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
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- Period of Performance: [August 1, 2016 to September, 30, 2017]
- Task(s):
    1. Task 1.1: Assess and inventory regional forest and agricultural biomass feedstock options.
    2. Task 1.2: Delineate the sustainability impacts associated with various feedstock choices including land use effects.
    3. Task 4: Biorefinery Infrastructure and Siting (Supporting Role)

Project Funding Level

Total Estimated Project Funding: $100,000
Total Federal and Non-Federal Funds: $200,000
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 – Graduate Student
- Bijay Sharma – 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 (1.1); and, the goal to delineate the sustainability impacts associated with various feedstock choices, including land use effects. Additionally, The University of Tennessee will support activities in Task 4 (Biorefinery Infrastructure and Siting) with information and insights on regional demand centers for aviation fuels and current supply chain infrastructure, as required.

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: Potentials include: 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*)

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.

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 pennycress budgets and the fact sheet.
3. Added cover crops Camelina, winter rye, and triticale to the potential feedstock candidates list and developed fact sheets for these crops. We are investigating yields
4. Address comments from 1 and develop new target pathway
5. Used the approach shown in Figure 1 and Figure 2.

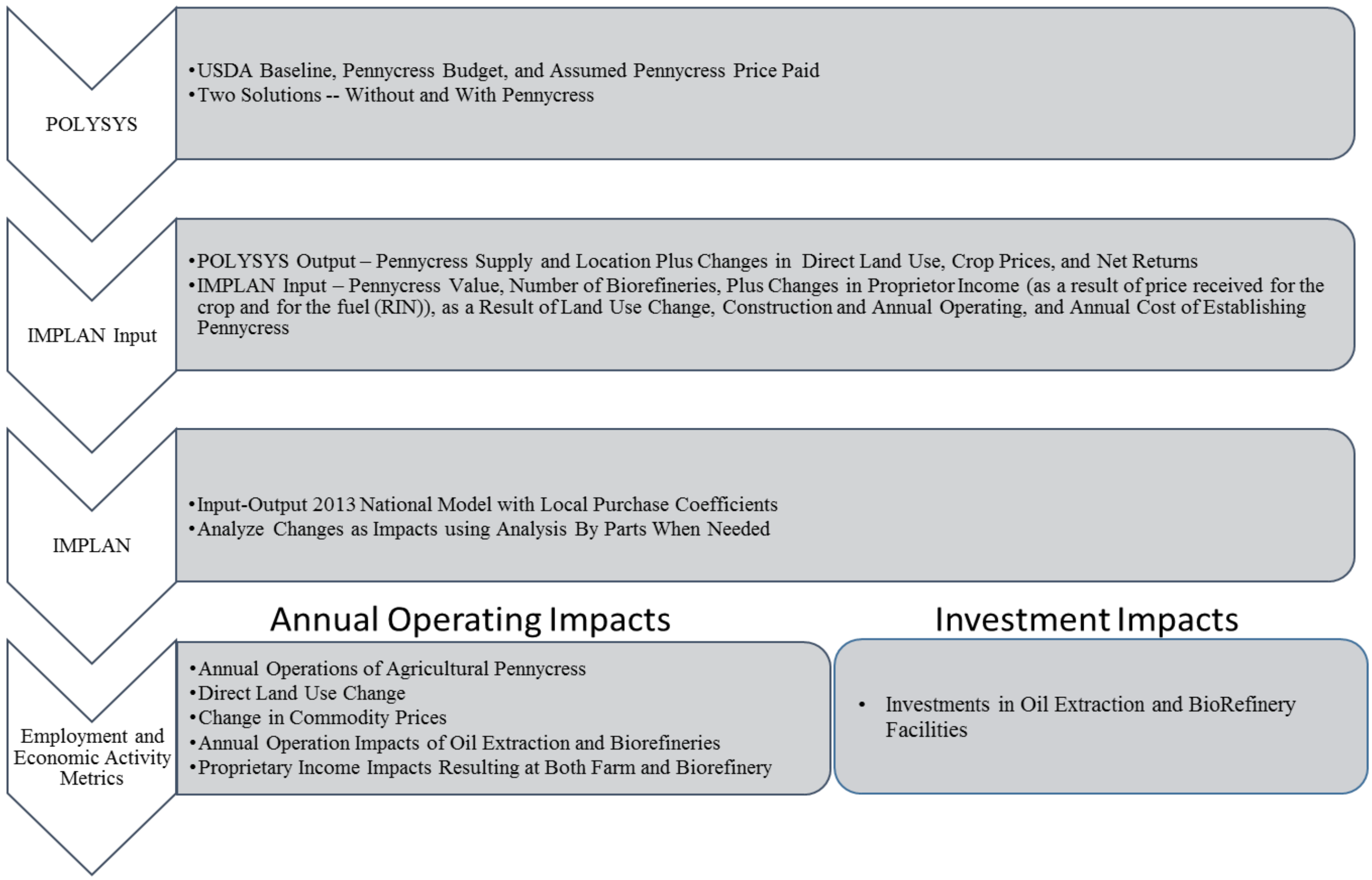

Figure 1. Approach to estimate economic impacts of using pennycress as a biofuels feedstock.

