Project 001(E) Alternative Jet Fuel Supply Chain Analysis

University of Tennessee

Project Lead Investigator

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University Participants

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- P.I.: T. Edward Yu, Professor
- FAA Award Number: 13-C-AJFE-UTenn, Amendments 09, 11, 13, 15, 17
- Period of Performance: October 1, 2021 to September 30, 2022
- Tasks:
    1. Assess and inventory regional forest and agricultural biomass feedstock options
    2. Develop national lipid availability analysis as feedstock for SAF
    3. Lay the groundwork for supplying lipid and/or biomass for SAF production in Tennessee and the Southeastern United States
    4. Perform biorefinery infrastructure assessment and siting (supporting role)

Project Funding Level

Total estimated project funding: $1,375,000 (total 6-year funding)/$800,000 (this year)
Total federal and non-federal funds: $1,375,000 (total 6-year funding)/$1,375,000 (this year)
The UT Institute of Agriculture, in support of the project, provided faculty salary. Additional non-federal support was derived from contributions from the stakeholder group.

Investigation Team

- Timothy Rials, Project Director (P.D.)/P.I. (UT) (Task 3)
- T. Edward Yu, co-P.D./P.I. (UT) (Tasks 1,2,4)
- Burton English, Faculty (UT) (Tasks 1-4)
- Kim Jensen, Faculty (UT) (Task 2)
- Jim Larson, Faculty (UT) (Task 2)
- Carlos Trejo-Pech, Faculty (UT) (Task 1)
- David Hughes, Faculty (UT) (Task 3)
- Jada Thompson, Faculty (UT) (Task 1)
- Tongtong Lee, Master's Graduate Student (UT) (Task 2)

Project Overview

UT will lead the feedstock production (Task 1) component of the project. This component targets the need to assess and inventory regional forest and agricultural biomass feedstock options and delineate the sustainability impacts associated with various feedstock choices, including land-use effects. UT will lead the national lipid supply availability analysis, using POLYSYS to develop information on the potential impacts and feasibility of using lipids to supply aviation fuel. The team at UT will facilitate regional deployment/production of jet fuel by laying the groundwork and developing a regional proposal for deployment. Additionally, UT will support activities in Task 3 with information and insights regarding feedstocks, along with potential regional demand centers for aviation fuels and coproducts, and information on current supply chain infrastructure, as required.

Major goals include the following:
1. Develop a rotation-based oilseed crop scenario and evaluate potential with POLYSYS
2. Reevaluate the production potential of biomass feedstocks and evaluate potential with POLYSYS
3. Develop a database on infrastructure for the Southeast United States
4. Continue monthly meetings with Central Appalachia stakeholders
5. Initiate aviation fuel supply chain studies in the Southeast by using pine and oilseeds
6. Continue with sustainability work for both goals 1 and 4

Task 1 - Assess and Inventory Regional Forest and Agricultural Biomass Feedstock Options

University of Tennessee

Objectives

1. Complete the economic viability analysis for switchgrass, short-rotation woody crops, crop residues, forest residues, and cover crops
2. Assist in risk–reward profit-sharing modeling by providing information from past work on cellulosic supply chains to Pennsylvania State University (PSU)
3. Develop new supply curves for both lignocellulosic and oilseed feedstock for sustainable aviation fuel (SAF). Because the markets for lignocellulosic biomass (LCB) feedstock, i.e., grasses, short-rotation woody crops, and agricultural residues, are currently not well established, evaluation of the feasibility of supplying those LCB feedstocks is important. The production, harvesting, and storage costs of the feedstocks are included in the assessment. A variety of potential crop and biomass sources will be considered in the feedstock path, including the following:

    Oilseed crops: potentially including pennycress (*Thlaspi arvense*), camelina (*Camelina sativa*), and carinata (*Brassica carinata*) as “cover crops”

    Perennial grasses: switchgrass (*Panicum virgatum*), miscanthus (*Miscanthus sinensis*), and energy cane (*Saccharum complex*)

    Short-rotation woody crops: poplar (*Populus* species), willow (*Salix* species), loblolly pine (*Pinus taeda*), and sweetgum (*Liquidambar styraciflua*)

    Agricultural residue: wheat straw, corn stover, and other agricultural residues

    Forest residue: forest residue
4. Evaluate the potential economic impacts of a mature SAF industry on regional, state, and national economies.

Research Approach

POLYSYS was used to estimate and assess the supply and availability of these feedstock options at the regional and national levels, and different feedstock farm-gate prices. County-level estimates of all-live total woody biomass, as well as average annual growth, removals, and mortality, were obtained from the Forest Inventory and Analysis Database. Mill residue data were not incorporated because most of that material already has a market. The Forest Sustainable and Economic Analysis Model (ForSEAM) will be used to estimate and predict forest residues. Forest residue encompasses removal of logging residues, thinnings, and unmerchantable trees. Forest residues exclude any logs from areas defined as supplying sawtimber but do include the logging residues that occur from sawtimber harvest. ForSEAM uses U.S. Forest Service Forest Inventory and Analysis data to project timber supply according to the demand projections from the U.S. Global Forest Product Model module of the Global Forest Product Model. Specific tasks related to this objective are outlined below. Estimates from 2020 through 2047 are made. The potential supply analysis is based on 2045 projections, although little difference exists in the national numbers between 2025 and 2045.

Two sets of POLYSYS scenarios were analyzed:
- The initial set examined the quantity of agricultural residues coming from traditional plantings from corn, sorghum, oats, barley, wheat, soybeans, cotton, and rice, along with the contributions of dedicated herbaceous energy crops and short-rotation woody crops at farm-gate prices of $30 to $80 per ton in $5 increments.

