National Institute of Food and Agriculture

- The Bioenergy, Bioproduct Bioeconomy (B3) Portfolio historically provides unique approaches to building supply chains and value propositions through research, education, and Extension
- Supports Bioeconomy through competitive and capacity grant programs

- **AFRI**: Agriculture and Food Research Initiative
  - **Coordinated Agricultural Projects** (CAPs)
    - Integrate research, development, demonstration, education/workforce development, Extension/outreach/tech transfer
    - Regional biomass supply chains linked to bioeconomic value propositions (biofuels, biobased chemicals and products)
  - **Foundational Program** grants address bioproducts (e.g. lignin, nano-cellulosics), policy, social and environmental impacts, crop development and evaluation

- **SBIR**: Small Business Innovation Research

- **USDA & DOE Joint Solicitations**
  - Plant Feedstock Genomics Program (with DOE-OS-BER)
  - Biorefinery Optimization (with DOE-BETO)
  - Biomass Research and Development Initiative (with DOE-BETO)
World’s First
Commercial Cellulosic Biofuels Flight
Two NEW AFRI CAPs Join the Community

SPARC led by University of Florida
• Partnering with Agrisoma and ARA
• Targeting alternative jet fuel and animal feed from the oilseed crop Brassica carinata (Carinata)

SBAR led by University of Arizona
• Partnering with Bridgestone America and Eastman Chemicals
• Targeting natural rubber, industrial chemicals, and alternative jet fuel from the dry land crops guayule (why-oo-ley) and guar.
CAP Feedstocks and Project Regions
Growing Jet Fuel on the Farm

Based on a True Story of

http://sparc-cap.org/
Winter Oilseed Crops in the Southeast

- Carinata
- Canola
- Camelina
Laying the foundation for SPARC

Field days, summits, outreach engaging multiple stakeholders for production and market updates

Over 10,000 acres of carinata produced from 2014 onwards through farmer contracts

ARA uses carinata oil for DoN campaign-2014

$1.1m grant from to demonstrate feedstock development in FL -2013

First jet flies on CH process based drop-in fuel from carinata-2012

Crop improvement and region-specific BMPs

Identified issues for SPARC-CAP
- identifying early adopters across SE
- improving system fit
- minimizing risk across supply chain

Carinata research plot trials initiated-2011-UF/Agrisoma/ARA
What is Carinata?

Carinata Characteristics

- Closely related to rapeseed
- Cold, heat, and drought tolerance
- High oil content
- Oil is high in erucic acid
- *Non-food oilseed crop*
- High protein seed meal

Oilseed Crops for Bioenergy

B. carinata (Ethiopian mustard) is an excellent non-food oilseed crop for biofuels

*Carinata seed is high in oil and produces more oil/acre

<table>
<thead>
<tr>
<th>% Seed Oil</th>
<th>Peanut</th>
<th>Canola</th>
<th>Carinata Plains</th>
<th>Carinata Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>43</td>
<td>42-45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Carinata: The jet-fuel oilseed feedstock**

- Brassica carinata is a jet-fuel feedstock
- Originated in Ethiopian highlands
- Cross between *B. nigra* and *B. oleracea*
- Heat and drought tolerant
- Disease and shattering resistant
- As a winter crop, carinata increases soil organic matter, reduce erosion, water and nutrient loss

- Carinata is planted in November and harvested in May in the US southeast
- 10000 acres produced in the past 3 yrs
- Large seeded mustard (120000 seeds/lb)
- Seeds are 45% oil and 30% protein
- Oil is nonedible partly due to high erucic acid (35%) and glucosinolate content
- High protein, low fiber seed meal

- 3500 lb seed/acre
- 200 gal oil/acre
- Cost of production: $275/acre
- Profit: $200-300/acre

---

Vegetative Stage
Mid January

Flowering
Mid March

Mature Carinata
Mid- Late May
Why Carinata?
Crop timing conducive for production and consistent feedstock supply

- Planted on fallowed underutilized lands
- Planted in fall and harvested in spring in the southeast
- Low water footprint
- Double cropped for increased farmer revenue—leaving May-October for summer crop