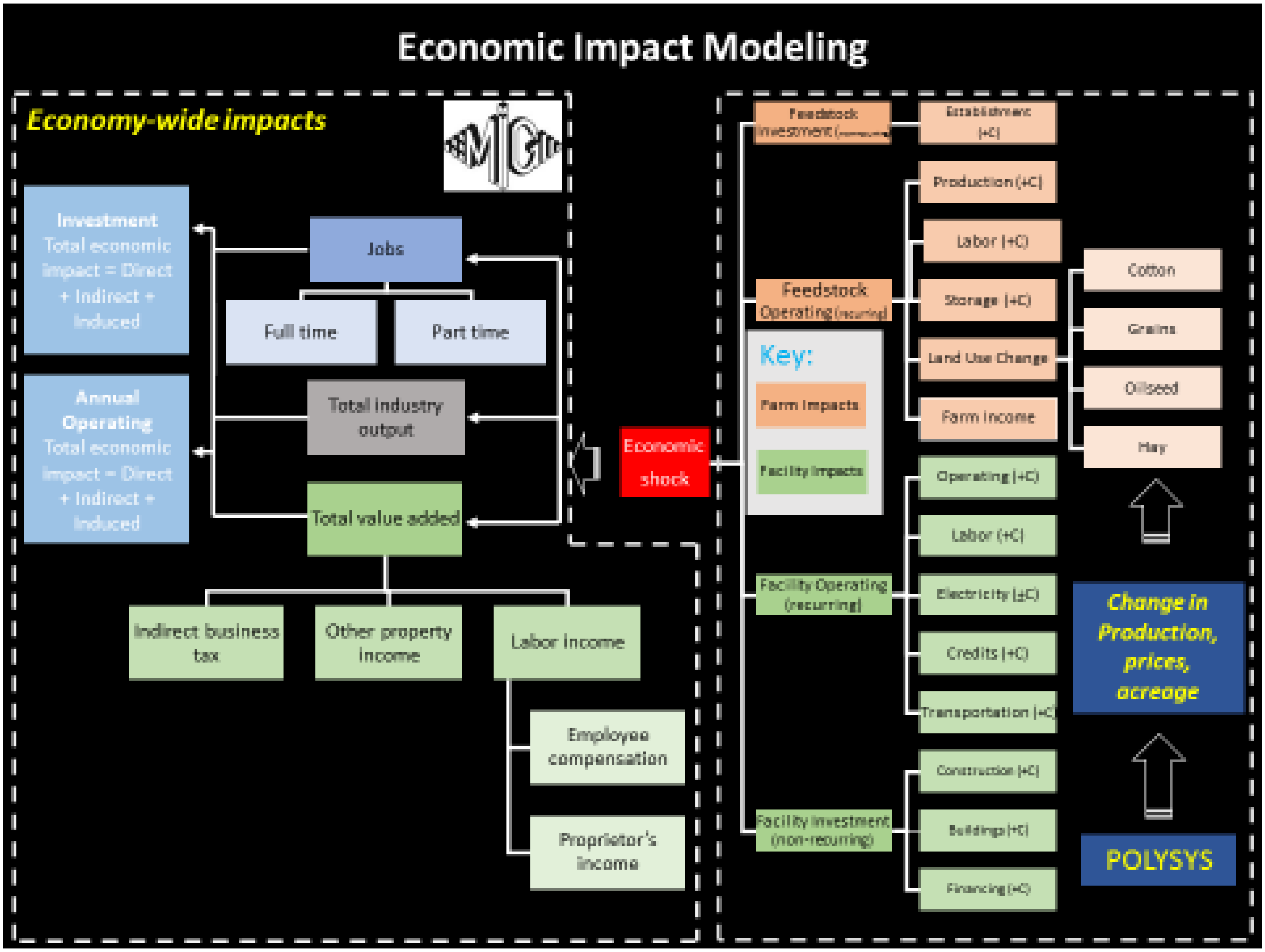

Figure 2. Schematic of the Information flow

Findings (1)

- Pennycress has the potential to supply both oil and biomass to the biofuels market.
- Pennycress is a winter crop that is typically planted in September and harvested the following May.
- It can be seeded in a corn stand via air and harvested before soybeans are planted.
- Following harvest, seed crushing and pre-processing, pennycress offers a suitable oil to allow conversion to a Hydro-processed Ester and Fatty Acid (HEFA) fuel.
- HEFA fuels are a second-generation alternative fuel that can be blended at 50/50 ratio with conventional jet fuels.
- Pennycress budget see Table 1. Other cover crops cost under review.

Table 1. Pennycress budget

	Units	$/Unit	$/Acre	
Pennycress [1]	lbs	1193	$0.20	$238.60
				$225.00
Seed [2]	lbs	5	$2.50	$12.50
Fertilizer & Lime	Acre	1	$28.50	$28.50
Chemical [3]	Acre	1	$0.00	$0.00
Repair & Maintenance [4]	Acre	1	$10.46	$10.46
Fuel, Oil & Filter [4, 9]	Acre	1	$5.90	$5.90
Operator Labor [4, 9]	Acre	1	$5.33	$5.33
Machinery Rental [5]	Acre	1	$10.00	$10.00
Crop Insurance [6]	Acre	1	$0.00	$0.00
Operating Interest [7, 9]	percent	$72.69	6.00%	$2.18
Other Variable Costs	Acre	1	$0.00	$0.00
				$74.87
				$163.73
Machinery [4, 9]				
Capital Recovery	Acre	1	$23.25	$23.25
Other Fixed Machinery Costs	Acre	1	$0.00	$0.00
Property Taxes	Acre	1	$0.00	$0.00
Insurance (Non-Machinery)	Acre	1	$0.00	$0.00
Other Fixed Costs [8]	Acre	1	$0.00	$0.00
