\sigma_k^2} + \frac{n+k}{n-k-2}.$$

AICc follows the same intuition as the AIC and the model with the minimal AICc is considered to have the best fit. For more information in the AICc, see Hurvich and Tsai (1989).

Bayesian information criterion (BIC)

$$\text{BIC} = ln\ \widehat{\sigma_k^2} + \frac{klog(n)}{n}.$$

BIC follows the same intuition as AIC but its origins come from a Bayesian perspective. BIC has a higher penalty for the number of parameters in the model when compared to AIC and AICc. The BIC model was derived by Schwartz (1978).

Table 1A gives the some of the SARIMA models fitted to the data along with their AIC, AICc, and BICc values. The model that is in bold is the one that fit the data the best under the AIC, AICc and BICc criterions.

Table 1A. Models with their AIC, AICc and BIC Values

Model	**AIC**	**AICc**	**BIC**
ARIMA(1,1,1)	-2.21	-2.13	-3.07
ARIMA(1,1,0)	-2.15	-2.13	-3.1
ARIMA(0,1,2)	-2.17	-2.15	-3.1
ARIMA(0,1,1)	-2.19	-2.17	-3.14
ARIMA(0,1,0)x(1,1,0)$_{12}$	-1.65	-1.63	-2.63
ARIMA(1,1,0)x(0,1,1)$_{12}$	-2.15	-2.13	-3.11
ARIMA(1,1,1)x(1,1,1)$_{12}$	-2.14	-2.12	-3.04
ARIMA(1,1,0)x(0,1,5)$_{12}$	**-2.31**	**-2.28**	**-3.16**

Section 1.5: Final Model

Since the model ARIMA(1,1,0)x(0,1,5)$_{12}$ fits the data the best under the AIC, AICc, and BIC measures, this was the model used to forecast future per gallon kerosene prices.

Estimates for the ARIMA(1,1,0)x(0,1,5)$_{12}$ with standard errors are given below

Equation 5

$$(1-0.19)(1-B)^d(1-B^s)^D\,Y_t = (1-1.19B^{12}-.093B^{24}+.25B^{36}+.026B^{48}+.16B^{60})\widehat{\omega_t}$$

(.102) (.45) (0.19) (.24) (.17) (.15)

To check whether the homoscedastic and normality assumptions hold the residuals were plotted against time. Also, a Q-Q plot, ACF and PACF plots where created for the residuals and a Shapiro-Wilk test was performed on the residuals to check for normality.

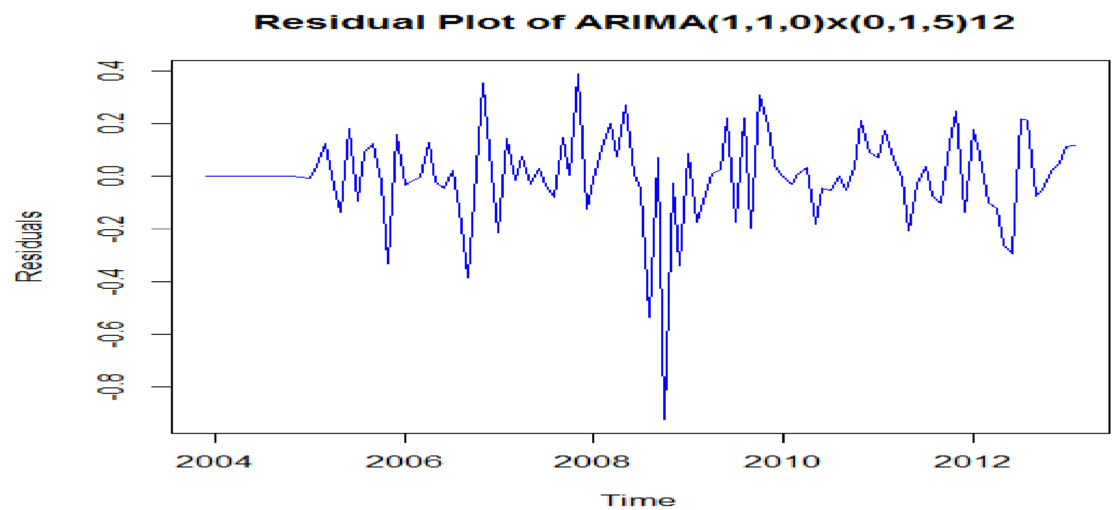


Figure 1F: ARIMA(1,1,0)x(0,1,5)$_{12}$ residuals plotted against time.

