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: 11712069
- Period of Performance: [August 1, 2017 to September, 30, 2018
- Task(s):
  - Task 1.1: Assess and inventory regional forest and agricultural biomass feedstock options.
  - Task 1.2: Delineate the sustainability impacts associated with various feedstock choices including land use effects.
  - Task 3: Lay the groundwork for lipid and/or biomass in TN & Southeast U.S.
  - Task 4: Biorefinery Infrastructure and Siting (Supporting Role).

Project Funding Level

Total 4-year funding/This year funding
Total Estimated Project Funding: $404,056/$225,000
Total Federal and Non-Federal Funds: $808,112/$450,000
Faculty salary was provided by The University of Tennessee, Institute of Agriculture, in support of the project.

Investigation Team

- Tim Rials – Project Director(s)/Principal Investigator (PD/PI)
- Burton English – Co-Principal Investigator (Co PD/PI)
- Chris Clark – Faculty
- Lixia He – Other Professional
- Kim Jensen – Faculty
- Dayton Lambert – Faculty
- Jim Larson – Faculty
- Ed Yu – Faculty
- Evan Markel – Graduate Student
- Katryn Pasaribu – Graduate Student
- Umama Rahman – Masters Graduate Student
- Bijay Sharma – Graduate Student
- McKenzie Thomas – Masters Graduate Student
- Ming-Jou Tsai – Maters Graduate Student

Project Overview

The University of Tennessee 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 University of Tennessee will lead the national lipid supply availability analysis employing 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, The University of Tennessee 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.

Finally, through a structured workshop, the University of Tennessee will garner stakeholder input on supply chain challenges as well as provide a forum for interdisciplinary dialogue and problem solving for alternative aviation fuels. The University of Tennessee is committed to hosting this workshop in early 2019 in Knoxville, TN. There has been valuable discussion of CAAFI perspectives and information needs, and aviation industry stakeholders have already been contacted for workshop input.

Major goals included:

1. Develop a rotation based oil seed crop scenario and evaluate potential with POLYSYS
2. Develop database on infrastructure and needs for Southeast
3. Organize and convene workshop on the alternative jet fuel supply chain for southeastern stakeholders
4. Initiate aviation fuel supply chain study in the southeast
5. Continue with sustainability work for both goals 1 and 4

Task 1.1- Assess and Inventory Regional Forest and Agricultural Biomass Feedstock Options

University of Tennessee

Objective(s)

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 opportunity cost of converting the current agricultural lands to LCB feedstocks production will be estimated. In addition, the production, harvest, storage and transportation 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:

- **Oilseed crops:**
  - Mustard/Crambe (*Sinapsis alba/Crambe abyssinicia*)
  - Pennycress (*Thlaspi arvense*)
  - Rapeseed/Canola (*Brassica napus/B. campestris*)
  - Safflower (*Carthamus tinctorius*)
  - Sunflower (*Helianthus spp.*)
  - Soybean (*Glycine max*);
  - Camelina (*Camelina sativa*)
  - Carinata
- **Perennial grasses**:
  - Switchgrass (*Panicum virgatum*)
  - Miscanthus (*Miscanthus sinensis*)
  - Energy Cane (*Saccharum complex*)
- **Short-rotation woody crops**:
  - Poplar (*Populus species*)
  - Willow (*Salix species*)
  - Loblolly pine (*Pinus taeda*)
  - Sweetgum (*Liquidambar styraciflua*)

  - Sycamore (*Plantanus occidentalis*)
- **Agricultural residue**:
  - Wheat straw
  - Corn stover
- **Forest residue**:
  - Logging and Processing Residue

POLYSYS will be used to estimate and assess the supply and availability of these feedstock options at regional and national levels. This U.S. agricultural sector model forecasts changes in commodity prices and net farm income over time.

County level estimates of all-live total woody biomass, as well as average annual growth, removals, and mortality will be obtained from the Forest Inventory and Analysis Database (FIADB). Mill residue data will be obtained from the USFS FIA Timber Product Output (TPO) data. The ForSEAM model will be used to estimate and predict logging residues. ForSEAM uses U.S. Forest Service FIA data to project timber supply based on USGPM demand projections. Specific tasks related to this objective are outlined below. These supply curves will be placed in POLYSYS and estimates into the future will be made.

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

0.1 Complete the economic viability analysis on switchgrass, short rotation woody crops, crop residues, forest residues, and cover crops to assist team with theme 1.3

1.3 Assist Risk-Reward Profit Sharing modeling by providing information from past work on cellulosic supply chains to PSU

1.4.1 Assist PSU in the National Survey of current and proposed programs that incentivize ecosystem services

1.4.2 Finish environmental impact analysis for the fore-mentioned crops looking at soil, water, greenhouse gas emissions and sequestration, and direct land use change

Research Approach

1. Using an existing model, POLYSYS, the price for a commodity or annual demands for feedstock are exogenously determined and placed into the model. For this year, analysis was conducted for a model cover crop – pennycress, an oil feedstock. A solution was generated that estimated the supply curve that pennycress might take ranging from \$0.00 to \$0.50 per pound. The feedstock streams were placed in ASCENT 1's Database. It was presented twice before the ASCENT 1 research team.
2. Completed the development of camelina and carinata budgets.
3. Added cover crops camelina and carinata to the potential feedstock candidates list and developed fact sheets for these crops. Yields for camelina have been developed as a cover crop in most of the U.S. and as a spring crop in the Pacific NW.
4. Estimated the Standard deviation and mean and initiated a stochastic spreadsheet analysis of camelina.
5. Contacted Temple Texas for assistance in developing carinata yields using EPIC. This is ongoing.
6. Conducted an POLYSYS analysis on Camelina with the flow as indicated in Figure 1.1. This is written up in a defended thesis and will be further developed as a journal article.

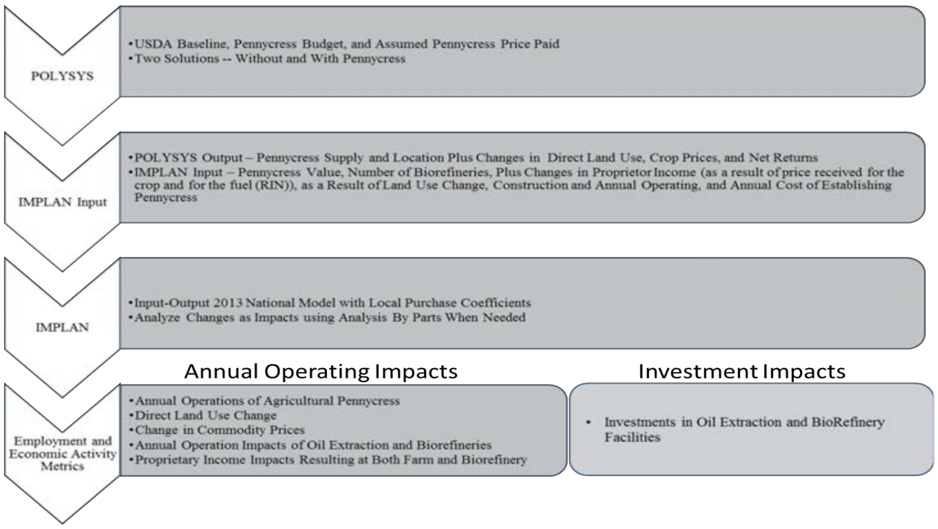

Figure 1.1. Approach to estimate economic impacts of using camelina as a biofuels feedstock.

New Findings

- Camelina has the potential to supply both oil and biomass to the biofuels market.
- Camelina, like pennycress, is a winter crop that is typically planted in September and harvested the following May.
- It can be planted after corn harvest and be harvested before soybeans are planted.
- Following harvest, seed crushing and pre-processing, camelina offers a suitable oil to allow conversion to a Hydro-processed Ester and Fatty Acid (HEFA) fuel. Camelina budget presented in Table 1.1, Table 1.2, and Table 1.3. Carinata costs under review. Table 1.1 indicates that if you receive $0.28 per pound of seed, total revenue could be equal to $293/acre at a cost of $123 per acre in variable costs and $33 per acre in fixed costs, yielding a per acre profit of $137 per acre.
- Tornado diagram developed and breakeven table generated (Figure 1.2). The diagram was developed by changing the variable of interest by + or – 20%. Findings indicate that price and yields impact profitability more than any other variable ranging from $80 to $200 per acre. Breakeven prices were estimated and displayed in Table 1.2 and range from $0.07 per pound at high yields and $0.27 per pound at low yields.
- Camelina supply curve generated. A spatial Camelina yield supply curve was estimated by EPIC. The supply curve indicates that sufficient Camelina feedstock would be generated to produce 450 million gallons if the feedstock price was $0.20 per pound (Figure 1.3).

Table 1.1. 2018 Field Camelina

	Unit	Quantity	Price	Total
Revenue			**Gross Revenue ($/Acre)**	
Camelina	lbs	1050	$0.28	$293.15
		Total Revenue	**$293.15**	
Variable Expenses				
Seed	lbs	5	$2.00	$10.00
Fertilizer	Acre	1	$45.30	$45.30
Chemical	Acre	1	$27.50	$27.50
Repair & Maintenance	Acre	1	$11.76	$11.76
Fuel, Oil & Filter	Acre	1	$8.50	$8.50
Operator Labor	Acre	1	$5.95	$5.95
Machinery Cost Broadcast Planting	Acre	1	$13.40	$13.40
Crop Insurance	Acre	1	$0.00	$0.00
Operating Interest [7]	Acre	1	$0.90	$0.90
Other Variable Costs	Acre	1	$0.00	$0.00
		Total Variable Expenses	**$123.31**	
		Return Above Variable Expenses	**$169.84**	
Fixed Expenses				
Machinery				
Capital Recovery	Acre	1	$27.08	$27.08
Other Fixed Machinery Costs	Acre	1	$0.00	$0.00
Taxes, Housing & Insurance	Acre	1	$5.96	$5.96
Other Fixed Costs	Acre	1	$0.00	$0.00
		Total Fixed Expenses	**$33.04**	
Return Above All Specified Expenses			**$136.80**	

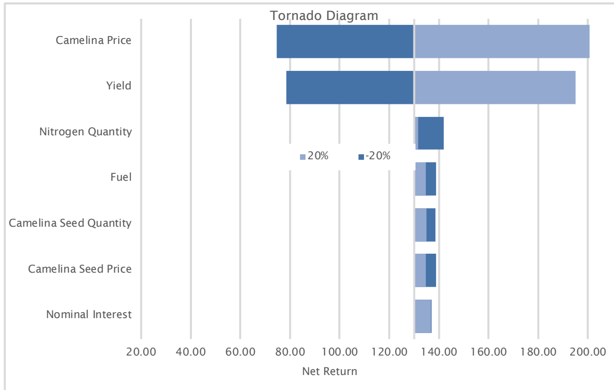

Figure 1.2. Camelina Tornado Diagram

Table 1.2. Breakeven Price for Selected Yield

Yield (lbs.)	Variable Cost ($/lbs.)	Total Specified Cost ($/lbs.)
450	$0.27	$0.35
600	$0.21	$0.26
750	$0.16	$0.21
900	$0.14	$0.17
1050	**$0.12**	**$0.15**
1200	$0.10	$0.13
1350	$0.09	$0.12
1500	$0.08	$0.10
1650	$0.07	$0.09

