

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

# Laying the Groundwork for Sustainable Aviation Fuel (SAF): Southeastern US Analysis ASCENT 1

Lead investigator: Tim Rials, UTIA  
Project manager: Nate Brown, FAA

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Alexandria, VA

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# Team Members



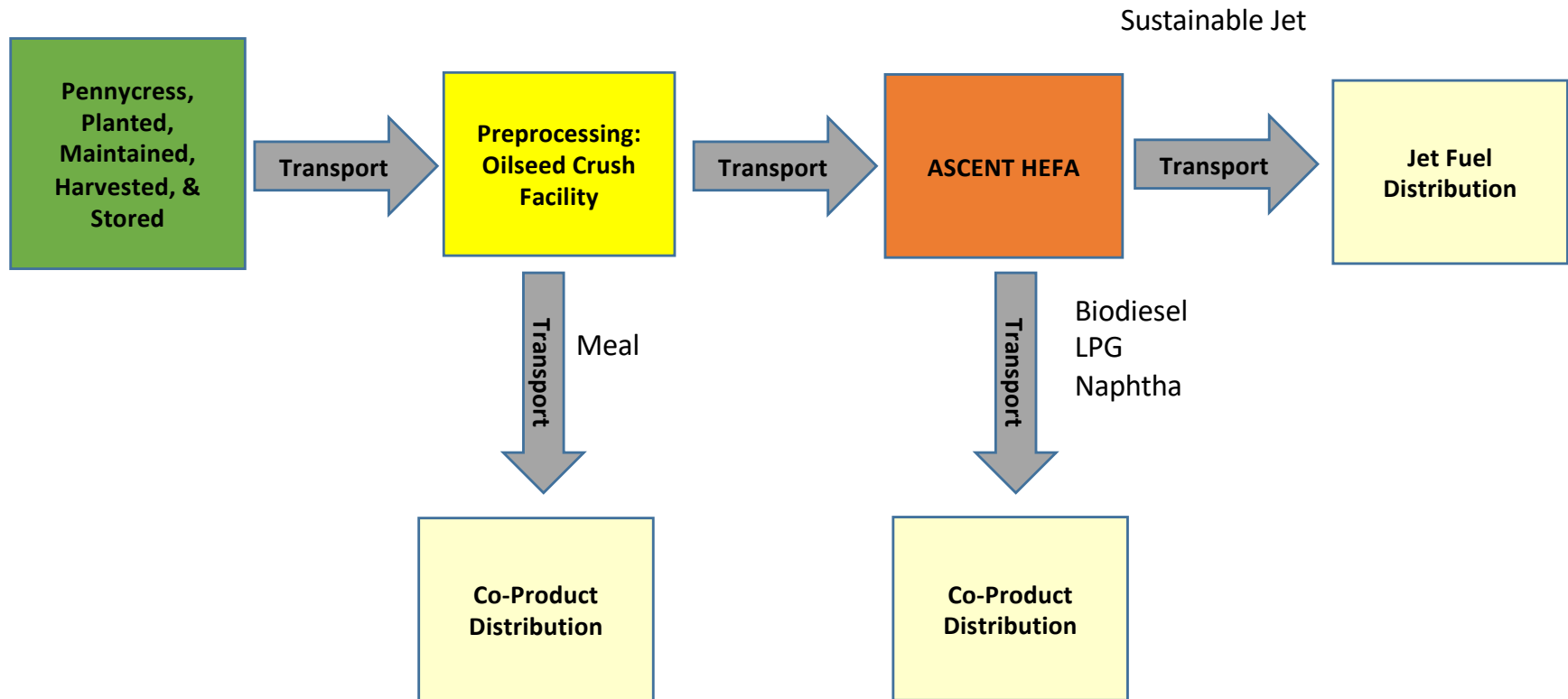
| Team Member                   | Activity  | Team Member Role |
|-------------------------------|---|------------------|
| Tim Rials                     | Co-PD; Expert Advisory Board, Lead  | PD. Faculty      |
| Burton C. English             | Lead Co-PD, Expert Advisory Board, Feedstock Analysis, Pathway Analysis                         | PI, Faculty      |
| Edward Yu                     | Feedstock Logistics, Lead   | Co PI, Faculty   |
| Kim Jensen                    | Market Analysis, Lead   | Co-PI, Faculty   |
| <a href="#">Jada Thompson</a> | Market Analysis   | Co PI, Faculty   |
| James Larson                  | Risk Analysis, Lead   | Co PI, Faculty   |
| <a href="#">David Hughes</a>  | Work Force Analysis, Lead; Stakeholders, Lead; Social and Human Capital; Expert Advisory Board; | Co PI, Faculty   |
| Carlos Trejo-Pech             | Finance, Lead   | Co-PI, Faculty   |
| Christopher Boyer             | Sustainability, Co-Lead   | Co-PI, Faculty   |
| Christopher Clark             | Legal, Lead; and Sustainability, Co-Lead  | Co-PI, Faculty   |