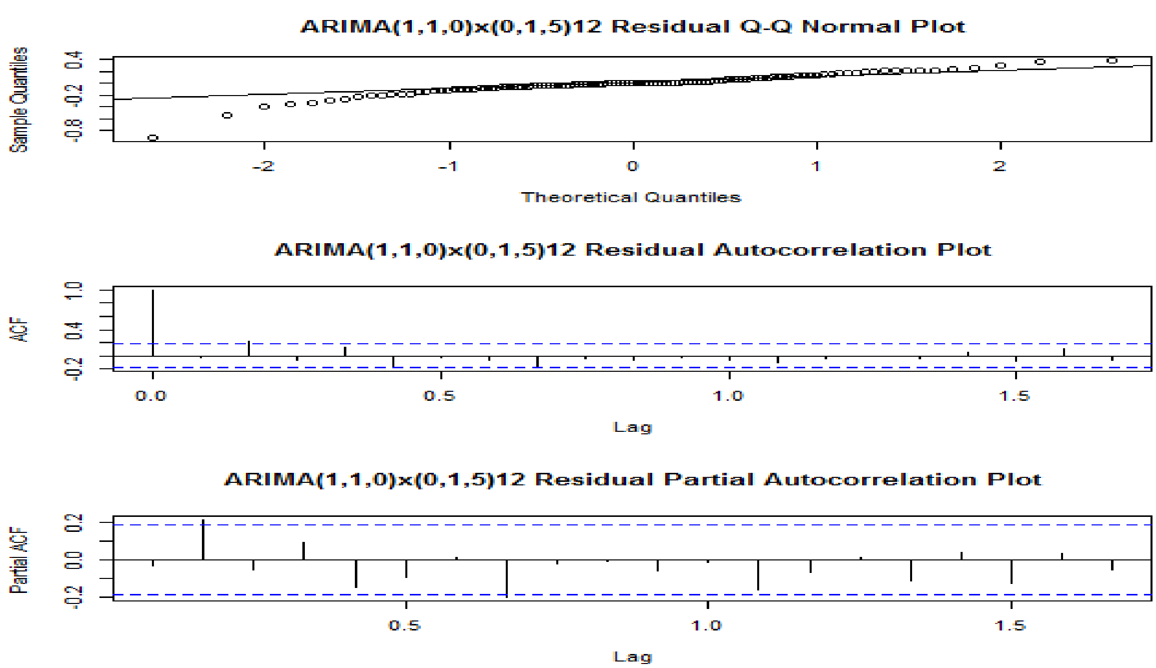


Figure 1G: The top figure is the residual Q-Q normal plot. The middle plot is the residual autocorrelation plot. The bottom plot is the residual partial autocorrelation plot.

Just like the ARIMA(0,1,1), the residual plot shows strong evidence of heteroskedasticity. Between years 2008 and 2009 the residual behavior clearly changes. This is due to the financial crises of 2008 having a drastic effect on the behavior of kerosene prices. The radical changes in pricing behavior unable the error terms of a SARIMA model to behave as if they were generated from a normal distribution.

Performing Shapiro-Wilk test on the fitted model given in equation 5 gives a P-value of $8.146\text{x}10^{-08}$ which rejects the null hypothesis that residuals are normally distributed at the .05 level. Attempts to remedy this problem consisted of deleting observations from 2008 and replacing them with fitted values. However, this procedure led to deleting a year's worth of data that led to greater violations of the normality assumption. Logging the data did not help stabilize prices. Another remedy to the problem was an attempt to use a Bayesian dynamic linear model to fit the data. However, due to time constraints any attempts to use Bayesian statistics where halted. Thus, with no remedy to the heteroskedasticity problem the project proceeds to use the fitted ARIMA(1,1,0)x$(0,1,5)_{12}$ with the caveat that the residuals are not normally distributed. However, since the project is forecasting prices 20 years into the future confidence intervals (credible intervals) from any model would be extremely large rendering them useless. Hence, confidence intervals will not be reported here nor will they be included in the analysis of this paper.