Southeast US Crop Acreage

<table>
<thead>
<tr>
<th></th>
<th>Florida</th>
<th>Georgia</th>
<th>Alabama</th>
<th>South Carolina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Acres</td>
<td>9,250,000</td>
<td>10,150,000</td>
<td>9,033,000</td>
<td>4,900,000</td>
</tr>
<tr>
<td>Summer Production</td>
<td>Tomato, Vegetables</td>
<td>Cotton, Peanut, Corn Soy</td>
<td>Cotton, Soy, Peanut</td>
<td>Peanut, Cotton</td>
</tr>
<tr>
<td>Rotation/Double Crop Options</td>
<td>Winter into vegetable crops (~1MM acres)</td>
<td>Winter rotations into Cotton, Peanut</td>
<td>Winter into Soy and Cotton</td>
<td>Winter into Peanut, Cotton</td>
</tr>
</tbody>
</table>
• Winter crop that fits in existing crop rotation scenarios with potential of 2 to 4 M acres of the 15 M acres in the 6 team states, enabling sustainable fuel and bioproducts production

  ▪ Has seen significant developments over the last 7 years that demonstrates this crop is on the verge of broad commercialization

  ▪ Has superior agronomic properties and oil and fuel characteristics; high value seed meal for feed and bioproducts (SE has a need for high protein meal)

  ▪ SPARC’s strategic industry partnerships and efforts intended to move carinata to an **FSRL 8**, and integrated with a CHJ conversion to **FRL 9** enabling commercialization initiation at significant scale (FSRL scale 1-9 with 1 being ID of feedstock, etc. and 9 being commercialization)
Production Goals

- 3500 lb seed/acre
- 200 gal oil/acre
- $200-300 profit/acre
What's in a bag of carinata seed?

Seed sold to farmers in 50 lb bags to plant 10 acres.

One bag of seed can produce 18 tons of seed.

18 tons of seed produces 2000 gallons of jet fuel which can fly most fully loaded regional jets for 9 hours of flight, from North Florida to California and back.

The amount of feed (meal) can produce 3600 pounds of beef or 6200 pounds of poultry.
SPARC Teams and Objectives

**Feedstock Development**
- University of Florida
- University of Georgia
- Mississippi State University
- North Carolina State University

**Activities**
- Optimum geno-pheno-type identification for various SE US regions
- Fertility management
- System fit of carinata in the SE cropping system context
- Weed management and product development
- Disease and pest management
- Systems modeling

**Fuel and Co-product Development**
- ARA
- Emery
- RDL Ag Services LLC
- NC State University

**Activities**
- Hydrothermal cleanup
- Production of unblended drop-in fuels
- Co-product production and testing

**Outreach, Education, Workforce Development**
- RCB Altman LLC
- Dawson, GA

**Activities**
- Link research and extension for feedback and project improvement
- Document drivers of adoption, assess stakeholder needs
- Develop extension learning tools
- Stakeholder engagement
- K-12, undergraduate and graduate education in bioenergy
- Internships and career development in the field of bioenergy and bioeconomy

**Meal Efficiency**
- University of Florida
- University of Georgia

**Activities**
- Nutritional evaluation in poultry
- Glucosinolates in carinata meal and performance in cattle
- Recovery of co-product streams from carinata meal

**System Metrics**
- University of Georgia
- RDL Ag Services LLC
- RCB Altman LLC

**Activities**
- Economic analysis
- Watershed modeling
- Life Cycle Analysis

**Supply Chain**
- RCB Altman LLC
- ARA

**Activities**
- Feasibility analysis for post-harvest logistics, infrastructure development
- Secure resilient 24/7 feedstock supply
Established Carinata Value Chain

**Develop, test and introduce Carinata to farmers**

- **50%+ Stable Gross Margin**
  - Significant IP controlling product
  - Effective Inventory Management
  - Low working capital
  - Low capex requirements

- **30% Highly Variable Gross Margin**
  - Highest Risk portion of Value Chain
  - Net Return to Farmer impacted by weather
  - Upside is 30% GM, downside can be negative
  - Farmers look for crop options to mitigate commodity swings

- **5-8% Gross Margin**
  - Relatively stable GM, Volume Dependant
  - Established Significant infrastructure & working capital investment
  - Multiple locations and service
  - Commodity business, low technology

- **11% Gross Margin**
  - GM variable, can go negative
  - Meal value key component in crush equation
  - Significant Capex investment
  - Large established capital infrastructure
  - Low differentiation

