Project 001(E) Alternative Jet Fuel Supply Chain Analysis

University of Tennessee

Project Lead Investigator

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University Participants

University of Tennessee

- P.I.(s): Burton English, Professor
- FAA Award Number: 13-C-AJFE-UTenn, Amendments 09, 11, 13, 15
- Period of Performance: October 1, 2020, to September 30, 2021
- Tasks:
    1. Assess and inventory regional forest and agricultural biomass feedstock options
    2. Develop national lipid analysis
    3. Lay the groundwork for lipid and/or biomass in Tennessee and the Southeastern United States
    4. Biorefinery infrastructure and siting (supporting role)
- Journal manuscripts will be prepared based on the biochar survey data, oilseed techno-economic analysis (TEA), agricultural residue availability and supply potential, and national oilseed analysis.
- McKenzie Thomas will complete her master's thesis using survey data.
- Jim Larson will complete his analysis on farmers' willingness to pay with a journal article and a department research manuscript.

Project Funding Level

Total 6-year funding/This year funding
Total Estimated Project Funding: $1,175,000/$600,000
Total Federal and Non-Federal Funds: $1,175,000/$1,175,000
The University of Tennessee Institute of Agriculture, in support of the project, provided faculty salary. Additional non-federal support derived from contributions from the stakeholder group.

Investigation Team

- Tim Rials – project director/principal investigator (PD/PI)
- Burton English – co-principal investigator (co-PD/PI)
- Kim Jensen – faculty
- Jim Larson – faculty
- Carlos Trejo-Pech – faculty
- Ed Yu – faculty
- David Hughes – faculty
- Jada Thompson – faculty
- Luis Vizcaya – master's graduate student
- A. Latif Patwary – master's student

Project Overview

The University of Tennessee (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. The 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 on feedstocks, along with potential regional demand centers for aviation fuels and coproducts, along with information on current supply chain infrastructure, as required.

Major goals included 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 database on infrastructure and needs for the Southeast U.S.
4. Continue monthly meetings with Central Appalachia stakeholders
5. Initiate aviation fuel supply chain studies in the Southeast 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

Task 1 Goals (support/continue ongoing work from previous year)

- Complete the economic viability analysis on switchgrass, short-rotation woody crops, crop residues, forest residues, and cover crops
- Assist Risk-Reward Profit Sharing modeling by providing information from past work on cellulosic supply chains to Pennsylvania State University (PSU)
- Provide measures of economic impacts through the development of renewable fuel.

Objectives

A. Develop new supply curves for both lignocellulosic and oilseed feedstock for sustainable aviation fuel (SAF). As the markets for lignocellulosic biomass (LCB) feedstock, i.e., grasses, short-rotation woody crops, and agricultural residues, are currently not well established, it is important to evaluate the feasibility of supplying those LCB feedstocks. The production, harvest, and storage cost 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: potentials include 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

B. Evaluate the potential economic impact 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 (FIADB). Mill residue data are not incorporated because that material already has a market, for the most part. 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 does include the logging residues that occur from sawtimber harvest. ForSEAM uses U.S. Forest Service Forest Inventory and Analysis data to project timber supply based on the U.S. Global Forest Product Model module of the Global Forest Product Model (USFPM/GFPM) demand projections. 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 there is little difference 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 (SRWCs) 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 grown historically 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 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) values and credits attributable to the conversion facility, along with land-use changes for growing the feedstock. Recent modeling emphasis has centered on the supply chain for liquid fuels 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 resulting transfer of money between different 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 impact 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 operate on the assumption that as consumers and institutions increase expenditures, demand increases for products made by local industries, who in turn make new purchases from other local industries and so forth. Stated another way, the multipliers in the model will 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, waste management) applied to the BEA multipliers, the value which reflects the BEA’s actual purchases. The analysis is achieved by using Analysis by Parts (ABP) methodology. ABP is conducted by 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 jobs 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 licenses taxes, and other taxes.