# Project Objectives and Progress

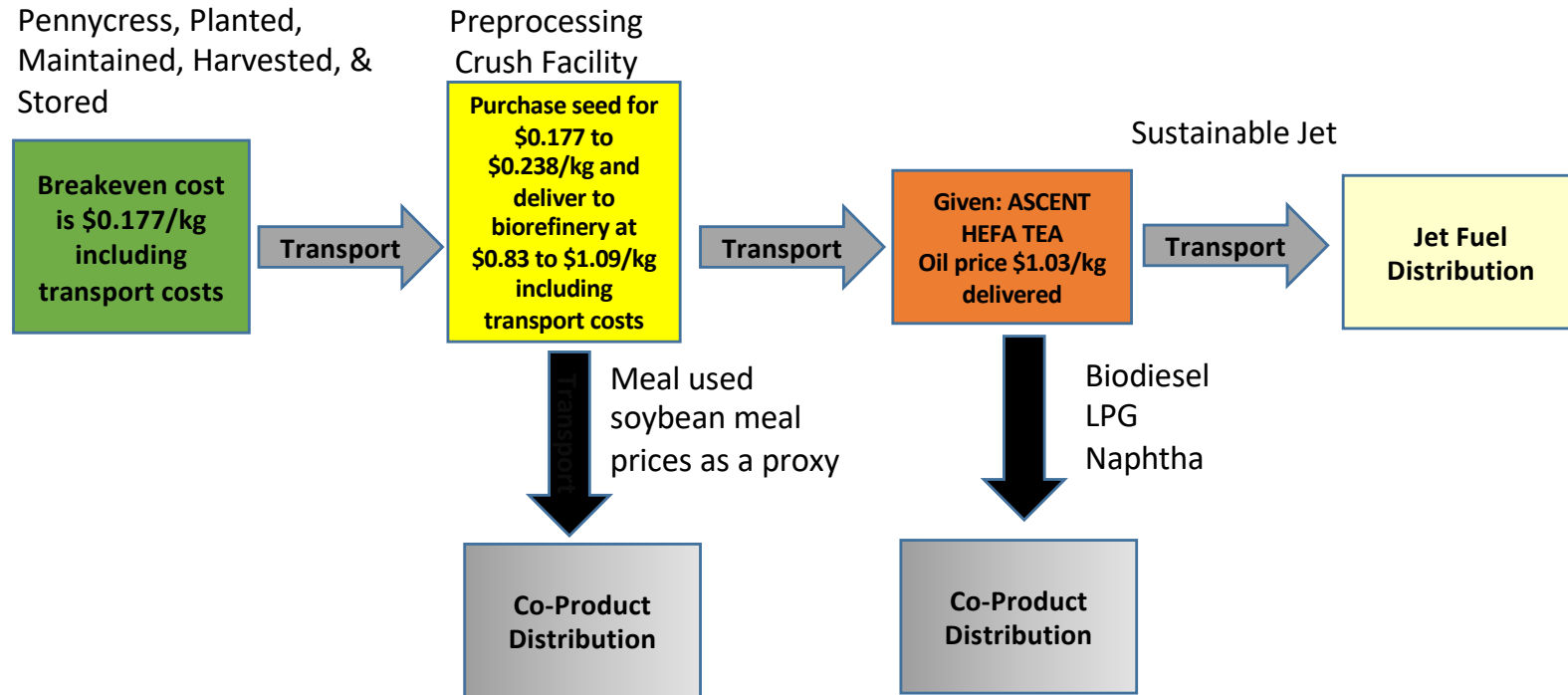


- Provide feedstock information to the ASCENT team
  - Done for herbaceous lignocellulosics, pine, logging residues,, crop residues, and pennycress
  - Still working on environmental impacts
- Evaluate SAF pathways for the southeast U.S.
  - Oilseeds for Nashville and Memphis
  - Pine, switchgrass, and blend of the two for location in Alabama
  - Hardwoods in Central Appalachia for a multitude of airports (to Be Funded)
- Develop Regional Development Plans for the three pathways incorporating stakeholder feedback
- Evaluate oilseed potential nationally
  - Pennycress analysis completed and published
  - Need to add other oilseed feedstocks to the analysis
- Economic impact analysis
  - Tools developed to quickly evaluate the economic analysis of projects through out the US.

# Pennycress Supply Chain Risk Assessment



# Pennycress Supply Chain Risk Assessment



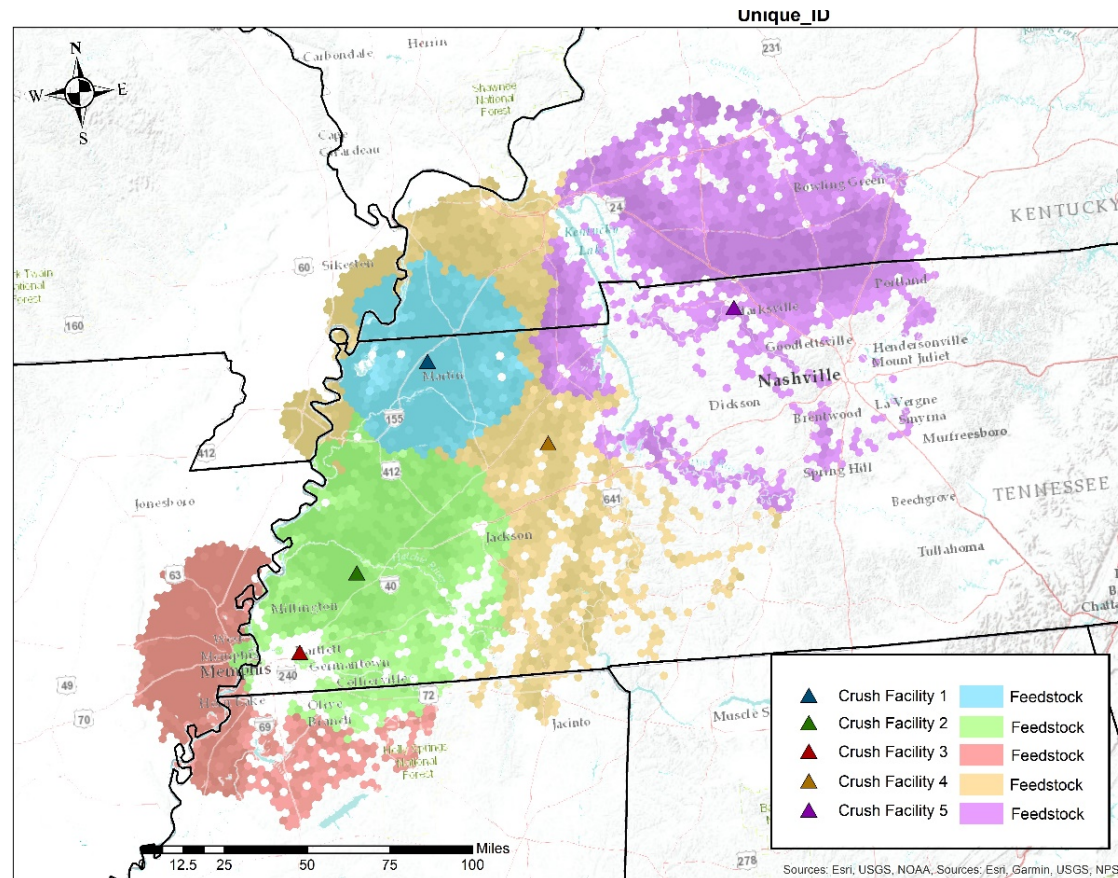
Trejo-Pech, C., J. A. Larson, B. C. English, and T. E. Yu. 2019. Cost and Profitability Analysis of a Prospective Pennycress to Sustainable Aviation Fuel Supply Chain in Southern USA. *Energies*, 12, no. 16: 3055.