**Biofuels: 18% Gross Margin**
- Low carbon markets driving margins
- Significant Capex required
- Feedstock costs & Regulatory key determinants of GM

**Feedlots: 5-20% Gross Margin**
- Commodity feedlots low GM%
- Speciality (e.g., Dairy) can drive to higher GM%
- Differentiation is key: Sustainable, non-GMO

**Customers**
Biofuels ISOCONVERSION Process (BIC)

Converts fats, oils, and greases from plants, animals, or algae into “drop-in” renewable fuels

Catalytic Hydrothermolysis (CH)
- Supercritical water
- Produces crude oil containing the same hydrocarbon types as petroleum crude

Hydrotreating
- Saturates olefins
- Removes residual oxygenates

Fractionation
- Produces finished fuels
- Jet and diesel that meet
- Meets petroleum specs without blending
- Renewable chemicals, and naphtha

2 Minutes
Converts fats oils and greases to crude oil

Conventional Refinery Processes
ARA’s Oil Conversion and Co-products

Unrefined Carinata Oil → HCU/Rapid Hydrolysis → Erucic Acid Recovery

HCU/Rapid Hydrolysis → CH Hydrothermal Conversion

CH Hydrothermal Conversion → Glycerin Recovery

Glycerin Recovery → Glycerin

Glycerin → Acetic Acid → Acetyl

Acetic Acid → Ethyl Acetate

Ethyl Acetate → Naphtha

Naphtha → Distillation

Distillation → Jet/kero

Jet/kero → Jet

Jet → Diesel

Diesel → LAB

LAB → n-Paraffin Recovery

n-Paraffin Recovery → n-Paraffins

n-Paraffins → Hydrotreat

Hydrotreat → Brassic acid

Brassic acid → Nylon 1313

Nylon 1313 → Solvents, Lubricants, Plasticizers Coatings, Specialty polyamides, Adhesives, Fragrances

Solvents, Lubricants, Plasticizers Coatings, Specialty polyamides, Adhesives, Fragrances

Behenic acid → Behenyl alcohol

Behenyl alcohol → Behenic acid

Behenic acid → Erucamide

Erucamide → Erucic Acid

Erucic Acid → Erucic Acid Recovery

Erucic Acid Recovery → Erucic Acid

Erucic Acid → N-Paraffins

N-Paraffins → n-Paraffins

n-Paraffins → n-Paraffins
Ongoing Activities....
Advancing carinata genetics

Value of variety or genotype testing—each evaluated for maturity, cold tolerance, yield and oil content and quality
Carinata Best Management Practices

Planting date
- Nov. PD
- Dec. PD
- Oct. PD

Row spacing
- 7”
- 14”
- 21”
- 35”

Nitrogen nutrition
- 0N
- 40N
- 80N
- 120N
Carinata Best Management Practices

Tillage
- No-till
- Chisel
- Disk

Planting date
- Nov. PD
- Dec. PD
- Oct. PD
Extension Efforts

Regional Production Meetings
Research & Production Summits
Plot Tours
Farm Field Days/Tours
Research translated to initiation of commercialization

Partnering with John Deere on combine setup

First shipment of carinata loaded at Cargill's port facility in Tampa from SE production
## Carinata Feedstock Readiness Level (FSRL, Scale 1 – 9)*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Current Status</th>
<th>Through SPARC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>3.2</td>
<td>8</td>
</tr>
<tr>
<td>Linkage to Conversion</td>
<td>6.2</td>
<td>9</td>
</tr>
<tr>
<td>Market</td>
<td>4.2</td>
<td>8</td>
</tr>
<tr>
<td>Policy</td>
<td>1.5</td>
<td>4.2</td>
</tr>
</tbody>
</table>

* From concept (1) to full commercialization (9)
## SPARC Vision for Commercial Deployment