Section 1.6: Evaluating Forecasting Accuracy

To evaluate the final model, ARIMA(1,1,0)x$(0,1,5)_{12}$, the dataset was split into a training dataset and a test dataset.

The training data set consisted of monthly per gallon kerosene prices from December 1, 2003 to December 1, 2011. The test data set consisted of monthly per gallon kerosene prices from January 1, 2012 to February 1, 2013.

The ARIMA(1,1,0)x$(0,1,5)_{12}$ model was fitted to the training dataset. Once parameter estimates were obtained we forecasted monthly per gallon kerosene prices from January 1, 2012 to February 1, 2012.

To evaluate forecasting accuracy we used two commonly used accuracy statistics for 12 month ahead forecasts, mean absolute error and mean absolute percentage deviation.

Let, x_{t+i} be an observed data point from the test dataset at time t +i and $\hat{x}_{t+i}$ be a predicted value from our final model at time t + i.

$$MAE(n) = \frac{1}{n}\sum_i^n |x_{t+i} - \hat{x}_{t+i}| \qquad \text{mean absolute error.}$$

$$MAPD(n) = \frac{1}{n}\sum_i^n \frac{|x_{t+i} - \hat{x}_{t+i}|}{x_{t+i}} \qquad \text{mean absolute percentage deviation.}$$

We chose MAE and MAPD as a measure for forecasting accuracy because they are straight forward to interpret and most intuitive. MAPD tells us by what percentage did we miss the target on average and MAE tells us by how much we missed the target on average. MAPD and MAE results are given below.

Mean Absolute Error	.26	stdv = .17
Mean Absolute Deviation Percentage Error	8.6 %	stdv = 6.5

Note that the mean absolute error was .26; however, because of the volatility of fuel prices in recent years and we used a 12 months ahead forecast, we consider this absolute error as acceptable.

Section 2: Forecasting Soybean oil Prices

Section 2.1: DATA

To forecast future Soybean oil prices we used U.S soybean oil monthly prices in U.S dollars per metric ton from March 1, 1983 to March 1, 2012 obtained from index mundi, a site containing country statistics, charts, and maps complied from multiple sources. The data originated form the Chicago Mercantile Exchange.

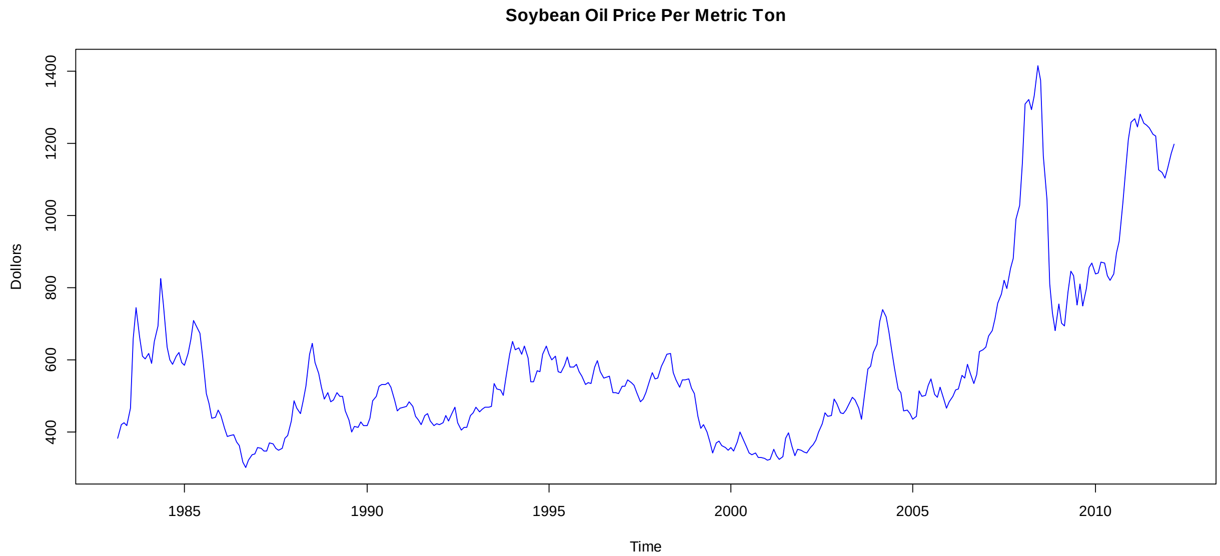


Figure 2A: Monthly Soybean oil Prices (Per Metric Ton)

Section 2.2: Methodology and Model Selection

The same methodology used to forecast kerosene price was used to forecast future soybean oil prices per metric ton. To build the forecasting model the data was separated into a test dataset and a training dataset. The test dataset consisted of monthly data points from April 2012 to March 2013 and the training data set consisted of monthly prices from March 1983 to March 2012.

