Analysis of the HEFA Conversion Facility using Pennycress Feedstock to Supply 30 to 40 Percent of Nashville Airport's (BNA) fuel requirements with Sustainable Aviation Fuel
ASCENT 1

Lead investigator: Tim Rials and Burton C. English
Presentation Authorship: Carlos Trejo-Pech, James Larson, Edward Yu, and Burton C. English
Project manager: Nate Brown, FAA

April 18-19, 2019
Alexandria, VA

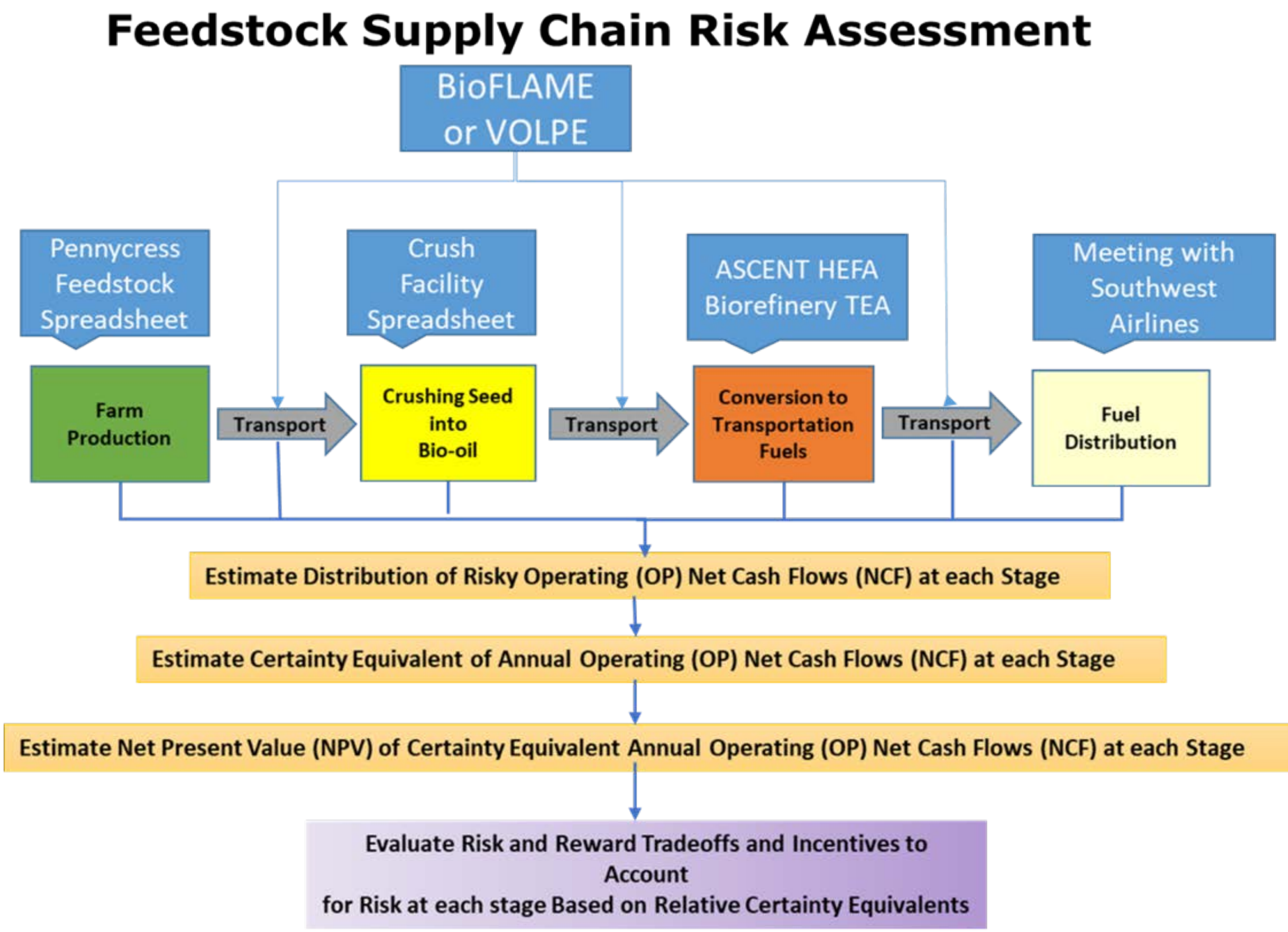
This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project {add project number here} through FAA Award Number {add grant number} under the supervision of {add PM names here}. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT
AVIATION SUSTAINABILITY CENTER

Introduction

- Motivations – Focus on Middle Tennessee and the Nashville Airport
- Objectives – Develop a pathway for Sustainable Aviation Fuel (SAF) at BNA, Nashville
- Outcomes and practical applications -- Develop tools and findings that indicate the potential of SAF in the southeastern United States
- Approach – Use tools developed by ASCENT 1 and spatial analysis to determine breakeven points in the entire supply chain.
- ASCENT assumptions included in the analysis
  - Close adoption of financial assumptions
  - Crush Facility was designed at UT from Southeast originated literature and the facility used in this analysis differs from the facility developed at WSU. A close comparison of the two crush facilities is underway.

