# An Analysis of Alternative Jet Fuel Supply for Manassas Regional Airport

# Final Presentation

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Samira Monshi
Seungwon Noh
Wilfredo Rodezno
Brian Skelly

# Agenda

- Project Overview
- Background on Alternative Jet Fuel
- Problem Description and Scope
- Technical Approach
- Analysis and Results
- Conclusion, Recommendations, and Next Steps

# Project Overview

- **Purpose:** Determine the best way to bring bio-based alternative jet fuel to Manassas Regional Airport.
- **Approach:**
  - Identified feasible options
  - Estimated to the cost of each alternative
    - Price Forecast
    - Cost Model
  - Compared cost of each alternative with "do nothing" option
- **Results:** Every option for alternative jet fuel is too expensive
- **Recommendation:** Wait for certain circumstances to change and be prepared to invest in alternative fuel when they do

# Project Stakeholder Involvement

**Dr. Lance Sherry and GMU CATSR – Project Sponsor**

Validated project assumptions and assisted in scoping effort

**Dr. Terry Thompson**
*Metron Aviation*

**Quinn Redden**
*App Jet Center*
*General Manager*

**Metron Aviation**

- Provided background information and guidance on estimating costs of bio fuel processing and considerations for logistical concerns

**Manassas Regional Airport Officials**

- Provided historical monthly fuel use information, fuel farm information and guidance on airport operations and jet fuel supply chain

**APP Jet Center**

- A fixed base operator and fuel distributor at Manassas Regional Airport
- Provided fuel pricing information and explained fuel storage and distribution process

**Dr. Bruno Miller**
*Metron Aviation*

**Jolene Berry**
*Manassas Regional Airport Operations*

**Richard Allabaugh**
*Manassas Regional Airport Operations*

# Aviation's Gas Problem

- Fuel costs are 30% of commercial aviation operating costs
- In 2013, jet fuel will cost the aviation industry **$216 billion**
- The aviation industry is powered by petroleum
  - Limited supply on Earth
  - Volatile and steadily rising prices


- Aviation has limited options in using alternate sources of power:

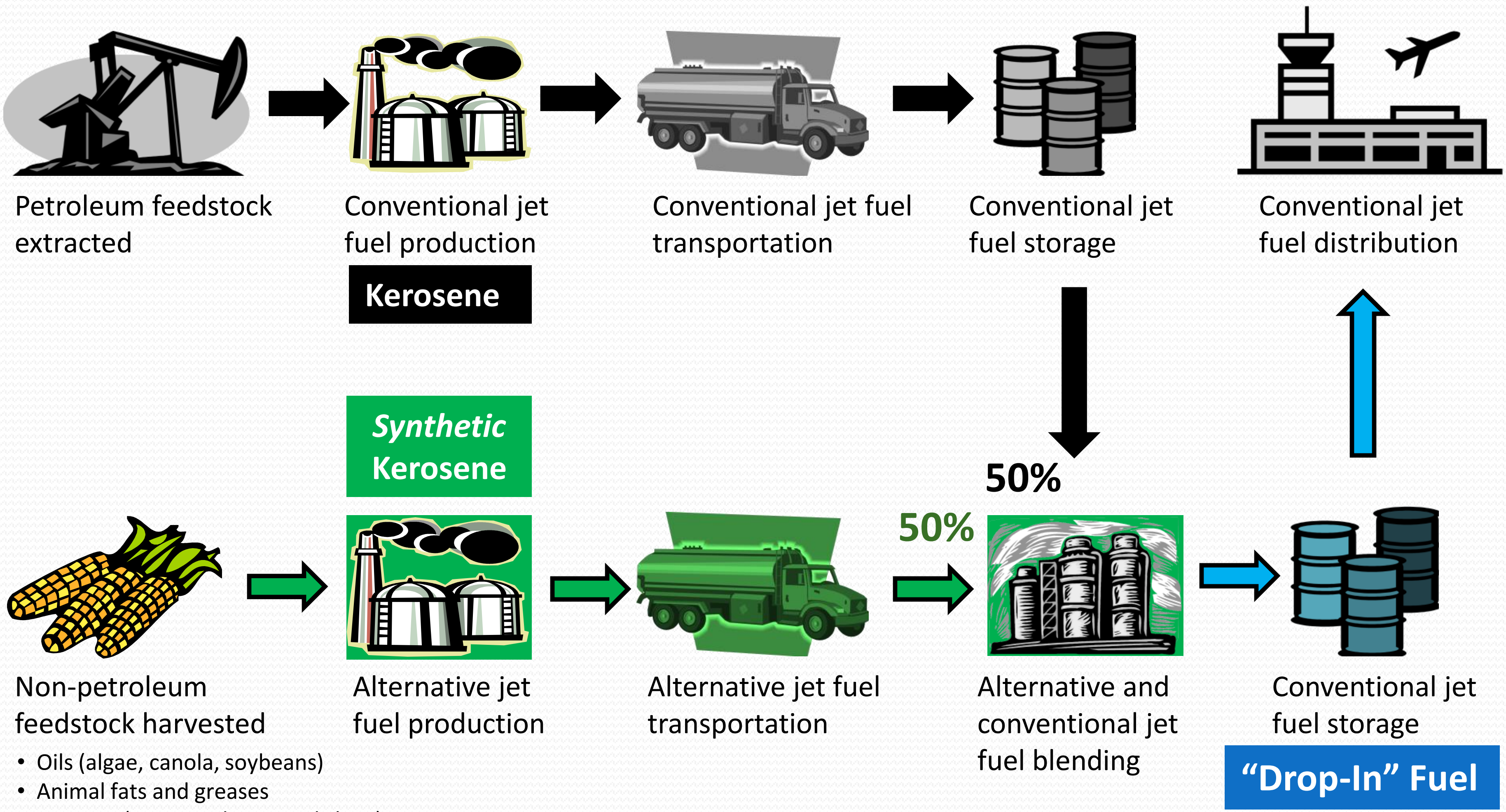
| | Energy Density | |
|---|---|---|
| ~~Batteries~~ | (1.8 MJ/kg) | Too heavy |
| ~~Nuclear~~ | ($83 \times 10^6$ MJ/kg) | Too dangerous |
| ~~Solar~~ | (0.5 MJ/kg) | Not powerful enough |
| Biofuel | (42.8 MJ/kg) | Too expensive? Maybe not |

**Only alternative to fossil fuel is biofuel**

# Drawbacks of Biofuel

- Many sources of biofuel are also sources of food
- Increased competition for these “feedstocks” will increase price of both biofuel and food
- More food needs to be farmed to make up loss to food supply
- Tilling new land for farming is a big source of greenhouse gas emissions