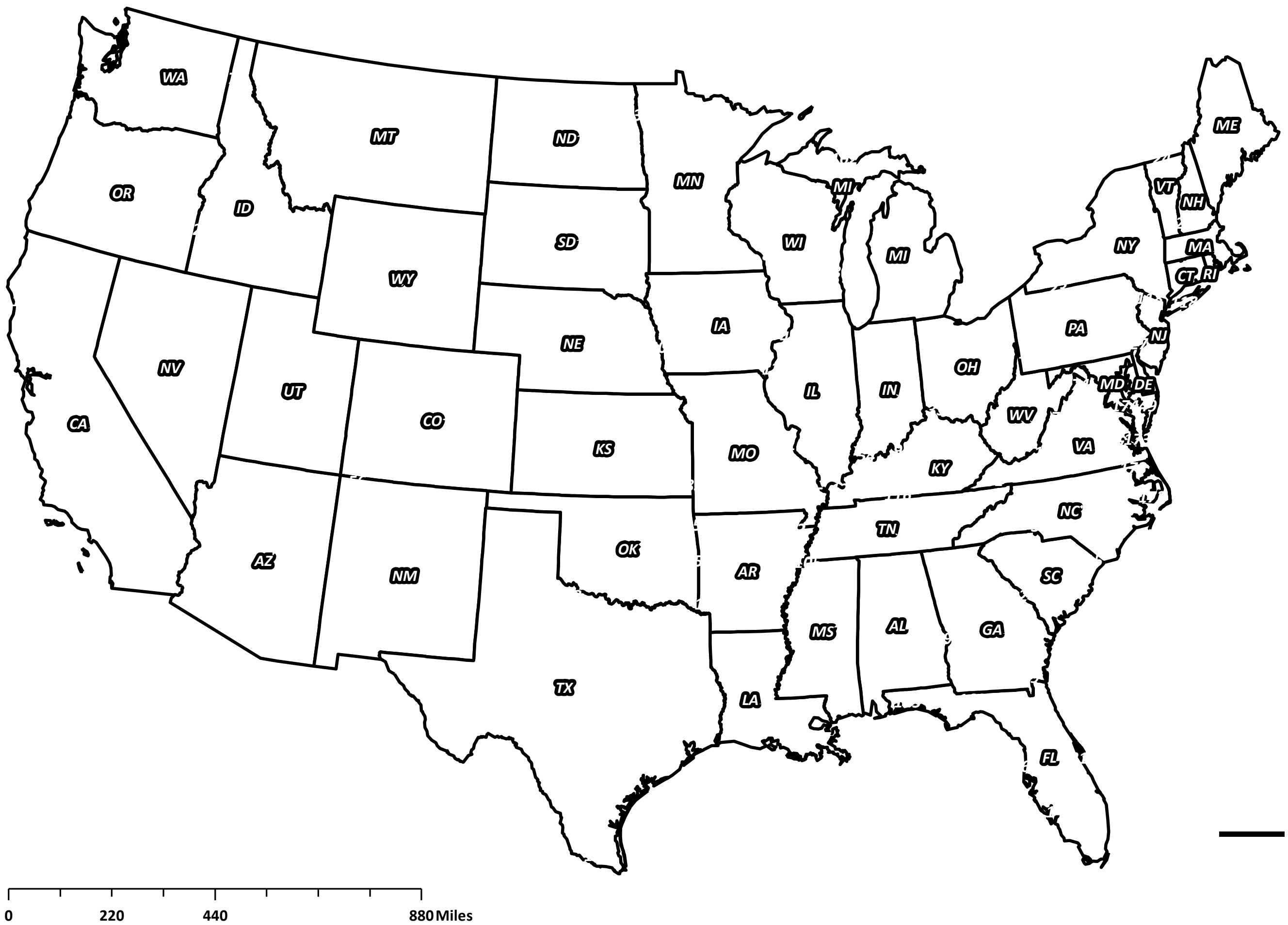


Figure 1. Bureau of Economic Analysis economic areas for input-output analysis modeling.

An example scenario is presented to show modeling capabilities. The conversion technology is a gasification Fischer-Tropsch (GFT) biorefinery with feedstock input of 545,000 tons per year of forest residue in Central Appalachia. 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. Working 330 days per year and 10 hours per day, an estimated 16-17 trucks must be emptied every hour (or one truck every four minutes) if truckloads are 20 tons of chips (longer trailers could haul 22.5 tons of chips and could unload 14-15 trucks per hour). Based on 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. Breakeven plant-gate fuel prices when assuming RINs and 12.2% return on investment 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, reducing the costs even more. Current legislation includes a blender's fee for biodiesel of $2 per gallon and for gasoline of $1 per gallon.

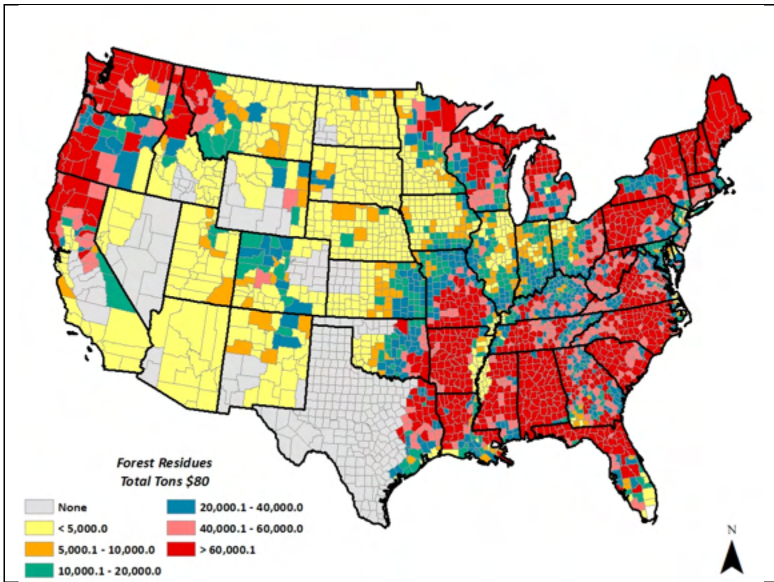
Based on IMPLAN estimated economic impacts, the annual economic impact to Central Appalachia if three biorefineries are established is $1.2 billion, based on an investment of $1.7 billion. Leakages occur as investment dollars leave the region based on the regional local purchase coefficients (i.e., LPPs), which totals $500 million. This results in $2.1 billion in economic activity 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. Gross regional product is estimated at $1.0 billion, and nearly 14,000 jobs are created during the construction period of the biorefineries, which results in $700 million in labor income with multiplier effects.

Milestones

- Generated data passed on to the ASCENT 1 database for hardwood and softwood forest residues in the Southeast U.S. for two sustainability scenarios
- Developed a pine pathway for the Southeast U.S. and conducted an evaluation of the potential that exists within the region using an ASCENT cellulosic pathway
- Delivered pennycress and crush facility spreadsheet to PSU for use in Risk-Reward Profit Sharing modeling
- Developed economic multipliers for FT-SPK using forest residues as the feedstock. producing SAF and naphtha