Schedule and Status



Recent Accomplishments and Contributions

Crushing Facility Results

- Pennycress oil revenues and pennycress meal revenues represented 66% and 34% of total revenues respectively (i.e., simple average over the ten year forecast).
- Operating margin, defined as operating income divided by revenues, equals 11.5% over the forecast period. With the exception of the first year of productive life, operating margins for the crushing facility are relatively stable around 11% and 12%.
- The return on investment (ROI) is also relatively stable and has a simple average of 11.1% over the forecast period.

Recent Accomplishments and Contributions

Crushing Facility Results

- Unlike all other inputs in the model, no assumption for pennycress feedstock cost is made. Instead, a maximum price that a potential crushing facility can pay for feedstock at the facility gate is calculated.
- The maximum pennycress oilseed buying price is **10.5 cents pound^{-1}** during the first year of production. This feedstock cost represents 63.6% of the forecast weighted average selling price of pennycress oil and pennycress meal the first year of production. This feedstock cost to weighted average selling price ratio is kept constant through the life of the project so that annual feedstock costs are assumed to vary in tandem with forecast selling prices and inflation rates.
- Thus, buying pennycress seed at 10.5 cents pound^{-1} during the first year of production and buying it at prices equivalent to 63.6% of the weighted average selling price from years two to ten yields an NPV equal to zero for the crushing facility. In other words, this is the willingness-to-pay feedstock price in order debtholders and shareholders in the crushing facility to obtain their expected rate of return (10% on average).

Recent Accomplishments and Contributions

Crushing Facility Results

Data and assumptions for the breakeven and one-way sensitivity analysis of maximum pennycress purchase prices for the crushing facility to obtain NPV=0.

Item	Base	Lower bound	Upper bound
Seed to oil conversion rate (% in tons equivalent)	0.329	0.315	0.340
Pennycress oil price (% deviation relative to baseline)	0.0%	-5.0%	5.0%
Pennycress meal price (% deviation relative to baseline)	0.0%	-5.0%	5.0%
Income tax rate (%)	40.0%	40.0%	16.9%
Days inventory	60	90	30
WACC	10.0%	15.0%	7.5%