# Alternative Jet Fuel Supply Chain



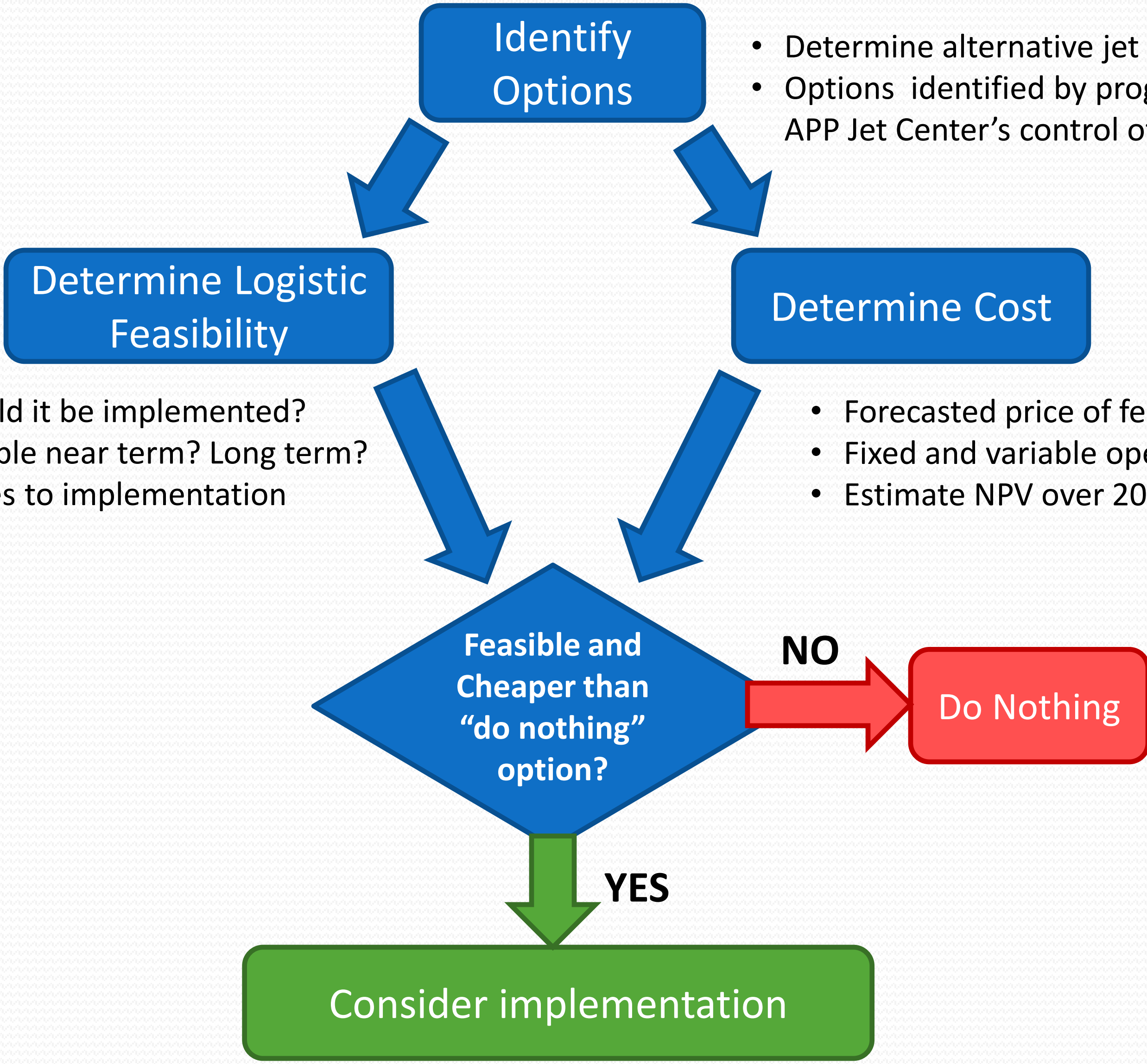

- Oils (algae, canola, soybeans)
- Animal fats and greases
- Biomass (crop residue, wood chips)
- Municipal solid waste
- Non-petroleum Fossil fuels (natural gas, coal)

# Problem Description and Scope

- **Purpose** - Determine the best way to bring bio-based alternative jet fuel to Manassas Regional Airport.
- **Scope**
- Studied from perspective of APP Jet Center, a fixed based operator and fuel distributor at Manassas Regional Airport
- Analysis over 20 year timeline
- Renewable Feedstock – Soybean Oil

| | Average Yield (gal/acre) | 2012 World Production ('000 Metric Ton) | 2012 U.S. Production ('000 Metric Ton) | 2012 Virginia Production ('000 Metric Ton) |
|---|---|---|---|---|
| Palm Oil | 635 | 54,320 | - | - |
| Soybean Oil | 48 | 43,090 | 9,490 | 118.0 |
| Rapeseed (Canola) Oil | 127 | 23,910 | 600 | - |
| Sunflower seed Oil | 102 | 13,840 | 260 | - |
| Palm Kernel Oil | 612 | 6,250 | - | - |
| Peanut Oil | 113 | 5,320 | 120 | 18.0 |

# Technical Approach




- Determine alternative jet fuel supply chain steps
- Options identified by progressively increasing APP Jet Center's control of steps

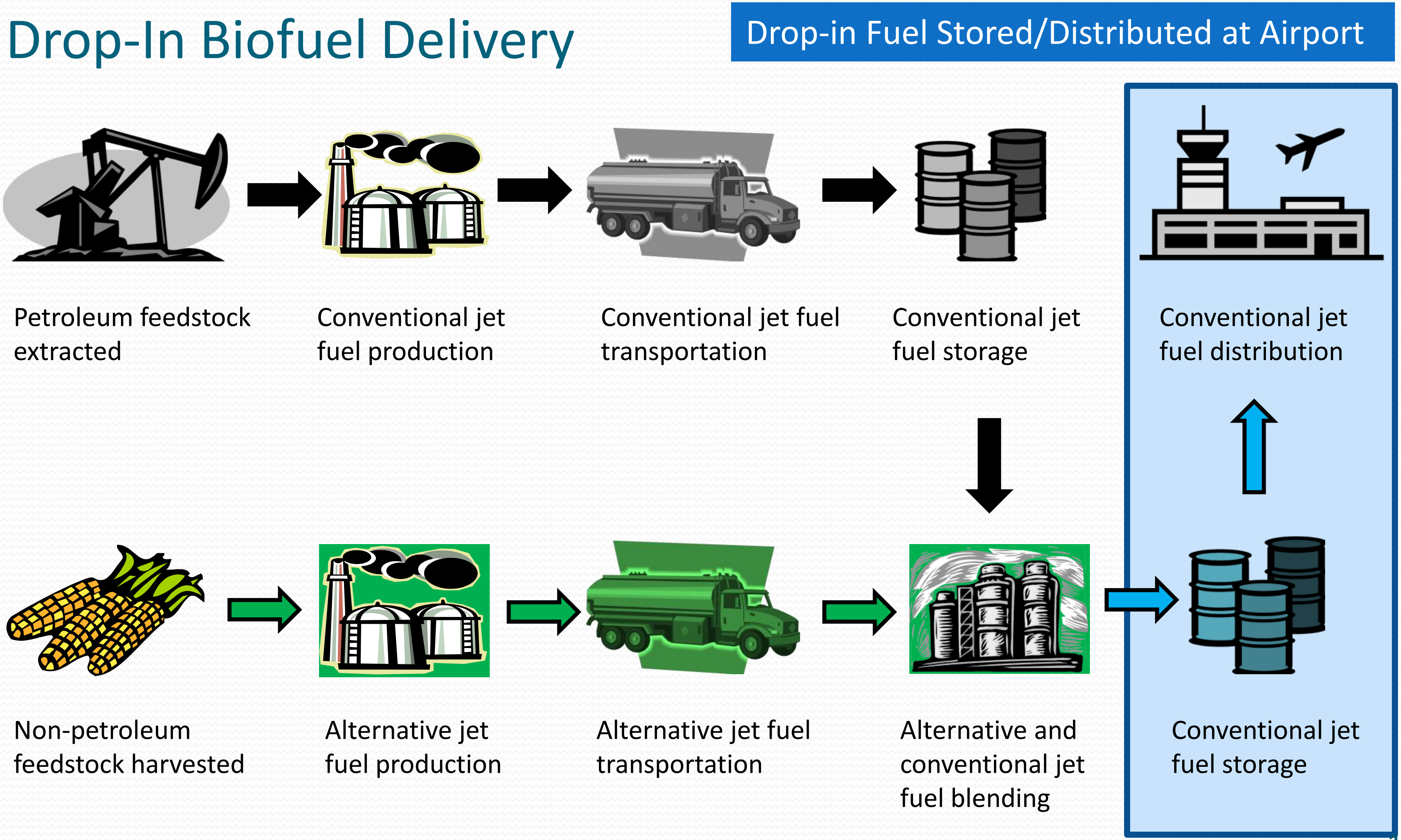
- How would it be implemented?
- Is it possible near term? Long term?
- Challenges to implementation