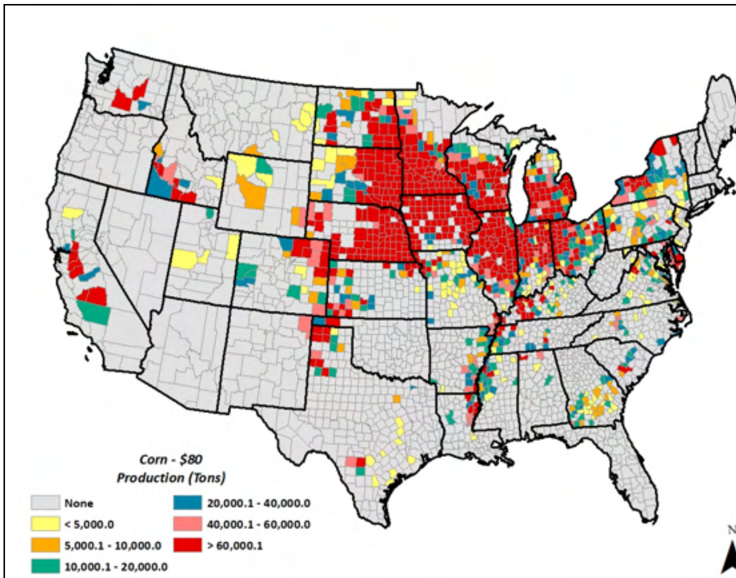
Major Accomplishments

Information to develop supply curves has been generated and the $40, $60, and $80 per ton scenario solutions have been mapped in draft form. Figures 2 (forest residues), 3 (agricultural residues), 4 (switchgrass), and 5 (miscanthus) for the $80/ton solution are shown below. These data are at the county level.



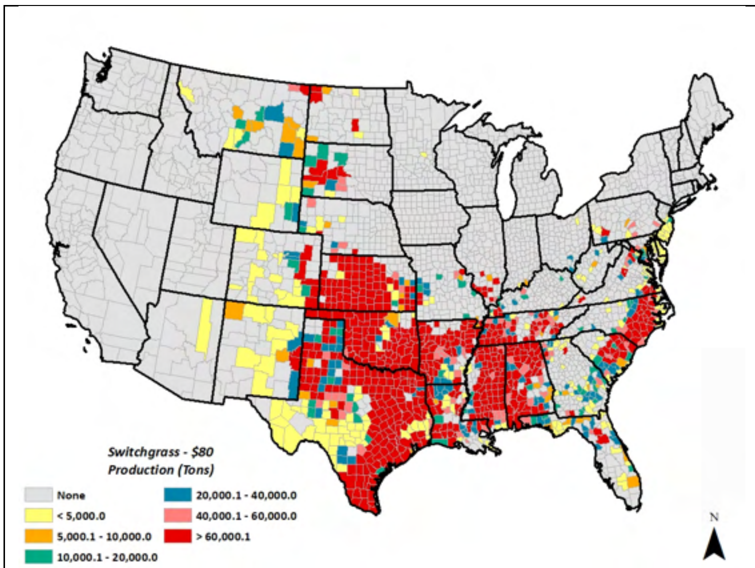
Type of wood	National quantity (tons)
Softwood	92,146,520
Hardwood	43,876,644
Total	136,023,164

Figure 2. Forest residues at $80 per ton chipped, in the truck and at the landing.



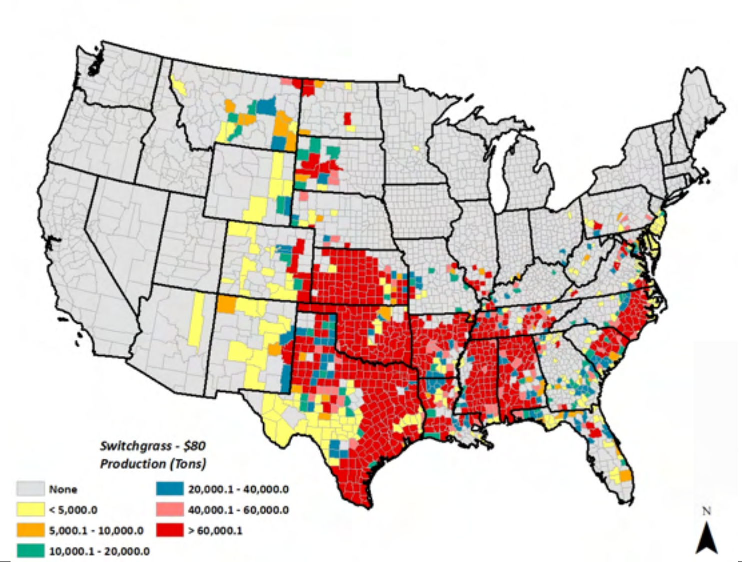
Crop	Residue harvested (acres)	Production (tons)
Barley	619,220	724,226
Corn	65,106,280	206,303,326
Cotton	171,391	57,539
Oats	167,792	176,289
Sorghum	975,592	1,205,416
Soybeans	2,428,491	2,321,166
Wheat	17,983,566	21,475,999
Total	87,452,332	232,263,961

Figure 3. Location of corn stover and information on other residues at a farm-gate price of $80 per ton.



Dedicated energy crop	Acres harvested	Production (tons)
Switchgrass	**30,645,632**	**137,206,759**
Poplar	479,679	13,508,568
Willow	658,219	17,648,695
Sweet sorghum	1,243,876	10,494,139
Miscanthus	38,844,871	242,585,459
Energy cane	60	500
	71,872,337	421,444,119

Figure 4. Location of switchgrass production and information on other dedicated energy crops at a farm-gate price of $80 per ton.



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Energy cane	60	500
	71,872,337	421,444,119

Figure 5. Location of miscanthus production and information on other dedicated energy crops at a farm-gate price of $80 per ton.

A thesis titled "The Effects of Inputs on Poultry Production Output," completed this year by Ty Wolaver, under the guidance of Dr. Jada Thompson, compared the nutritional content of camelina meal to soybean meal used in a poultry broiler diet. Using poultry nutritional requirements, a minimum cost diet using linear programming was developed. Decreasing the price of camelina meal relative to soybean meal allowed the model to provide estimated meal demand curves. Prices were reduced in intervals, and 5,000 stochastic simulations were run at each price point.