Table 1.3. Breakeven Yield for Selected Price

Price ($/lbs.)	Variable Cost (lbs./acre)	Total Specified Cost (lbs./acre)
$0.18	688	873
$0.20	604	766
$0.23	538	682
$0.25	485	615
$0.28	**442**	**560**
$0.30	405	514
$0.33	375	475
$0.35	348	441
$0.38	325	412

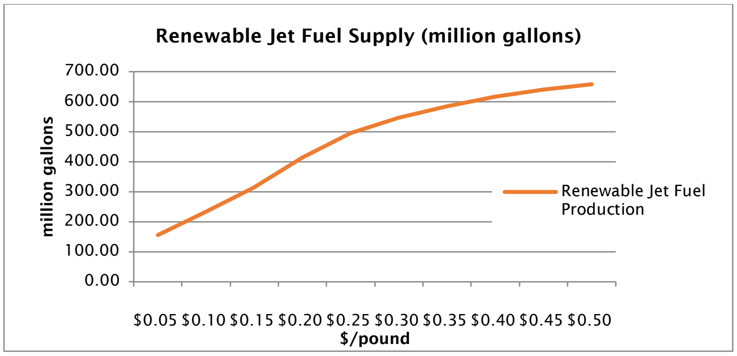

Figure 1-3. Renewable Jet fuel supply curve generated using POLYSYS assuming ASCENT HEFA conversion process

Milestone(s)

- Generated data passed on to ASCENT 01 database for camelina feedstock.
- Camelina pathway developed.
- Other cover crops costs have been derived and under review.
- Delivered pennycress and crush facility spreadsheet to PSU for use in Risk reward profit sharing modeling.

Major Accomplishments

1. Journal Article on pennycress stemming from Evan Markel's dissertation published.
2. Developed two posters examining impacts of feedstock risk.
3. Evaluated the impact of BCAP on cellulosic feedstock risk
4. Developed economic multipliers for:
   - FT-SPK; Feedstock - Conversion temp. - 1200~1600 deg. C; Product - jet and naphtha; I have an excel model of economic analysis
   - ATJ-SPK; Feedstock - yeast biocatalyst converts purified sugar to **ethanol**, followed by oligomerization and hydrogenation; Product - jet fuel.

Publications

Evan Markel, Burton C. English, Chad Hellwinckel, R. Jamey Menard (2018) Potential for Pennycress to Support a Renewable Jet Fuel Industry. in Ecology, Pollution and Environmental Science, *SciEnvironm* 1:121 accessed at http://hendun.org/journals/EEO/EEO-121.php.

Outreach Efforts

None

Awards

None

Student Involvement

We have had a PhD student, Evan Markel, working on this project. He gathered information on Pennycress and developed an analysis looking at pennycress as a feedstock. Another Ph.D. student, Katryn Pasaribu, along with a Masters student, Umama Rahman, worked on the cover crop spreadsheets, and Bijay Sharma worked on risk analysis.

Plans for Next Period

Complete cover crop analysis for feedstock costs and yields. Develop POLYSYS analysis for both camelina, carinata, and winter rye. Upload information gained into Box. Present material on Webinar in March or April.

Task 1.2- Delineate the Sustainability Impacts Associated with Various Feedstock Choices Including Land Use Effects

University of Tennessee

Objective(s)

Environmental Sustainability – Regarding environmental sustainability, the impacts associated with lignocellulosic biomass (LCB) feedstock production, such as greenhouse gas (GHG) flux and soil erosion are estimated based on local geographic characteristics. The GHG flux related to land use change and LCB feedstock production is analyzed using the POLYSYS model. Different agricultural land use systems have varied effects on soil erosion or soil loss. The impact on soil erosion from different LCB feedstock productions is simulated with the Universal Soil Loss Equation and the 1997 NRI data base.

Economic/Social Sustainability – The IO analysis provides estimates of output, employment and income multipliers, which measure the response of the economy to a change in demand or production[9, 22]. The economic multipliers measure the indirect and induced effects of a change in final demand (direct effects) for a particular industry (for example, the introduction of biorefineries and preprocessing facilities in a region). The indirect effects are the secondary effects or production changes when input demands change due to the impact of the directly-affected industry (for example, construction sector, agriculture producers, and transportation sectors). The induced effects represent the response by all local industries caused by changes in expenditures by households and inter-institutional transfers generated from the direct and indirect effects of the change in final demand. Projections of changes in jobs (job creation), economic activity, The FT-SPK and ATJ-SPK multipliers have been estimated for the entire 48 contiguous states and maps developed that will allow estimation of the economic impacts of the direct investment and operating transactions to be reflected in the economic impacts of a given area within the country. The model regions are the 187 Bureau of Economic Analysis (BEA) regions in the country. This was completed and information available for Total Industry Output, Value Added, and Employment.

Research Approach

Develop impact analysis for economic and environmental parameters.

New Findings

IO Analysis

For the ASCENT TEA's developed by WSU, estimate the impacts for Total Industry Output, Value Added, and Employment. Using the Bureau of Economic Analysis (BEA) regions (Figure 1.4), develop a spatial surface of the multipliers for three indicators for both investment (one time) impacts and annual operating impacts. These impacts have been developed for the conversion facility, feedstocks, land use change, proprietor income and transportation for alcohol to jet, Fast Pyrolysis, and HEFA pathways. Economic Impacts result from changes in agricultural operations from feedstock establishment, profit, land use change, and commodity price change; investment changes in preprocessing and conversion facilities from investment expenditures, salaries and wages; transportation; and from annual operations of preprocessing and conversion facilities including operation expenditures, profit/loss including the value of the RIN less the value of the transfer payment that occurred as a result of the RIN transfer, and salaries and wages. Below are examples of these spatially-oriented economic impact layers (SEIL) that were developed for a single facility located in a particular BEA for investment (Figure 1.5-1.7) and annual operating transactions (Figures 1.8-1.10) as well as employment impacts (Figures 1.11-1.16).

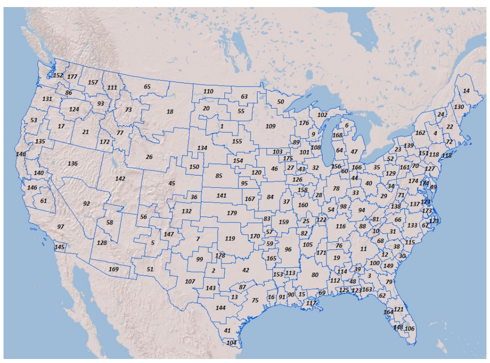

Figure 1.4. Bureau of Economic Administration trading areas

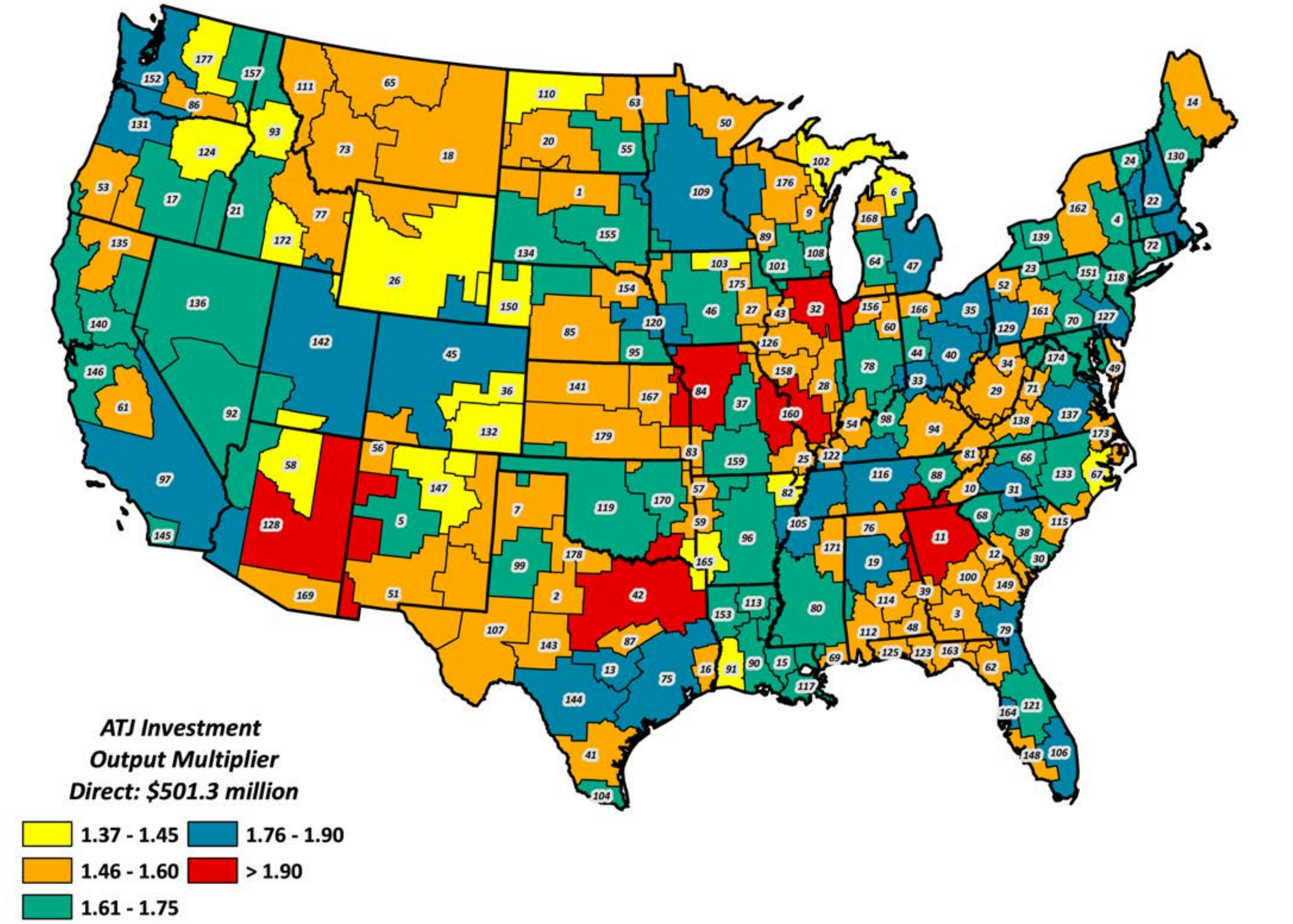

Figure 1.5. Economic impacts from investing in a single alcohol to jet (ATJ) facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