- Forecasted price of feedstock and jet fuel
- Fixed and variable operating expenses
- Estimate NPV over 20 year span

- Sensitivity Analysis
- What to watch for

# Option 1

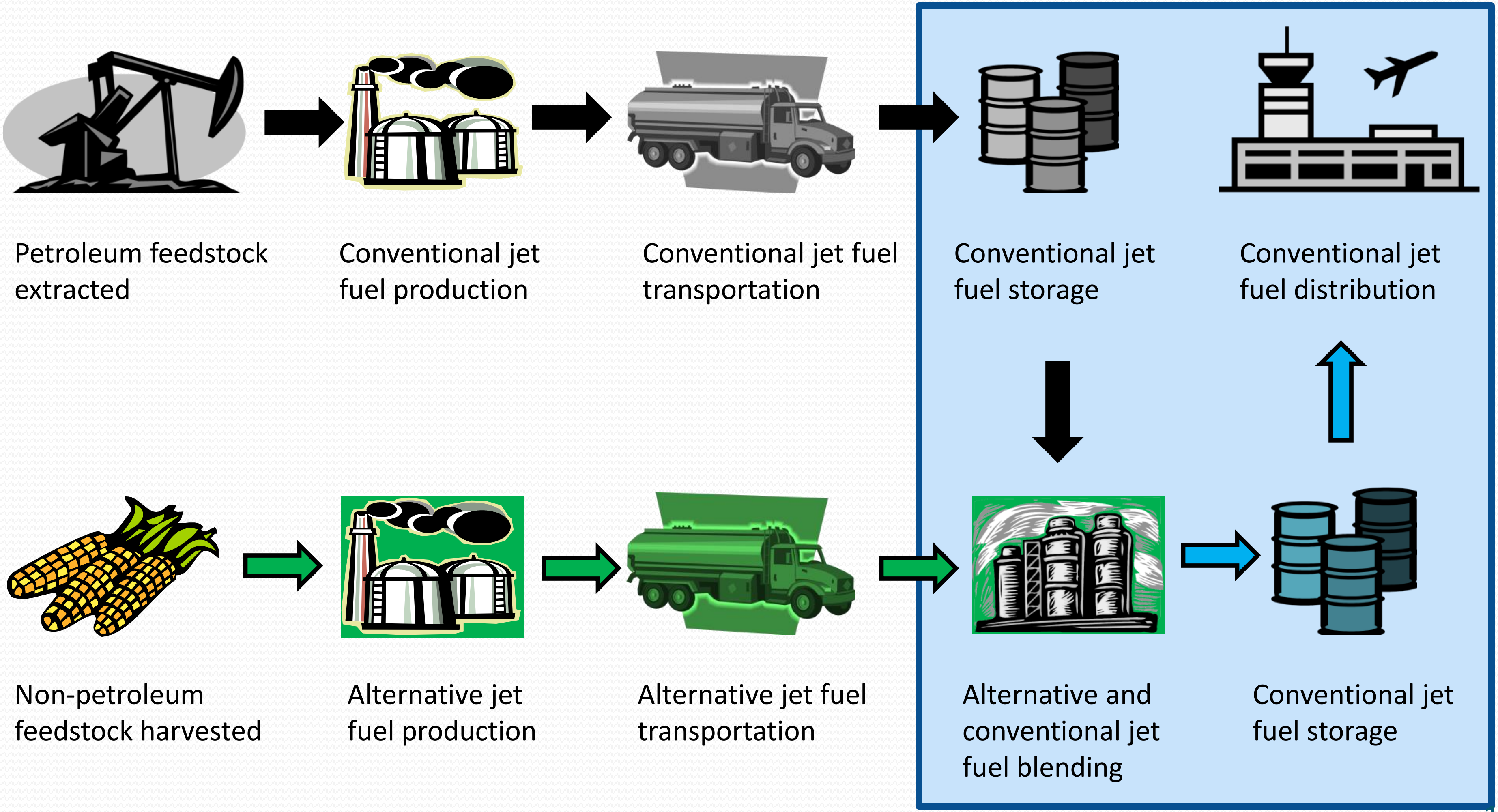
## Drop-In Biofuel Delivery



# Option 2

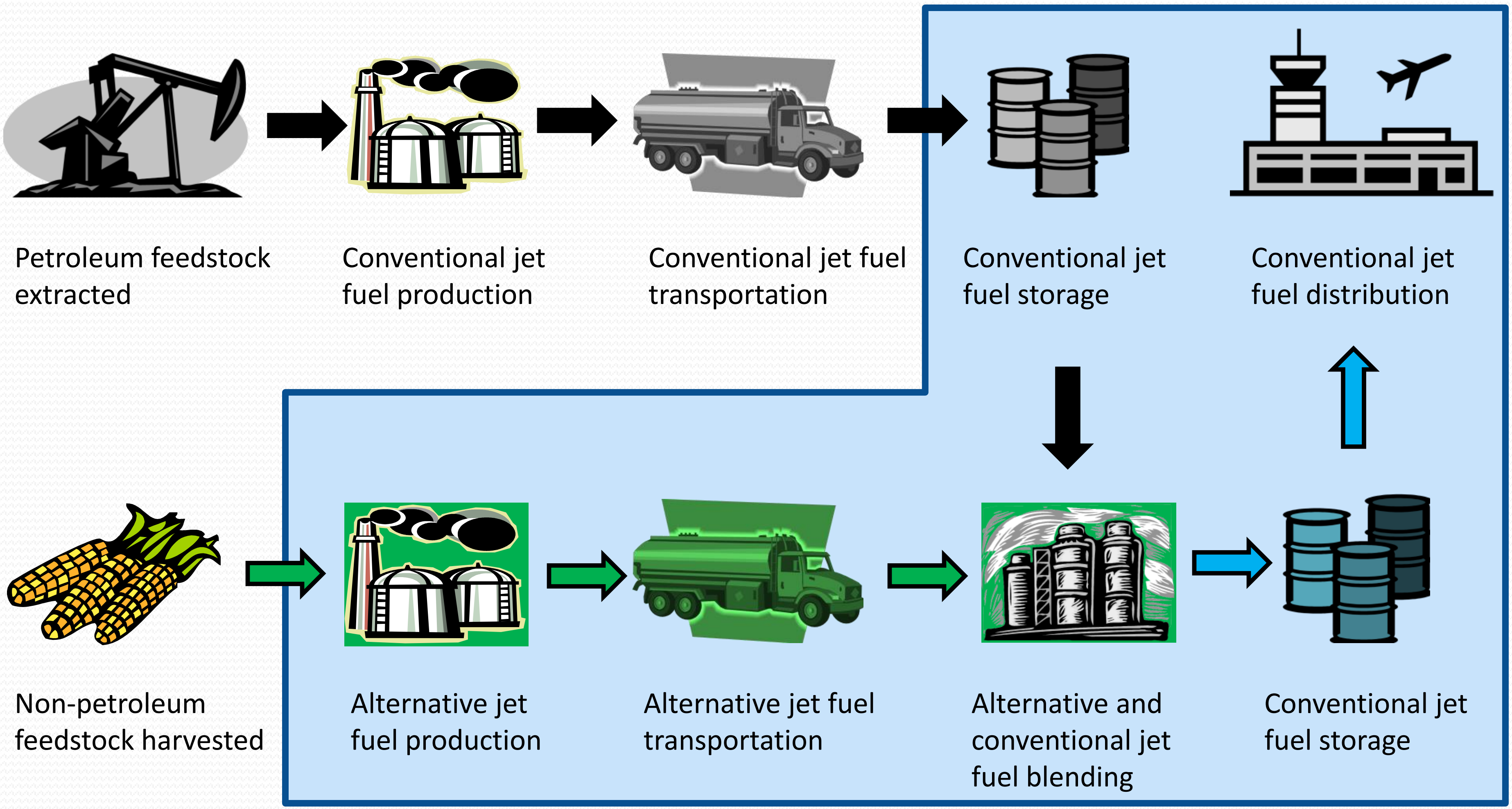
## On-site Biofuel Blending

Biofuel Blended at Airport
Drop-in Fuel Stored/Distributed at Airport



# Option 3
## On-site Biofuel Processing

Bio Feedstock Refined at Airport
Biofuel Blended at Airport
Drop-in Fuel Stored/Distributed at Airport