Initially, just as in forecasting kerosene prices, exploratory analysis was performed on the training set using acf and pacf plots.

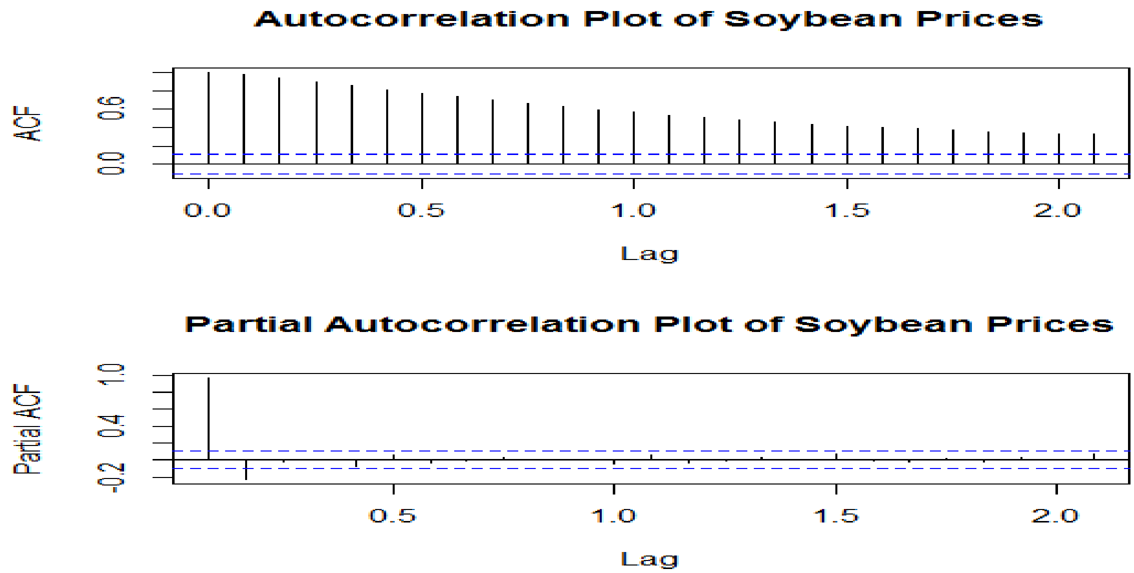


Figure 2B: (Top) Autocorrelation plot of soybean prices per metric ton from March 1983 to March 2012. (Bottom) Partial autocorrelation plot of soybean prices per metric ton from March 1983 to March 2012.

Just as in the Kerosene dataset there is a clear upper trend in the data. Thus, soybean oil prices were differenced for consecutive months to get a better understanding of how the data behaves and to obtain a stationary time series.