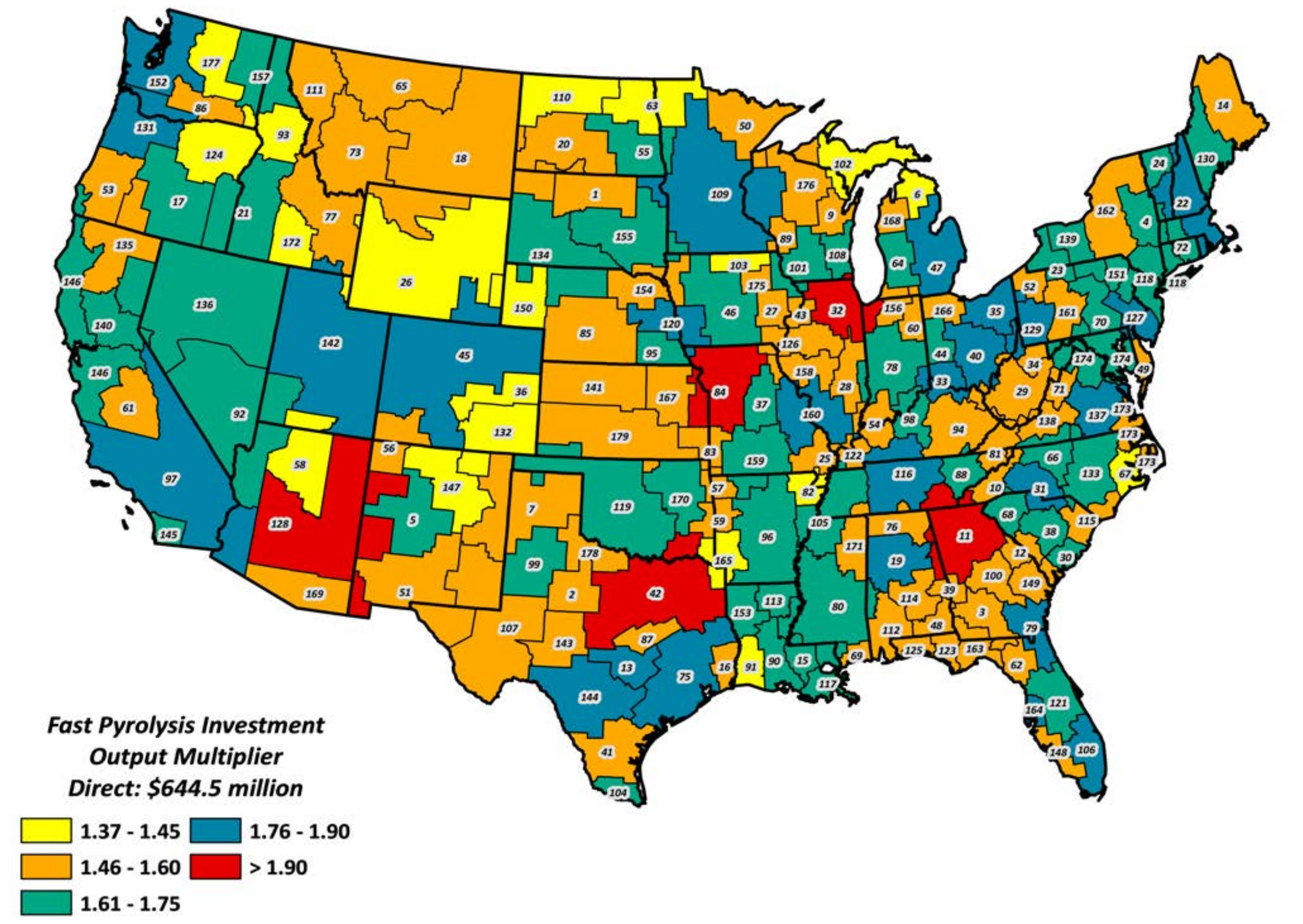

Figure 1.6. Economic impacts from investing in a single fast pyrolysis facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

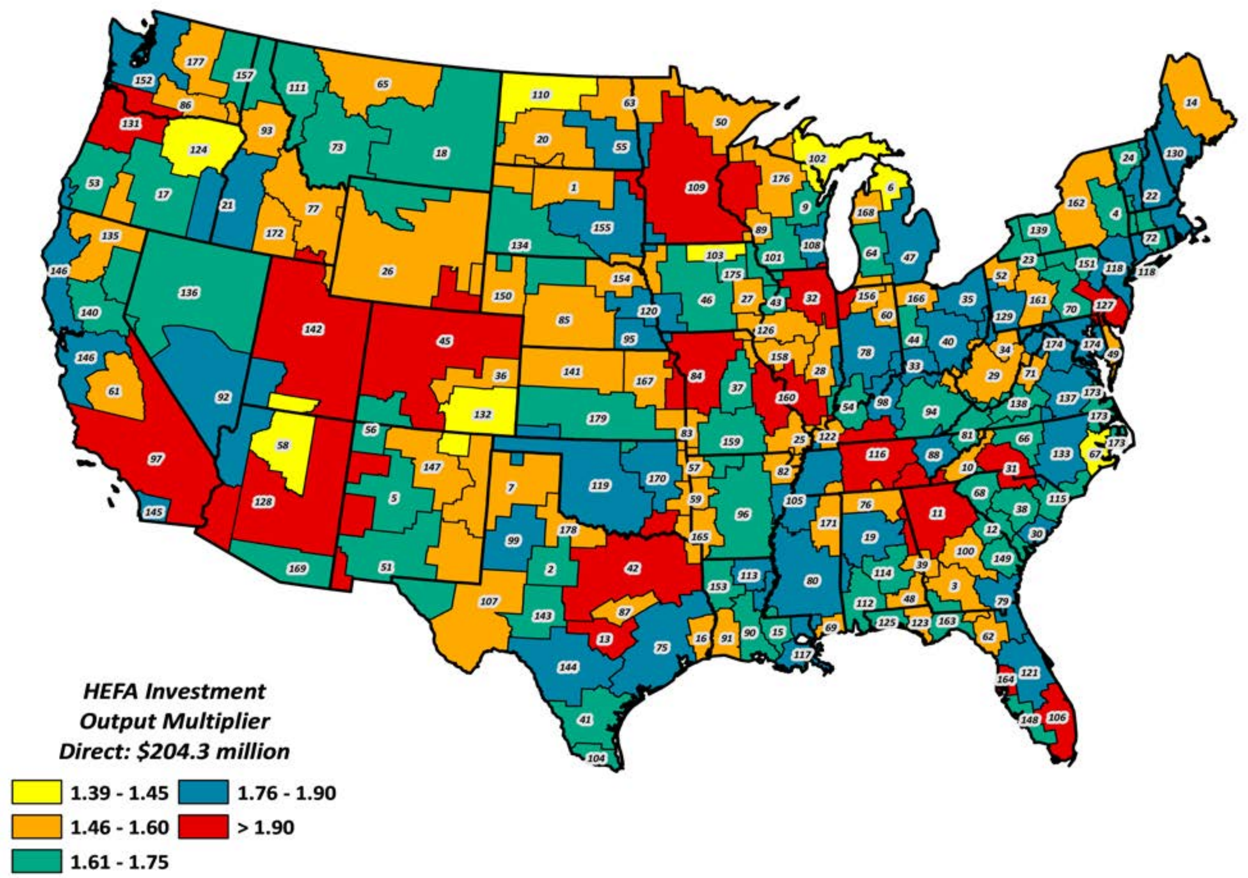

Figure 1.7. Economic impacts from investing in a single HEFA facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

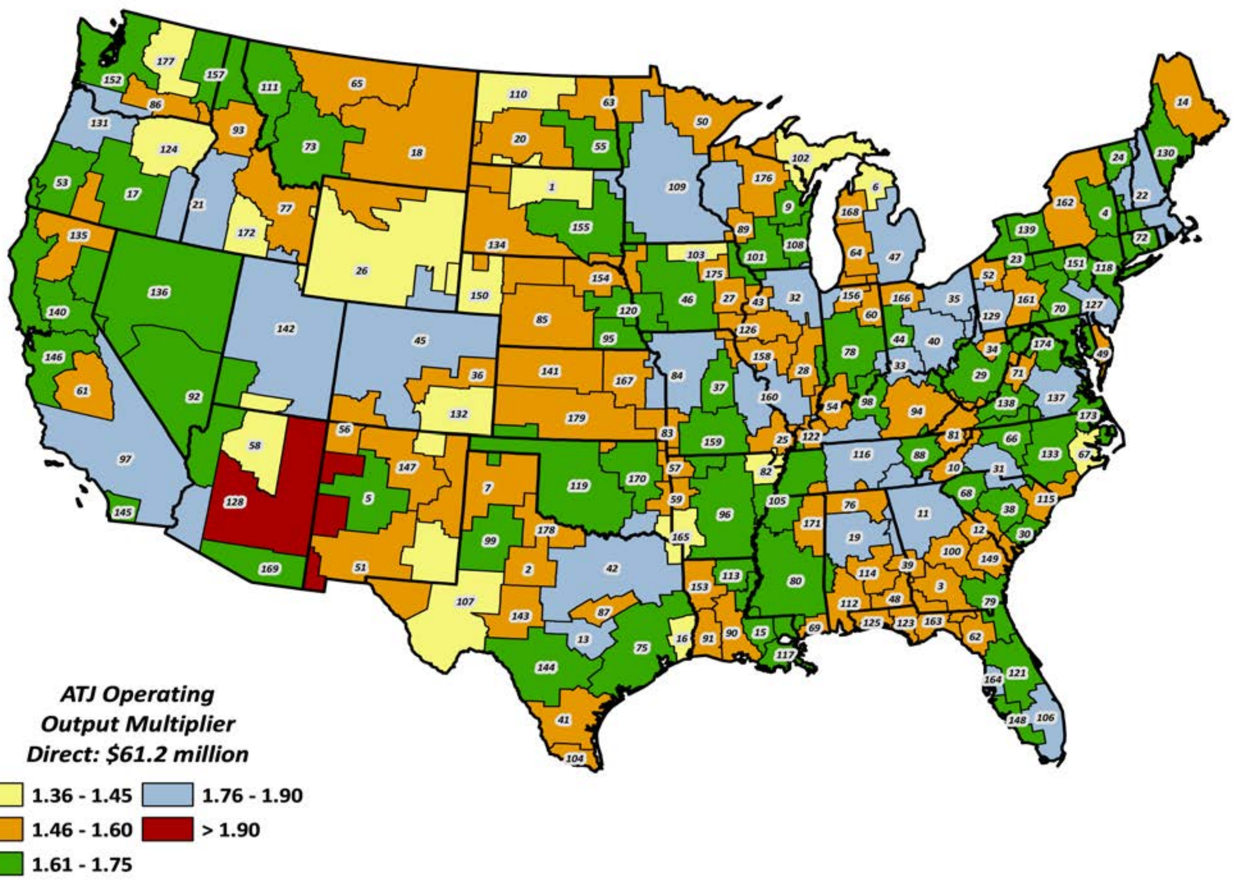

Figure 1.8. Annual Economic impacts from operating a single alcohol to jet (ATJ) facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