# Price Forecasting

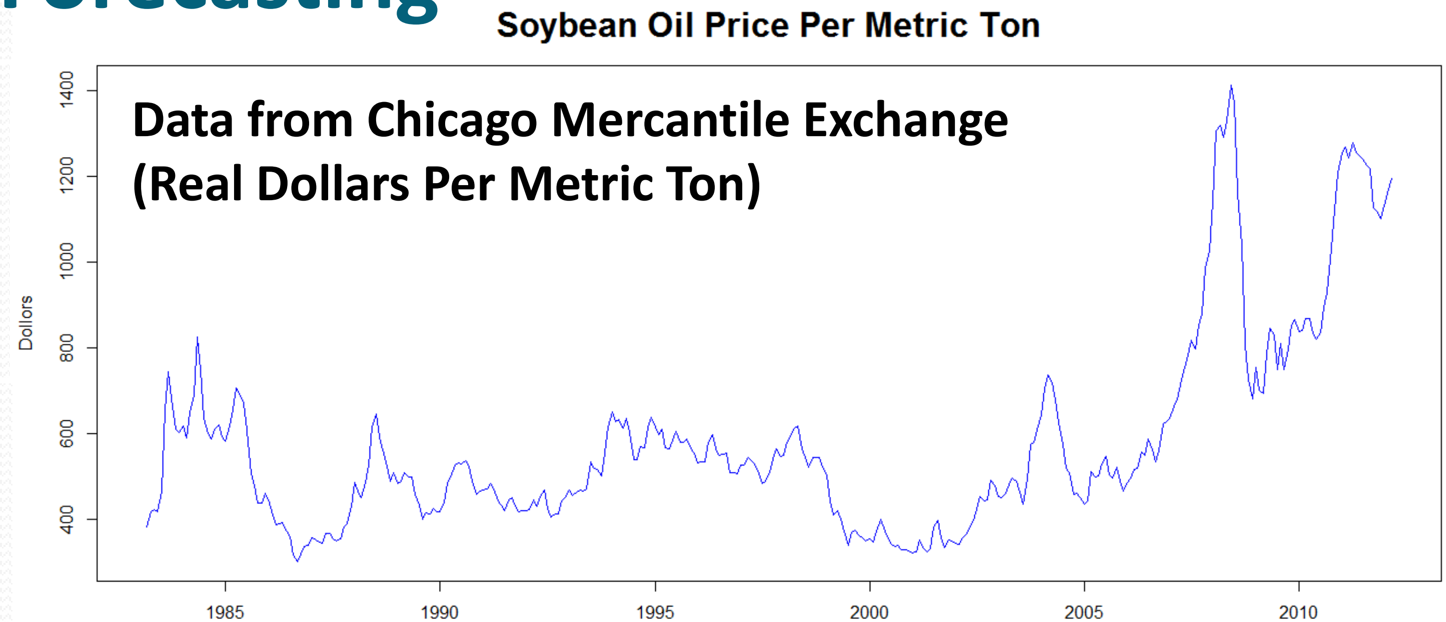
**Soybean Oil**

Training Data Range

3/83 - 3/12

Test Data Range

4/12 - 3/13



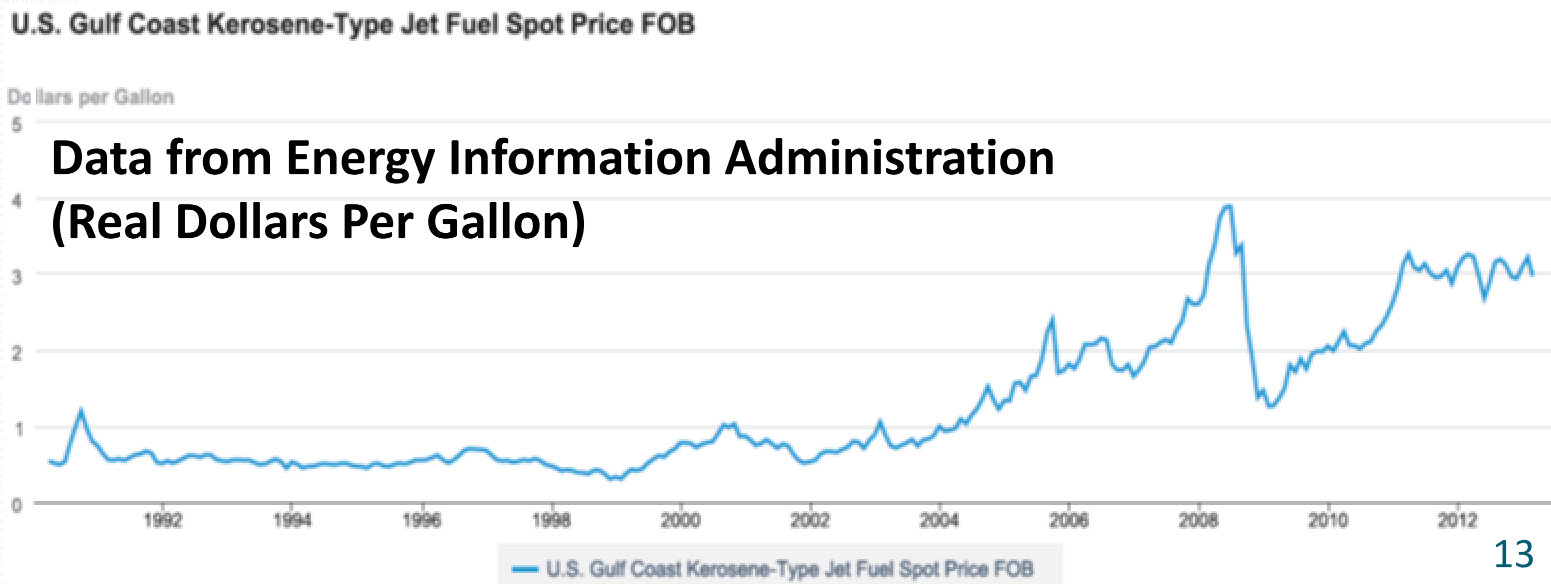

**Kerosene**

Training Data Range

12/03 - 12/11

Test Data Range

1/12 - 2/13



# Price Forecasting

- **Soybean Oil Prices (Simple Model)**
- **Forecasting Model:** Seasonal Integrated Moving Average (IMA).
- **Final Model:** IMA(1,1)
- $$Y_t = Y_{t-1} + \underset{(.0042)}{.0035} - \underset{(.0455)}{.3517}\widehat{\omega_{t-1}} + \widehat{\omega_t}$$

- AIC:-2.13 AICc: -2.1 BIC: -3.05

**Mean Absolute Deviation Percentage Error:** 8.42 %

**Mean Errors:** -89.28

# Price Forecasting

**Soybean Oil Prices**
**Forecasting Model:** Seasonal Integrated Autoregressive Moving Average (SARIMA).
**Final Model:** ARIMA(0,1,1)x(0,1,1)$_{12}$

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

(.0457) (.0476)

AIC: -4.69 BIC: -5.67 AICc: -4.69
**Mean Absolute Deviation Percentage Error:** 6.25%
**Mean Errors:** -59.21

# Price Forecasting

- **Kerosene Prices**
- **Final Model:** ARIMA(1,1,0)x(0,1,5)$_{12}$
- $(1-0.19)(1-B)^d(1-B^s)^D Y_t = (1-1.19B^{12} - .093B^{24} + .25B^{36} + .026B^{48} + 6B^{60})\widehat{\omega_t}$