Currently, the analysis has focused on $40, $60, and $80 per ton. Analysis has been extended to $90, $100, and $110 per ton.

- A second scenario focused on oilseeds as "cover crops." This analysis allowed for areas where corn and/or cotton and soybeans were historically grown to add a crop between the row crop and soybeans. The analysis assumed a 6.5% decrease in soybean yield if the region switched from corn (or cotton)/soybeans to corn (or cotton)/cover crop/soybean rotations. The data generated in these runs provided results for Task 2.

The UT Department of Agricultural & Resource Economics models supply chains for liquid and/or electricity-generating technologies currently in use or forthcoming for the bio/renewable-energy industry by using the input–output model IMPLAN. The approach for ethanol, biodiesel, and liquid fuels includes the establishment and production of the feedstock, the transportation of the feedstock to the plant gate, and the one-time investment and annual operating of the facility that converts the feedstock to a biofuel. This modeling approach may also include the preprocessing and storage of feedstocks at depots. Also included in the supply chain analyses are the labor/salary requirements for these activities, renewable identification numbers (RINs) and credits attributable to the conversion facility, and land-use changes for growing the feedstock. Recent modeling has centered on the supply chain for liquid fuels by using the 179 economic areas of the Bureau of Economic Analysis (BEA) as modeling regions (Figure 1). The data layers necessary to estimate the economic impacts are contained in the Renewable Energy Economic Analysis Layers (REEAL) modeling system.

IMPLAN (version 3.0, using basic data for 2018) contains an input–output model based on county-level data that can be used to estimate the supply chain economic impacts of the bio/renewable-energy industry. Data are aggregated to BEA economic areas and then converted to BEA input–output models to measure changes in economic activity. As with all input–output models, IMPLAN describes the buying and selling of products and the resulting transfer of money among various industries and institutions within a BEA. Output from the model provides descriptive measures of the economy, including total industry output (the value of all sales), employment, labor income, value added, and state/local taxes for 546 industries in each BEA.[1] Each BEA IMPLAN model provides estimates of multiplier-based impacts (e.g., how siting a conversion facility will affect the rest of the BEA economy). In analysis of the impacts of the supply chain activities, the indirect multiplier effect (i.e., the impact on the supply chain part of the economy in this case) is also included. Multipliers are based on the assumption that as consumers and institutions increase expenditures, demand increases for products made by local industries, which in turn make new purchases from other local industries, and so forth. Stated another way, the multipliers in the model measure the response of the entire BEA economy to a set of changes in production for liquid fuel technologies currently located within the region and/or forthcoming for the bio/renewable-energy industry. The analysis uses IMPLAN's available local purchase percentage (LPP) option, which affects the direct impact value applied to the multipliers. Instead of a 100% direct expenditure value (i.e., electricity, water, construction, manufacturing, or waste management) applied to the BEA multipliers, the value reflects the BEA's actual purchases. The analysis is achieved with Analysis by Parts, through splitting the inputs purchased into the industries that receive the purchase and their corresponding impacts. The total impact is the aggregation of all the parts. Each part represents an industry that provides input into the industry under consideration. In addition, labor impacts and the impacts of changes in proprietor income are included.

[1] Total industry output is defined as the annual dollar value of goods and services that an industry produces. Employment represents total wage and salary employees, as well as self-employed people in a region, for both full- and part-time workers. Labor income consists of employee compensation and proprietor income. Total value added is defined as all income to workers paid by employers (employee compensation); self-employed income (proprietor income); interests, rents, royalties, dividends, and profit payments; and excise and sales taxes paid by individuals to businesses. State/local taxes comprise sales tax, property taxes, motor vehicle license taxes, and other taxes.