# BioFLAME was used

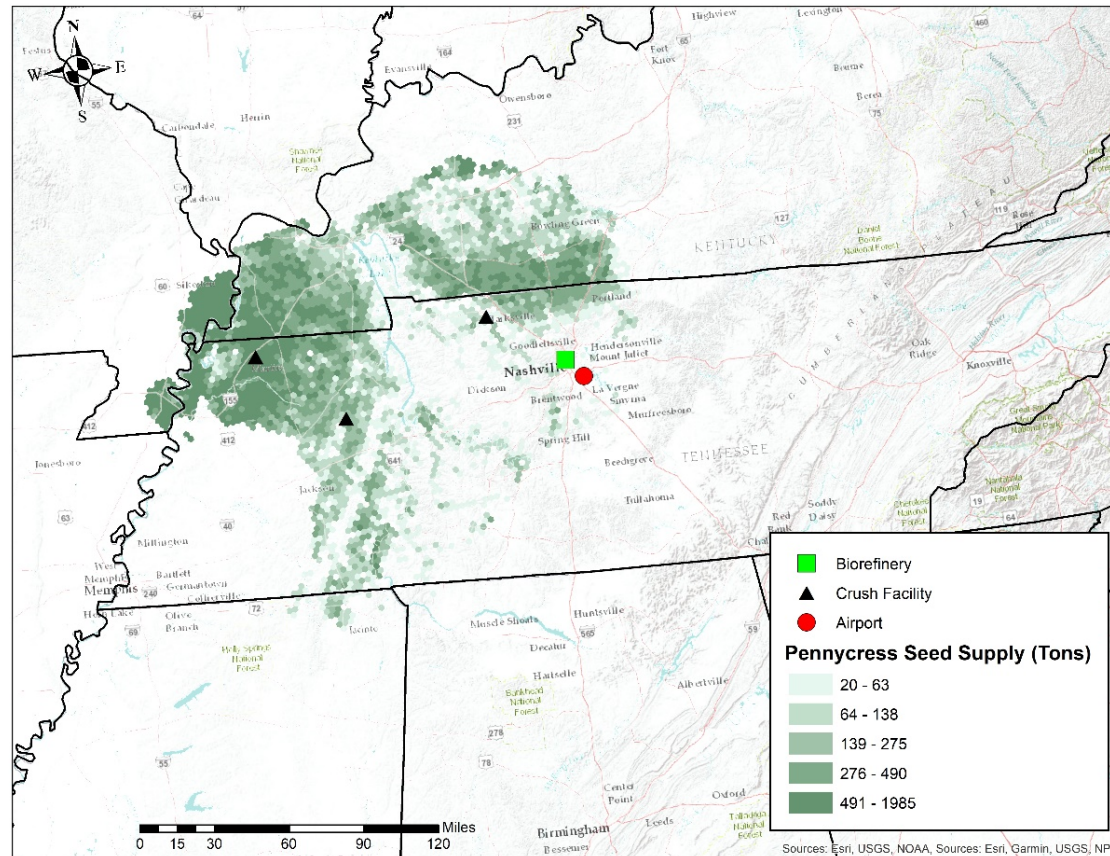


- Three step process
  - Step 1: Locate the Crush facilities such that feedstock costs are minimized
  - Step 2: Determine the crushing facilities that minimize the feedstock and transportation costs to the International Nashville Airport
  - Step 3: Work transportation costs into the Pennycress production and Crush facility spreadsheets to determine the cost of delivering feedstock to the biorefinery.

# Map of the Crushing Facility Locations along with feedstock production locations



# Feedstock Supply Chain for SAF at the Nashville International Airport





# Economic Impact -- Investment



| Investment type     | Investment<br>Required | Impacts                        |       |
|---------------------|------------------------|--------------------------------|-------|
|                     |                        | Direct                         | Total |
|                     | Million \$ (Labor)     | Employment (jobs)              |       |
| Crushing Facilities | \$20                   | 333                            | 527   |
| Biorefinery         | \$84                   | 1,267                          | 2,915 |
| Total               |                        | 1,600                          | 3,442 |
|                     |                        | Economic Activity (Million \$) |       |
| Crushing Facilities | \$66                   | \$39                           | \$67  |
| Biorefinery         | \$204                  | \$175                          | \$409 |
| Total               | \$270                  | \$214                          | \$476 |

# Economic Impact -- Annual Operations



| Investment type                | Annual Expenditures | Impacts      |              |
|--------------------------------|---------------------|--------------|--------------|
|                                |                     | Direct       | Total        |
| Economic Activity (Million \$) |                     |              |              |
| Agricultural Operations        | \$49                | \$49         | \$80         |
| Crushing Facilities            | \$20                | \$12         | \$19         |
| Biorefinery                    | \$35                | \$17         | \$31         |
| Transportation                 | \$10                | \$10         | \$17         |
| Profit                         | \$38                | \$38         | \$67         |
| RIN                            | \$82                | \$82         | \$154        |
| <b>Total</b>                   | <b>\$234</b>        | <b>\$208</b> | <b>\$369</b> |

# Economic Impact – Annual Operations (Labor)



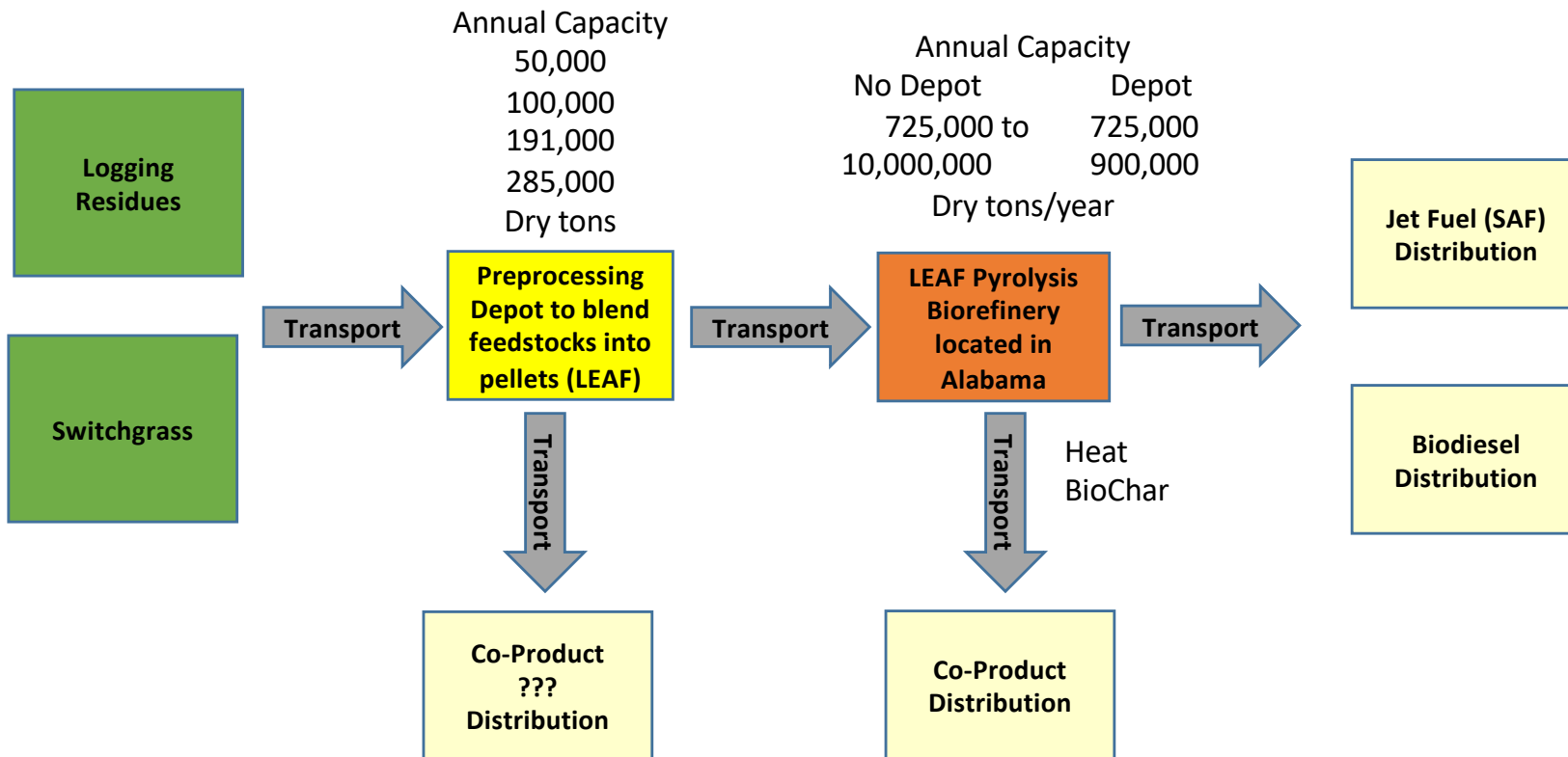
| Investment type         | Annual Expenditures | Impacts           |              |
|-------------------------|---------------------|-------------------|--------------|
|                         |                     | Direct            | Total        |
|                         | Million \$          | Employment (jobs) |              |
| Agricultural Operations | \$21                | 496               | 727          |
| Crushing Facilities     | \$3                 | 49                | 90           |
| Biorefinery             | \$8                 | 115               | 211          |
| Transportation          | \$5                 | 116               | 172          |
| Profit                  | \$38                | 0                 | 226          |
| RIN                     | NA                  | 0                 | 512          |
| <b>Total</b>            | <b>\$76</b>         | <b>775</b>        | <b>1,939</b> |