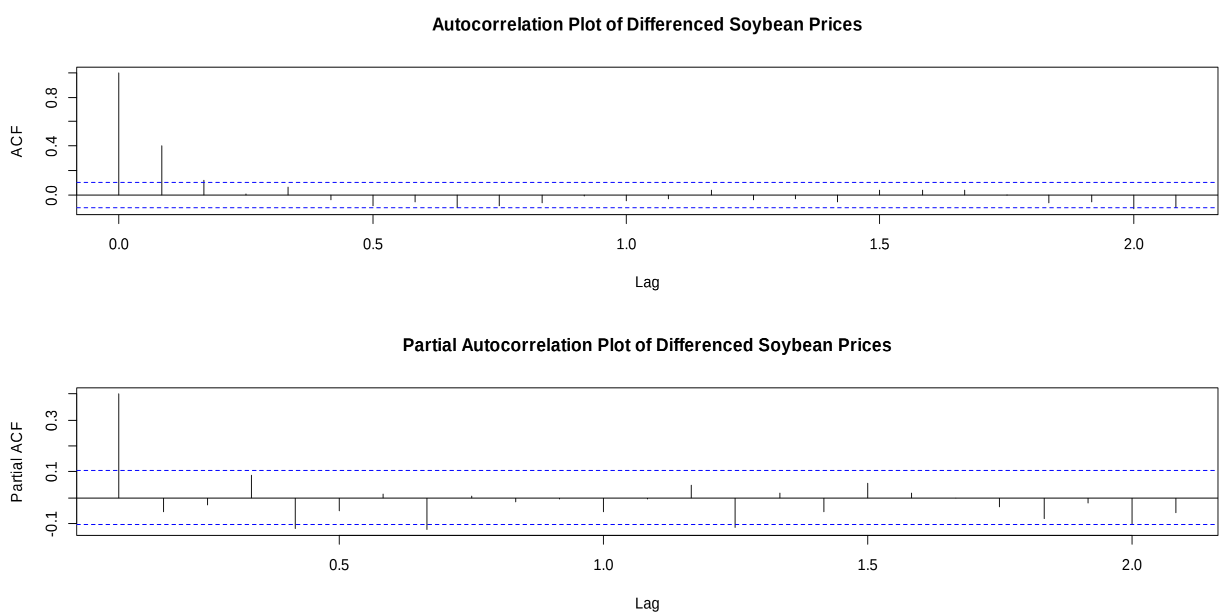


Figure 2C: (Top) Autocorrelation plot of differenced soybean prices per metric ton from March 1983 to March 2012. (Bottom) Partial autocorrelation plot of differenced soybean prices per metric ton from March 1983 to March 2012.

The autocorrelation and partial autocorrelation plots indicate that perhaps an ARIMA(0,1,1) would fit the data well. Also, like fuel prices soybean oil prices are known to behave seasonally. Thus, various SARIMA models where fitted to the data and using AIC, AICc, and BIC measures of performance a model was picked to forecast future soybean oil prices. In order to help stabilize soybean price, prices were logged. The table below gives a sample of models fitted with their corresponding AIC, AICc, and BIC values. The model in bold fit the data the best under the BIC criterion.

Table 2A. Models with their AIC, AICc, and BIC values

Model	**AIC**	**AICc**	**BIC**
ARIMA(0,1,1)	-4.68	-4.67	-5.66
ARIMA(1,1,0)	-4.68	-4.67	-5.66
ARIMA(0,1,0)x$(1,1,0)_{12}$	-4.10	-4.09	-5.09
ARIMA(0,1,1)x$(0,1,1)_{12}$	**-4.71**	**-4.7**	**-5.69**

Section 2.3: Final Model

Estimates for the ARIMA(0,1,1)x$(0,1,1)_{12}$ for logged soybean oil prices per metric ton with standard errors are given below

Equation 6

$$(1-B)^d(1-B^s)^D\,Z_t = (1-1B^{12}\,)(1+\,.37)\,\widehat{\omega}_t$$

(.0425) (.0476)

where Z_t = logged soybean oil prices per metric ton at month t

To check whether the homoscedastic and normality assumptions hold, the residuals were plotted against time. Also, a Q-Q plot, and ACF and PACF plots were created for the residuals. A Shapiro-Wilk test was also performed on the residuals to check for normality.