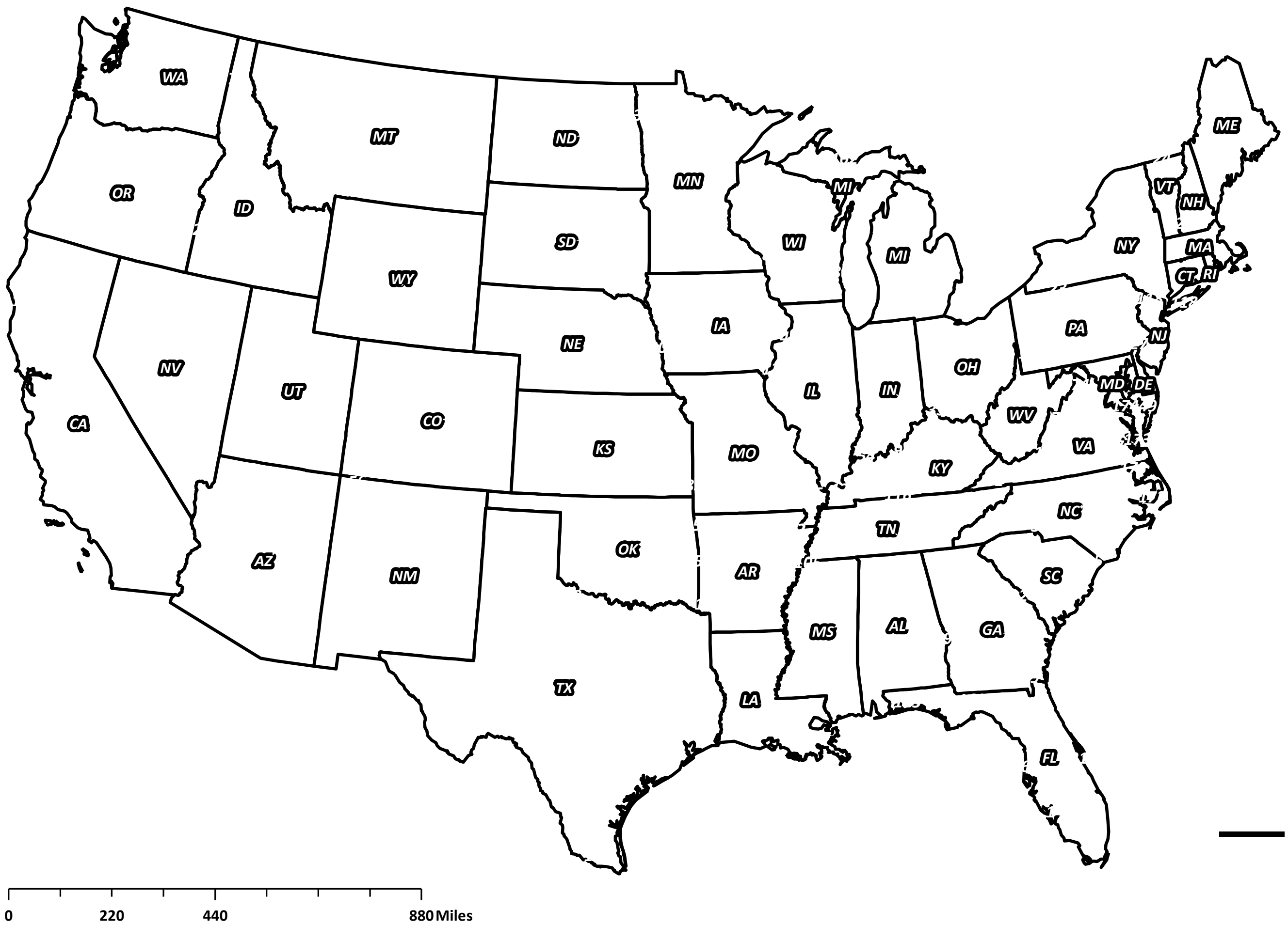

Figure 1. Bureau of Economic Analysis economic areas for input–output analysis modeling.

An example scenario is presented to show modeling capabilities. The conversion technology is a gasification Fischer–Tropsch biorefinery with a feedstock input of 545,000 tons per year of forest residue in Central Appalachia. The distance for a logging road for the feedstock is less than 1 mile. The biorefinery is expected to produce SAF, diesel, and naphtha. An estimated 1.1 million tons of forest residue is required at 10% moisture content. If work is conducted for 330 days per year and 10 hours per day, an estimated 16 or 17 trucks must be emptied every hour (or one truck every 4 minutes) if a truckload comprises 20 tons of chips (longer trailers could haul 22.5 tons of chips and could unload 14 or 15 trucks per hour). Based on the techno-economic analysis (TEA) information, for the Central Appalachia region, three biorefineries could be sited, each producing 545,000 dry short tons or 495,000 dry metric tons per year. Each biorefinery could produce 12.6 million gallons of SAF, 10.7 million gallons of diesel, and 6.2 million gallons of naphtha. Gross revenues for fuel are estimated at $425.0 million, with RINs contributing an additional $52.0 million. The break-even plant-gate fuel prices, when RINs and 12.2% return on investment are assumed, are $4.90 per gallon for SAF, $5.05 per gallon for diesel, and $4.26 per gallon for naphtha. In addition, a blender's fee of $1 to $2 per gallon for SAF fuel might be available, thus further decreasing the costs. Current legislation includes a blender's fee of $2 per gallon for biodiesel and $1 per gallon for gasoline.

According to IMPLAN-estimated economic impacts, the annual economic impact to Central Appalachia if three biorefineries were established is $1.2 billion, on the basis of an investment of $1.7 billion. Leakages occur as investment dollars leave the region; according to the regional local purchase coefficients (i.e., LPPs), the total amount is $500 million. Thus, the economic activity is $2.1 billion, with a multiplier of 1.7. In other words, for every 1 million dollars spent, an additional $0.7 million in economic activity is generated in the regional economy. The estimated gross regional product is $1.0 billion, and nearly 14,000 jobs are created during the construction period of the biorefineries, thus resulting in $700 million in labor income with multiplier effects.

Milestones

- Generated data have been passed on to the ASCENT 1 database for hardwood and softwood forest residues in the Southeast United States for two sustainability scenarios.
- A pine pathway for the Southeast United States was developed, and the potential that exists within the region was evaluated by using an ASCENT cellulosic pathway.
- A pennycress and crush facility spreadsheet was delivered to PSU for use in risk-reward profit-sharing modeling.
- Economic multipliers were developed for Fischer-Tropsch synthetic paraffinic kerosene, by using forest residues as the feedstock, and producing SAF and naphtha.

Major Accomplishments

Recent modeling emphasis has centered on the supply chain for liquid fuels by using the Bureau of Economic Analysis's 179 economic trading areas as modeling regions. These various data layers, which are necessary to estimate the economic impact, are contained in UT's REEAL modeling system. This analysis provides an example scenario to demonstrate REEAL's modeling capabilities. The conversion technology modeled is a gasification Fischer-Tropsch biorefinery with feedstock input of 495,000 metric tons per year of forest residue transported to a logging road that is less than 1 mile in distance. The biorefinery is expected to produce SAF, diesel, and naphtha. An estimated 1 million tons of forest residue is required at 50% moisture content. On the basis of a TEA developed by ASCENT and the quantity of hardwood residues available in the Central Appalachian region, three biorefineries could be sited, each utilizing 495,000 dry metric tons per year. The feedstock cost at the biorefinery gate is shown in Figure 2.