				$23.25
				$140.49

- The breakeven price for various yields are displayed in Table 2.

Table 2. Breakeven Price For Selected Yield

Yield (lbs)	Variable Cost ($/lbs)	Total Specified Cost ($/lbs)
800	$0.09	$0.12
900	$0.08	$0.11
1,000	$0.07	$0.10
1,100	$0.07	$0.09
1,200	$0.06	$0.08
1,300	$0.06	$0.08
1,400	$0.05	$0.07
1,500	$0.05	$0.07
1,600	$0.05	$0.06

Hydroprocessing Scenario

1. Conversion process was assumed to be a Hydro Processed Renewable Distillate Facility
2. Conversion rate 7.22 gallons jet fuel /100 pounds of oil plus other energy fuels
3. Requiring 58.8 million gallons per year of oil.
4. Need 1.84 crush facilities to meet the demand of the biorefinery.
5. Production at $0.20/pound of pennycress seed is estimated to require 22.1 million acres which will yield an average of 1300 pounds/acre.
6. 22 conversion facilities and 41 oil extraction facilities will be required.
7. Estimated the economic impact of the hydro-processing and crush facilities.
8. Partial equilibrium simulation results from POLYSYS suggest that pennycress has the potential to supply approximately 800 million gallons nationally to an alternative aviation fuel industry. The economic impact of this industry has the potential to increase national economic activity by almost $19 billion and add 66,000 jobs. Many of these jobs will occur in rural areas; therefore adding value to pennycress seed by converting the oil into biofuel could enhance rural American economies.