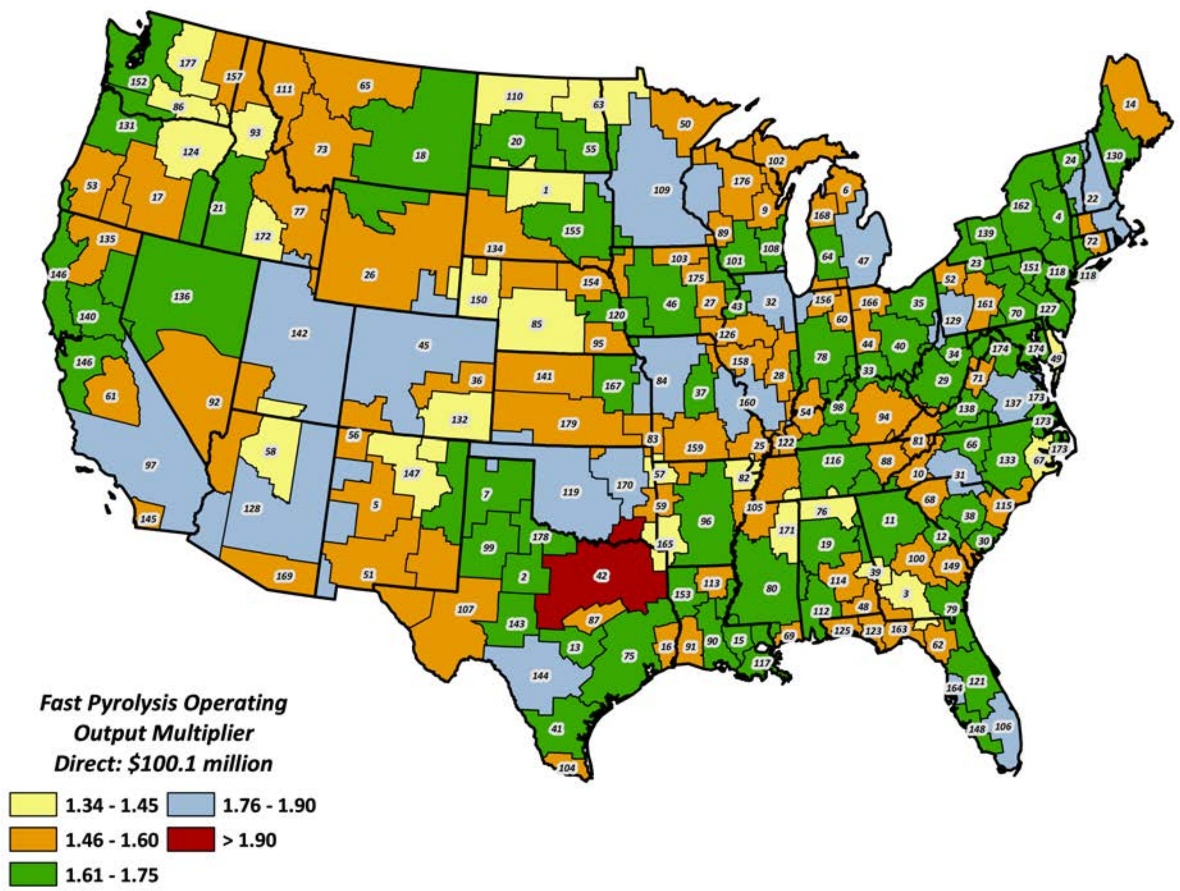

Figure 1.9. Annual Economic impacts from operating a single fast pyrolysis facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

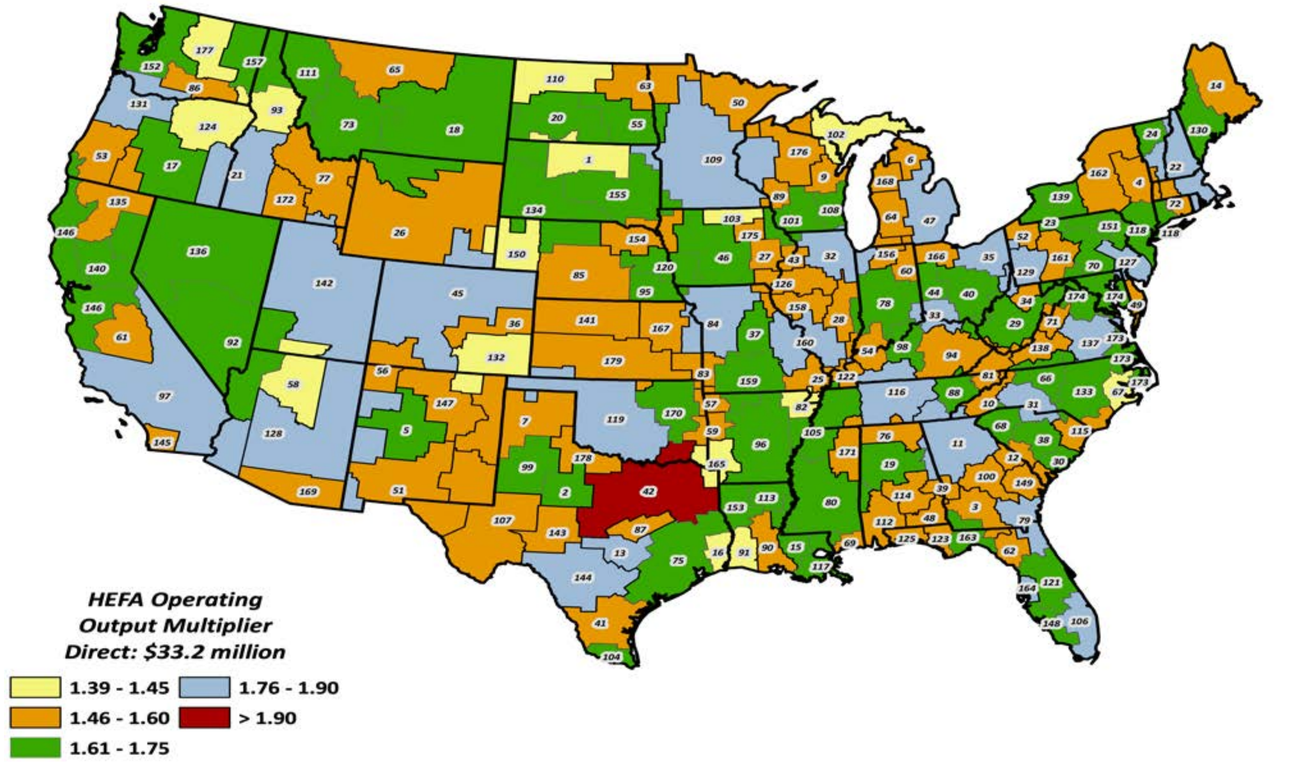

Figure 1.10. Annual Economic impacts from operating a single HEFA facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

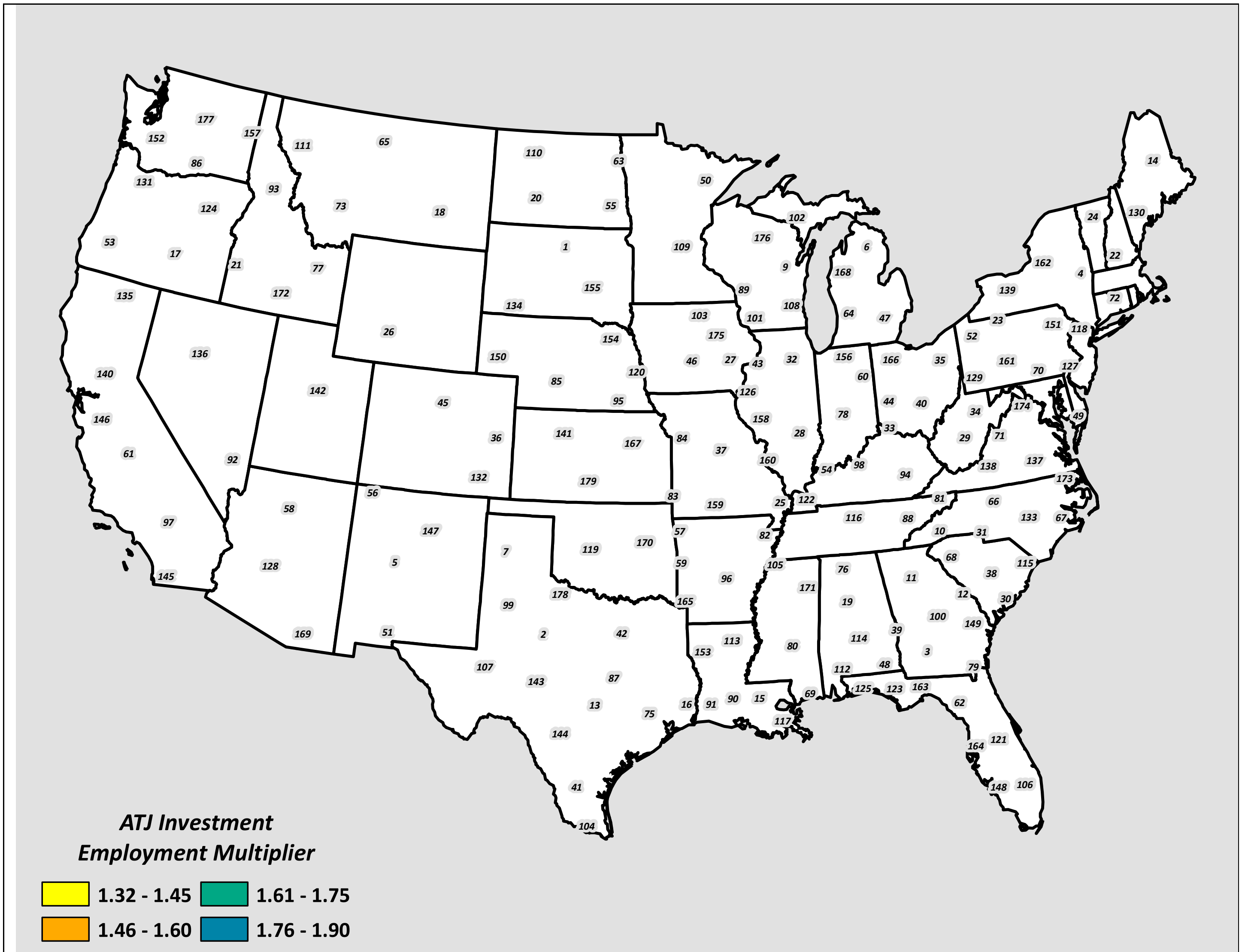

Figure 1.11. Employment impacts from constructing a single alcohol to jet (ATJ) facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