  (.102) (.45) (0.19) (.24) (.17) (.15)
- **AIC: -2.31 BIC: -3.16 AICc: -2.28**
- **Mean Error:** -.08
- **Mean Absolute Deviation Percentage Error** 8.6%

# The "Theoretical Alternative Jet Fuel Supplier"

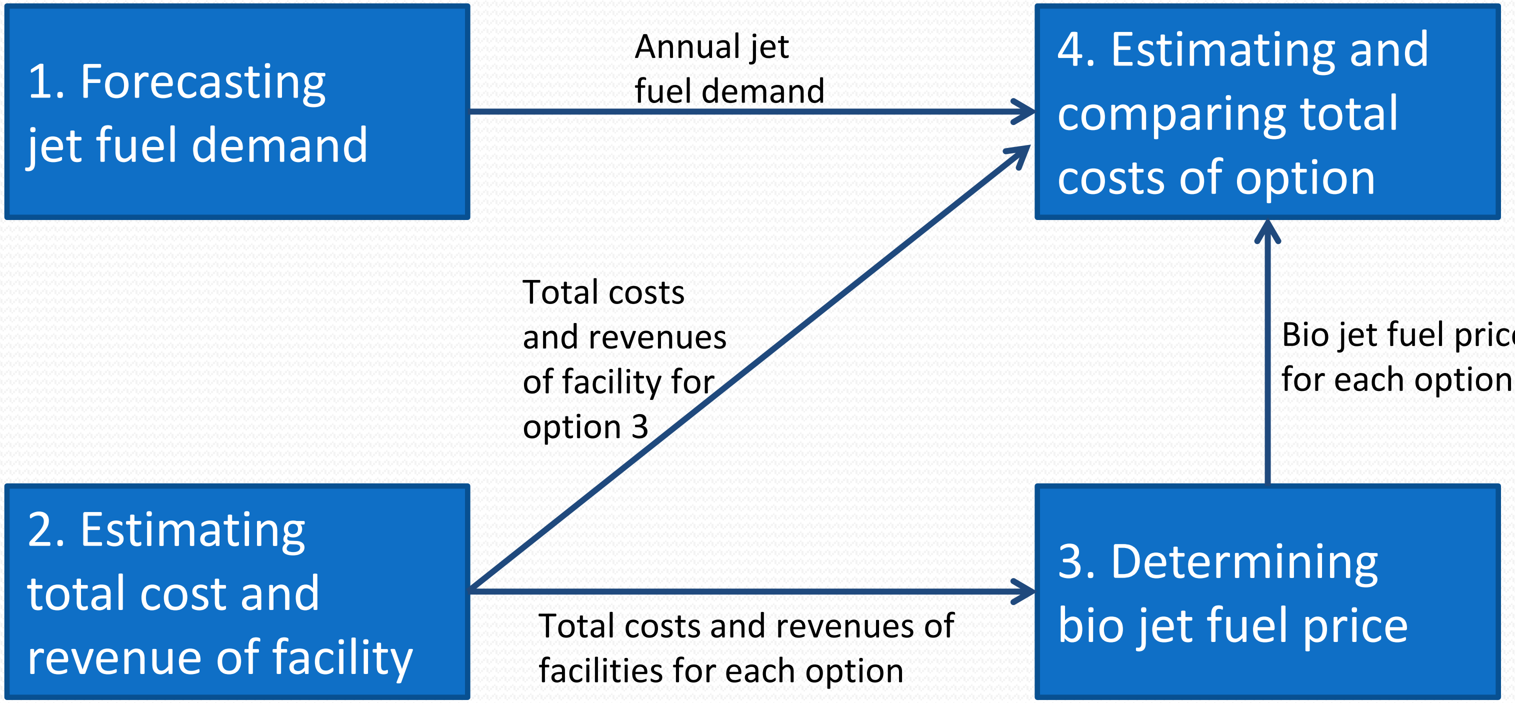
- Commercially available bio-based alternative jet fuel does not exist, but will in the near future
  - First biojet powered test flight – December 2008
  - First biojet powered commercial flight – November 2011
  - Many companies want to produce on a commercial scale
- To evaluate options 1 and 2, we predict at what price a supplier could sell its alternative jet fuel today
  - Cost of constructing production facility
  - Fixed and variable operating expenses
  - Cost of feedstock
- This is the same approach used for evaluating option 3, but on a larger (commercial) scale