Recent Accomplishments and Contributions

Crushing Facility Results

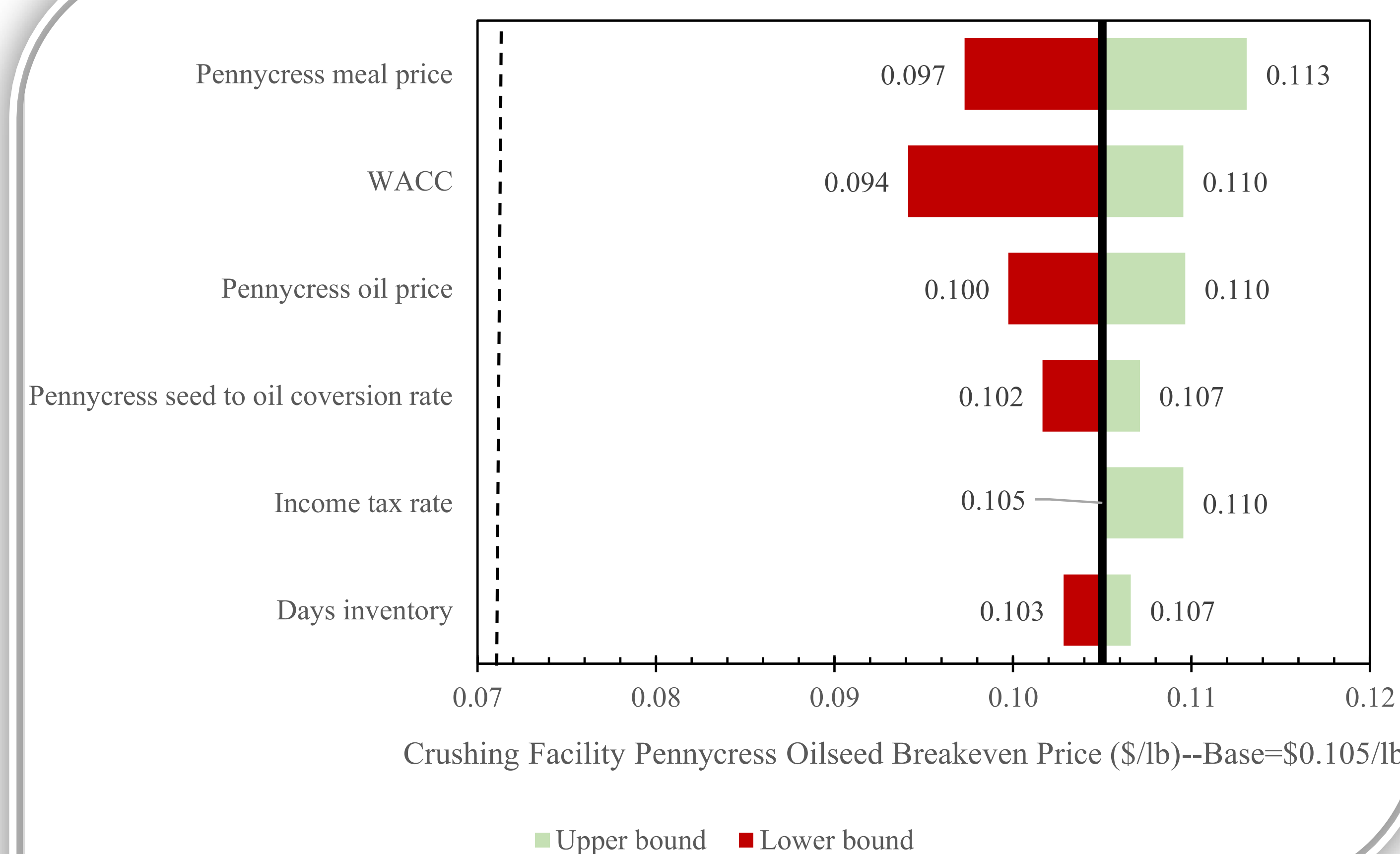


Figure illustrates this estimated maximum (breakeven) buying price and the one-way sensitivity analysis showing lower and upper bound maximum buying prices the first year of production according to assumptions in the preceding table

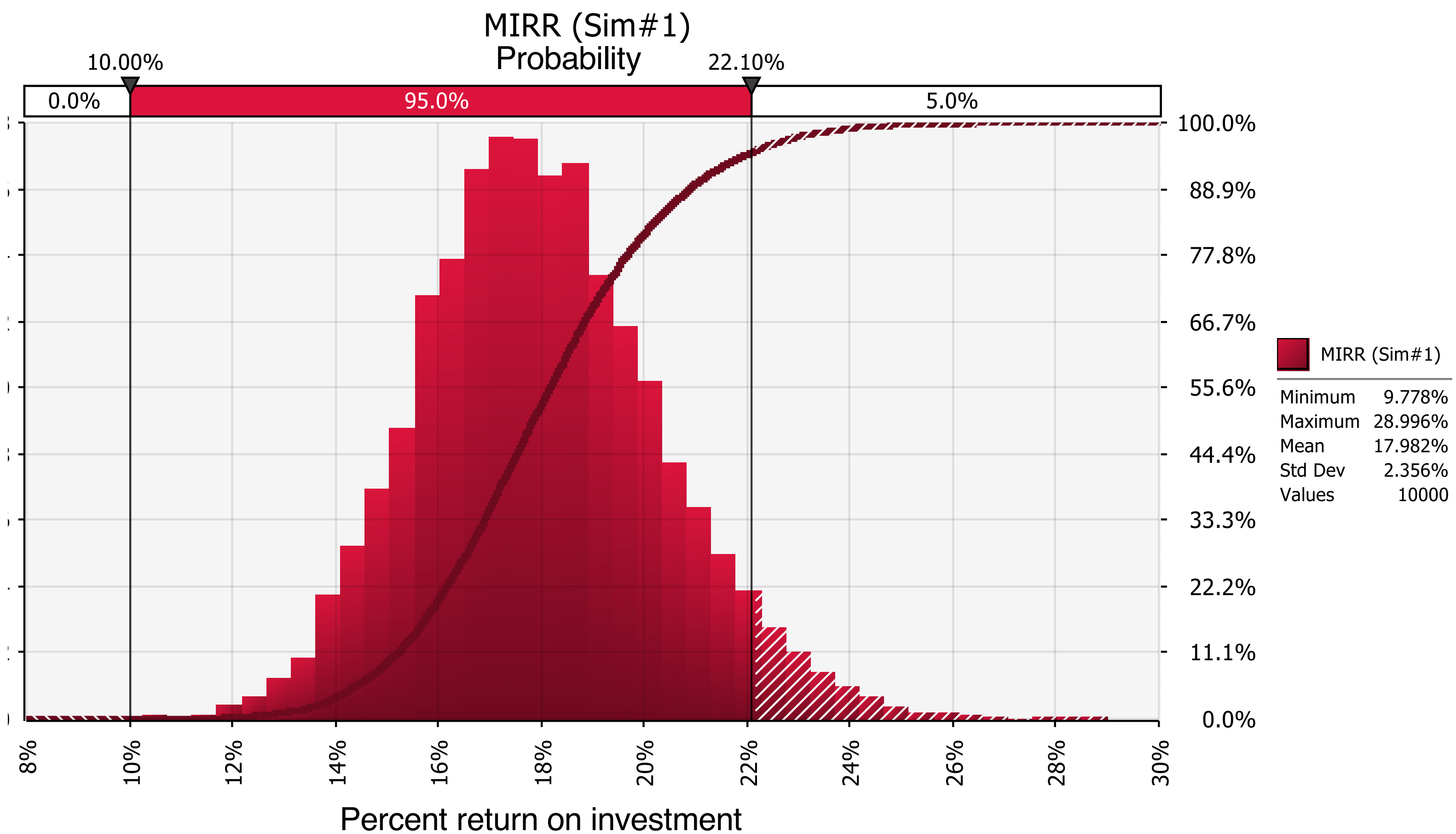
Recent Accomplishments and Contributions