# Products to Date



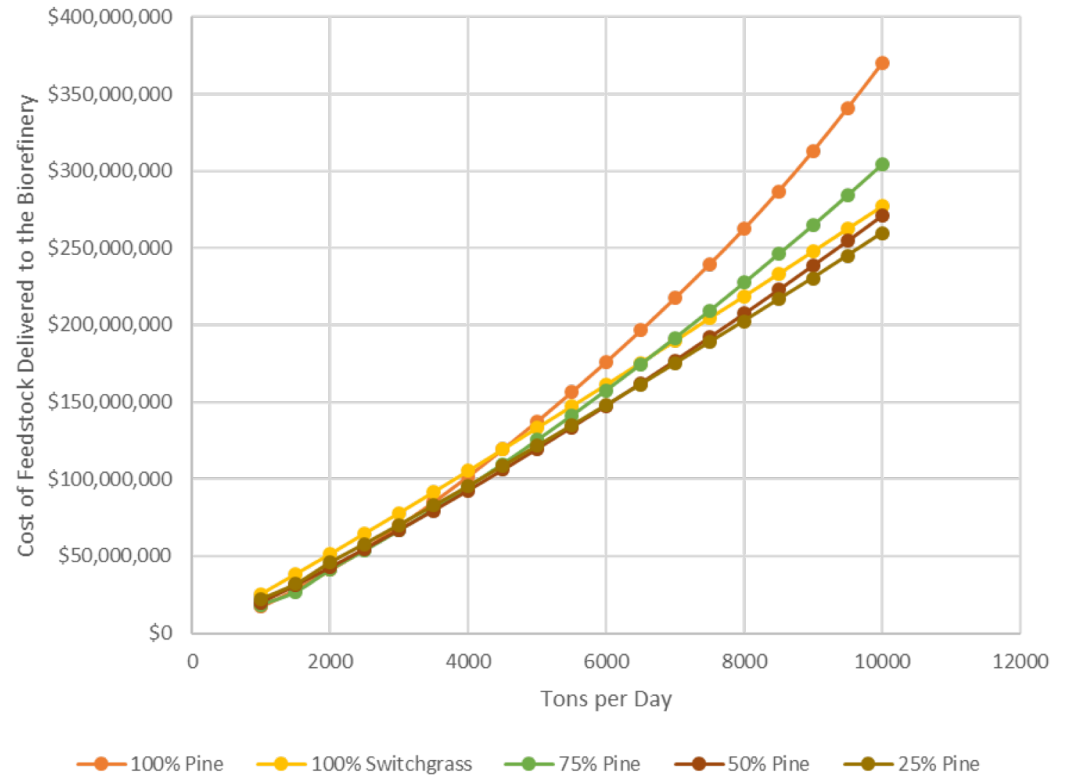
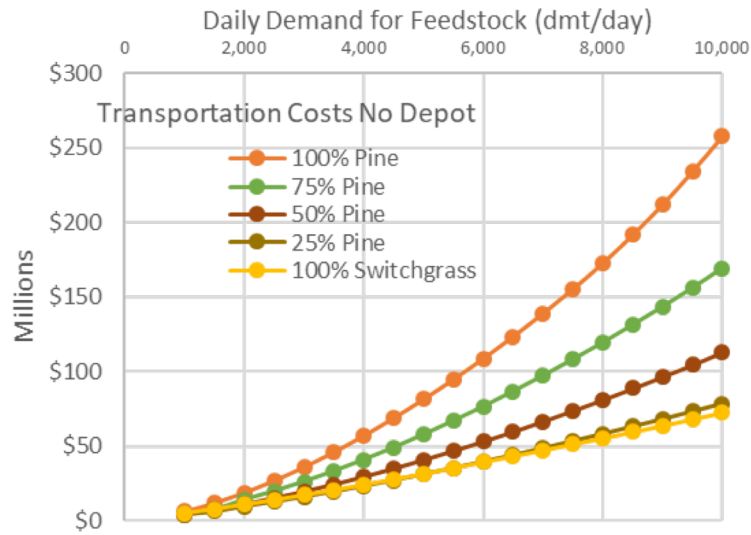
- Two spreadsheets
  - Pennycress
  - Crushing Facility
- Journal Article
- Planned article on risk with this facility
- Planned article on economic impacts of this system (perhaps incorporating sustainability and social capital also)

# Wood/Switchgrass Supply Chain Risk Assessment



Logistics of Enhanced Attribute Feedstock (LEAF)