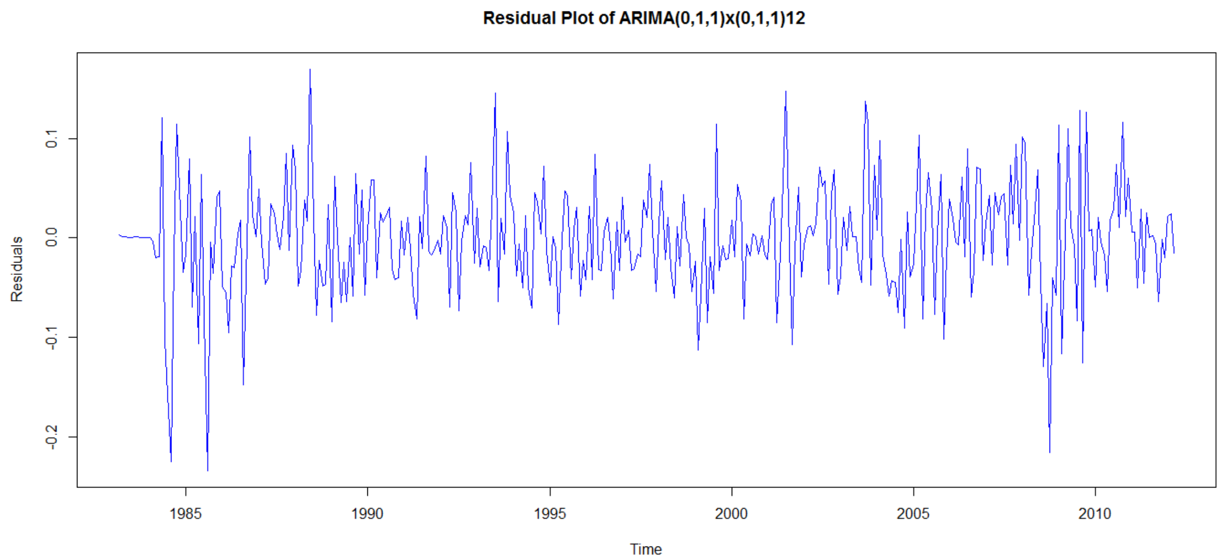


Figure 2D: ARIMA(0,1,1)x(0,1,1)$_{12}$ residuals plotted against time.

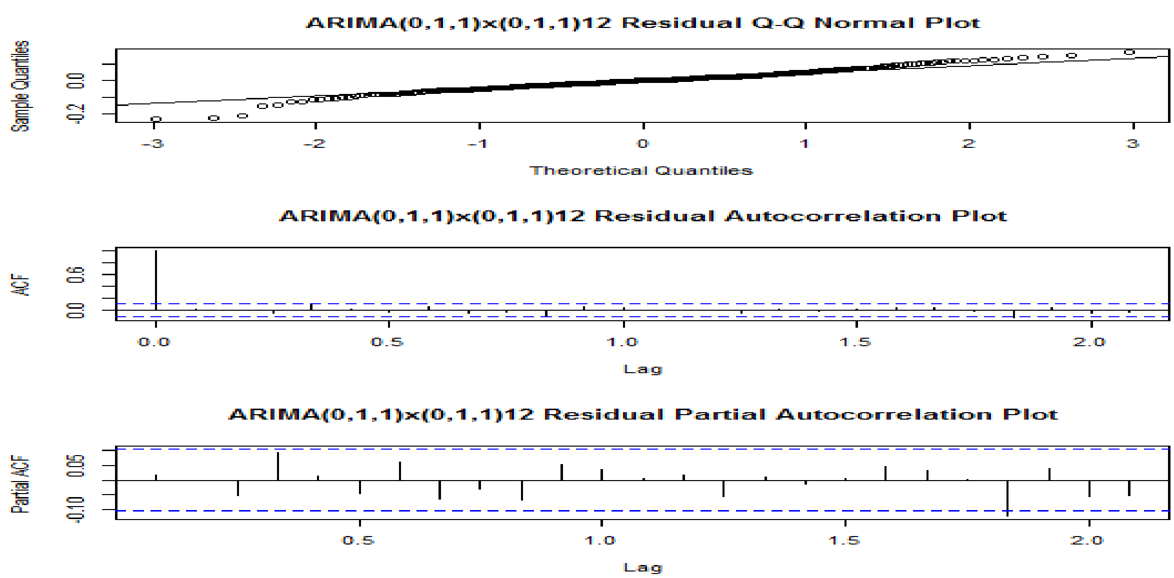


Figure 2E: The top figure is the residual Q-Q normal plot. The middle plot is the residual autocorrelation plot. The bottom plot is the residual partial autocorrelation plot at lags.

Like the model for forecasting kerosene prices, the SARIMA model in equation 6 suffers from heteroskedasticity and the residuals do not seem to be normally distributed. The Shapiro-Wilk test gives a P-value of $1.397X10^{-5}$, clearly rejecting the null at the .05 level. Nevertheless forecasts for logged prices per metric ton of soybean oil were made using fitted estimates from equation 6.

Section 2.4: Evaluating Forecasting Accuracy

To evaluate the ARIMA(0,1,1)x$(0,1,1)_{12}$ model the dataset was split into a training dataset and a test dataset. Both the test and training datasets were defined in section 2.2

Predicted values from the model were exponentiated and compared with the observed values in the test dataset.