Crushing Facility Results

- The baseline model shows that the maximum pennycress seed buying price for the crushing facility to be a positive NPV project @ 10% cost of capital is around 10.5 cents $pound^{-1}$.
- 10,000 iterations were then performed on three simulations examining seed purchase prices of 8, 9, 10, and 11 cents/pound using @Risk

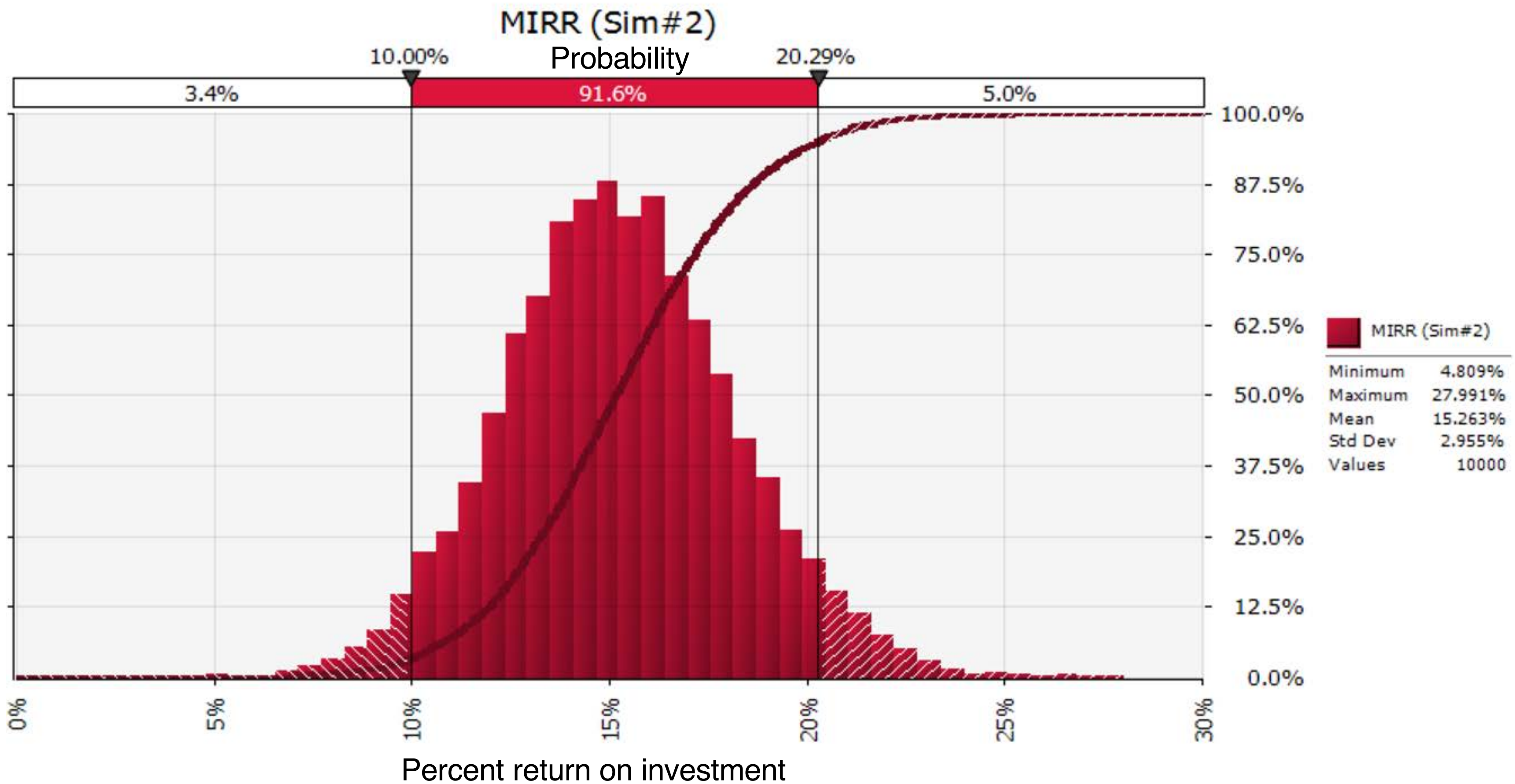
Recent Accomplishments and Contributions