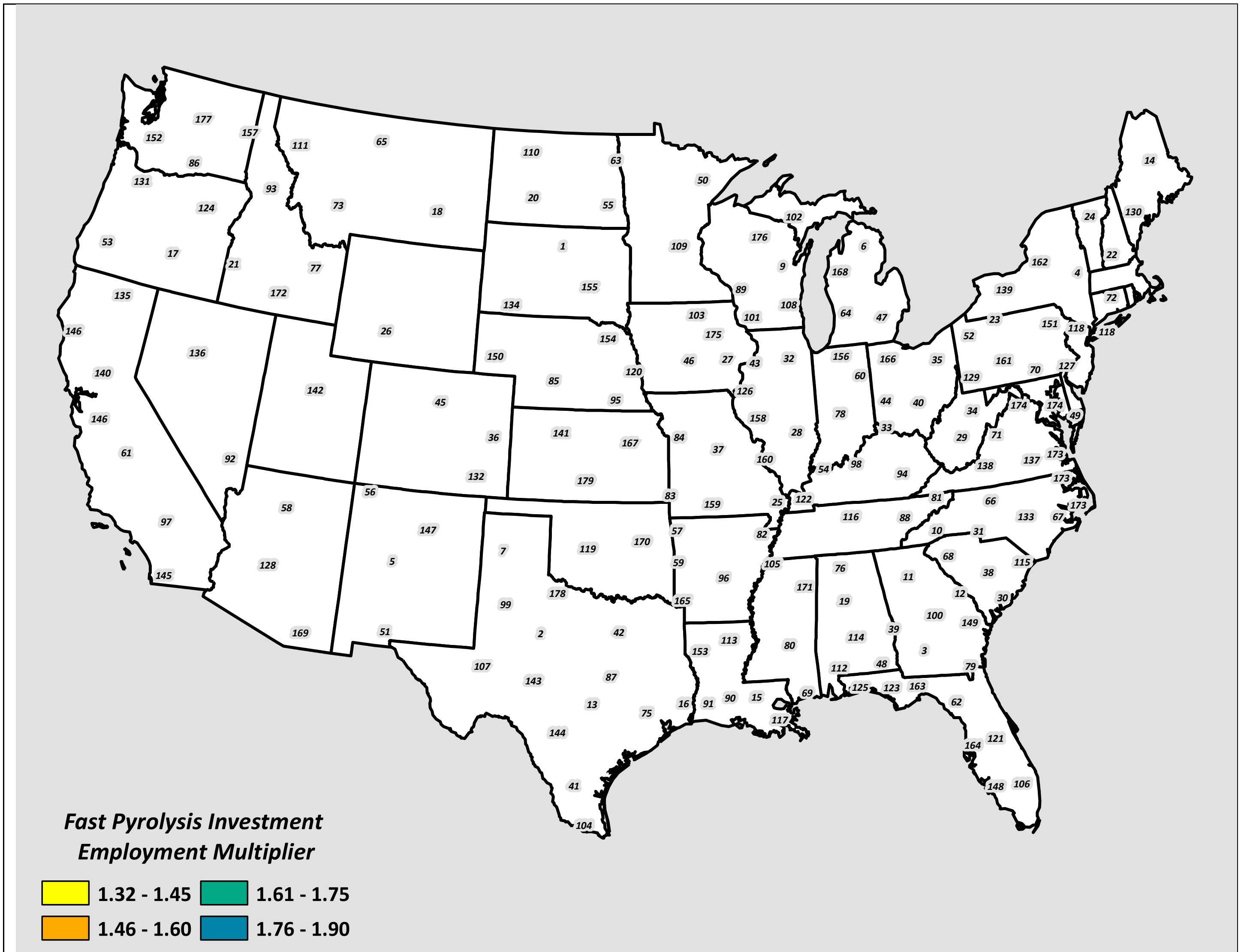

Figure 1.12. Employment impacts from constructing a single fast pyrolysis facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

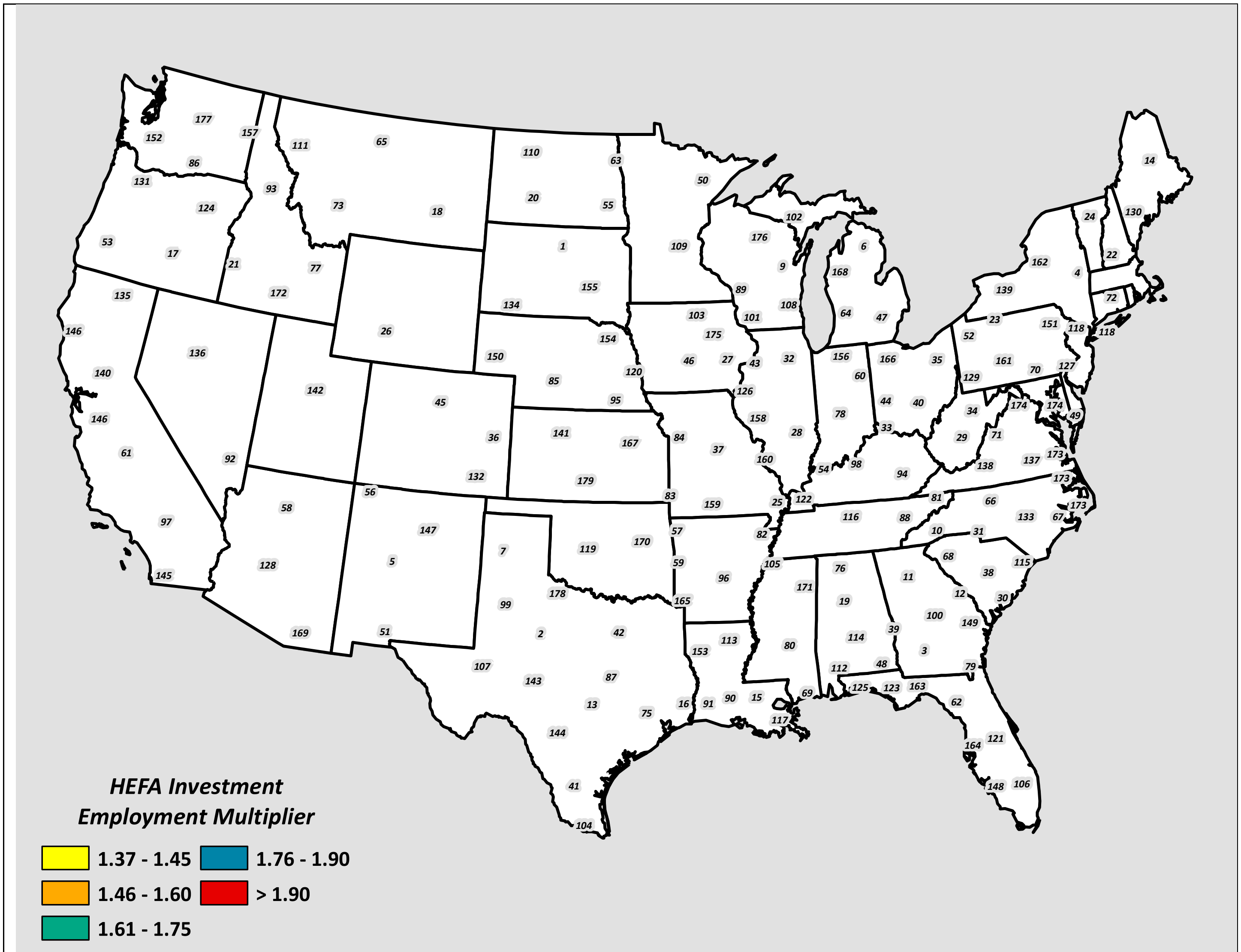

Figure 1.13. Employment impacts from constructing a single HEFA facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

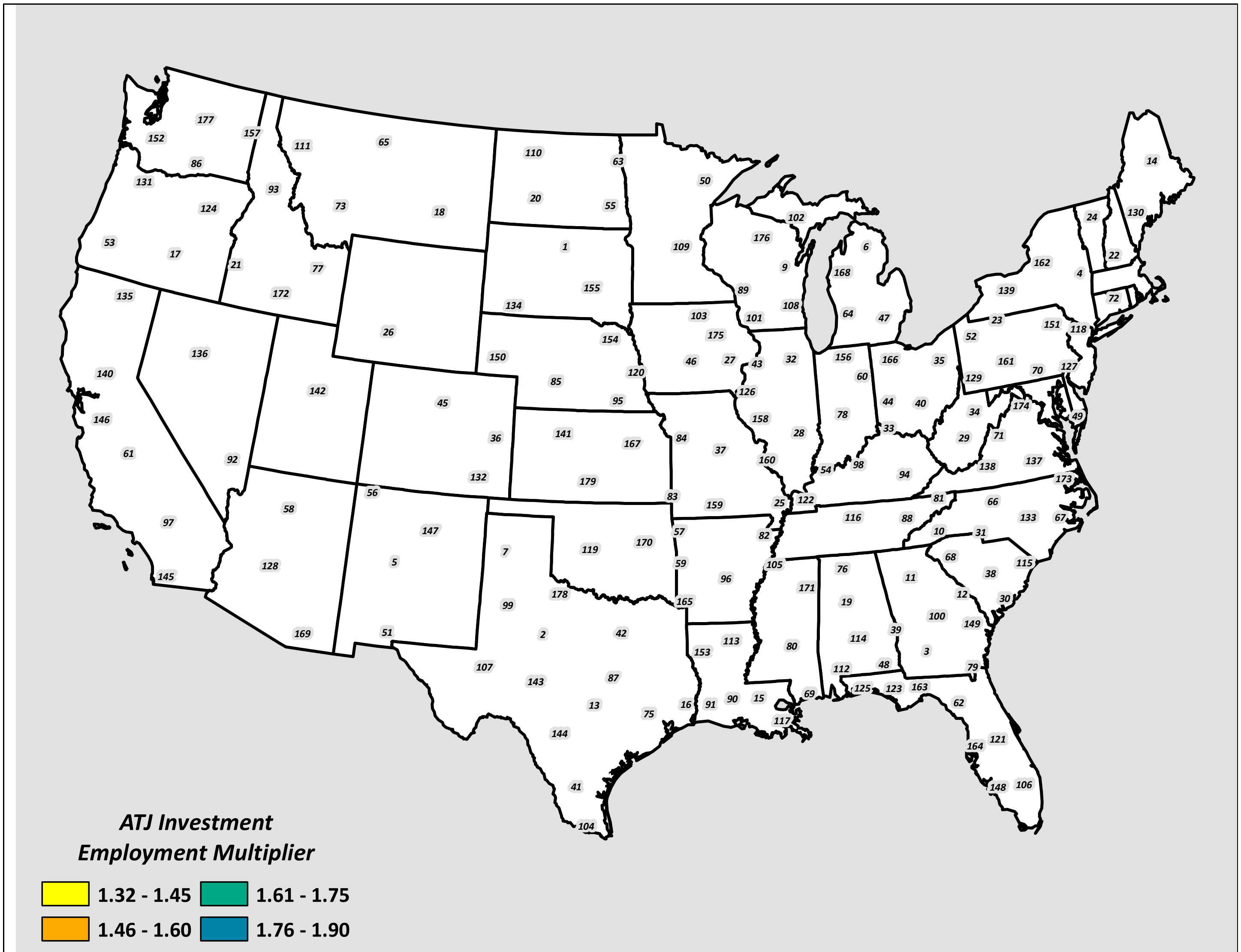

Figure 1.14. Annual operating Employment impacts from a single alcohol to jet (ATJ) facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