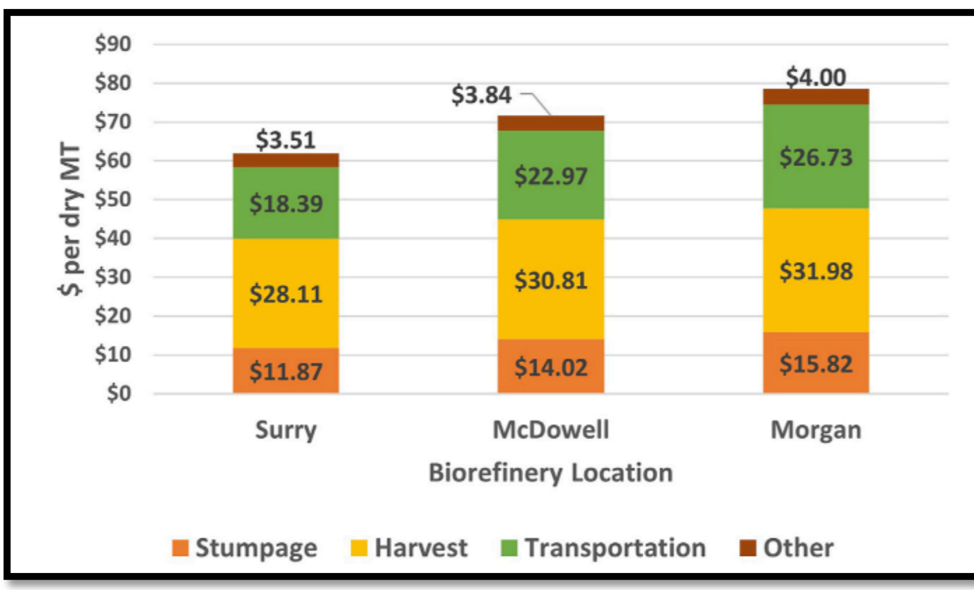

Figure 2. Costs of delivered feedstocks per dry metric ton for each of the biorefineries.

Each biorefinery could produce 47.5 million liters of SAF, 40.3 million liters of diesel, and 23.6 million liters of naphtha. The annual gross revenue for fuel required for the biorefineries to break even is estimated at $193.7 million per biorefinery. The break-even plant gate fuel prices, if RINs and 12.2% return on investment are assumed, are $1.12 per liter for SAF, $1.15 per liter for diesel, and $0.97 per liter for naphtha. On the basis of IMPLAN, with an input–output model and an investment of $1.7 billion, the estimated economic annual impact to the Central Appalachian region if the three biorefineries are sited exceeds half a billion dollars. Leakages occur as investment dollars leaving the region; according to the region's local purchase coefficients (i.e., LPPs), the total is $500 million. This results in an estimated $2.67 billion in economic activity with a multiplier of 1.7; i.e., for every million dollars spent, an additional $0.7 million in economic activity is generated in the regional economy. Gross regional product is estimated at $1.28 billion, and employment of nearly 1,200 jobs is created during the construction period of the biorefineries, thereby resulting in $700 million in labor income with multiplier effects. The economic activity for the feedstock operations (harvesting and chipping) is estimated at slightly more than $16.8 million, thus resulting in an additional $30 million economic impact. The stumpage and additional profit from the harvesting of forest residues result in $40 million flowing directly to the resource and logging operation owners. Their subsequent expenditures result in a total economic activity increase of $71.4 million. These operations create an estimated 103 direct jobs, for a total of 195 with multiplier effects. Direct feedstock transportation expenditures exceeding $36.7 million provide an estimated increase in economic activity of almost $68 million, accounting for the multiplier effects (Figure 3).

Item causing the impact	Multiplier	Direct	Total
—	—	Million $	
Biorefineries			
Investment:	—	—	—
Economic activity	1.68	$1,589.5	$2,671.9
Gross regional product	1.76	$725.5	$1,277.5
Employment (jobs)	1.64	11,265	18,429
Annual operations:	—	—	—
Economic activity excluding salaries	1.68	$198.8	$333.2
Salary	1.98	$17.7	$35.2
Annual economic activity generated	—	$216.5	$368.3
Gross regional product	1.61	$128.6	$206.6
Feedstock operations			
Annual operations:	—	—	—
Feedstock to landing:	—	—	—
Economic activity excluding salaries	1.79	$11.1	$19.9
Salary	1.76	$5.7	$10.1
Resource and logging operation owners	—	$40.2	$71.4
Annual economic activity generated	1.78	$57.1	$101.3
Gross regional product	1.55	$12.7	$19.8
Feedstock transportation:	—	—	—
Economic activity	1.85	$36.7	$67.8
Gross regional product	1.80	$20.3	$36.5

Figure 3. Economic activity generated by the three biorefinery industries.

A preliminary analysis for the SAF Grand Challenge was initiated. Several goals were examined by using crop residues, dedicated energy crops, and forest residues as feedstocks for the GTP pathway. Waste streams from human consumption were not included, nor was oilseed production. The analysis included four scenarios of meeting 25%, 50%, 75%, and 100% of the SAF Grand Challenge target with these feedstocks.