# No Depot



| Plant Capacity | Annual Capacity |            |
|----------------|-----------------|------------|
|                | Metric Ton      | Short Tons |
| 1,000          | 328,500         | 362,007    |
| 1,500          | 492,750         | 543,011    |
| 2,000          | 657,000         | 724,014    |
| 2,500          | 821,250         | 905,018    |
| 3,000          | 985,500         | 1,086,021  |
| 3,500          | 1,149,750       | 1,267,025  |
| 4,000          | 1,314,000       | 1,448,028  |
| 4,500          | 1,478,250       | 1,629,032  |
| 5,000          | 1,642,500       | 1,810,035  |
| 5,500          | 1,806,750       | 1,991,039  |
| 6,000          | 1,971,000       | 2,172,042  |
| 6,500          | 2,135,250       | 2,353,046  |
| 7,000          | 2,299,500       | 2,534,049  |
| 7,500          | 2,463,750       | 2,715,053  |
| 8,000          | 2,628,000       | 2,896,056  |
| 8,500          | 2,792,250       | 3,077,060  |
| 9,000          | 2,956,500       | 3,258,063  |
| 9,500          | 3,120,750       | 3,439,067  |
| 10,000         | 3,285,000       | 3,620,070  |

Assumes 90% operating efficiency

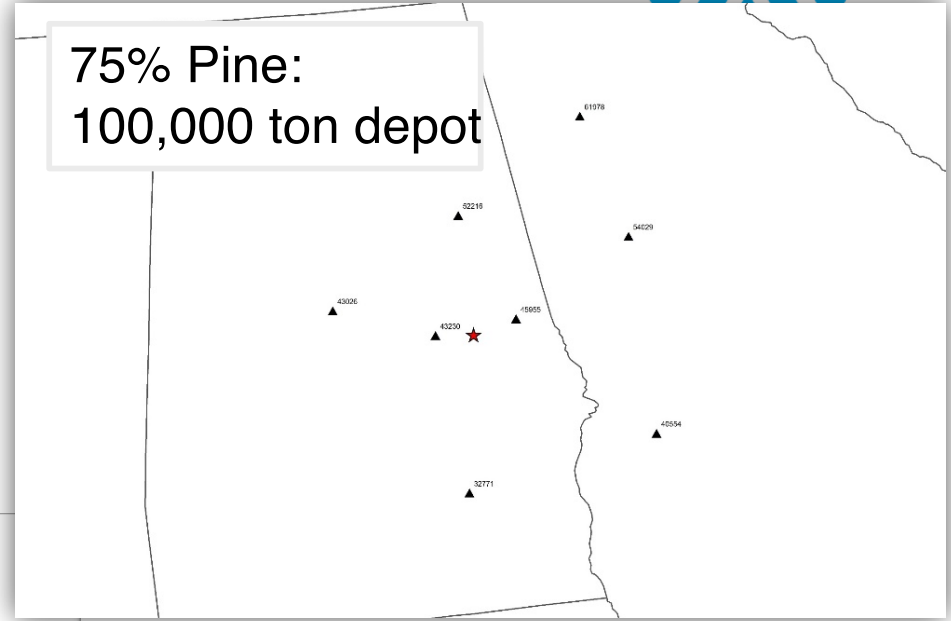
# Average miles a ton travels give a specific plant capacity and blend rate (Southern Eastern Alabama)

| Average miles each ton travels by mixture and plant capacity with No Depots |                                 |                  |          |          |          |
|---|---------------------------------|------------------|----------|----------|----------|
| Plant Capacity  | Average Transportation Distance |                  |          |          |          |
|   | 100% Pine                       | 100% Switchgrass | 75% Pine | 50% Pine | 25% Pine |
| Tons/day  | Miles                           |                  |          |          |          |
| 1000  | 55                              | 19               | 37       | 24       | 18       |
| 1500  | 71                              | 22               | 40       | 31       | 19       |
| 2000  | 84                              | 24               | 56       | 37       | 25       |
| 2500  | 96                              | 26               | 64       | 42       | 28       |
| 3000  | 107                             | 28               | 72       | 46       | 30       |
| 3500  | 117                             | 30               | 78       | 50       | 33       |
| 4000  | 127                             | 32               | 85       | 54       | 35       |
| 4500  | 136                             | 34               | 91       | 58       | 37       |
| 5000  | 145                             | 35               | 97       | 61       | 39       |
| 5500  | 154                             | 37               | 102      | 65       | 41       |
| 6000  | 162                             | 39               | 108      | 68       | 43       |
| 6500  | 169                             | 40               | 113      | 71       | 45       |
| 7000  | 177                             | 41               | 118      | 74       | 47       |
| 7500  | 185                             | 42               | 123      | 77       | 48       |
| 8000  | 192                             | 43               | 127      | 80       | 50       |
| 8500  | 201                             | 44               | 132      | 82       | 52       |
| 9000  | 210                             | 45               | 136      | 85       | 53       |
| 9500  | 220                             | 46               | 141      | 88       | 54       |
| 10000   | 229                             | 47               | 145      | 90       | 56       |

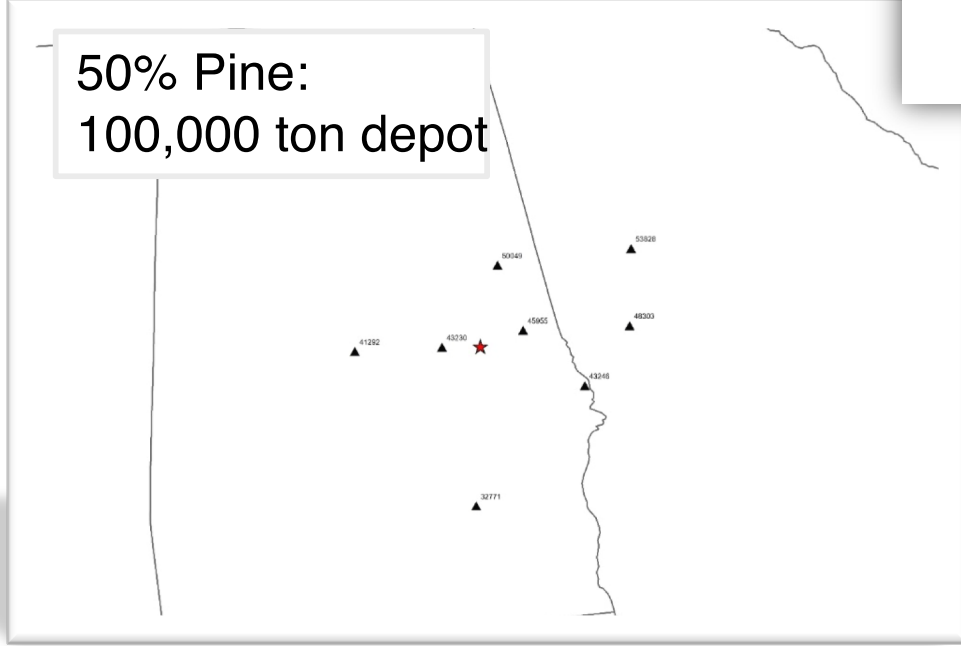


**With Depot:  
725,000 mdt/year**

75% Pine:  
100,000 ton depot



50% Pine:  
100,000 ton depot





# Sustainable Aviation in the Southeast



The Aviation Sustainability Center at the University of Tennessee is pleased to announce a workshop on **“Sustainable Aviation In the Southeast: Moving From Strategic to Tactical”**. The 1-½ day meeting will be held in Knoxville, TN. The program will gather information on logistical challenges to building a complete and flexible supply chain for the industry. Topics to be addressed include:

- **Fuel production technology pathways**
- **The resource base for biomass and oilseed crops**
- **Feedstock supply chain limitations and required developments**
- **Product distribution infrastructure barriers**

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**April 24-25, 2019**

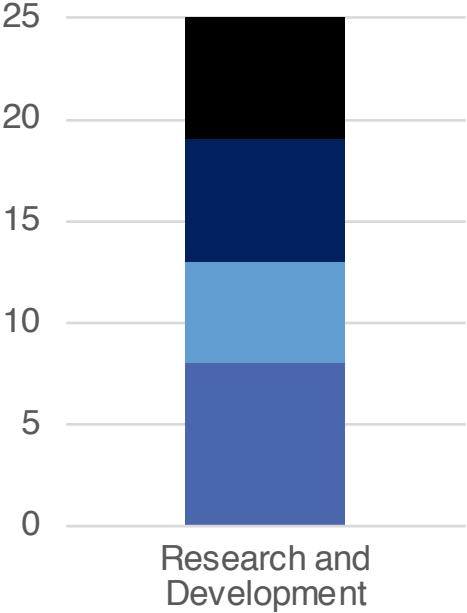
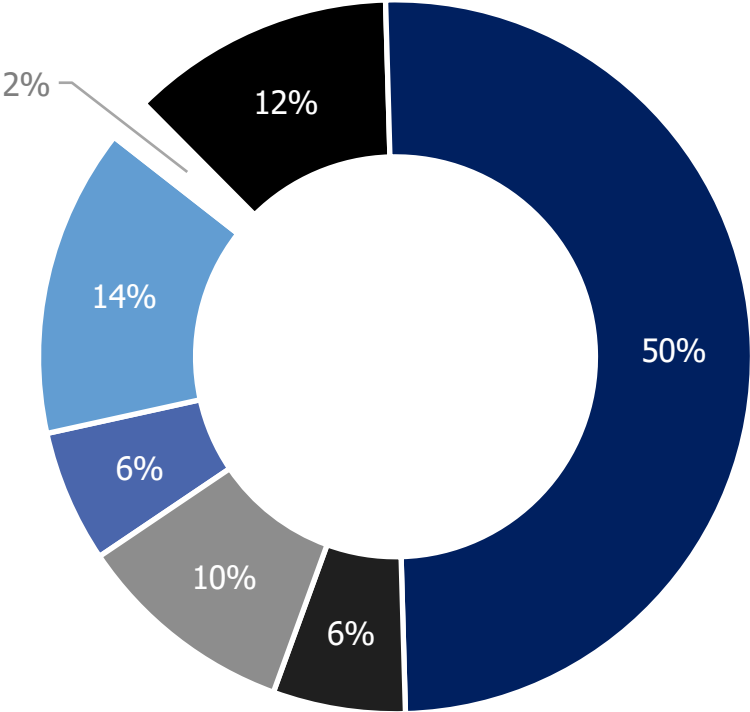
**The University of Tennessee  
Institute of Agriculture  
Knoxville, Tennessee**



# Workshop Participants: The Numbers



## Supply Chain Identification



- Feedstock/Harvester/Aggregator
- End User
- Government
- Technology Processor/Upgrader
- Research and Development
- Transport/Logistics
- Industry Association

# Workshop Participants: The Numbers

1

## Brainstorming

### What is Brainstorming?

Brainstorming can creatively and effectively generate a high volume of ideas in a non-judgmental way. It is a process that involves:

- Encouraging open thinking
- Involving all team members
- Preventing a few team members from dominating the conversation
- Allowing team members to build on each other's ideas while others are still thinking

### Structured Brainstorming

In structured brainstorming, each team member offers ideas in turn.

1. State the agreed-upon brainstorming question in writing.
2. Each team member gives an idea in turn. No idea is criticized.
3. Write each idea in large, visible letters on a flip chart or other visible surface.
4. Continue generating ideas until all are exhausted.
5. Review the list and clarify ideas if necessary. Discard duplicate ideas.

### Unstructured Brainstorming

In unstructured brainstorming, team members offer ideas as they come. Examples include:

**Visual Brainstorming:** Team members develop a picture of how they see the problem.

**Analogies/Free Word Association:** Ask team members to compare the problem to objects or words (e.g., if the problem was an animal, what kind of animal would it be?).

- 5-3-5 Brainstorming:**
1. Each person has five minutes to write down three ideas.
  2. Each person passes his/her sheet of paper to the next person.
  3. Repeat as many times as there are team members.

### Affinity Diagrams

An affinity diagram allows seemingly random ideas or suggestions are often used after a round of structured or unstructured brainstorming.

Find sources, examples, and more information from [this link](#).

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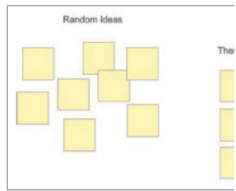
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## Affinity Diagram

### What is an Affinity Diagram?

An affinity diagram is a method of brainstorming, in which seemingly random ideas are organized within natural groupings.

- Affinity diagrams are a great way to **organize a large volume of ideas** that are overwhelming.
- Affinity diagrams also allow a group to **make connections** between ideas that might not seem obvious at first.
- Affinity diagrams can help groups **reach consensus** on organizational themes.
- Affinity diagrams can also allow team members to **complete** each member of a team or group can contribute ideas to the full scope of the problem.



### How Do I Draft an Affinity Diagram?

#### 1. Clarify the Problem

Start by drafting a problem statement, or clearly defining the issue to which everyone can see it and refer back to it.

#### 2. Brainstorm Ideas

Start generating ideas using the principles of brainstorming (QI Toolbox) or, allow team members to group ideas. At this point, your team should piggyback off of each other's ideas, and be prepared to suspend judgment. Record ideas on Post-It™ notes, and post them underneath the problem statement.