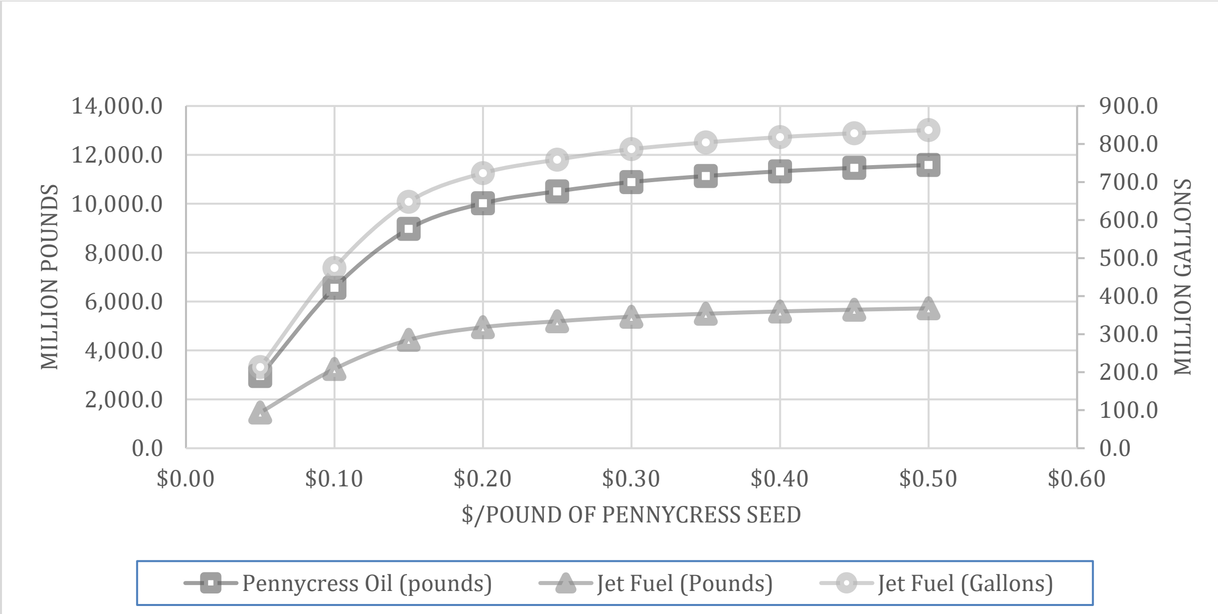

Figure 3. Pennycress and jet fuel production at different feedstock prices

Milestone(s)

Generated data passed on to ASCENT 1 database for pennycress feedstock.
Pennycress pathway developed
Other cover crops costs have been derived

Major Accomplishments

1. Completed Journal Article for submittal.
2. Developed 2 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; and
- ATJ-SPK; Feedstock - yeast biocatalyst converts purified sugar to **ethanol**, followed by oligomerization and hydrogenation; Product - jet fuel;

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement
We have had a PhD student, Evan Markel, working on this project. He is gathering information on Pennycress and developing 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 camellia and winter rye. Upload information gained into Box. Present material on Webina 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 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.

The SPARROW module generates ex ante forecasts of the impacts land use changes have on water quality and is fine tuned for the Southeast. While the geographic resolution is flexible and can be expanded to model all 48 contiguous states, this has not been attempted. Input from the deterministic models (POLYSYS) provides data for the SPARROW analysis. The approach we use is entirely general. The SPARROW model has been calibrated to analyze changes in water quality as determined by land use driven by demand for cellulosic bioenergy in the Southeast.

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.

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, develop a spatial surface of the multipliers for three indicator for both investment (one time) impacts and annual operating impacts. These impacts will be developed for the conversion facility, feedstocks, land use change, proprietor income and transportation,

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 by crop was estimated from the same dataset for conventional, reduced, and no Tillage practices. 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: Schwartz found a much smaller C factor in his research.

C factors for cover crops are not readily available so some assumptions will be required. 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.

Work with SPARROW has not been undertaken at this point in time. It is ready for use for the Southeast region, but to this point we have been conducting national studies.

Carbon emissions information is needed from MIT. This will be pursued this year. However, 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.

Milestone(s)

1. Completed conversion facility economic impact analysis for FT and ATJ – SPK technologies. See Figure 4.
2. Developed ACCESS data base for Soil Erosion Estimation.