The impacts on agricultural prices (Figure 4a) were evaluated, along with changes in land use (Figure 4b). Pressure on commodity prices for the grains decreased slightly over all alternative scenarios, with prices remaining the same for other program crops. Corn acreage increased as demand for stover for SAF production increased. Meeting the 2030 market did not substantially affect the crop markets. Figure 4c summarizes the main source of biomass feedstock over time to meet the 100% SAF Grand Challenge target. Corn stover serves as the major source (47%) of biomass feedstock, followed by wood residues (39%) and switchgrass (34%), in 2045.

Crop price	Change from baseline (2030) 25% target		50% target		75% target		100% target	
	$	%	$	%	$	%	$	%
Corn ($/bu)	−0.06	−1.64%	−0.06	−1.64%	−0.06	−1.64%	−0.06	−1.64%
Grain sorghum ($/bu)	−0.01	−0.29%	−0.01	−0.29%	−0.01	−0.29%	−0.01	−0.29%
Oats ($/bu)	−0.02	−0.67%	−0.02	−0.67%	−0.02	−0.67%	−0.02	−0.67%
Barley ($/bu)	−0.01	−0.22%	−0.01	−0.22%	−0.01	−0.22%	−0.01	−0.22%
Wheat ($/bu)	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Soybeans ($/bu)	0.08	0.84%	0.08	0.84%	0.08	0.84%	0.08	0.84%
Cotton ($/lb)	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Rice ($/cwt)	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Hay ($/ton)	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%

Figure 4a. Change in commodity prices with respect to the baseline solution under the SAF Grand Challenge.

Harvested land	Change from baseline (2030) 25% target		50% target		75% target		100% target	
	Million acres	%	Million acres	%	Million acres	%	Million acres	%
Corn	0.33	0.40%	0.33	0.40%	0.33	0.40%	0.33	0.40%
Grain sorghum	0.01	0.19%	0.01	0.19%	0.01	0.19%	0.01	0.19%
Oats	−0.01	−1.11%	−0.01	−1.11%	−0.01	−1.11%	−0.01	−1.11%
Barley	−0.01	−0.42%	−0.01	−0.42%	−0.01	−0.42%	−0.01	−0.42%
Wheat	−0.04	−0.10%	−0.04	−0.10%	−0.04	−0.10%	−0.04	−0.10%
Soybeans	−0.27	−0.32%	−0.27	−0.32%	−0.27	−0.32%	−0.27	−0.32%
Cotton	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Rice	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
Hay	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%

Figure 4b. Change in land use with respect to the baseline solution under the SAF Grand Challenge.

Biomass	2030	2035	2040	2045
Stover (mil.dt)	140.4	143.3	151.9	168.7
Straw (mil.dt)	0	0	12	17.4
Switchgrass (mil.dt)	0	0	39.7	121.8
Miscanthus (mil.dt)	0	0	5.3	79.7
Wood residues (mil.dt)	20.1	21.8	67.7	137.7
Willows (mil.dt)	0	0	0	0.8

Figure 4c. The biomass feedstock for the SAF Grand Challenge.

Publications

Peer-reviewed journal publications

Burton, C., English, R., Menard, J., & Wilson, B. (2022). The Economic Impact of a Renewable Biofuels/Energy Industry Supply Chain Using the Renewable Energy Economic Analysis Layers Modeling System, *Frontiers in Energy Research*, *10*:3389. doi: 10.3389/fenrg.2022.780795

Sharma, B.2, T.E. Yu, B.C. English, and C.N. Boyer. 2021. Economic Analysis of Developing a Sustainable Aviation Fuel Supply Chain Incorporating with Carbon Credits: A Case Study of the Memphis International Airport. *Frontiers in Energy Research*, *9*:802. doi: 10.3389/fenrg.2021.775389.

Trejo-Pech, C. J., Larson, J. A., English, B. C., & Yu, T. E. (2021). Biofuel discount rates and stochastic techno-economic analysis for a prospective Pennycress (Thlaspi arvense L.) sustainable aviation fuel supply chain. *Frontiers in Energy Research*, *9*:867. doi: 10.3389/fenrg.2021.770479

Outreach Efforts

The UT Institute of Agriculture and the Commercial Aviation Alternative Fuels Initiative have partnered to identify sites with optimal woody biomass and essential supply chain infrastructure, because these factors present challenges for processors with limited resources to conduct site assessments with sufficient detail to attract investment capital. The initial attempt will highlight the availability of woody biomass in the region and thereby extend its potential utilization. Analysis has been initiated for DRAX Group and USA BioEnergy.

Awards

None.

Student Involvement

Plans for Next Period

- Develop a forest harvest model
- Complete several manuscripts
- Continue our work on the forest sector
- Continue our work on the stochastic analysis focusing on pennycress feasibility in the Southeast United States
- Continue to work on the Memphis airport region analysis using camelina and pennycress as feedstocks
- Work on feedstock sustainability issues
- Continue working with stakeholders

Task 2 - Develop National Lipid Supply Availability Analysis

University of Tennessee

Objective

The UT team will complete the national lipid supply availability analysis by using POLYSYS to develop information on the potential impacts and feasibility of using lipids to supply aviation fuel.

Research Approach

POLYSYS was used to estimate and assess the supply and availability of these feedstock options at the regional and national levels. This U.S. agricultural sector model forecasts changes in commodity prices and net farm income over time. Analysis requires consistency among the crops. Budgets have been reevaluated for pennycress, camelina, and carinata for consistent assumptions, where possible. These budgets have been uploaded into the PSU BOX platform and sent to Washington State University, and are available at https://arec.tennessee.edu/. Yields have been compared with literature sources and are available at https://arec.tennessee.edu/.