# Cost Modeling

✓ Historical Data
- # of aircraft operations
- Avg. fuel consumption

✓ Forecasting Data
- Annual Growth in Aviation

✓ Total Discounted Costs

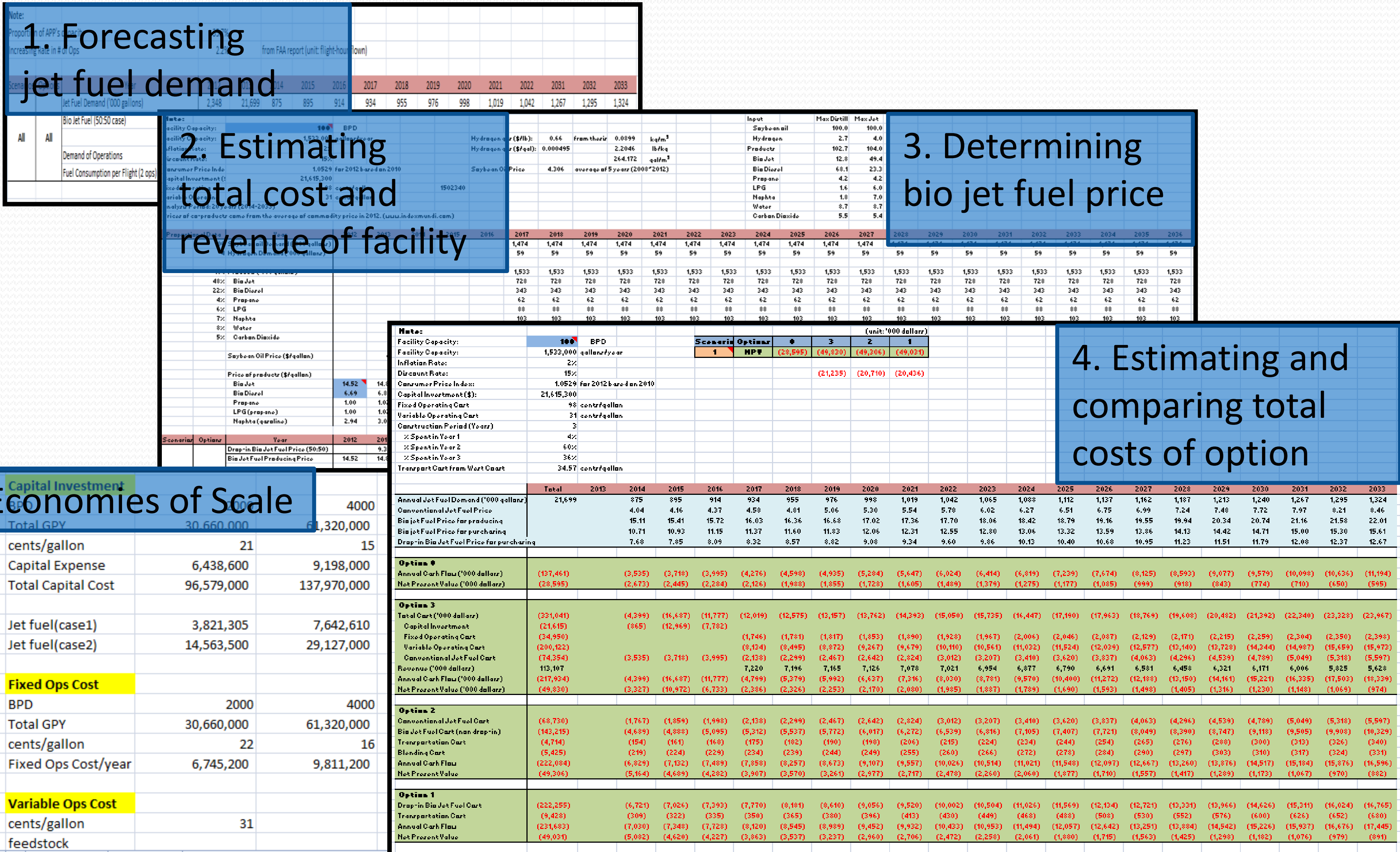



✓ Cost for facility
- Capital & Operating Cost
- Economies of Scale

✓ Revenue for facility
- Product Profile
- Prices of Co-products

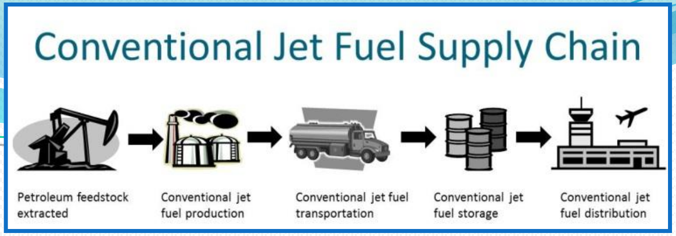
✓ By setting NPV to zero

# Cost Model




## Economies of Scale

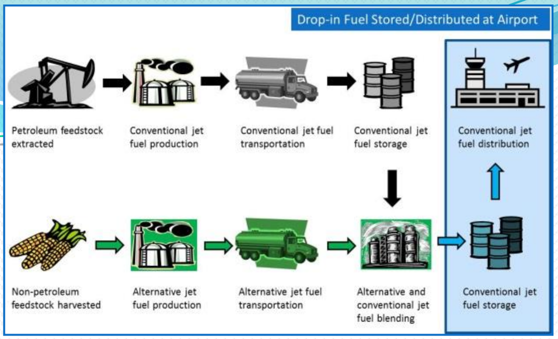
| | | | |
|---|---|---|---|
| | Capital Investment | | |
| | BPD | 2000 | 4000 |
| | Total GPY | 30,660,000 | 61,320,000 |
| | cents/gallon | 21 | 15 |
| | Capital Expense | 6,438,600 | 9,198,000 |
| | Total Capital Cost | 96,579,000 | 137,970,000 |
| | | | |
| GPY | Jet fuel(case1) | 3,821,305 | 7,642,610 |
| GPY | Jet fuel(case2) | 14,563,500 | 29,127,000 |
| | | | |
| | **Fixed Ops Cost** | | |
| | BPD | 2000 | 4000 |
| | Total GPY | 30,660,000 | 61,320,000 |
| | cents/gallon | 22 | 16 |
| | Fixed Ops Cost/year | 6,745,200 | 9,811,200 |
| | | | |
| | **Variable Ops Cost** | | |
| | cents/gallon | 31 | |
| | feedstock | | |




# Base Case – "Do nothing Option"

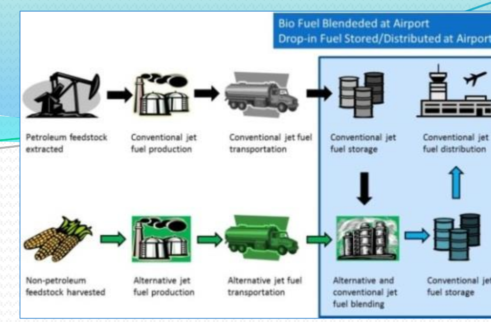
- Fuel deliveries are made by truck in 8,000 gallon intervals
- Eastern Aviation can make deliveries the same day they are scheduled and the delivery cost is minimal
- APP Jet Center can order fuel on an "as-needed" timeframe, which is generally three times per week
  - "Cash in the tank or cash in the bank"
- APP Jet Center's jet fuel cost per gallon includes:
  - Eastern Aviation's price for jet fuel
  - Fixed freight rate cost
  - Federal Excise Tax
  - An extended term and dealer link fee
  - Virginal Motor Fuel Tax

# Option 1 – Drop-In Delivery



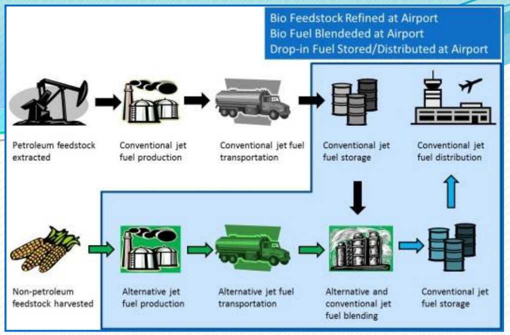

- No commercial suppliers of bio-based alternative jet fuel
- Use “theoretical supplier” approach to estimate price of alternative jet fuel
- Find real suppliers that may come online soon and estimate transportation cost and logistics
  - No potential suppliers on East coast
  - Byogy Renewables, Inc, estimates it will come online in 2014
    - Located in San Jose, CA (3,000 miles from Manassas, VA)
  - Manassas Regional Airport is 0.9 miles from VRE train station
    - At only 3.5¢ per ton-mile, shipping by freight is not cost prohibitive
      - Cost from a Virginia supplier would be similar
    - Shipping fuel cross-country by rail may take as much as 7-10 days
    - Theoretically feasible, but requires attention to inventory

# Option 2 – On Site Blending





- "Splash Blending" is the cheapest method for blending alternative jet fuel with conventional jet fuel
- APP has two 20,000 gallon JET-A Fuel tanks.
  - One would be used for distribution while the other is used for blending
- Blended batch must be tested for ASTM D7655 compliance
  - Test costs about $4,000
  - Can take more than a week for results
- APP Jet Center only has 4-6 days of capacity in one tank



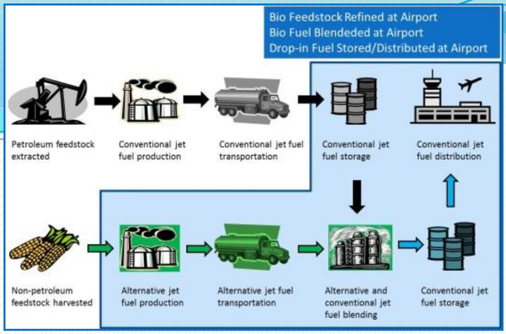

# Option 3 – On Site Production

**Economies of Scale Calculation:**
(*From Gary and Handwerk 2001)

$$\frac{\text{Plant A cost}}{\text{Plant B cost}} = \left(\frac{\text{Plant A capacity}}{\text{Plant B capacity}}\right)^{0.5}$$

| | Option 3 | Options 1 and 2 |
|---|---|---|
| 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 |

(*From Pearlson 2011)

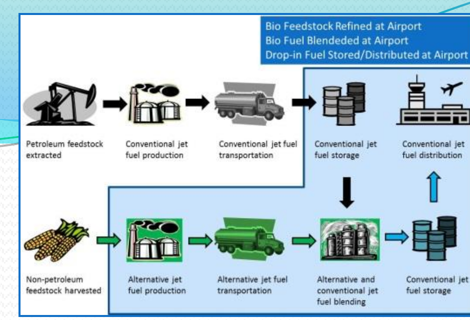



# Product Profile of Biofuel Facility

| 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 |

(*From Pearlson 2011)