The price point intervals included (1) 80 to 99% of soybean meal, (2) 60 to 80% decrease from soybean meal, and (3) 30 to 60% decrease from soybean meal prices. When the price of camelina meal varied between 99% and 80% of the price of soybean meal, camelina meal demand average ranged from 62.53 to 68.38 kg of the 200 kg of dry meal requirement in a 1,000-kg feed ration. soybean meal was replaced from 31.3% to 34.2%. Based on the quantity of soybean meal demanded for broiler finisher feed, there would be a demand of 5.61 million kg to 6.13 million kg for broiler finisher feed in Tennessee creating gross sales of $19.81 million to $19.69 million per year. When the price of camelina meal is 70% of the price of soybean meal, camelina meal demand averages 74.23kg of the 200kg of dry meal necessary in a 1000kg feed ration or 37.1% of the dry meal necessary. This amounts to a demand for camelina meal of 6.65 million kg for broiler finisher feed in Tennessee. This would create a gross sale of $16.63 million. Finally, when the price of camelina meal is 30% to 60% of the price of soybean meal, camelina meal demand averages from 83.71 million kg to 86.34 million kg of the 200 kg of dry meal necessary in a 1,000-kg feed ration or 41.9% to 43.2% of the dry meal necessary. This would create gross sales of $8.21 million to $16.57 million.

Camelina has been shown to have potential substitutability, at least in theory, for soybean meal in broiler finisher rations if the camelina meal is priced at a discount to soybean meal. An increasing quantity of camelina meal is selected as the price lowers with respect to soybean meal prices. However, the quantity demanded does not change much once camelina meal is priced at 60% to 70% of the soybean meal price.

If feasible, the broiler industry could save on feed cost and decrease risks from price volatility in the soybean market on broiler feed cost. By having camelina meal as an option, broiler feed mills would not be totally dependent on the current price of soybeans as more camelina meal can be introduced into broiler finisher feed as the price of soybean meal rises.

Publications

1. Thomas, M., Jensen, K. L., Lambert, D. M., English, B. C., Clark, C. D., & Walker, F. R. (2021). Consumer preferences and willingness to pay for potting mix with biochar. Energies *14*(12), 3432. https://doi.org/10.3390/en14123432
2. Burton, C., English, R., Menard, J., & Wilson, B. (2021). The economic impacts of a renewable biofuels/energy industry supply chain using the Renewable Energy Economic Analysis Layers (REEAL) modeling system [Manuscript submitted for publication].
3. Trejo-Pech, C. J., Larson, J. A., English, B. C., & Yu, T. E. (in press). Biofuel discount rates and stochastic techno-economic analysis for a prospective Pennycress (Thlaspi arvense L.) sustainable aviation fuel supply chain. Frontiers in Energy Research.
4. Zhou, X. V., Jensen, K. L., Larson, J. A., & English, B. C. (2021). Farmer interest in and willingness to grow pennycress as an energy feedstock. Energies, *14*(8), 2066. https://doi.org/10.3390/en14082066
5. Wolaver, T. M. (2021). The effect of inputs on poultry production output. [Master's Thesis, University of Tennessee]. https://trace.tennessee.edu/utk_gradthes/6191
6. Vizcaya, L. A. Effect of harvesting schemes on forest residue supply chain for biofuel production: A case study in tennessee. [Master's Thesis, University of Tennessee].

Outreach Efforts

The UT Institute of Agriculture (UTIA) and the Commercial Aviation Alternative Fuels Initiative (CAAFI) have partnered to identify sites with optimal woody biomass and essential supply chain infrastructure, as these factors present challenges for processors with limited resources to conduct site assessments with enough 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 and USAENERGY.

Awards

None

Student Involvement

Luis Vizcaya completed a forest harvesting model and biorefinery siting given forest residue availability. Vizcaya was included in the project to analyze the optimal harvest pattern of forestry residues that will be the derived supply for biorefineries.

Ty Wolaver completed and defended his thesis and we are working to publish a paper on oilseed meal.

Latif Patwary was included in the project to examine the potential environmental benefits.

Plans for Next Period

- Complete blend study
- Develop Forest Harvest model
- Complete several manuscripts
- Continue our work on the forest sector
- Develop a stochastic analysis focusing on pennycress, carinata, and camelina feasibility in the Southeast U.S.
- Continue to work on Memphis airport region analysis using camelina and pennycress as feedstocks
- Work on feedstock sustainability issues
- Continue working with stakeholders

Task 2 - Develop National Lipid Analysis

University of Tennessee

Objective

The UT team will complete the national lipid supply availability analysis 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 Penn State BOX platform, sent to Washington State University, and are available at https://arec.tennessee.edu/. Yields have been compared with literature sources and are presented in Figures 6, 7, and 8 and are available at https://arec.tennessee.edu/.