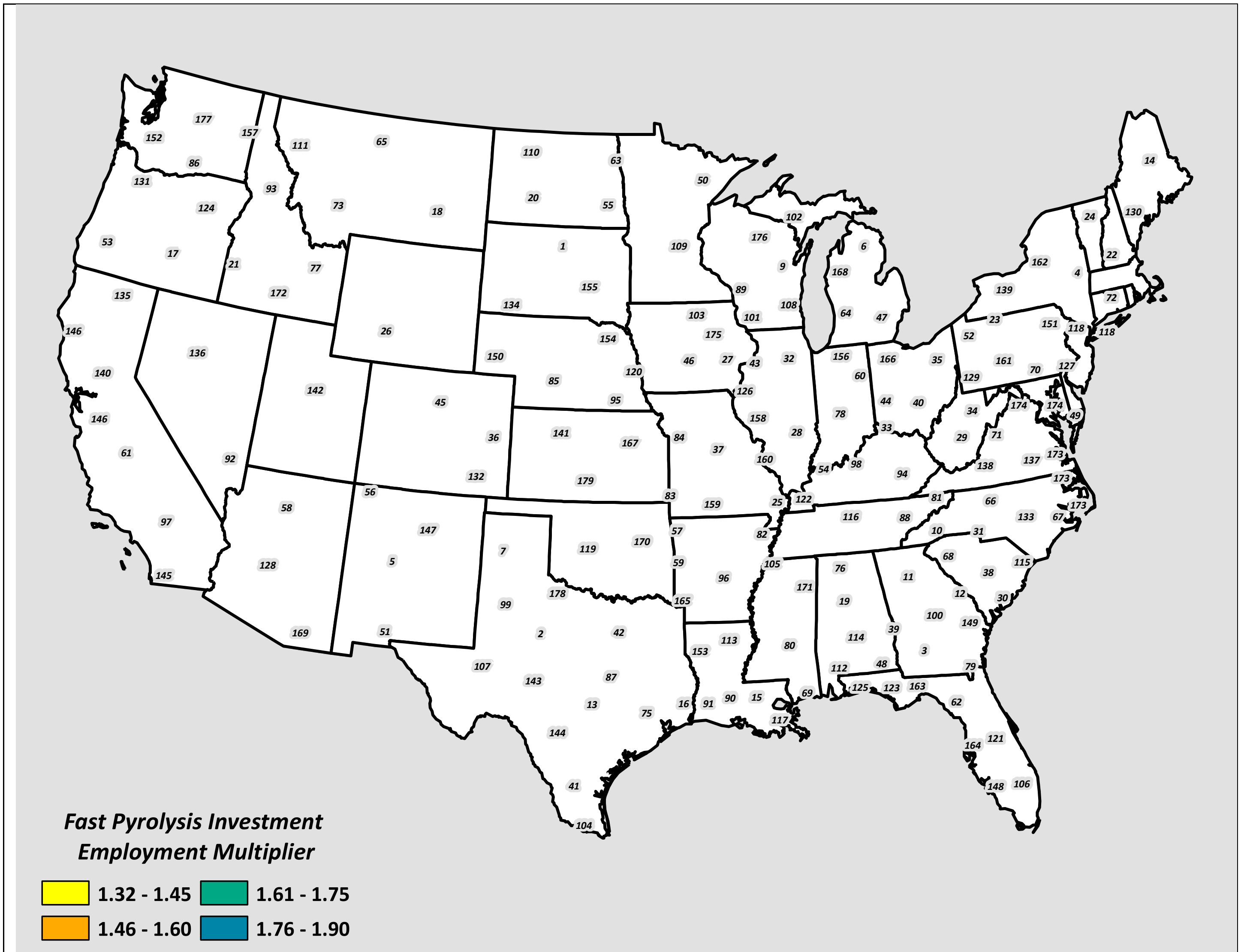

Figure 1.15. Annual operating Employment impacts from a single fast pyrolysis facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

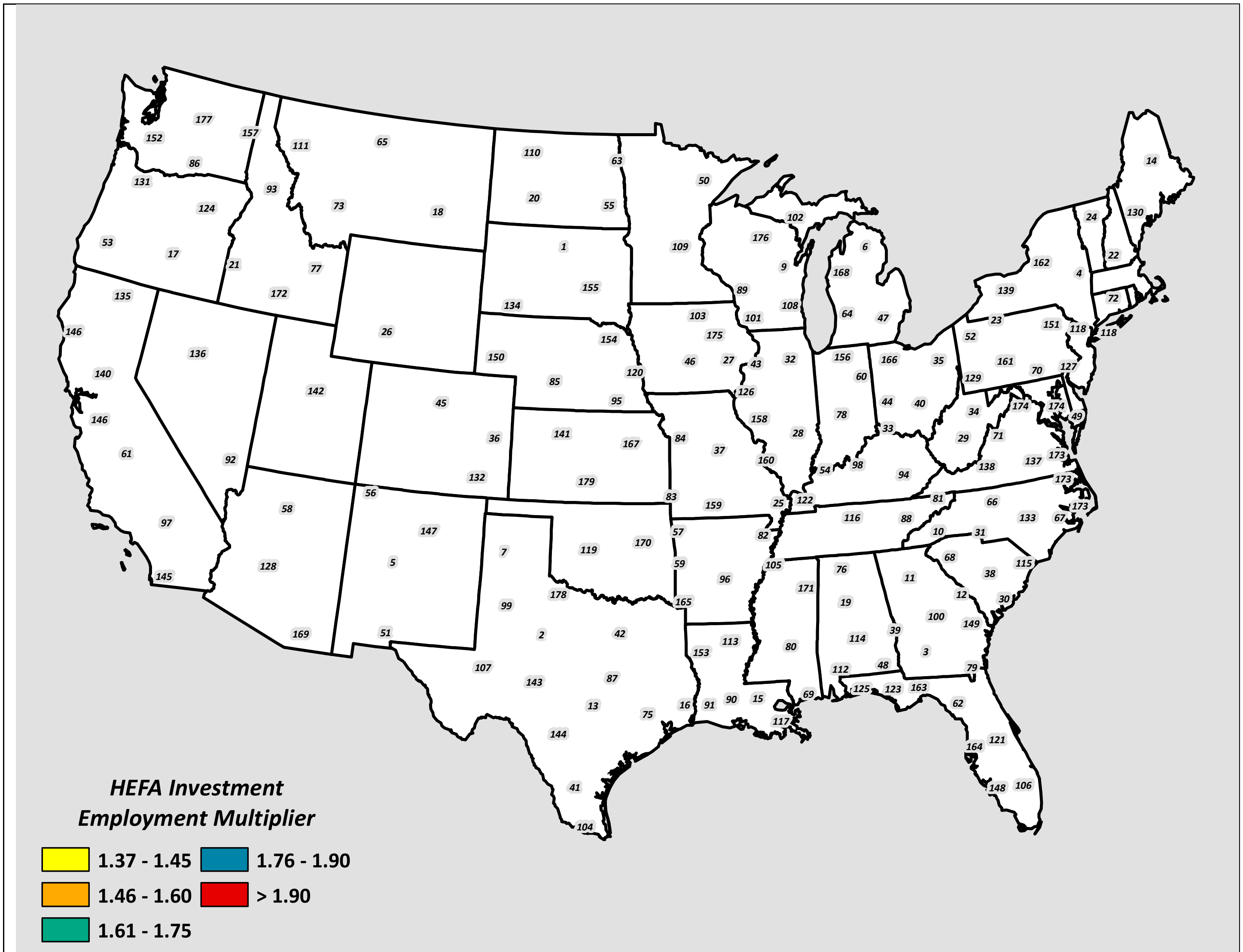

Figure 1.16. Annual operating Employment impacts from a single HEFA facility within a BEA region

Projections of changes in economic activity as a result of this investment through multiplier effects are estimated using Analysis By Parts (ABP) methodology with United States IMPLAN datasets aggregated to BEA region.

Environmental Parameters
Access database is developed with soil characteristics and climate characteristics defined (RKLS factors in the Universal Soil Loss Equation). Soils were identified for crop land, CRP land, and pasture land for each agricultural Statistical District in the U. S. using the 1997 NRI. A C factor, as defined in the Universal Soil Loss equation, was estimated for each crop from the same dataset for conventional, reduced, and no tillage practices[1]. The P factor was assumed to equal 1. For any new crop, a C factor will need to be defined. Based on information from the IBSS project, a C factor of 0.04 is used for switchgrass. Note that Schwartz found a much smaller C factor in his research. We are still researching the C factors for cover crops as they are not readily available. A C factor for a corn soybean rotation ranges from 0.1 to 0.45 depending on tillage and cover. With winter cover this range should be lower than 0.1 since the land cover is year around and not relying on residues for a portion of the year.

In examining welfare analysis of potential carbon credits, resulting from a land use change, to the renewable aviation fuel production in west TN, we found that:

- Carbon credits induced farmers to convert more crop lands with high opportunity costs into feedstock production, resulting in lower farmers' surplus.
- Carbon credits led a net welfare gain to the RJF sector, primarily due to increment in the airlines' surplus (equivalently, reduction in the processor's cost).
- The RJF and its co-products achieved a 62.5% LCA-based GHG emissions reduction. The GHG emissions reduction increased to 65% with carbon credit through displacement of the CJF and fossil fuels.
- Carbon credit had positive influence on aviation GHG emissions reduction, and net welfare of RJF sector. However, RIN credits heavily influenced the economic feasibility of RJF.
- We have carbon emissions coefficients in POLYSYS and those are available to indicate percent changes as a result of changes in land use as well as input application.
- Solutions of the Baseline Model indicate that the RJF processor's cost is $1.16 billion whereas the aggregate profit of farmers is around $16.88 million annually. A total of 657 thousand acres farmland is used for feedstock production including 382 thousand acres of pasture land (Figure 1.17). More than 57% of farmers received a margin ranging from 10 to 47 % over their opportunity costs of land conversion (Figure 1.18).

[1] The Universal Soil Loss Equation estimates annual soil erosion (A) expressed as A=RKLSCP. Four of the factors RKLS are related to the physical location of the soil and two factors C and P are related to management of the crop. A C factor is the crop management factor and provides the ratio of soil loss from land cropped under specified conditions compared to tilled continuous fallow conditions. The P factor is equal to 1 unless the land is planted on the contour, strip cropped, or terraced.