# Option 3 – On Site Production

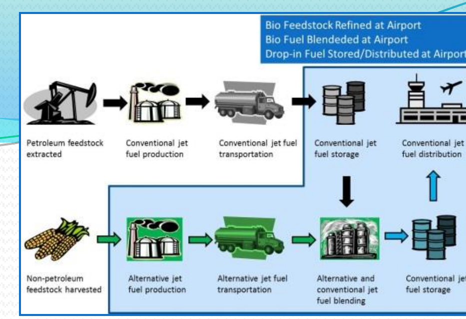




- Fuel Farm located away from active runway and taxiway operations
- Logistically, it makes sense to build a production facility near fuel farm to limit additional infrastructure required to transport the biofuel from the facility to fuel farm
- Unused land near the KHEF fuel farm is also some of the only unused land on the airport
- Already zoned for industrial use
- Processing facilities require 1 – 5 acres of land
- Based on forecasted jet fuel demand at Manassas Regional Airport, a 100 BPD facility (small – 1 acre) would satisfy demand

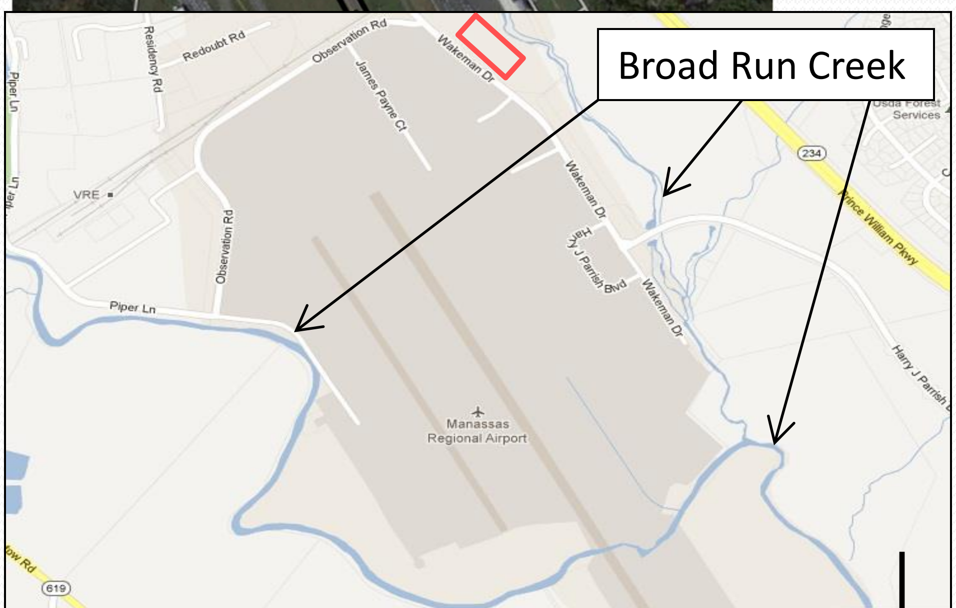
# On Site Production

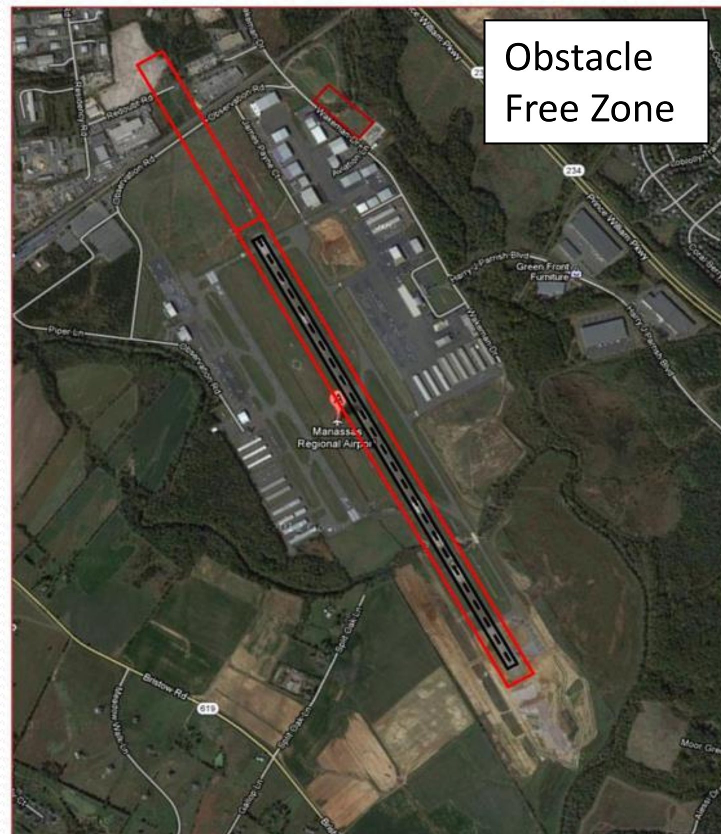
## Proposed location:




**Safety Risk** – Outside RPZ and OFZ

**Environmental Risk** – Broad Run Creek runs through airport property and flows into Occoquan Reservoir, drinking water supply for +1 million


**Occoquan Reservoir**

# Results

Preferred Option – Do Nothing

| 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** | Yes | Yes | $ 0 | $ 3.89 |
| **Option 1** | No | Yes | $ (20,436) | $ 7.49 |
| **Option 2** | No | Yes | $ (20,710) | $ 7.20 |
| **Option 3** | Yes | Yes | $ (21,235) | $ 9.35 |

# Sensitivity Analysis – Price Increases

- Conventional Jet fuel increases and soybean oil stays constant
  - Jet fuel increased 160 % over 15 month span from January 2007 to April 2008

| % Increase | Price per gal Increase | Do Nothing ('000 dollars) | 1 - Drop In Delivery ('000 dollars) | 2 – On Site Blending ('000 dollars) | 3- On Site Production ('000 dollars) |
|---|---|---|---|---|---|
| 30% | $ 1.06 | 0 | (17,075) | (16,757) | (18,292) |
| 50% | $ 1.77 | 0 | (14,835) | (14,121) | (16,330) |
| 100% | $ 3.53 | 0 | (9,234) | (7,532) | (11,425) |
| 160% | $ 5.65 | 0 | (2,514) | **375** | (5,539) |

Net Present Value Over 20 Years

# Sensitivity Analysis – Price Decreases

- Soybean oil decreases and jet fuel stays constant
  - Current prices would need to revert to 2001 levels

| % Decrease | Price per gal Decrease | Do Nothing ('000 dollars) | 1 - Drop In Delivery ('000 dollars) | 2 – On Site Blending ('000 dollars) | 3- On Site Production ('000 dollars) |
|---|---|---|---|---|---|
| 10% | $ 0.43 | 0 | (16,441) | (16,715) | (18,831) |
| 30% | $ 1.29 | 0 | (9,646) | (9,920) | (14,024) |
| 50% | $ 2.15 | 0 | (4,217) | (4,491) | (9,216) |
| 70% | $ 3.00 | 0 | **1,212** | **938** | (4,409) |

Net Present Value Over 20 Years

# Sensitivity Analysis – Price Divergence

- Simultaneous conventional Jet fuel increases and soybean oil decrease
  - Jet Fuel returns to 2008 peak and soybean oil falls to 2007 levels

| Jet Fuel Increase | Soybean Oil Decrease | Do Nothing ('000 dollars) | 1 - Drop In Delivery ('000 dollars) | 2 – On Site Blending ('000 dollars) | 3- On Site Production ('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 |

# What to watch for – Algae

- Grows 20-30 times faster than food crops
- Produces 300 times more oil per unit area than soybeans
- Does not compete with food supply
- Lower Greenhouse-Gas Emissions (No land use change)
- In 2010, DARPA announced it was extracting pond algae at $2/gal and could refine oil at total cost of $3/gal
- **However…**
- Technological limitations suggest biofuel commercially produced from algae is "probably further" than 25 years away from being a reality - March 2013, Exxon Mobil Corporation Chairman and CEO, Rex Tillerson
  - Despite Exxon Mobil's $600 million investment in algae research