Milestone

The potential oilseed cover crops and SAF production have been estimated and will be included in a manuscript.

Major Accomplishments

1. Consistent assumptions regarding the prices of inputs were reviewed, and budgets were updated. POLYSIS was updated with the changes.
2. The pennycress spreadsheet incorporating risk into the analysis was completed and is still under review.
3. The assumptions among the three oilseed crops were compared, and we have attempted to develop spreadsheets containing similar price data and other assumptions.
4. Analysis was run in POLYSYS by assuming on-farm prices of $0.05 to $0.20 per pound. Supplies of the oilseed were estimated and impacts to the national and rural economies are being estimated.

Figure 5 shows the potential production areas of the three oilseed cover crops—pennycress, carinata and camelina—under two scenarios: (a) corn/oilseed/soybeans and (b) cotton/oilseed/soybeans. The major production concentrates in the north-central region or Corn Belt. Figure 6 presents the total oilseed cover crop production, given the six external price levels. On the basis of the oilseed production, the potentially production of SAF and co-products under the six oilseed price levels was determined (Figure 7). At $0.11 per pound, 54 billion pounds of oilseed could be produced and converted to nearly 5 million short tons of oil, and eventually make 0.75 billion gallons of SAF plus other renewable fuels, if 20 facilities generating hydrotreated esters and fatty acids are operated, 259,000 short tons would be required annually. At the highest price level ($0.20/lb), 75 billion pounds of seed could be produced and could make 1 billion gallons of SAF, thereby meeting one-third of the 2030 target. Among those three oilseeds, the primary cover crop is pennycress (77%), followed by camelina (17%) and carinata (6%).

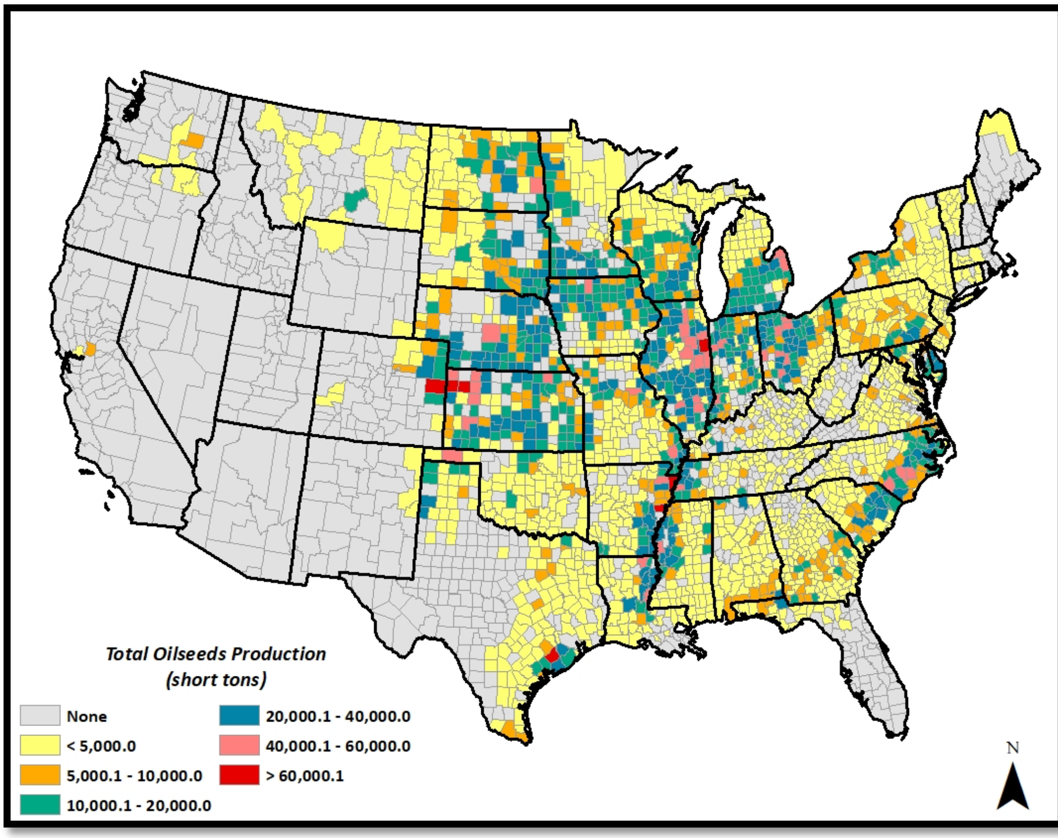

Figure 5. Total production of three oilseed cover crops in the United States.