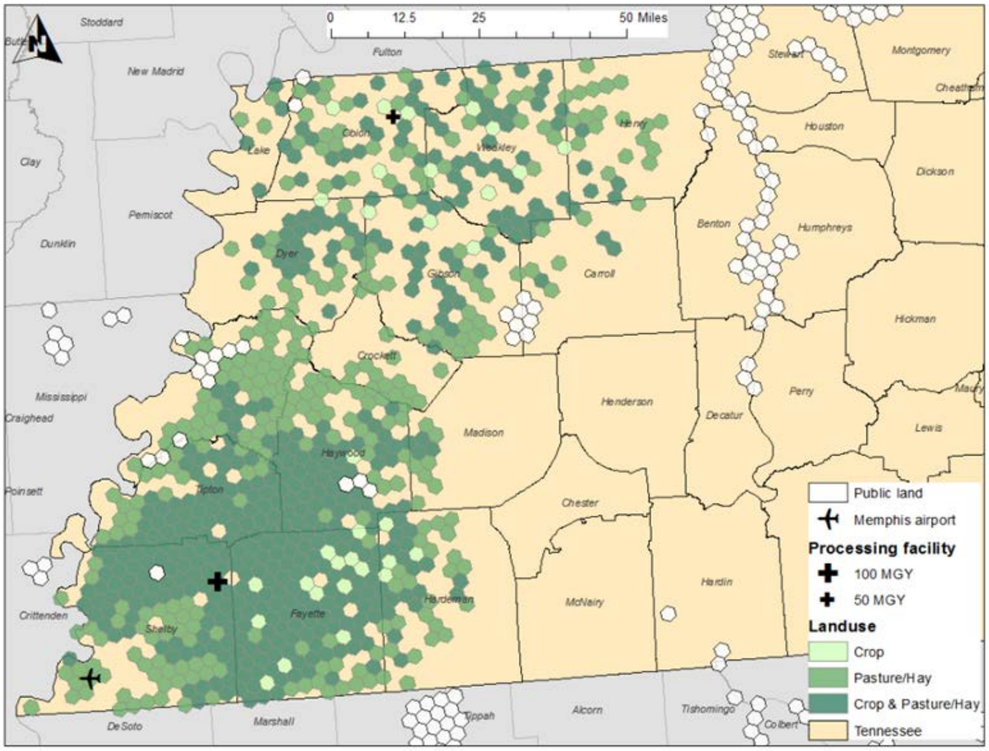

Figure 1.17 Optimal land use for switchgrass production and facility locations to deliver renewable aviation fuel to the Memphis International Airport

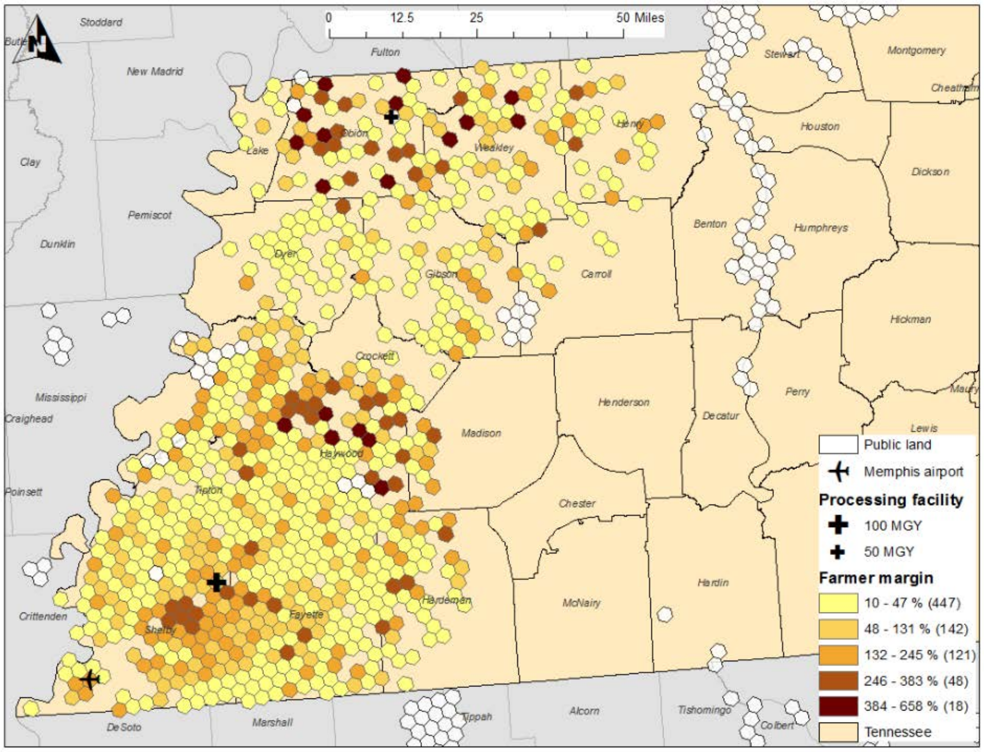

Figure 1.18. Margins of switchgrass feedstock suppliers

Milestone(s)

1. Completed conversion facility economic impact analysis for HEFA pathway.
2. A chapter in Bijay Sharma's Dissertation was completed on welfare analysis linked to carbon credits.

Major Accomplishments

National economic impact spatial analysis (NEISA) was completed for three ASCENT technologies.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

None

Plans for Next Period

Incorporate NEISA into camelina study and the Tennessee pennycress analysis.

Task 2- Supports the Lipid Focused Comprehensive Analyses in ASCENT Project 1 Strategy

University of Tennessee

Sub Task 2.2.1 – Provide national analysis for Lipid based feedstocks

Sub Task 2.2.2 - Complete supply potential analysis for each lipid fuel pathway incorporating supply chain costs, preprocessing and conversion facility costs for selected fuel pathways incorporating social capital and environmental tradeoff components. (WSU, PSU)

Sub Task 2.3- Continue to conduct analysis on new lipid feedstocks and achieve a month turn around on national analysis with documentation to follow (contributes to subtask 2.2 as well)

Objectives

See Task 1

Research Approach

Same as in Task 1 focused on oilseed analysis

New Findings

See Task 1

Milestone(s)

1. Completed conversion facility economic impact analysis for HEFA pathway.
2. Published pennycress article
3. Thesis completed with 1 chapter focused on national analysis of camelina

Major Accomplishments

National economic impact spatial analysis (NEISA) completed for three ASCENT technologies

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

None

Plans for Next Period

Incorporate NEISA into camelina study and the Tennessee pennycress analysis

Task 3- Lay the Groundwork for Lipid and/or Biomass in Tennessee & Southeast U.S.

University of Tennessee

Objective

The University of Tennessee will lead the groundwork for lipid and/or biomass in Tennessee & the Southeast U.S.
Supply Chain Analysis

- Identify 2 potentially viable supply chains to support a specific airport and end user in the Southeast U.S. and provide a proposal for a specific (tactical) deployment project,
- Delineate sustainability impacts associated with different feedstock choices,
- Assess viable conversion technologies,
- Identify stakeholders and partners
- Initiate a stochastic analysis of the system,
- Evaluate markets for potential co-products for Task 3 groundwork and deployment projects, and
- Assist in the development of social capital spatial analysis to be incorporated in regional analysis.

Research Approach

We used similar techniques as displayed in Task 1 but focused on the Southeast. We will develop a budget or use information from the modeling effort behind the billion ton 2016 analysis. We will use BioFLAME, a GIS model that has 5 sq. mile hexagons defined as supply regions. Information supplied by ForSEAM will be used on logging residue locations downscaling its estimates from agricultural statistical districts to the supply regions using the NASS crop supply layer as a means to achieve this. The analysis will be run to find where a sufficient supply might be available to provide a sustainable logging residue feedstock.

In examining potential coproduct markets, the research seeks to determine whether home gardeners would pay a premium for potting mix containing 25 percent biochar using the contingent valuation method. The method used follows a Random Utility framework (McFadden 1974). Responses are structured as a binary variable, with respondents choosing the base product being counted as zeroes, and those who choose the 25 percent biochar product counted as ones. Respondents are also given the option to select neither product. In the contingent valuation approach used, the prices of the base and biochar-potting mix products are provided to respondents, who may select either or neither product (Hanemann 1984). The probability of choosing the biochar product is then a function of price, demographics, expenditure patterns, and attitudes. The model is estimated as a logit model and willingness to pay is calculated using the estimates.

New Findings

1. Two feedstocks have been identified – oilseed cover crop (such as pennycress, camelina or carinata) and logging residues
2. Forest Residue
   - From a different project, logging residues are explored and facility location developed for Alabama. Pathway selected for analysis is logging residues delivered directly to ASCENT's Fast Pyrolysis' biorefinery in chipped form.
   - Biorefineries requiring 545,000 to 720,000 dry tons cannot be located in the S.E. with a maximum transportation distance of 70 miles.
   - Logging residue location determined. We quantified available logging residues using the model (ForSEAM) that supplied the 2016 Billion Ton study information forest biomass. It was decided that only softwoods would be used in the analysis (Figure 3.1).
   - If we add collection points where preprocessing can be achieved, then 5 biorefineries could be established at 720,000 dry tons/year if maximum driving distance increased to 150 miles (Figure 3.2).
   - Average feedstock cost and transportation distance for the Alabama location are still being reviewed.
   - Locating the facility in Alabama and increasing maximum transportation distance to 150 miles, the facility can run at capacity stated (Figure 3.3)

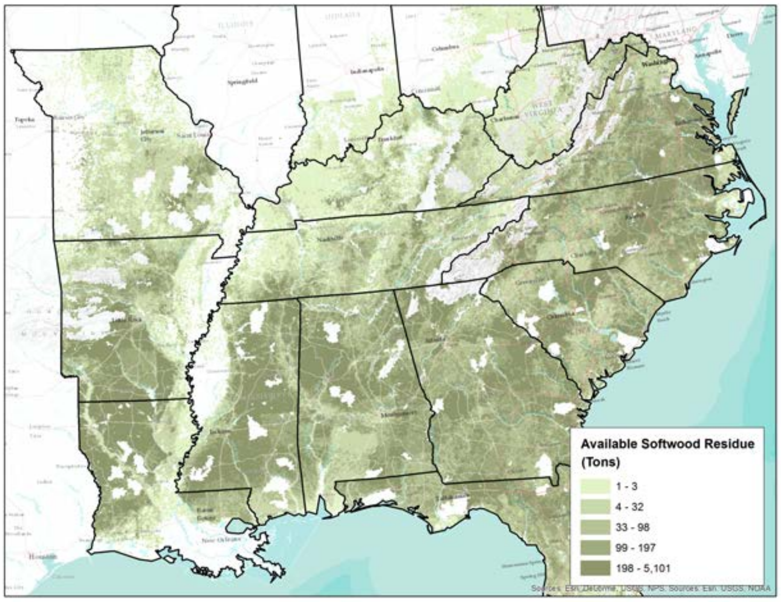

Figure 3.1. Estimated Available Logging Residues, 2020

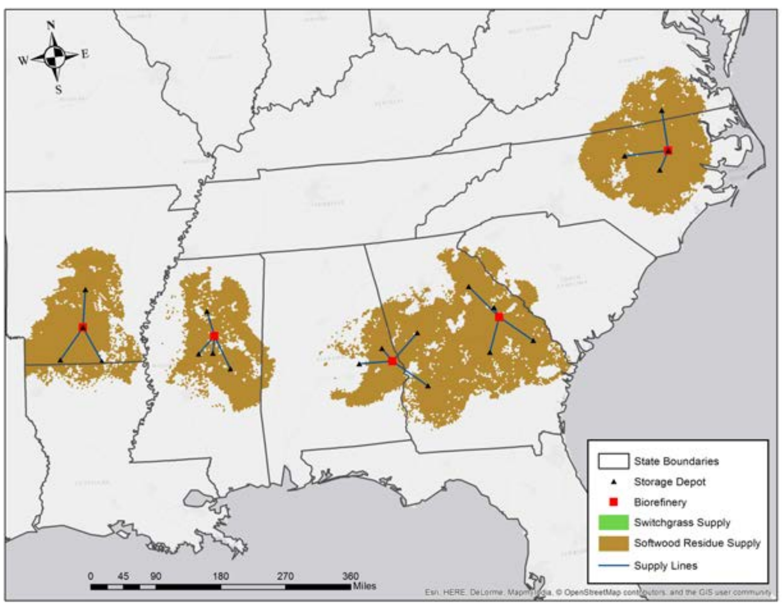

Figure 3.2. Biorefinery locations that are supported with 720,000 tons of logging residue per year.