# What to watch for – Incentives

- Biofuel Grants
  - Biomass R&D Initiative (USDA) - $3-7  million
  - Advanced Energy Research Project Grant (DOE) - $1-10 million
  - Biofuels Production Grant (Virginia) - $0.125 /gal
- Biofuel Tax Incentives
  - Biodiesel Mixture Excise Tax Credit - $1.00 /gal
  - Alternative Fuel Excise Tax Credit - $0.50 /ga/
  - Small Agri-Biodiesel Producer Tax Credit - $0.10 /gal
- EPA Renewable Fuel Standard – Biofuel production targets
  - Market exchange for biofuel credits
  - 2012 biodiesel credit averaged $1.45 /gal

# What to watch for - Summary

| What to watch for | 1 - Drop In Delivery ('000 dollars) | 2 – On Site Blending ('000 dollars) | 3- On Site Production ('000 dollars) |
|---|---|---|---|
| **NPV based on analysis** | **$ (20,440)** | **$ (20,710)** | **$ (21,240)** |
| Non-edible feedstock with less volatile price, rising only with inflation | +$ 8,710 | +$ 8,710 | +$ 5,070 |
| Potential tax incentives (1: $0.50 /gal; 2: $1.00 /gal; 3: $1.25 /gal) | +$ 2,690 | +$ 5,390 | +$ 6,730 |
| VA biofuel supplier instead of CA (3,000 miles to 300 miles at $0.035 /ton-mi) | +$ 1,930 | +$ 970 | -- |
| Cheaper ASTM Testing ($1,000 per test instead of $4,000) | -- | +$ 1,010 | +$ 400 |
| Research Grant funding potential | -- | -- | +$ 11,360 |
| EPA Renewable biofuel credit potential | -- | -- | +$ 5,370 |
| **Revised NPV** | **$ (7,110)** | **$ (4,630)** | **$7,690** |

# Questions?

**Project Testimonial**

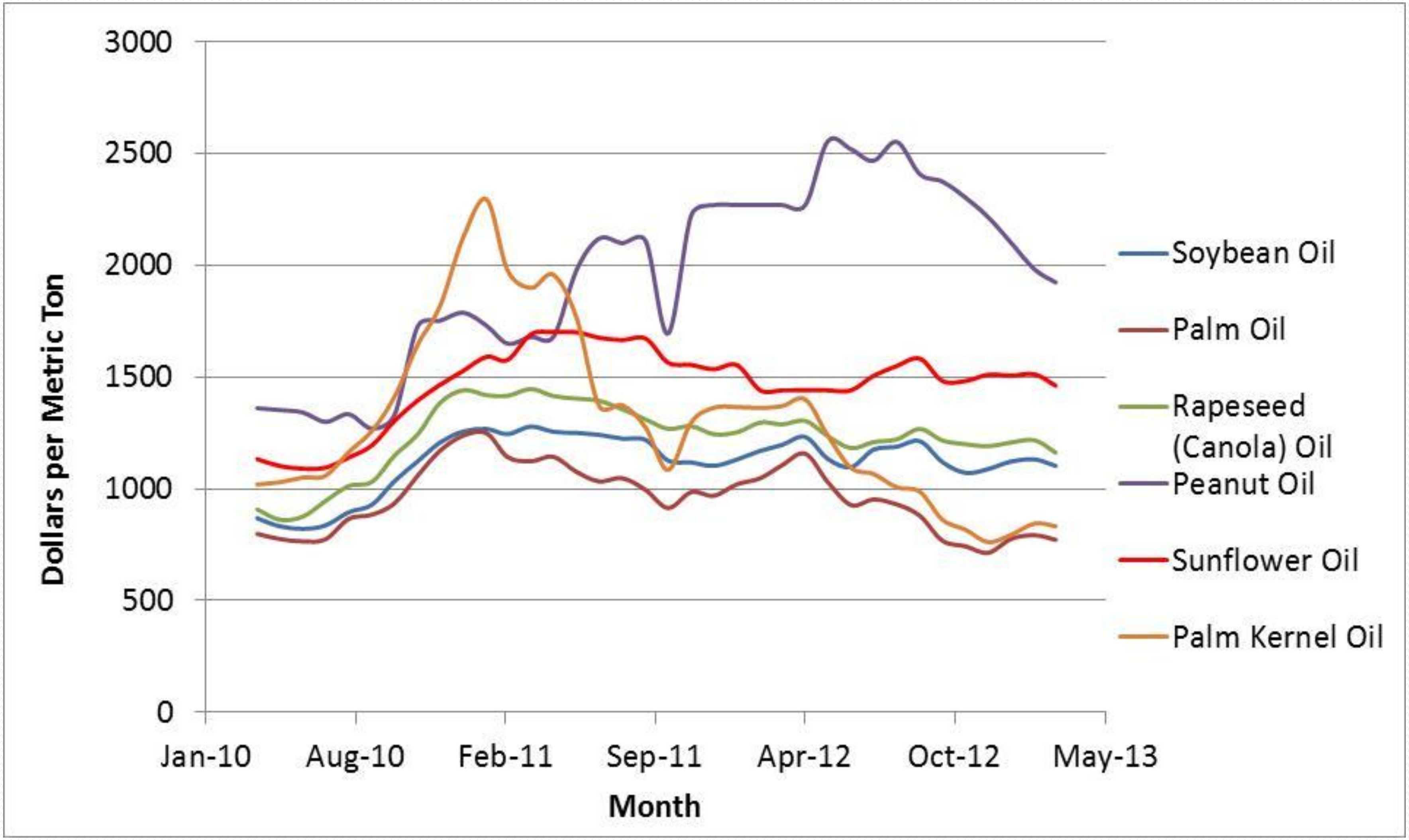
*"Metron Aviation is very pleased with the design, analysis and modeling performed by the team. This has extended analysis undertaken for ACRP and provides very useful insights regarding technical, business, and regulatory aspects of alternative aviation fuels in the context of a specific Virginia airport. Such local determinants of the overall business case are of key importance in understanding how such fuels may become a substantial part of the aviation fuel mix."*

- Metron Aviation, May 2013

# Back-Up Slides

# Problem Scope

- Renewable Feedstock – Soybean Oil



# Conventional Jet Fuel Supply Chain

Petroleum feedstock extracted

Conventional jet fuel production

Conventional jet fuel transportation

Conventional jet fuel storage

Conventional jet fuel distribution

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# Equations

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

**Option 1**

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

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

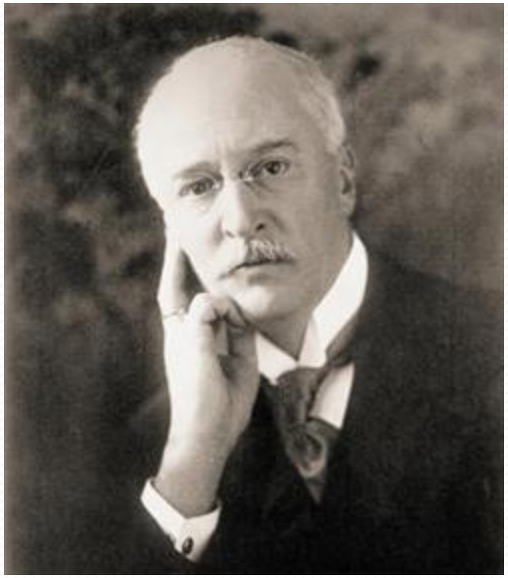
**Option 2**

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

# Drop-in Alternative jet fuel

**Drop-in Fuel**

- Alternative must be capable of replacing regular jet fuel without requiring new infrastructure.
  - Storage tanks and pipelines in the fuel supply chain
  - Fuel system that powers the engines on an aircraft.
- An alternative jet fuel capable of achieving this type of interoperability is known as a “drop-in” 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 ATSM Specification D1655.
  - ASTM Specification D7566, for bio-based alternative jet fuel includes all D1655 requirements and more
- Why drop-in fuel?
  - Changes to existing aircraft fleets or fuel distribution networks would make alternative jet fuel practically infeasible



Rudolf Diesel - Inventor of the Diesel engine

“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."

- Rudolf Diesel, 1912