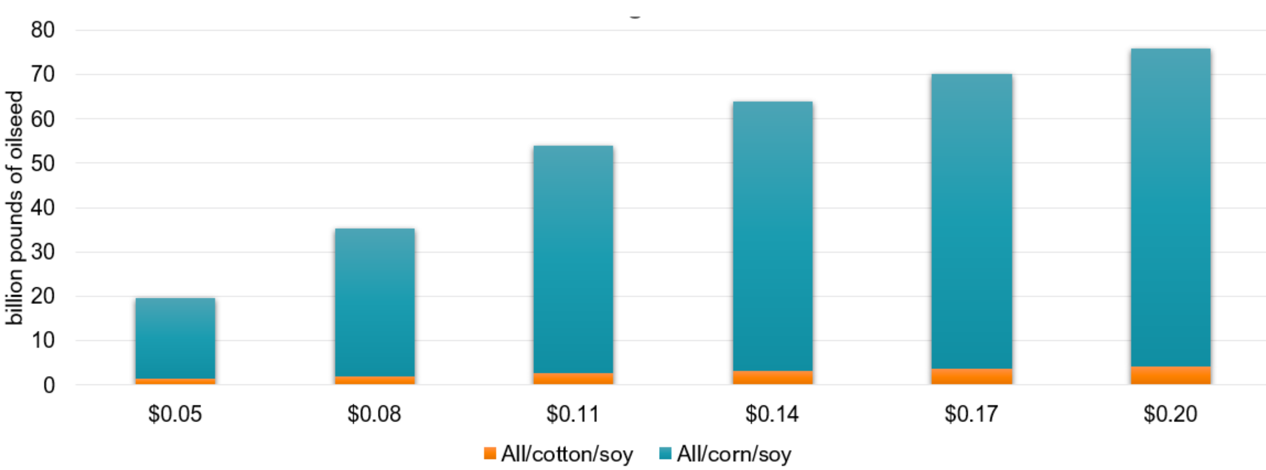

Figure 6. Total production of three oilseed cover crops under various external prices.

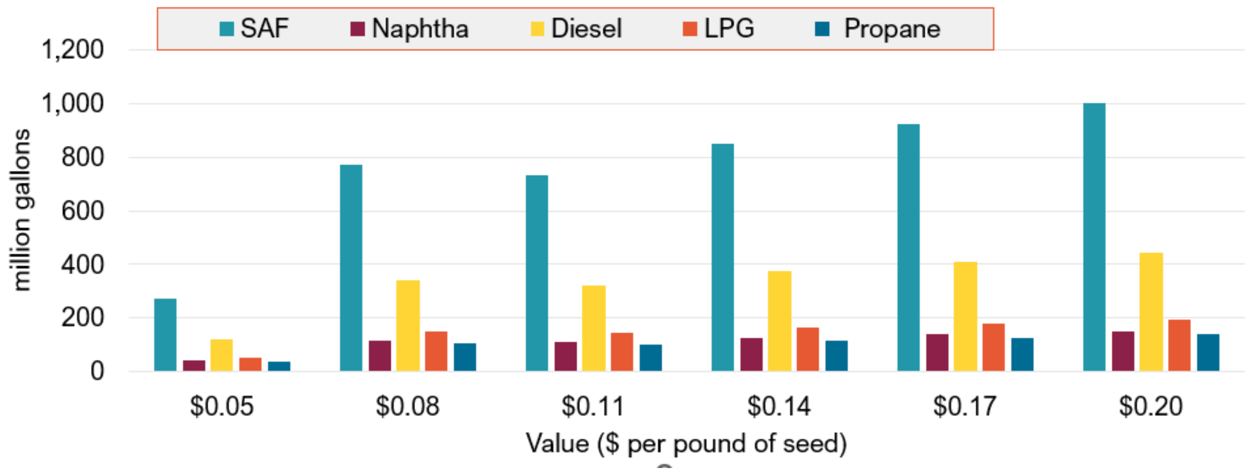

Figure 7. Total SAF and co-products derived from three oilseed cover crops under various external prices.

Publications
See Task 1 above for publications.

Outreach Efforts
None.

Awards
None.

Student Involvement
Alan Robertson examined the impacts of fertilizer on switchgrass yield and ash content, and evaluated the biorefinery's desired level of fertilizer application.
Tongtong Li was included in the project to develop the stochastic budget model for pennycress.

Plans for Next Period
We plan to produce a manuscript based on the analysis.

Task 3 - Lay the Groundwork for Supplying Lipid and/or Biomass for SAF Production in Tennessee and the Southeast United States
University of Tennessee

Objectives
The team at UT will facilitate regional deployment/production of renewable jet fuel by completing the groundwork phase of the regional oilseed feedstock-to-biofuel pathway and developing a proposal for regional deployment in the Southeastern United States and in Central Appalachia, thus leading to the development of SAF Regional Deployment Plans for the Southeast and Appalachia.

Research Approach
- The approach is as in Task 1, but is focused on small areas such as Central Appalachia, Memphis, and Nashville.
- Softwood analysis is focused on the Southeast, and findings were provided in last year's report.

- A seed trial for oilseed cover crops was developed with funding from UT seed money; we will incorporate findings in this report for the first year under subproject 2.

Central Appalachia: second year of a multi-year project
The project was initiated at the start of the COVID-19 pandemic and was subsequently rearranged to reflect laboratory closures and travel restrictions.

The research approach was somewhat modified to reflect these changes. A hardwood forest residue layer was developed for BioFLAME and the Freight and Fuel Transportation Optimization Tool (FTOT) (Figures 7 and 8). An initial FTOT analysis has been run, and adjustments to the analysis are underway.

A stakeholder group has been formed and has met multiple times. Typically, the meeting occurs on the second Thursday of each month.

A summary of the work accomplishments under the subcontract with the Center for Natural Capital to assist in the Central Appalachia area is provided below. Item 8 has been cancelled because of the funding decrease for 2021–2022. In addition, the Center continues to play an active and vital role in stakeholder meetings even though the funding for the project covered the initial year, and future years were not funded. Initial-year funding was extended for a second year through a no-cost extension.