As with kerosene prices, MAE and MAPD were used to evaluate forecasting accuracy. Results are given below.

Mean Absolute Error	69.71
Mean Absolute Percentage Deviation	6%

A MAPD of 6% suggests that the model performed decently well in predicting per metric ton soybean oil prices.

B. Appendix B - Cost Model

Note:		
Facility Capacity:	100	BPD
Facility Capacity:	1,533,000	gallons/year
Inflation Rate:	2%	
Discount Rate:	15%	
Consumer Price Index:	1.0529	for 2012 based on 2010
Capital Investment ($):	21,615,300	
Fixed Operating Cost	98	cents/gallon
Variable Operating Cost	31	cents/gallon
Construction Period (Years)	3	
% Spent in Year 1	4%	
% Spent in Year 2	60%	
% Spent in Year 3	36%	
Transport Cost from West Coast	34.57	cents/gallon

(unit: '000 dollars)

Scenario	Options	0	3	2	1
1	NPV	(28,595)	(49,830)	(49,306)	(49,031)
			(21,235)	(20,710)	(20,436)

	Total	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Annual Jet Fuel Demand ('000 gallons)	21,699		875	895	914	934	955	976	998	1,019	1,042	1,065	1,088	1,112	1,137	1,162	1,187	1,213	1,240	1,267	1,295	1,324
Conventional Jet Fuel Price			4.04	4.16	4.37	4.58	4.81	5.06	5.30	5.54	5.78	6.02	6.27	6.51	6.75	6.99	7.24	7.48	7.72	7.97	8.21	8.46
Bio jet Fuel Price for producing			15.11	15.41	15.72	16.03	16.36	16.68	17.02	17.36	17.70	18.06	18.42	18.79	19.16	19.55	19.94	20.34	20.74	21.16	21.58	22.01
Bio jet Fuel Price for purchasing			10.71	10.93	11.15	11.37	11.60	11.83	12.06	12.31	12.55	12.80	13.06	13.32	13.59	13.86	14.13	14.42	14.71	15.00	15.30	15.61
Drop-in Bio Jet Fuel Price for purchasing			7.68	7.85	8.09	8.32	8.57	8.82	9.08	9.34	9.60	9.86	10.13	10.40	10.68	10.95	11.23	11.51	11.79	12.08	12.37	12.67
Option 0																						
Annual Cash Flow ('000 dollars)	(137,461)		(3,535)	(3,718)	(3,995)	(4,276)	(4,598)	(4,935)	(5,284)	(5,647)	(6,024)	(6,414)	(6,819)	(7,239)	(7,674)	(8,125)	(8,593)	(9,077)	(9,579)	(10,098)	(10,636)	(11,194)
Net Present Value ('000 dollars)	(28,595)		(2,673)	(2,445)	(2,284)	(2,126)	(1,988)	(1,855)	(1,728)	(1,605)	(1,489)	(1,379)	(1,275)	(1,177)	(1,085)	(999)	(918)	(843)	(774)	(710)	(650)	(595)
Option 3																						
Total Cost ('000 dollars)	(331,041)		(4,399)	(16,687)	(11,777)	(12,019)	(12,575)	(13,157)	(13,762)	(14,393)	(15,050)	(15,735)	(16,447)	(17,190)	(17,963)	(18,769)	(19,608)	(20,482)	(21,392)	(22,340)	(23,328)	(23,967)
Capital Investment	(21,615)		(865)	(12,969)	(7,782)																	
Fixed Operating Cost	(34,950)					(1,746)	(1,781)	(1,817)	(1,853)	(1,890)	(1,928)	(1,967)	(2,006)	(2,046)	(2,087)	(2,129)	(2,171)	(2,215)	(2,259)	(2,304)	(2,350)	(2,398)
Variable Operating Cost	(200,122)					(8,134)	(8,495)	(8,872)	(9,267)	(9,679)	(10,110)	(10,561)	(11,032)	(11,524)	(12,039)	(12,577)	(13,140)	(13,728)	(14,344)	(14,987)	(15,659)	(15,973)