<table>
<thead>
<tr>
<th>Demonstrate capacity</th>
<th>Increase Demand</th>
<th>Ramp up capacity</th>
<th>Build resilient supply chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Refine feedstock production and expansion for maximum productivity</td>
<td>▪ Provide renewable fuel and co-product samples to multiple endusers</td>
<td>▪ Policy informed by scientific process and stakeholder engagement</td>
<td>▪ Develop comprehensive support system-from producer to end user</td>
</tr>
<tr>
<td>▪ Develop risk mitigation and optimization tools to support scaling</td>
<td>▪ Demonstrate value of meal based co-products</td>
<td>▪ Scale SE US carinata production</td>
<td>▪ Ensure economic value and low risk across supply chain through robust supply chain modeling</td>
</tr>
<tr>
<td>▪ Establish communities of practice and stakeholder consortia spurring sustained interest and investment</td>
<td>▪ Demonstrate value along entire supply chain</td>
<td>▪ Drive infrastructure establishment to support carinata enterprise</td>
<td>▪ Build workforce to sustain carinata supply chain</td>
</tr>
</tbody>
</table>
SPARC-Challenges

- Maximizing yields within the SE US - commercialization and sustainability closely linked to yields
- Scaling up adoption - several barriers exist (rotational fit, markets, production know-how etc.)
- Limited regional infrastructure - adoption will justify infrastructure development (excellent commercial involvement)
- Policy around carinata incentives still to evolve - very early stages
Thank you!
SBAR

Sustainable Bioeconomy for Arid Regions

Kimberly Ogden
University of Arizona

CAAFI Presentation
10/13/17

Funded by the AFRI CAP Program

Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.
Sustainable Bioeconomy for Arid Regions

GUAR

FEEDSTOCK LOGISTICS

FEEDSTOCK PRODUCTION

PORTATION
Harvest
Storage
Staging

SPECIALTIES
Polysaccharide
Rubber
High-Value Derivatives

FUEL
Jet Fuel
Gasoline
Diesel

OMIC & ENVIRONMENTAL SUSTAINABILITY
Sustainable Bioeconomy for Arid Regions

GUAR

GUAYULE (WHY-U-LEE)
SBAR
Sustainable Bioeconomy for Arid Regions

Feastock Logistics

Sustainable Feastock Production

Feastock Development

Inputs
- Seeds
- Irrigation
- Nutrients
- Herbicides
- Pesticides

Plants
- Guayule
- Guar

Transportation
- Harvest
- Storage
- Aging

Specialties
- Polysaccharide
- Rubber
- High-Value Derivatives

Fuel
- Jet Fuel
- Gasoline
- Diesel

Social, Economic & Environmental Sustainability

Feedback
Impacts

Center of Excellence

- Add value to the bioeconomy for rural, arid regions through production of rubber, fuel, guar gum, and high value products

- Long term sustainability of water usage in Southwest through cultivation of drought resistant crops

- Increase student diversity in STEM fields
SBAR Presentation Outline

- Background to SW and the feedstocks
- Feedstock Development
- Sustainable Feedstock Production
- Feedstock Logistics
- Extension, Education and Outreach
Agriculture in the Southwest

Sustainability

**HARVESTED ACRES IN ARIZONA 2015**
(USDA/NASS)

- Lettuce: 4%
- Corn: 1%
- Barley: 5%
- Sorghum: 2%
- Wheat: 21%
- Cotton: 15%
- Other Vegetables and Fruit: 5%
- Hay and Haylage: 47%

**HARVESTED ACRES IN NM 2015**
(USDA/NASS)

- Lettuce: 4%
- Corn: 7%
- Barley: 1%
- Sorghum: 13%
- Wheat: 35%
- Hay and Haylage: 38%
- Cotton: 5%
- Other Vegetables and Fruit: 2%
Agriculture in the Southwest

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- Sorghum: 13%
- Hay and Haylage: 38%
- Cotton: 5%
- Wheat: 35%
- Other Vegetables and Fruit: 2%
Agriculture in the Southwest

ARIZONA 2020
- Guayule and Guar: 22%
- Corn: 5%
- Sorghum: 2%
- Wheat: 15%
- Cotton: 8%
- Lettuce: 5%
- Barley: 1%
- Hay and Haylage: 42%

NEW MEXICO 2020
- Guayule and Guar: 28%
- Corn: 10%
- Sorghum: 17%
- Wheat: 3%
- Cotton: 2%
- Other Vegetables and Fruit: 3%
- Hay and Haylage: 37%
## Suitable Land

### Sustainability

<table>
<thead>
<tr>
<th>Estimated Available, Suitable Land in Region (ha)</th>
<th>Guayule</th>
<th>Guar</th>
</tr>
</thead>
<tbody>
<tr>
<td>110,000 ha (5 years in AZ)</td>
<td></td>
<td>240,000</td>
</tr>
</tbody>
</table>