1. Form an expert advisory board
    a. Develop an invitee list of potential advisory board members
    b. Hold Zoom calls and obtain input regarding stakeholder invitees
2. Group formed
    a. Monthly calls held
3. Monthly calls
    a. Advise the expert advisory board regarding the needs of the airline industry
    b. Identify and engage consultants with substantial experience in airline industry fuels
4. Assemble a stakeholder cabinet
5. Assist UT in identifying potential brown and green field locations
6. Review and comment on UT's determination of the ability and willingness of forest landowners, agricultural producers, and reclaimed mine landowners to make land available for feedstock production
7. Procure and deliver to UT 50–60 different hybrid poplar samples in chipped form from Powell Project Travel to Powell River Project, with assistance from Virginia Tech; collect samples; cut pieces of hybrid poplar and return them to Rapidan, Virginia, for processing into chips
    a. A total of 110 pounds of hybrid poplar tree trunks only (without stems and leaves) have been procured and delivered to UT.
    b. Samples have been collected and processed; boles of hybrid poplar have been cut and sent to UT for analysis.
8. Assist Don Hodges and his students in procuring hardwood forest residue samples from ongoing logging activities in the region by identifying current logging operations
9. Form a task force to prepare proposals to fund follow-on work
    a. A group of energy-related companies has been compiled, and contacts are being made to solicit interest in building a biorefinery in the region. One company has prepared a high-level proposal to install wood pyrolysis systems to break down feedstock and deliver it to a biorefinery.
10. Make considerable efforts to reach out to other related projects in the region
    a. The most notable project is MASBIO based at West Virginia University. The MASBIO leadership took the lead on a proposal to the U.S. Department of Commerce.

The team initiated a workforce analysis for the Appalachian region. The goal is to assess the nature of the demand for workers (quantity and quality) that a wood-based biofuel processing facility would have on a regional economy, and the ability and willingness of workers in the area to meet this demand, by using BEA region 66 as an example. To assess the former, the level of employment required by the biofuel firm (IMPLAN sector 163) is translated into a set of demand for specific workers by occupation. Occupations are then translated into a set of skill sets via IMPLAN's analysis of O*NET skills by occupation analysis. To assess the latter, we estimate changes in the local workforce to determine candidates likely to seek employment. Major changes in employment by economic sector are translated into occupational changes and then skill changes by using the IMPLAN-O*NET analysis. A weighted average is then used to provide a supply of workers by skill set; the skill sets in turn are compared with those likely to be sought in prospective workers at the biofuel firm.

As shown in Table 1, in terms of the skill characteristic ability, workers assumed to be regional job seekers do not necessarily have the skills sought by the biofuel processing firm. Attributes that show a "good" match in terms of worker demand (IMPLAN sector 163) and supply (job seekers) include oral comprehension and expression, deductive reasoning, and inductive reasoning. However, attributes such as written comprehension, written expression, and originality are relatively important to the biofuel firm, but the ability of job seekers to supply such attributes may be lacking. Across all 52 ability attributes that we examined, a Wilcoxon test statistic (646.5) indicated a significant difference in rank (alpha = .01 level) indicating a possible mismatch between the skills desired by the firm and the ability of the available regional workforce to readily supply such skills.

Table 1. Ability as an example: Biofuel firm's (sector 163) vs. regional job seekers' rank of attribute importance (more than 52 attributes) with respect to worker skills.

Ability category	IMPLAN sector 163	Job seekers
Oral comprehension	1	1
Written comprehension	**2**	**20**
Oral expression	3	3
Written expression	**4**	**26**
Fluency of ideas	**5**	**29**
Originality	**6**	**31**
Problem sensitivity	7	4
Deductive reasoning	8	8
Inductive reasoning	9	10
Information ordering	10	6

Note: Underlining indicates a close match, and bold denotes a possible mismatch, between the demand for worker skills and the ability of local workers to provide such skills.

The hybrid poplar samples were evaluated by the Center of Renewable Carbon's lab headed by Niki Labbe. Collaborating with a hardwood National Institute for Food and Agriculture project, the laboratory characterized the feedstock performance and conversion potential of Central Appalachia region hardwood forest thinnings, harvest residuals, and short-rotation woody crops from university experimental plots and reclaimed surface mine lands, and the invasive species that have colonized formerly mined lands; in addition, their locations and costs were defined. Hardwood residue biomass was collected from various locations and preprocessed (drying and size reduction) for near-infrared data collection and wet-chemistry analysis.

Major Accomplishments

- The Nashville modeling work using cover crop oilseeds has been completed. The next step will be to develop a regional deployment plan after risk and uncertainty are evaluated.
- The Memphis modeling work has been initiated, but analysis has not begun. Analysis will be initiated during the second quarter of 2023.
- The Central Appalachian Project has a regular stakeholder group meeting and held its initial workshop online to discuss state and national incentives for SAF development in the region.

Publications

None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period (Year)
- Complete the Central Appalachian Regional Deployment Plan
- Continue to work on the Nashville Regional Deployment Plan
- Continue to work on the Southeast Regional Deployment Plan
- Continue to work on the Memphis Regional Deployment Plan

Task 4 - Biorefinery Infrastructure and Siting (Supporting Role)
University of Tennessee

Objective
Provide feedstock support to other members of ASCENT as requested.

Research Approach
This task involves providing necessary input through research efforts by using feedstock tools developed before or as part of this project. The approach will vary as questions arise from other universities. We have received two requests, which were met this year: a request from PSU regarding the cost of feedstock production and a request from FTOT for information on feedstock availability in the Central Appalachian region. We also discussed the potential of assisting the University of Hawaii with economic analysis of the Hawaii feedstock and conversion effort.

Milestones
- Delivered the feedstock spreadsheets on oilseeds
- Developed a hybrid poplar spreadsheet, which is under review
- Worked with WSU in TEA assessment

Major Accomplishments
See Tasks 1 and 3 above.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period
- Enhance economic indicator analysis
- Review feedstock spreadsheets, and make them available online