Crushing Facility Results: Pennycress price = $0.08/pound



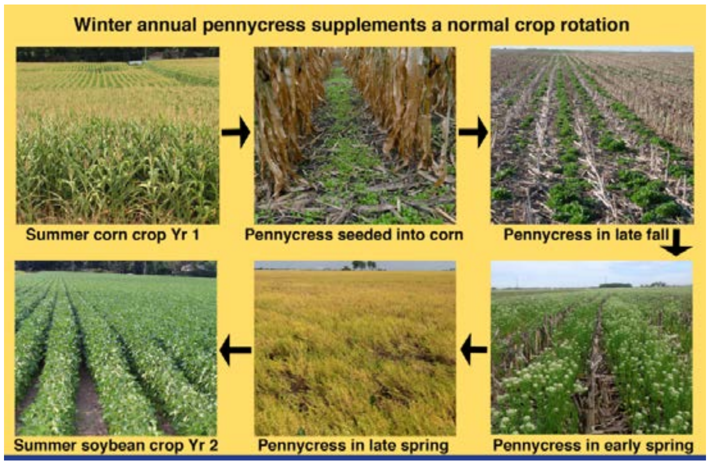
Recent Accomplishments and Contributions

Crushing Facility Results: Pennycress price = $0.10/pound



Recent Accomplishments and Contributions

Pennycress is a Winter Cover Crop that can be used in a Corn-Soybean Rotation



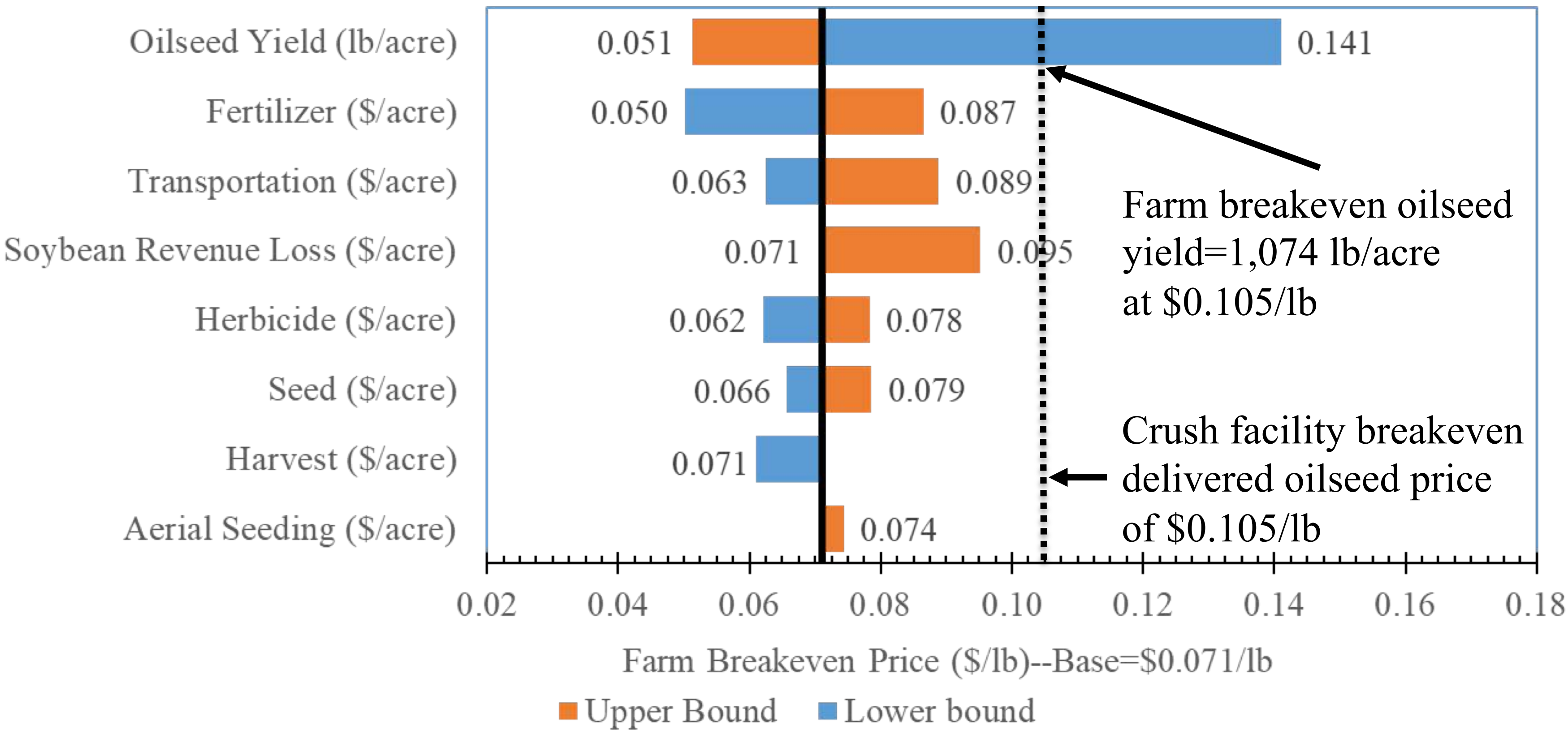
Source: https://public.ornl.gov/site/gallery/highressurvey.cfm