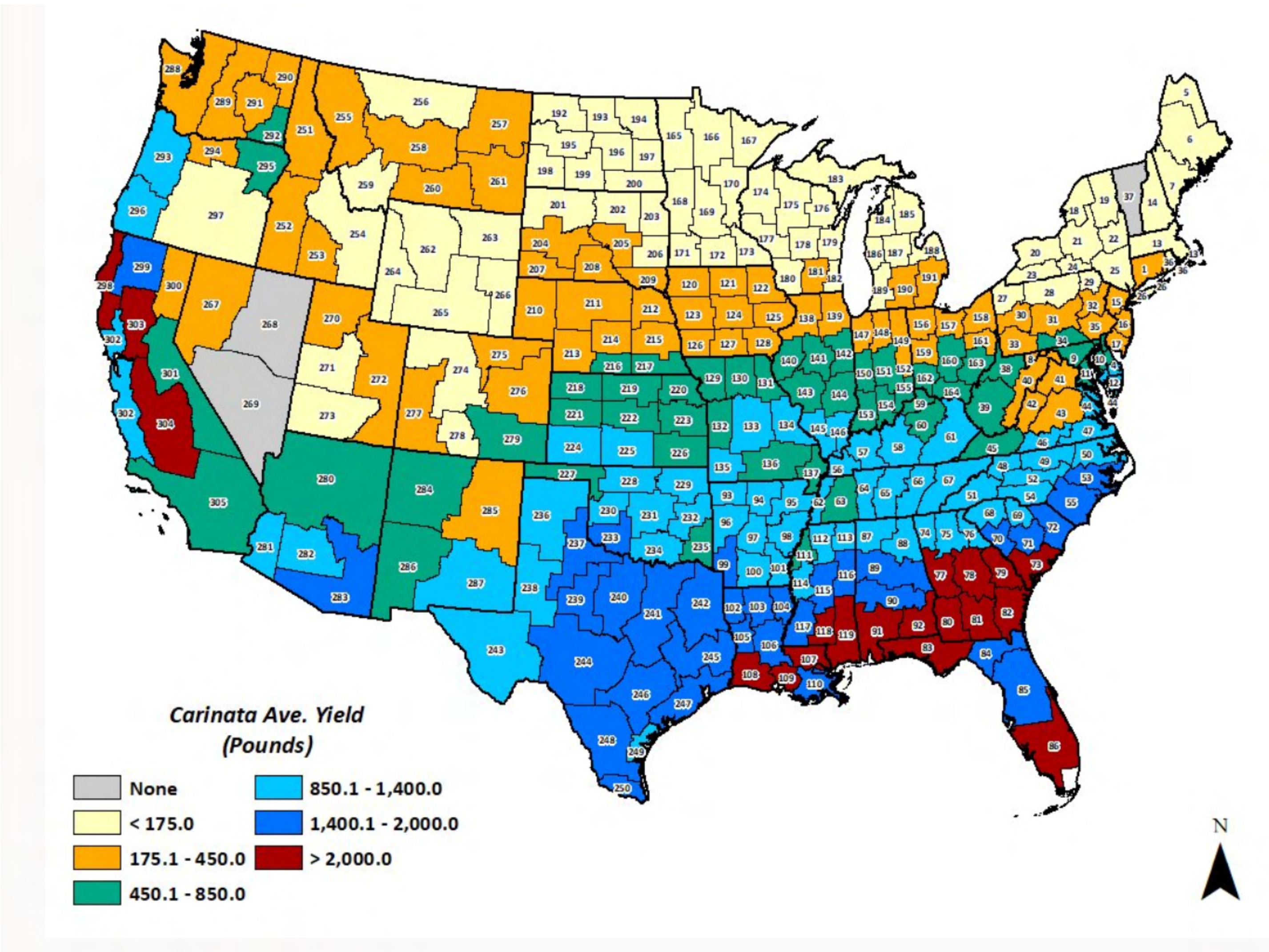

Figure 6. Yield map for carinata.

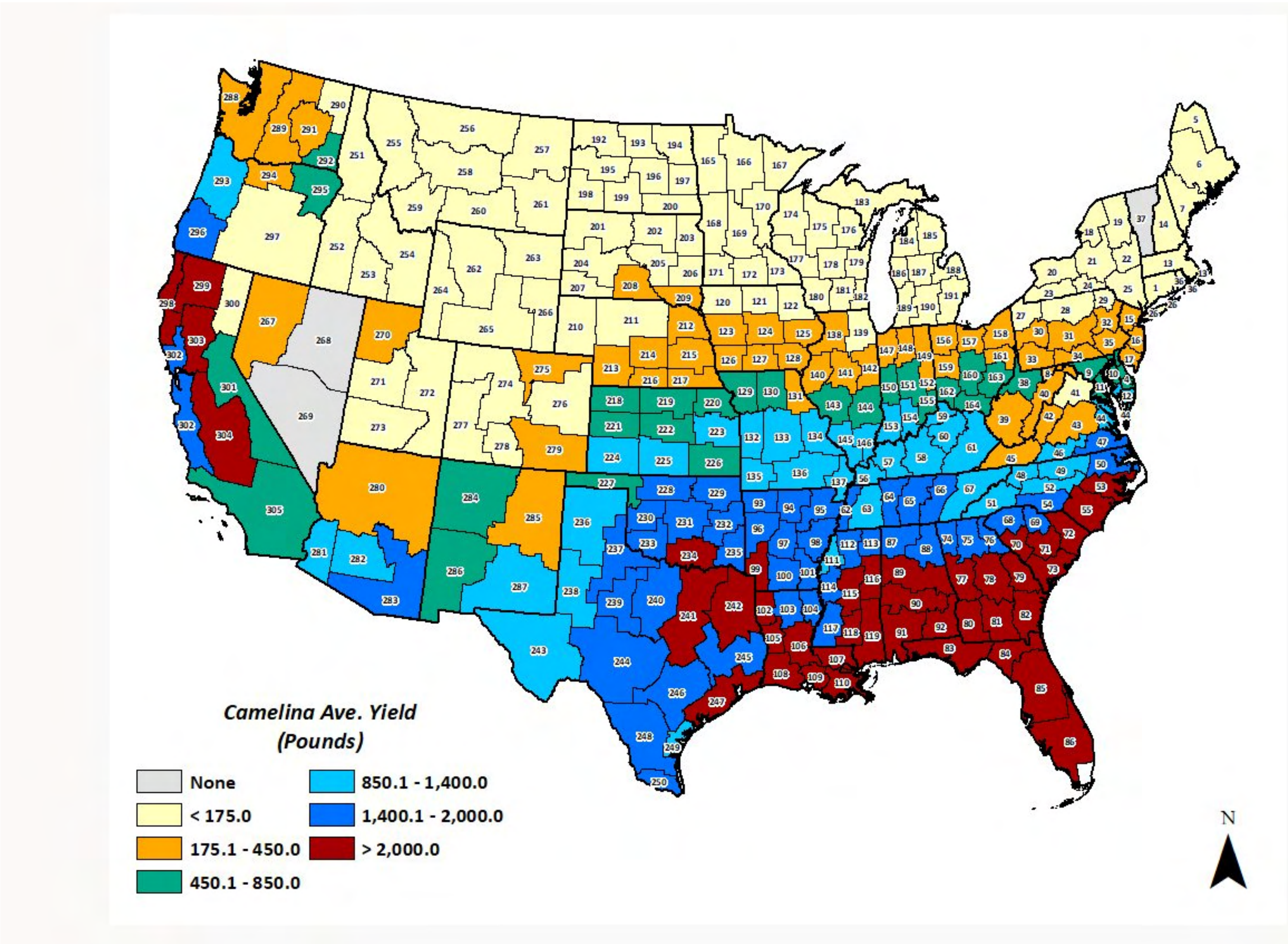

Figure 7. Yield map for camelina.