3 million ha in SW US (Long term)
Guayule

Sustainability

Bio-fractionation

- Natural Rubber: 440,000 MT/yr
- Bagasse: 3.65 Million MT/yr
- Resin: 285,000 MT/yr

Products

- Natural Rubber: $3.10 kg⁻¹
- Bio-Jet: $3 gal⁻¹
- Adhesives: (10 billion)
- Tackifiers: (billions)
- Fragrances: (billions)
- Pharmaceutical: (100s billion)

Market Size

- Total Market: $5.6 Billion
- Bio-Jet: $88 Billion

- Natural Rubber: $3.10 kg⁻¹
- Bio-Jet: $3 gal⁻¹
- Adhesives: (10 billion)
- Tackifiers: (billions)
- Fragrances: (billions)
- Pharmaceutical: (100s billion)
Feedstock Readiness Level Guayule

Sustainability

<table>
<thead>
<tr>
<th>Feedstock:</th>
<th>Guayule</th>
<th>Region: AZ/SW US</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSRL Scoring Summary</td>
<td>Production</td>
<td>Market</td>
</tr>
<tr>
<td>Current Status</td>
<td>6.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Anticipated Status</td>
<td>7</td>
<td>6.2</td>
</tr>
</tbody>
</table>
Guar Gum

Bio-fractionation

Products

Seeds
340,000 MT/yr

Bagasse
1 Million MT/yr

Guar Gum
95,000 MT/yr

Animal Feed
245,000 MT/yr

Bio-Jet
Total Market $88 Billion

Market Size

$3.30 to $26 kg⁻¹

$0.10 kg⁻¹

$3 gal⁻¹
### Feedstock Readiness Level - Guar

**Feedstock:** Guar  
**Region:** AZ/SW US

<table>
<thead>
<tr>
<th>FSRL Scoring Summary</th>
<th>Production</th>
<th>Market</th>
<th>Policy</th>
<th>Guar Gum Conversion</th>
<th>Linkage to Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Status</td>
<td>2.3</td>
<td>2.2</td>
<td>4.2</td>
<td>5.1</td>
<td>1</td>
</tr>
<tr>
<td>Anticipated Status</td>
<td>4.1</td>
<td>4.1</td>
<td>5.4</td>
<td>7</td>
<td>4.1</td>
</tr>
</tbody>
</table>

#### Guar Import ($millions USD)

![Graph showing Guar import from 2008 to 2016](image)

- **Guar Import ($millions USD):**
  - 2008: 0
  - 2010: 0
  - 2012: 0
  - 2014: 1000
  - 2016: 2000
## Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Shrub biomass Improvement</td>
</tr>
<tr>
<td>1.2</td>
<td>High-throughput phenotyping</td>
</tr>
<tr>
<td>1.3</td>
<td>Superior genotypes of guayule and guar for regional growers</td>
</tr>
</tbody>
</table>

High throughput phenotyping tractor with sensors and geo-referencing
## Outcomes

**Feedstock Development**

<table>
<thead>
<tr>
<th>Expected Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved shrub biomass.</td>
</tr>
<tr>
<td>Better understanding of the reproduction for guayule accessions.</td>
</tr>
<tr>
<td>Deployment of guayule and guar genotypes to growers.</td>
</tr>
<tr>
<td>Optimum planting dates for guar.</td>
</tr>
<tr>
<td>Selection tools developed.</td>
</tr>
<tr>
<td>Better understanding flowering control in guayule.</td>
</tr>
</tbody>
</table>
### Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Agronomics:</td>
<td>nutrients, salinity, herbicides, irrigation</td>
</tr>
<tr>
<td>2.2 Soil quality and health – sustainability</td>
<td></td>
</tr>
<tr>
<td>2.3 Identify Economic co-products</td>
<td></td>
</tr>
</tbody>
</table>