3

## Interrelationship Digraph

### What is an Interrelationship Digraph?

Interrelationship digraphs show cause-and-effect relationships, and help analyze the natural links between different aspects of a complex situation. An interrelationship digraph:

- Encourages team members to think in multiple directions rather than linearly
- Explores the cause and effect relationships among all the issues, including the most controversial
- Allows key issues to emerge naturally rather than to be forced by a dominant or powerful team member
- Systematically surfaces the basic assumptions and reasons for disagreements among team members
- Allows a team to identify root cause(s) even when credible data does not exist

### When to Use an Interrelationship Digraph

- When trying to understand links between ideas or cause-and-effect relationships
- When a complex issue is being analyzed for causes
- When a complex solution is being implemented
- After generating an [affinity diagram](#), [fishbone diagram](#), or [tree diagram](#), to more completely explore the relations of ideas

### How to Construct an Interrelationship Digraph

#### 1. Draft a Problem Statement

- If using an original statement (not from a previous tool or discussion), write a complete sentence
- Everyone needs to clearly understand and agree on the problem statement
- Write or place the problem statement at the top of the workspace

#### 2. Brainstorm Ideas

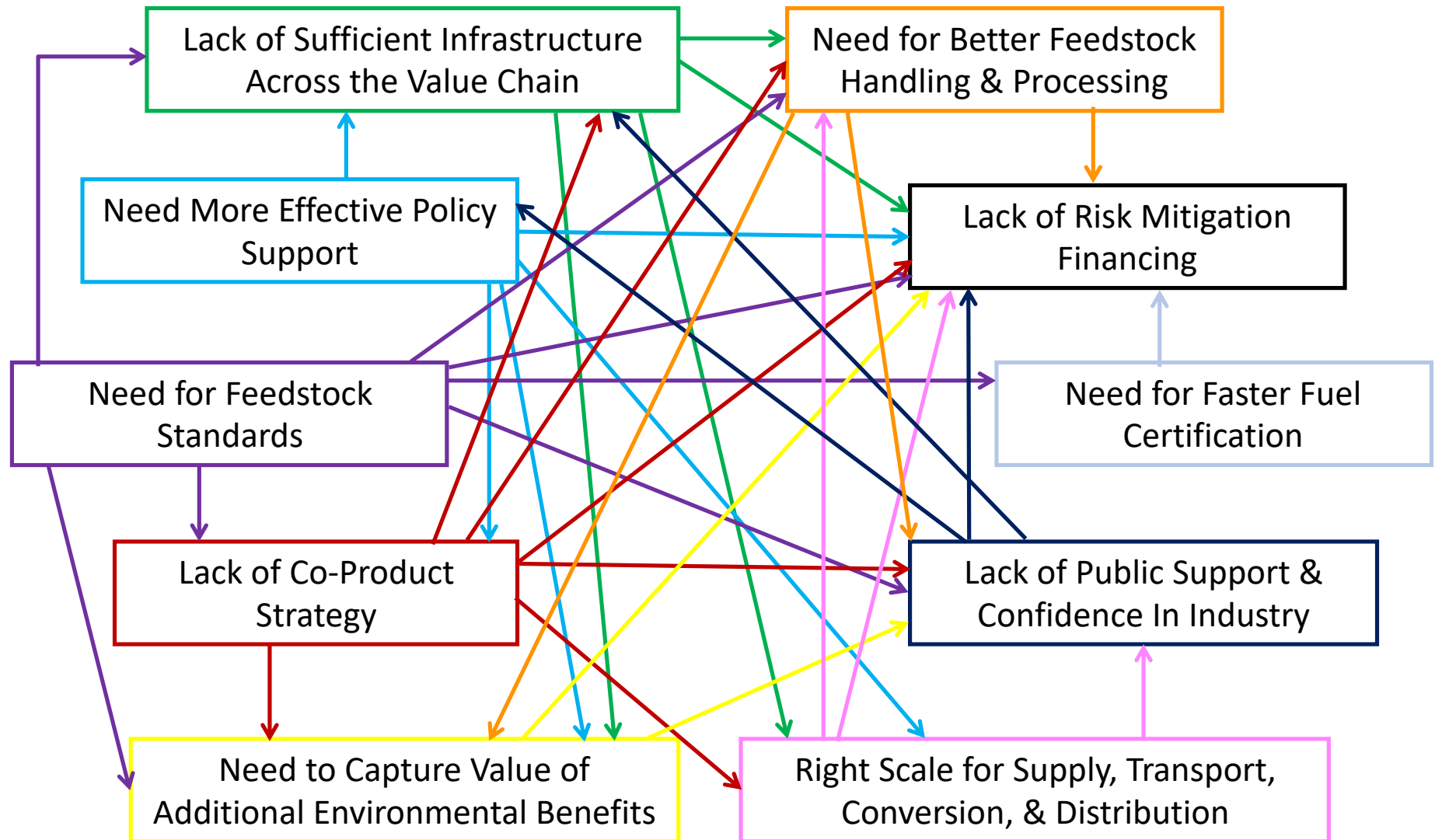
[Brainstorm](#) ideas and write each one on a separate note card or piece of paper (QI Toolbox: Brainstorm).

If using with another tool (e.g., affinity diagram, fishbone diagram), take ideas from the most detailed row or final branches. Use these ideas to brainstorm other ideas.