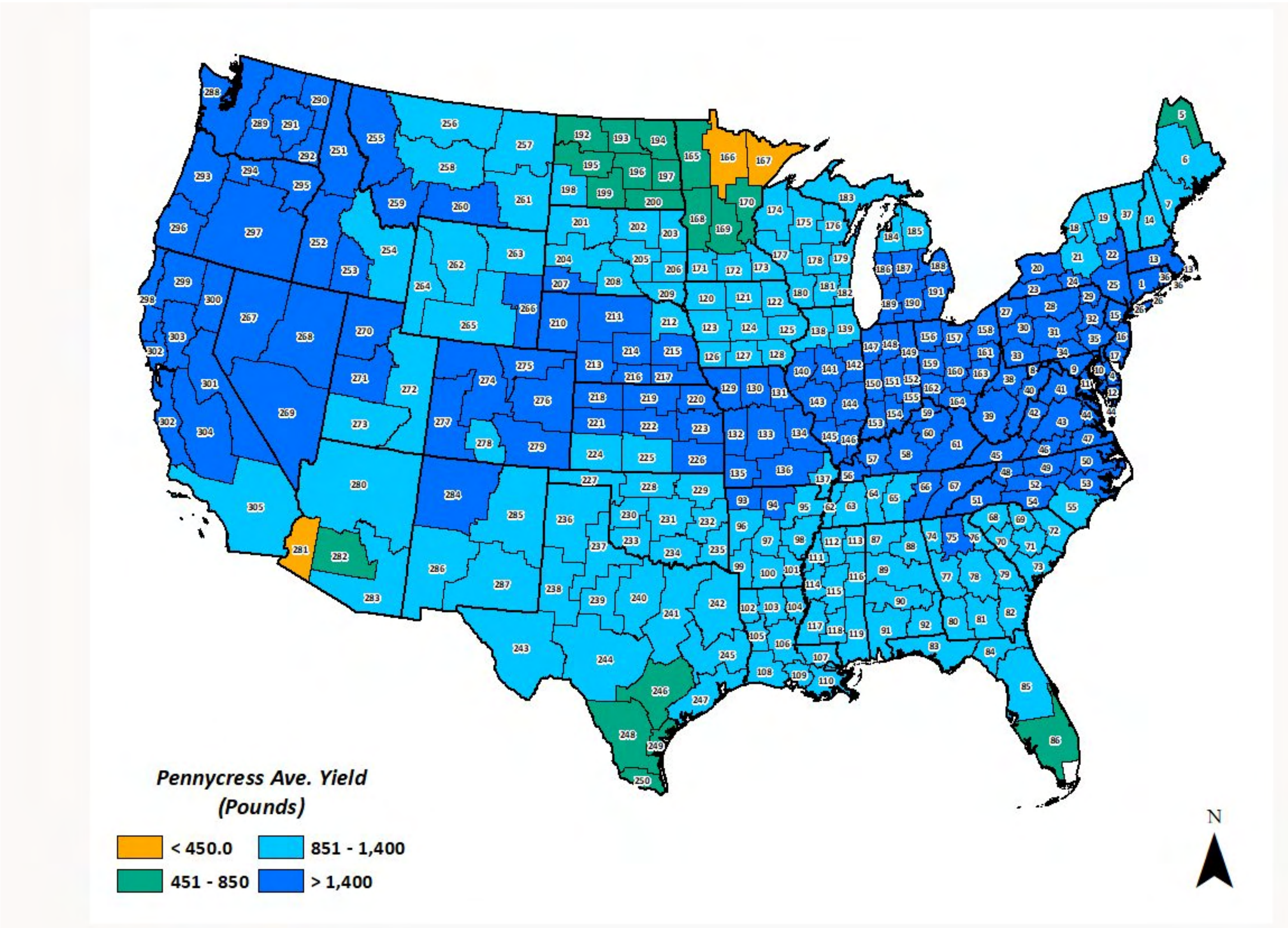

Figure 8. Yield map for pennycress.

Milestones

This project is behind because COVID-19 limited my access to POLYSYS. Although the planned article is not yet written, it is hoped that it will be included in a special issue of *Frontiers in Energy* that will feature the work of ASCENT Project 001. The article will address both feedstock and economic sustainability regarding oilseed cover crops.

Major Accomplishments

1. Consistent assumptions regarding prices of inputs were reviewed and budgets updated. POLYSIS was updated with the changes.
2. Completed the carinata spreadsheet incorporating risk into the analysis. The spreadsheet is still under review.
3. Compared the assumptions between the three oilseed crops and attempted to develop spreadsheets that contain similar price data and other assumptions.
4. Analysis has been run in POLYSYS assuming on-farm prices of $0.05 to $0.20 per pound. Supplies of the oilseed are estimated and impacts to the national and rural economies are being estimated.

Analysis indicates that without expanding to non-cropped lands, 93 million acres could be planted in a “three crop every two year” system (Table 1). This would produce 67 billion pounds of oilseed ranging from 0.32% to 0.4% oil. Assuming a hydroprocessed esters and fatty acids (HEFA) processing technology, this would result in 23,450,000,000 pounds of oil or10 million metric tons of oil per year. Using ASCENT technology spreadsheets, this would provide sufficient feedstock for 11 biorefineries to produce 1.58 billion gallons of SAF along with 632 million, 228 million, and 466 million gallons of diesel, naphtha, and propane, respectively, assuming an average oil content of 35%.

Table 1. Projected Oilseed Production at Farm-Gate Prices of $0.05 to $0.20 per Pound.