Drip Irrigated Guayule
## Outcomes

### Sustainable Feedstock Production

<table>
<thead>
<tr>
<th>Expected Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web app: irrigation, fertilizer, salinity, and pest management</td>
</tr>
<tr>
<td>Herbicide SLN registrations for DS guayule</td>
</tr>
<tr>
<td>Understanding of microbial community populations that support optimal production</td>
</tr>
<tr>
<td>Guayule &amp; Guar Best Management Practices</td>
</tr>
<tr>
<td>Yield increases in guayule and guar</td>
</tr>
<tr>
<td>Identify natural products – commercialization</td>
</tr>
</tbody>
</table>

Drip tape installation
### Objectives

3.1 Understand timing effects on quality

3.2 Optimize shipping and handling

3.3 Demonstrate bagasse to fuel

---

Guayule bales ready for transport for processing
Transportation Plan

Feedstock Logistics

- Model shipping and handling system
  - Mixed integer optimization
  - Decomposition-based algorithms
- Compare to existing models
  - Volpe’s Biofuel Transportation Analysis Tool
  - ORNL’s feedstock data and visualization tools
- Optimize harvest, collection levels, storage, and transportation routes

Guayule Harvest
# Bagasse to Fuel Routes

**Feedstock Logistics**

<table>
<thead>
<tr>
<th>Route</th>
<th>Feedstock</th>
<th>Bio-oils</th>
<th>Liquid Intermediates</th>
<th>Fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Pyrolysis (ISU)</td>
<td>Feedstock</td>
<td>Bio-oils</td>
<td>Liquid Intermediates</td>
<td>Fuels</td>
</tr>
<tr>
<td>Hydrothermal Liquefaction (PNNL &amp; NMSU)</td>
<td>Feedstock</td>
<td>Bio-crude Oils</td>
<td>Liquid Intermediates</td>
<td>Fuels</td>
</tr>
<tr>
<td>REACH® Process (Mercurius Biofuels)</td>
<td>Feedstock</td>
<td>Sugars</td>
<td>Liquid Intermediates</td>
<td>Fuels</td>
</tr>
<tr>
<td>Gasification + Fisher Tropsch</td>
<td>Feedstock</td>
<td>Syngas</td>
<td>Liquid Intermediates</td>
<td>Fuels</td>
</tr>
<tr>
<td>Extraction + Trans-esterification</td>
<td>Feedstock</td>
<td>Lipids</td>
<td>Liquid Intermediates</td>
<td>Fuels</td>
</tr>
</tbody>
</table>
# Technology Readiness of Conversion Partners

## Feedstock Logistics

<table>
<thead>
<tr>
<th>Process</th>
<th>Fast Pyrolysis</th>
<th>Hydrothermal Liquefaction</th>
<th>REACH ®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial TRL</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Final TRL</td>
<td>6</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

- **Fast Pyrolysis PDU at Iowa State University**
- **Modular Hydrothermal Liquefaction System at PNNL**

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## Expected Outcomes

<table>
<thead>
<tr>
<th>Feedstock Logistics</th>
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</thead>
<tbody>
<tr>
<td>Feedstock chemical profiles by time and handling</td>
</tr>
<tr>
<td>Transportation model optimized for guar and guayule</td>
</tr>
<tr>
<td>Feedstocks linked to conversion technologies</td>
</tr>
<tr>
<td>Data to sustainability model</td>
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</tbody>
</table>

Hydrothermal Liquefaction PDU at NMSU
Objective 4.1: System model for sustainability assessment

Objective 4.2: Utilize data for model validation and provide data feedback

Objective 4.3: Interface with regional growers
Outcomes

Expected Outcomes

Coupling of Sustainability, Experimental, Extension
Web-delivered analysis tool
Socio-economic Impact
# Overview

Extension, Education and Outreach

<table>
<thead>
<tr>
<th><strong>Objectives</strong></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>5.1 Produce Extension materials</td>
<td></td>
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<tr>
<td>5.2 Show-and-tell for growers</td>
<td></td>
</tr>
<tr>
<td>5.3 Train the trainers</td>
<td></td>
</tr>
<tr>
<td>5.4 Develop bioeconomy K-12 modules</td>
<td></td>
</tr>
<tr>
<td>5.5 Involve youth through 4-H and camps.</td>
<td></td>
</tr>
</tbody>
</table>
Impacts

Center of Excellence

- Add value to the bioeconomy for rural, arid regions through production of rubber, fuel, guar gum, and high value products
- Long term sustainability of water usage in Southwest through cultivation of drought resistant crops
- Increase student diversity in STEM fields