Pennycress Cost of Production Scenarios

Item	Base	Lower bound	Upper Bound
Seed ($/acre)[a]	12.50	5.00	25.00
Aerial seeding ($/acre)[b]	10.00	10.00	16.00
Fertilizer ($/acre)[c]	31.50	0.00	56.50
Herbicide ($/acre)[d]	0.00	-12.97	12.97
Harvest ($/acre)[e]	40.17	25.00	40.17
Transportation ($/acre)[f]	13.43	3.61	39.23
Oilseed yield (lb/acre)[g]	1,600.	800.	2,200.
Soybean revenue loss ($/acre)[h]	0.00	0.00	39.56

Recent Accomplishments and Contributions

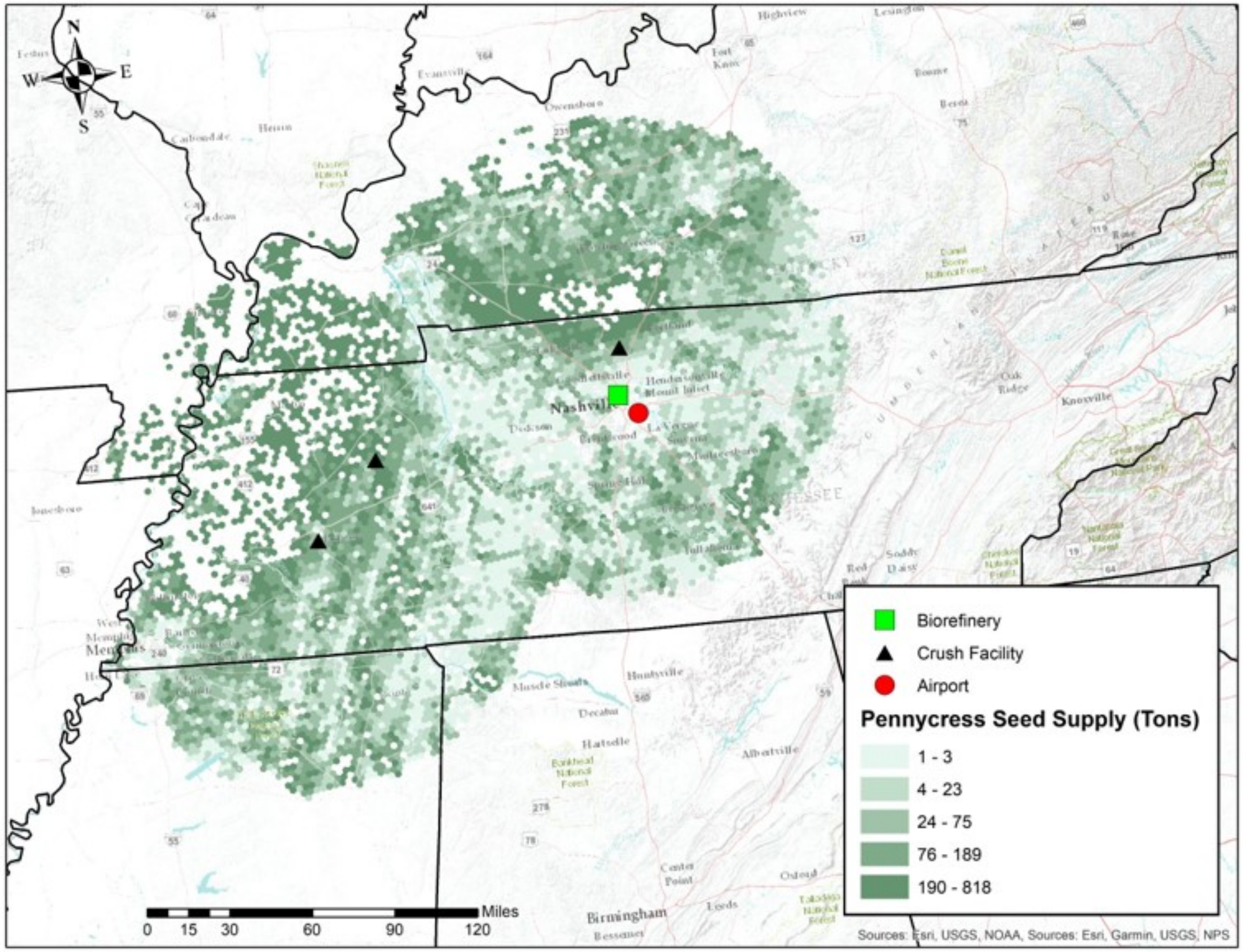
One-Way Sensitivity of Farm-Level Breakeven-Oilseed Prices