Farm-Gate Price ($/pound)	Acres	Production	Yield on 1/2 acre
0.05	34,242,819	25,223,413,311	736.6045
0.08	49,066,461	36,049,776,550	734.7132
0.11	69,156,754	50,008,883,134	723.1236
0.14	80,617,744	58,105,888,041	720.7581
0.17	87,921,175	63,546,048,466	722.7616
0.2	93,451,551	67,476,879,966	722.052

An initial draft of this study's findings is nearing completion.

Publications
See Task 1 above for publications.

Outreach Efforts
None.

Awards
None.

Student Involvement
Alan Robertson – examined the impact of fertilizer on switchgrass yield and ash content and evaluated at what level the biorefinery would like fertilizer application to occur.

Plans for Next Period
Complete national oilseed analysis

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

Objective(s)
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 U.S. and in Central Appalachia, leading to the development of SAF Regional Deployment Plans for the Southeast and Appalachia.

Research Approach
- Same as Task 1 but focused on small areas such as Central Appalachia, Memphis, and Nashville regions
- Softwood analysis is focused on the Southeast, and findings were provided in last year's report
- Developed seed trial for oilseed cover crops using funding from UT seed money; will incorporate findings in this report for the first year under sub-project 2

Central Appalachia – second year of a several-year project
The project was initiated when COVID-19 hit; the project was rearranged to reflect laboratory closures and travel restrictions.

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

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

The following represents a summary of the work accomplishments under the subcontract with the Center for Natural Capital to assist in the Central Appalachia area. Item 8 has been canceled because of the funding decrease for 2021-2022. In addition, the Center continues to play an active and vital role in the stakeholders' 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 expert advisory board
    a. Develop invitee list of potential advisory board members
    b. Hold Zoom calls and get input on 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 consultant with significant experience in airline industry fuels
4. A stakeholder cabinet will be assembled.
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 Virginia Tech assistance and collect samples. Cut pieces of hybrid poplar and return them to Rapidan, Virginia, for processing into chips. Samples acquired, processed, and delivered to UT.
    a. Procure and deliver 110 pounds of hybrid poplar tree trunks only (without stems and leaves) from Powell Project Travel to Powell River Project with Virginia Tech assistance and collect samples.
    b. Cut boles of hybrid poplar and return them to Rapidan, Virginia.
    c. Samples acquired, processed, and delivered to UT.
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. Some participants of the group have formed a task force to prepare proposals to fund follow-on work. 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. Considerable effort has been made to reach out to other related projects in the region. The most notable is the MASBIO project based at West Virginia University. The MASBIO leadership took the lead on a proposal to the U.S. Department of Commerce.

The hybrid poplar samples were evaluated by the UT BEST lab headed by Niki Labbe. In concert with a hardwood National Institute for Food and Agriculture (NIFA) project, the lab was to characterize feedstock performance and conversion potential of Central Appalachia region hardwood forest thinnings, harvest residuals, and SRWCs from university experimental plots and reclaimed surface mine lands, and the invasive species that have colonized formerly mined lands and define their locations and costs. This was accomplished by collecting hardwood residue biomass from various locations and preprocessing (drying and size reduction) for near-infrared data collection and wet chemistry analysis.

In total, 71 chipped hybrid poplar biomass samples were collected from two sites at the Powell River Project plantings on reclaimed mine land in Appalachian regions with GPS locations at 37.01557/−82.6606, and 37.00776/−82.6942. After milling the biomass materials, quality data were assessed by measuring their ash content. The ash content ranged from

1.53% to 4.41% with a mean of 2.4% (± 0.6) on an oven dry basis (Figure 9). In addition, near-infrared (NIR) spectroscopy was used to obtain a chemical fingerprint of the materials, and a model for ash was constructed by correlating the NIR spectral data with the ash content using partial least squares regression. Table 2 shows the model performance metrics for ash with a correlation of 0.67.

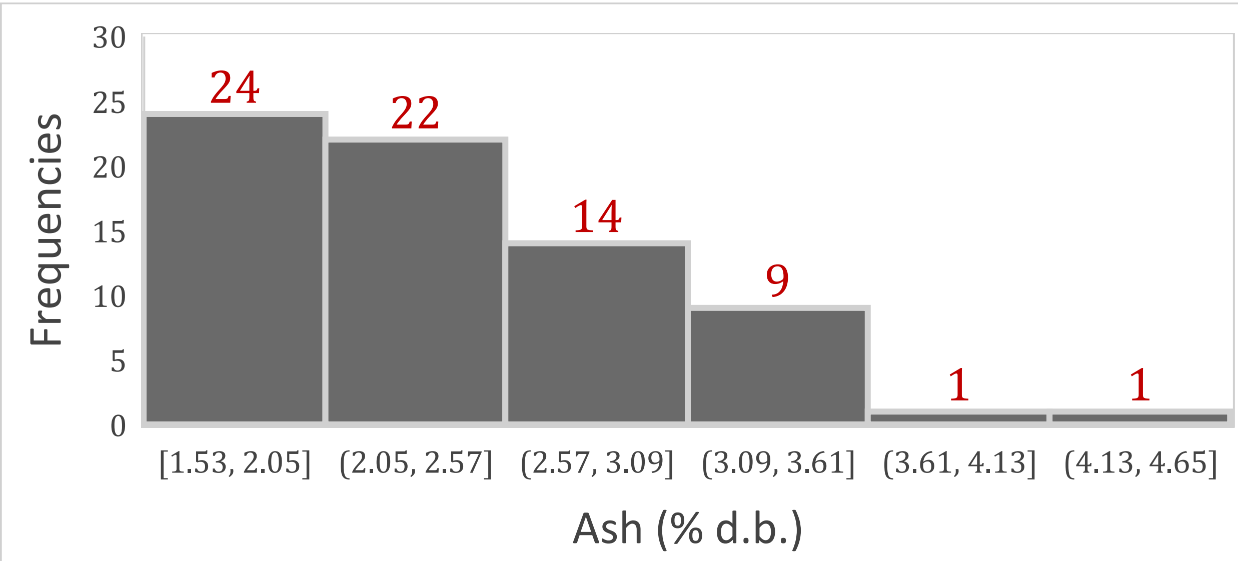

Figure 9. Percent ash (dried basis) distribution for 71 ASCENT samples.