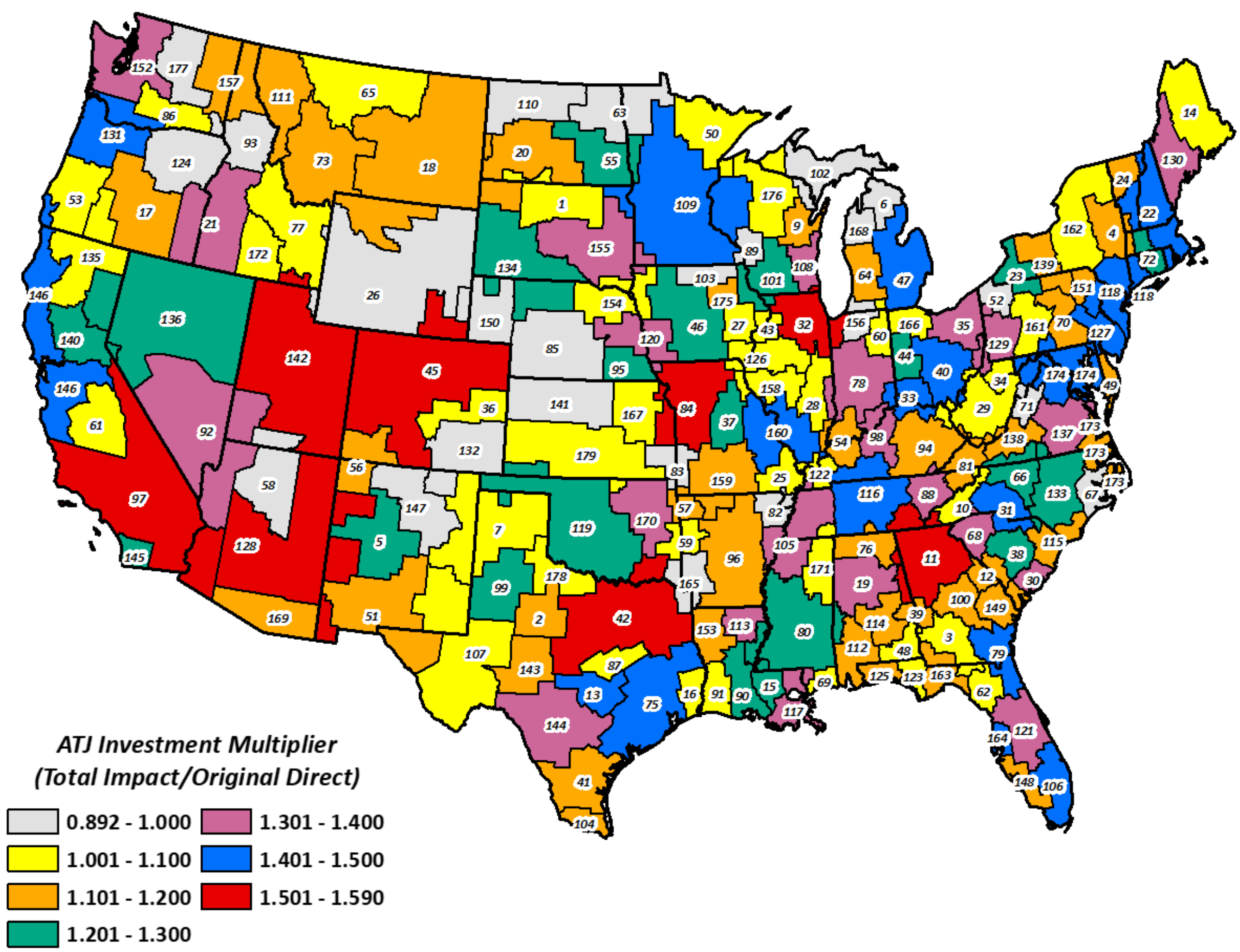

Figure 4. Projected ATJ Investment Total Industry Output Multiplier

Major Accomplishments
Plant run

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
None

Plans for Next Period
Develop impact analysis for economic and environmental parameters.

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 the BOX

Milestone(s)
WSU provided ATJ and FT - SPK TEAs for economic indicator development
Economic indicators are developed for those two technologies.

Major Accomplishments
None

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
None

Plans for Next Period
None