Recent Accomplishments and Contributions

Biorefinery

- Pennycress available area estimated by using the minimum of the corn or soybean acres
- Yield is assumed to be 1600 pounds per acre.
- Each crushing facility required 263,000 tons of pennycress seed supplying 86,600 tons of bio-oil per year.
- Two step optimization process. First step located 7 potential locations of crushing facilities and the second step assuming these sources of supply existed where would the biorefinery be located.



- Biorefinery requires 263,000 tons of bio-oil to produce 36.9 million gallons of jet fuel plus diesel (17.2 Mgal), naphtha 6.5 Mgal), and LPG (7.5 Mgal).
- Have not examined co-product transportation yet.

Recent Accomplishments and Contributions

Biorefinery

Transportation

- 3 crush facilities with maximum transportation of 128 miles from field to crush facility were needed
- To transport oil from crush facilities to biorefinery required transportation distance in a range of 22 to 133 miles
- From the biorefinery to the airport -- 15 miles

Average per ton cost

- From field to Crush facility -- $17/ton
- From Crush to biorefinery to airport -- $31/ton

Summary

- Farm fields
  - Breakeven cost with no profit assumed is \$0.071/pound.
  - Assumes 1600 pounds of pennycress seed per acre.

- Crush facility
  - Allowing for a 10% return, the crushing facility can purchase seed at \$0.105/pound providing the meal produced can be used in livestock operations and both the oil and meal receive prices similar to soybeans.
  - A 5% decrease in meal price received by the crush facility results in a decrease in this breakeven to \$0.09/pound. If oil price decreases by 5% the price for the purchase of pennycress decreases to \$0.10/pound.

Summary

- Crush facility
  - Prices used to value output from the crush facility
    - Meal – $176.7/ ton – Average of historical prices USDA, Marketing Service
    - Oil -- $0.317/pound – combination of USDA and FAPRI projected prices along with future prices from the Chicago Mercantile Exchange (Change every year) or $0.699/kg.
- ASCENT HEFA Tea
  - Assumes veg. oil purchase price of $1.12/kg

Summary

- Early Conclusion
  - Seed costs farmer $0.071/pound if they get 1600 pounds/acre
  - Crush facility can afford to pay $0.105/pound for seed if they get $0.317/pound or $0.699/kg for the oil and $176.7/ton for the meal.
  - ASCENT HEFA technology assume oil feedstock price is $1.12/kg.
- A top priority is research on agronomic practices and their effects on oilseed yields and feedstock quality in Tennessee and other Southeastern states.

Next Steps

- Present to stakeholders
- Economic Impact Analysis
- Pass the Crush Facility spreadsheet to Penn State along with a revised Pennycress spreadsheet
- We are currently working with Tyner on pennycress in the Midwest linking our feedstock supply chain to conversion facilities in Iowa and Indiana.
- Need to pass potential pennycress feedstock cost and quantities to Kristin's tools if assumptions after review are accepted.

Acknowledgements

- This work was funded in part by the US Federal Aviation Administration (FAA) Office of Environment and Energy as a part of ASCENT Project 1 under FAA Award Number: 13-C-AJFEUTENN-Amd 5. Funding also was provided by USDA through Hatch Project TN000444 and Hatch Multi-State project 1012420. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA or other ASCENT sponsor organizations.

Participants

- The authors would like to acknowledge the work of Evan Markel, PhD, Umama Rahman, and Katryn Pasaribu, PhD. for their work on covercrop spreadsheet analysis; Brad Wilson for the work on BioFLAME and spatial analysis; and Jamey Menard in assisting in this project.

One-Way Sensitivity Assumptions

[a] Seed costs: base seeding rate is 5 pound per acre (Markel et al. 2018); lower bound seeding rate is 2 pound per acre (Phippen et al., 2010) ; upper bound seed rate is 10 pound per acre (AgMRC, 2018; Johnson et al., 2015). A seed price of $2.50 per pound is used to calculate costs (AgMRC 2018).

[b] Aerial seeding costs: base (Markel et al. 2018); upper bound (AgMRC, 2018; Johnson et al., 2013).