Table 2. Near-infrared model performance metrics for 71 ASCENT samples (on dry basis).

Model	**N**	**Range (%)**	**Factors**	**$RMSE_{Cal}$ (%)**	**R^2_{Cal}**	**$RMSEC_{Val}$ (%)**	**R^2_{Val}**
Ash	71	1.53-4.41	3	0.31	0.75	0.33	0.72
N = number of samples included in the models. $RMSE_{Cal}$ = root mean square error of calibration. R^2_{Cal} =Coefficient of variation $RMSEC_{Val}$ = root mean square error of cross validation. R^2_{Val} = Coefficient of variation							

To improve the ash model, we selected 200 hardwood residue samples from our biomass library and reconstructed the NIR model for ash (Figure 10). The biomass materials were collected from commercial sites located in Alabama, Florida, Georgia, South Carolina, Tennessee, and Virginia, primarily collected for analysis required by an Agriculture and Food Research Initiative (AFRI) project. In addition to ash, inorganics (alkali and alkaline earth metals combined [Na, K, Mg, and Ca]; AAEM) and higher heating values (HHV) models were constructed by correlating these characteristics to the corresponding NIR spectral data using partial least squares regression. Table 3 summarizes the performance of the developed models. The AAEM and HHV data for the ASCENT samples will be included in the models as soon as the data become available. The robustness of these models will be improved by including the ASCENT samples, which will expand the range of the properties of interest.

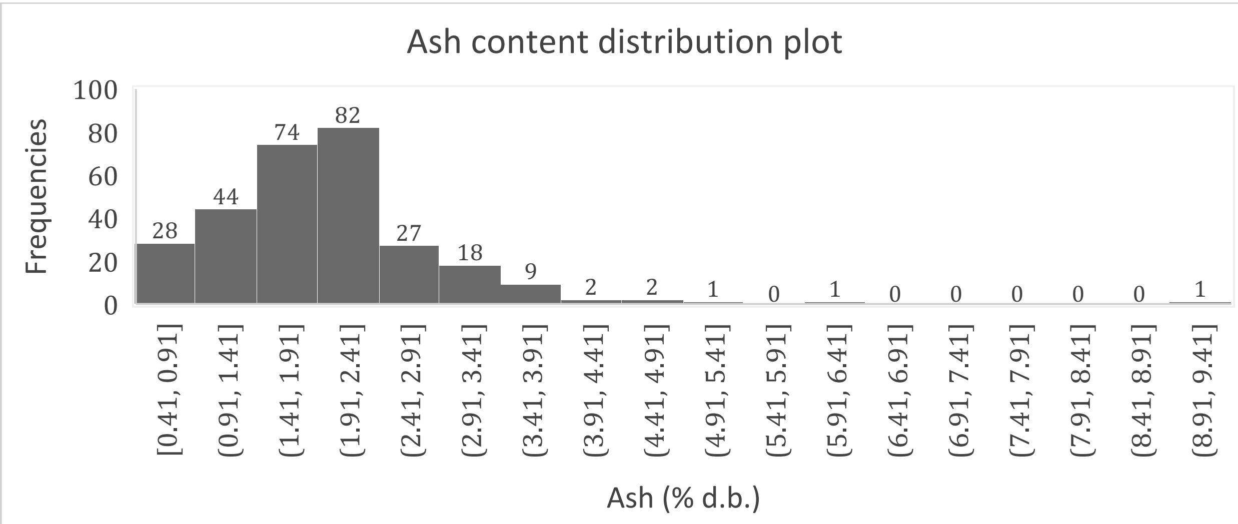

Figure 10. Distribution plot for 289 hardwood samples collected from the Southeast United States.

Table 3. Near-infrared model performance metrics for all hardwood residues from the Southeast United States.

Model	N	Range	Factors	$RMSE_{Cal}$	R^2_{Cal}	$RMSEC_{Val}$	R^2_{Val}
Ash (%)	268	0.41–4.75	6	0.34	0.79	0.37	0.75
AAEM (mg/kg)	185	1,594–18,062	9	1,052	0.89	1,185	0.86
HHV (MJ/kg)	179	19.04–20.29	8	0.10	0.81	0.11	0.77

N = number of samples included in the models.
AAEM = alkali and alkaline earth metals combined (Na, K, Mg, and Ca).
HHV = higher heating value.
$RMSE_{Cal}$ = root mean square error of calibration.
$RMSEC_{Val}$ = root mean square error of cross validation.

Major Accomplishments

- The Nashville modeling work using cover crop oilseeds is completed. The next step will be to develop a regional deployment plan once risk and uncertainty are evaluated.
- The Memphis modeling work is initiated but analysis has not begun. Analysis will be initiated during the second quarter of 2022.
- The Central Appalachian Project has a regular stakeholders group meeting and will have its initial workshop on state and national incentives to SAF development in the region. This workshop will be online.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement
None.

Plans for Next Period (Year)
- Complete Central Appalachian Regional Deployment Plan
- Complete Nashville Regional Deployment Plan
- Continue working on Southeast Regional Deployment Plan
- Continue working on 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
Provide necessary input through research efforts using feedstock tools developed before or as part of this project. Approach will differ as questions surface from other universities. We have had two requests, which were met this year: a request from Penn State on the cost of feedstock production and from FTOT asking 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 Hawaii feedstock and conversion effort.

Milestone
Delivered the feedstock spreadsheets on oilseeds.

Major Accomplishments
See Tasks 1 and 3 above.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period (Year)
- Complete FTOT-BioFLAME comparison findings
- Enhance economic indicator analysis