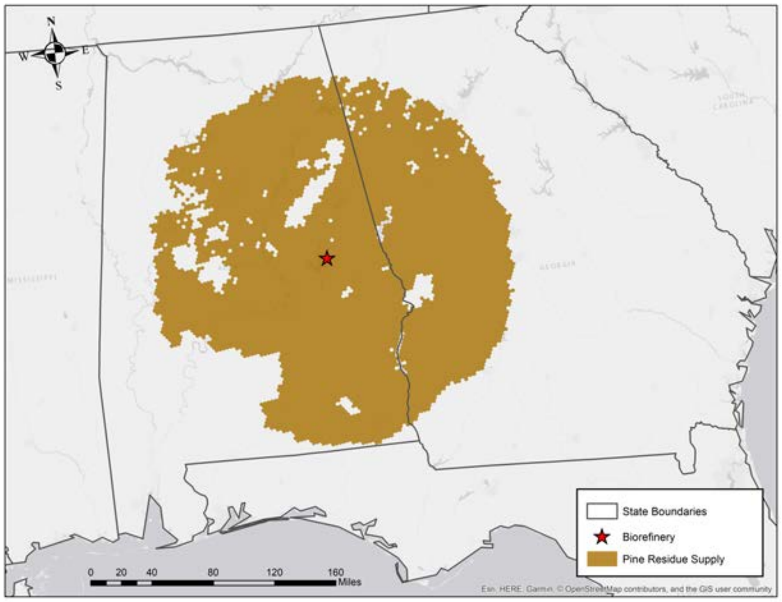

Figure 3.3. Biorefinery location in Alabama using 725,000 tons of logging residues.

3. Pennycress analysis has been conducted for middle Tennessee with fuel delivery to Nashville. This analysis is currently under review.
   - Using ASCENT HEFA technology and pennycress cover crop as a feedstock, we explored the feasibility of supplying the Nashville airport with alternative fuels.
   - Met with Southwest personnel and others in Nashville to see how fuel is stored and distributed at the airport. Discussions indicated that the Colonial Pipeline, the primary means of obtaining fuel, was running at 100% capacity and air travel growth out of Nashville would require additional fuel.
   - Designed an 800-900 ton per day mechanical crush facility which is under modification now with WSU consultation.
   - The ASCENT HEFA biorefinery requires 259,000 tons of oil/year and produces 68.2 million gallons gasoline equivalent of this, 39.9 million gallons in jet.
   - Conducted a four biorefinery analysi,s locating both the biorefineries and crush facilities (Figure 3.4). However, after examining fuel use, the Nashville airport would require 40 million gallons to replace 50% of its current fuel consumption with renewable aviation fuel.

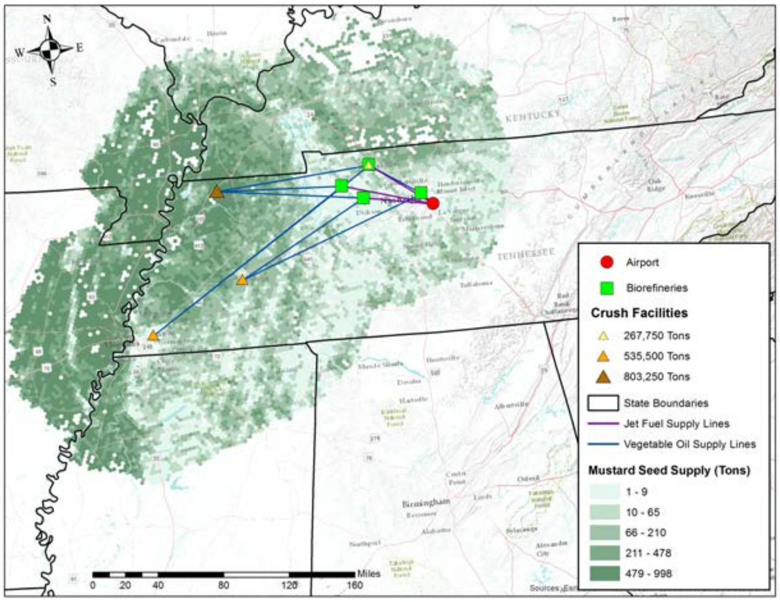

Figure 3.4. Location of biorefineries and crush plants to supply 160 million gallons of renewable aviation fuel.

4. Evaluated high investment risks and novelty of the feedstock-based conversion technologies and the barriers associated with that investment in a Dissertation that:

   - Used a two-stage stochastic model to evaluate the impact of federal subsidies in designing a switchgrass-based bioethanol supply chain in west Tennessee wherein decisions driven by minimized expected and Conditional Value-at-Risk of system cost reflected the risk-neutral and risk-averse perspective of the biofuel sector, respectively. A major contribution of this study is the impact assessment of Biomass Crop Assistance Program (BCAP) on investment decisions (including land allocation) of a risk-sensitive biofuel industry under feedstock supply uncertainty.
   - Evaluated the impacts of renewable jet fuel (RJF) production from switchgrass on farmland allocation. GHG emissions are estimated in response to fulfilling the RJF demand at the Memphis International Airport in Tennessee. A potential carbon market is used to explore the impact of hypothetical carbon credits on the GHG emissions reduction and net supply-chain welfare while addressing the economic motives of the supply-chain participants. This study highlights the importance of Renewable Identification Number (RIN) credits and tradable carbon credits in achieving the desired economic viability and emission abatement goals.
   - Examined the cost-efficiency of cost-ranked and cost-benefit-ranked auction-based payment designs for forest-based carbon sequestration with varying degree of correlation between opportunity costs of afforestation and carbon sequestration capacities, when bidders learn in multi-round procurement auctions. Simulation outcomes can guide decision makers in choosing an optimal payment design that ensures efficiency gains for auction-based payments compared to fixed-rate payments, and more importantly ensures minimal loss in cost-efficiency in a dynamic setting.

5. The need for advanced biofuels to meet the RFS, along with relatively high costs of production, has spurred interest in the economic viability of the coproducts of advanced biofuel production. The Department of Energy has identified a lack of high-value co-products as a leading barrier to large scale production of biofuels (Bozell and Peterson 2010). With pyrolysis, lignocellulose can be converted into bio-oil which then can be used to produce second-generation transportation fuels (Garcia-Perez, Lewis, and Kruger, 2010; Jones et al., 2009; Garcia-Perez et al., 2009). Along with this bio-oil, biochar is produced as a primary co-product. The objective of this analysis is to ascertain consumers' preference and willingness to pay a premium for gardening product (potting mix) that contains biochar in a 25 percent mixture. Potting mix is selected as a product because it is a commonly used household gardening product and is used by both indoor and outdoor gardeners. Mason et al (2008) note that sales of products related to container gardening have been one of the fastest growing lawn and garden categories. A potting

mix/biochar blend would provide consumers with a convenient pre-mixed product with a 25 percent blend. As part of achieving the overall objective, sub-objectives include the following:

a. Estimate WTP for a potting mix with 25 percent biochar compare to a base (conventional) product with no biochar.
b. Provide information on the impact of consumer demographics and attitudes on WTP.
c. Ascertain the relative importance of various biochar attributes on consumer preference for the potting mix with biochar.
d. Project market potential for a 25 percent biochar potting mix product based on potting mix expenditures among the survey respondents.

Results of our survey show that compared with a base price of $4.99 for conventional potting mix, respondents would pay $8.56 for an 8 quart bag of potting mix with a 25 percent biochar blend. Factors influencing this willingness to pay included age(-), percent of household income spent on gardening supplies (+), among of potting mix purchased per year (+), participating in organic gardening and recycling gardening supplies packaging (+), usually purchasing biochar at gardening centers (+), importance of biofuels development (+), and personal actions influencing the environment and environmental responsibility (+). Based upon the results, it is projected that garden centers would be a good place to initially market a biochar potting mix. If we assume that garden centers are the first to offer biochar potting mix products, about 11.44 percent usually purchased potting mix at garden centers (about 95,181 households). Overall the percentage electing to purchase the biochar potting mix was 50.11 percent (accounting for those who chose the conventional product and those who chose neither). This would suggest that 47,695 households might try a biochar mix. The responding gardeners had a median purchase of 32 quarts of potting mix per year. This would give a total of 1.53 million quarts of potting mix. The WTP for an 8 quart bag was $8.56 or $1.07 per quart. This would suggest that around 190,780 8 quart bags of biochar potting mix per year, or potential sales of $1.63 million statewide.

Milestone(s)

1. Completed conversion facility economic impact analysis for HEFA pathway.
2. Dissertation defended and several presentations made
3. Biochar for soil amendment of potential TN consumers completed

Major Accomplishments

National economic impact spatial analysis (NEISA) completed for three ASCENT technologies

Publications

Sharma, B. 2018. Analyzing the Impacts of Policy Supports and Incentive Programs on Resource Management. Ph.D. dissertation. University of Tennessee.

Sharma, B., T.E. Yu, B.C. English, and C.N. Boyer. “Economic Analysis of Renewable Jet Fuels: A Game-theoretic Approach,” Selected presentation at the 7th International Conference on Transportation and Logistics, Dalian, China. September 8-10, 2018.

Sharma, B., T.E. Yu, B.C. English, C.N. Boyer, and J.A. Larson. “Stochastic Optimization of Cellulosic Biofuel Supply Chain under Feedstock Yield Uncertainty,” Selected presentation at the 10th International Conference on Applied Energy, Hong Kong. August 22-25, 2018.

Sharma, B., T.E. Yu, B.C. English, and C.N. Boyer. “Analyzing the Economics of Renewable Jet Fuels Using a Game-theoretic Approach,” Selected Presentation at Applied and Agricultural Economics Association annual meeting, Washington D.C. August 5-7, 2018.

Thomas, McKenzie, Kimberly Jensen, Christopher Clark, Dayton Lambert, Burton English, and Forbes Walker. (2019 forthcoming). Consumer Preferences for Potting Mix with Biochar. Paper to be presented at 2019 Southern Agricultural Economics Association Meetings, Birmingham, AL.

Outreach Efforts
None

Awards
None

Student Involvement
None

Plans for Next Period
Incorporate NEISA into camelina study and the Tennessee pennycress analysis
A journal manuscript will be prepared based on the biochar survey data.
McKenzie Thomas will complete her M.S. thesis using this data.

Task 4- Biorefinery Infrastructure and Siting (Supporting Role)
Washington State University

Objective(s)
The University of Tennessee team will play a supporting role in this task. Several models are available to contribute to the effort, including: 1) BioSAT (currently available for the 33 Eastern states), 2) BioFLAME (we hope to expand its geographic scope from its current southeast U.S. regional focus to the contiguous 48 states).

Research Approach
- Provide feedstock information (location, price, quantity) to ASCENT Database
- Contact WSU for ASCENT conversion technologies
- Pennycress feedstock information provided to VOLPE and saved to shared folders available to all ASCENT Project 001 researchers
- Working with WSU on developing a TEA for the crush facility

Milestone(s)
- WSU provided HEFA, ATJ and FT – SPK TEAs for economic indicator development
- Economic indicators are developed for those three technologies.
- Have made a comparison between the two crush technologies and established basic assumptions to be used by both technologies

Major Accomplishments
None

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
None

Plans for Next Period
Complete the TEA for the crush facility and compare solvent based to mechanical based crush facilities.