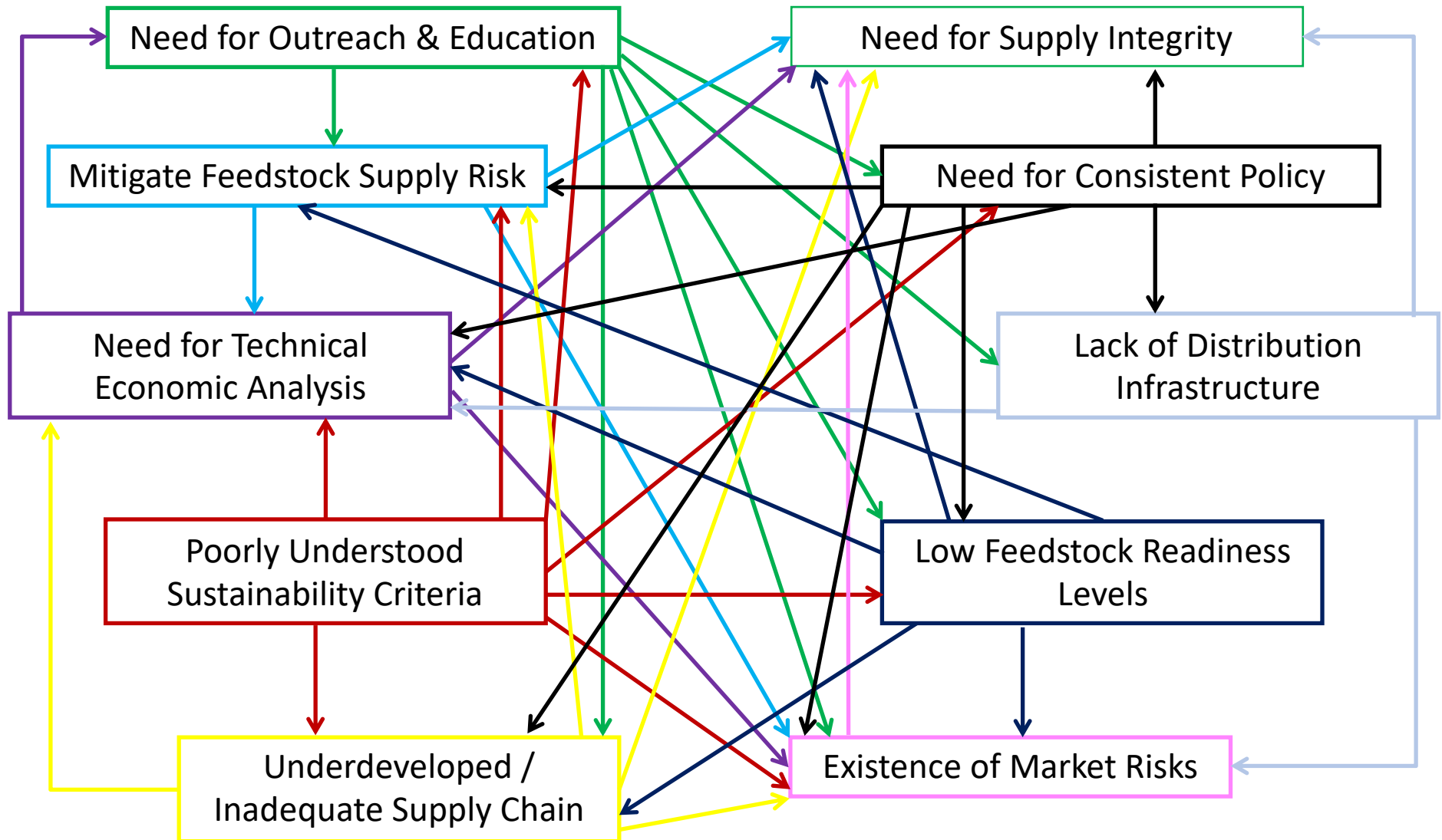
WWW.HEALTH.STATE.MN.US/QI

- More than 50 invited leaders from the region met to discuss critical barriers to increasing availability of SAF in the SE
- Groups were split with 20-25 individuals per group
  - Lignocellulosic group led by Chris Tindal
  - Oilseed group led by Christina Sanders and Daniel Mueller
- The group included individuals experienced in the different unit operations that make up the biofuel supply chain, and brought industry, university, and government perspectives to the dialogue

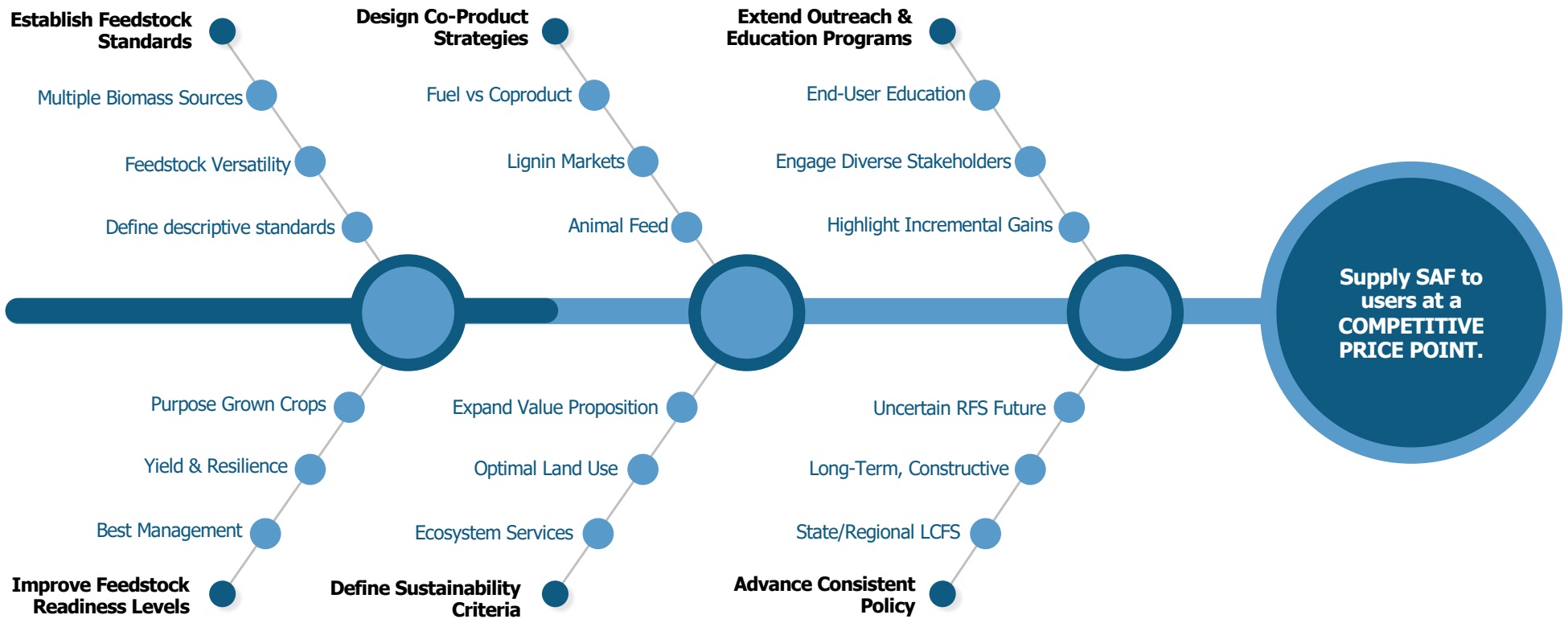
# Lignocellulosic Pathway Barriers



# Oilseed Pathway Barriers



# Top Tier SAF Challenge Areas - SE



To maintain the momentum established during the workshop, six of the top barriers were selected as near-term targets for the alliance to address. The individual teams will work to better define the barrier and develop strategic approaches to reduce the challenges they present.

## **Addressing the Need for Consistent Policy**

- Rodney Hadley
- Valerie Thomas
- Charles Etter
- Dave Meyer
- Nate Brown

## **Addressing Poorly Understood Sustainability Criteria**

- Rodney Hadley
- Valerie Thomas
- Jesse Nikkel
- Dave Meyer
- Tim Theiss

## **Advancing the Need for Outreach and Education**

- Rodney Hadley
- Charles Etter
- Christina Sanders

## **Lack of Co-Product Strategy**

- Gerald Tuskan
- Niki Labbé
- Nour Abdoulmoumine
- Dave Lanning
- Richard Molsbee
- Phil Weathers

## **Addressing Low Feedstock Readiness Level**

- Burt English
- Niki Labbé
- Nour Abdoulmoumine
- Dave Meyer
- Dave Lanning
- Randy Rousseau
- Gerald Tuskan

## **Addressing Low Feedstock Readiness Level**

- To be developed

# Other Components



- Initiated risk analysis similar to that conducted at Purdue on the oilseed feedstock supply chain.
- Initiated the Social Capital Analysis for Nashville
- Conducted consumer study regarding biochar and its use in potting soil
- Initiated a Tennessee variety yield analysis for oilseed crops
- Started sustainability analysis on oilseed covercrops using Virginia Dale's (ORNL) methodology



# Questions