Conventional Jet Fuel Cost	(74,354)		(3,535)	(3,718)	(3,995)	(2,138)	(2,299)	(2,467)	(2,642)	(2,824)	(3,012)	(3,207)	(3,410)	(3,620)	(3,837)	(4,063)	(4,296)	(4,539)	(4,789)	(5,049)	(5,318)	(5,597)
Revenue ('000 dollars)	113,107					7,220	7,196	7,165	7,126	7,078	7,021	6,954	6,877	6,790	6,691	6,581	6,458	6,321	6,171	6,006	5,825	5,628
Annual Cash Flow ('000 dollars)	(217,934)		(4,399)	(16,687)	(11,777)	(4,799)	(5,379)	(5,992)	(6,637)	(7,316)	(8,030)	(8,781)	(9,570)	(10,400)	(11,272)	(12,188)	(13,150)	(14,161)	(15,221)	(16,335)	(17,503)	(18,339)
Net Present Value ('000 dollars)	(49,830)		(3,327)	(10,972)	(6,733)	(2,386)	(2,326)	(2,253)	(2,170)	(2,080)	(1,985)	(1,887)	(1,789)	(1,690)	(1,593)	(1,498)	(1,405)	(1,316)	(1,230)	(1,148)	(1,069)	(974)
Option 2																						
Conventional Jet Fuel Cost	(68,730)		(1,767)	(1,859)	(1,998)	(2,138)	(2,299)	(2,467)	(2,642)	(2,824)	(3,012)	(3,207)	(3,410)	(3,620)	(3,837)	(4,063)	(4,296)	(4,539)	(4,789)	(5,049)	(5,318)	(5,597)
Bio Jet Fuel Cost (non drop-in)	(143,215)		(4,689)	(4,888)	(5,095)	(5,312)	(5,537)	(5,772)	(6,017)	(6,272)	(6,539)	(6,816)	(7,105)	(7,407)	(7,721)	(8,049)	(8,390)	(8,747)	(9,118)	(9,505)	(9,908)	(10,329)
Transportation Cost	(4,714)		(154)	(161)	(168)	(175)	(182)	(190)	(198)	(206)	(215)	(224)	(234)	(244)	(254)	(265)	(276)	(288)	(300)	(313)	(326)	(340)
Blending Cost	(5,425)		(219)	(224)	(229)	(234)	(239)	(244)	(249)	(255)	(260)	(266)	(272)	(278)	(284)	(290)	(297)	(303)	(310)	(317)	(324)	(331)
Annual Cash Flow	(222,084)		(6,829)	(7,132)	(7,489)	(7,858)	(8,257)	(8,673)	(9,107)	(9,557)	(10,026)	(10,514)	(11,021)	(11,548)	(12,097)	(12,667)	(13,260)	(13,876)	(14,517)	(15,184)	(15,876)	(16,596)
Net Present Value	(49,306)		(5,164)	(4,689)	(4,282)	(3,907)	(3,570)	(3,261)	(2,977)	(2,717)	(2,478)	(2,260)	(2,060)	(1,877)	(1,710)	(1,557)	(1,417)	(1,289)	(1,173)	(1,067)	(970)	(882)
Option 1																						
Drop-in Bio Jet Fuel Cost	(222,255)		(6,721)	(7,026)	(7,393)	(7,770)	(8,181)	(8,610)	(9,056)	(9,520)	(10,002)	(10,504)	(11,026)	(11,569)	(12,134)	(12,721)	(13,331)	(13,966)	(14,626)	(15,311)	(16,024)	(16,765)
Transportation Cost	(9,428)		(309)	(322)	(335)	(350)	(365)	(380)	(396)	(413)	(430)	(449)	(468)	(488)	(508)	(530)	(552)	(576)	(600)	(626)	(652)	(680)
Annual Cash Flow	(231,683)		(7,030)	(7,348)	(7,728)	(8,120)	(8,545)	(8,989)	(9,452)	(9,932)	(10,433)	(10,953)	(11,494)	(12,057)	(12,642)	(13,251)	(13,884)	(14,542)	(15,226)	(15,937)	(16,676)	(17,445)
Net Present Value	(49,031)		(5,082)	(4,620)	(4,227)	(3,863)	(3,537)	(3,237)	(2,960)	(2,706)	(2,472)	(2,258)	(2,061)	(1,880)	(1,715)	(1,563)	(1,425)	(1,298)	(1,182)	(1,076)	(979)	(891)