[c] Fertilizer rates and costs: Base is 50 pounds of nitrogen (N) per acre at planting (Markel et al. 2018). Lower bound is no fertilizer application at planting (Metro Ag Energy 2019). Upper bound is 50 pounds of N per acre, 20 pounds of phosphorous (P) per acre, and 20 pounds per acre of potassium (K) applied at planting (AgMRC 2018). Fertilizer prices used to calculated costs were $0.63 per pound of N, $0.74 per pound of P, and $0.51 per pound of K. Costs calculated using average fertilizer prices for 2007-2016 (USDA ERS , 2019) expressed in 2017 dollars using the Implicit GDP Price Deflator (Federal Reserve Bank of t Louis, 2019)

[d] Base: burn down herbicide applied after harvesting pennycress and before planting no-tillage soybeans in a corn-soybean rotation. This practice is common in no-tillage cropping and therefore no additional cost is applied to the pennycress enterprise. Lower bound: cost of a burn down herbicide application (boom applicator and materials costs) before planting no-tillage soybeans is eliminated with the addition of pennycress in a no-tillage corn-soybean rotation. Upper bound: burn down herbicide application is made before harvest to prevent seed shattering (Metro Ag Energy 2019). Burn down herbicide materials, labor, and applicator machinery costs are from University of Tennessee Extension no-tillage soybean budget (UT Extension , 2017).

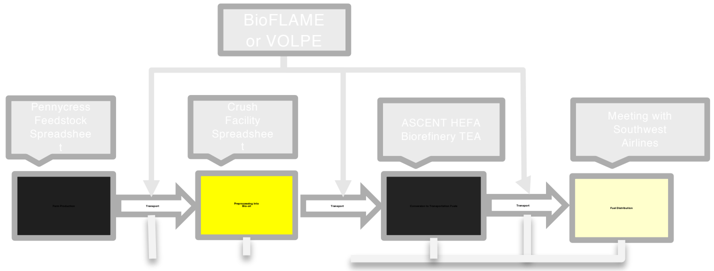
[e] Harvest cost: base is author budgeted for a combine with a 30 foot cutter grain head, tractor, and grain cart based on equipment assumptions of Markel et al. (2018). Lower bound cost is from a budget produced by Metro Ag Energy (2019).

[f] Transportation costs: Base mileage is a 100 mile round trip from farm to the crush facility (Fan et al. 2013). Lower bound mileage is a 50 mile round trip from farm to crush facility. Upper bound mileage is a 200 mile round trip from farm to crush facility. Average semi-truck and trailer speed is 35 miles per hour (Turhollow and Epplin 2012). Author budgeted cost per hour for the semi-truck, trailer, and driver (800 bushels or 40,000 pounds per load) is $146.33 per hour.

[g] Author conducted review of literature of the range of pennycress oilseed yields with minimal fertilizer inputs.

[h] Base and lower bound assumes no soybean revenue loss due to delayed soybean planting because of pennycress harvest. Upper bound assumes a 28-day soybean planting delay from mid-May to Mid-June with an expected yield reduction of 8 percent or 4 bu/acre (Boyer et al. 2015). The yield loss is treated as an opportunity cost to the pennycress enterprise and is valued using a soybean price of $9.89/bu, the average for 2002/03-2016/17 with the high and low values dropped and expressed in 2017 dollars using the Implicit GDP Price Deflator (FABRI, 2018; Federal Bank of St. louis, 2019).

Crushing Facility Assumptions



- Stochastic capital budgeting analysis is implemented to analyze financial performance distributions and scenarios for a facility processing approximately 263k tons per year.
- The cost structure, plant design, and feedstock capacity for the pennycress oilseed crush facility are based on Shumaker et al. (2000) and English, Jensen, and Menard (2002).
- Cash flows are forecasted during 10 years of pennycress oil and pennycress meal production, with production starting after two years of facility establishment.
- After the forecast period, a salvage value is estimated using a perpetuity under the assumption of the constant growth model (Schill, 2017; Brigham and Houston 2017).
- Inputs such as CAPEX, Working Capital, OPEX, and seed–to–oil conversion rates are taken from the literature.
- Pennycress oil price (main product): Similar to Fan et al. (2013), in this study it is assumed that pennycress oil will be sold at soybean oil prices. Nominal price long-term projections by the USDA are used for the ten years forecast period in this study (USDA 2018).
- Pennycress meal price (co-product): As in Fan et al. (2013), prices of distillers' dried grain with solubles (DDGS) are used to proxy pennycress meal prices.
- Prices are simulated using historical series of DDGS and soybean oil monthly prices from 2014 to 2018 –CPI adjusted as of the end of 2018–, and assuming log normal distributions. Simulations include correlations.
- The feedstock to oil conversion rate is assumed to follow a triangular distribution, according to reported pennycress feedstock to oil conversion rate parameters in the literature.