Bioenergy Research at OSU from FIELD to FUEL

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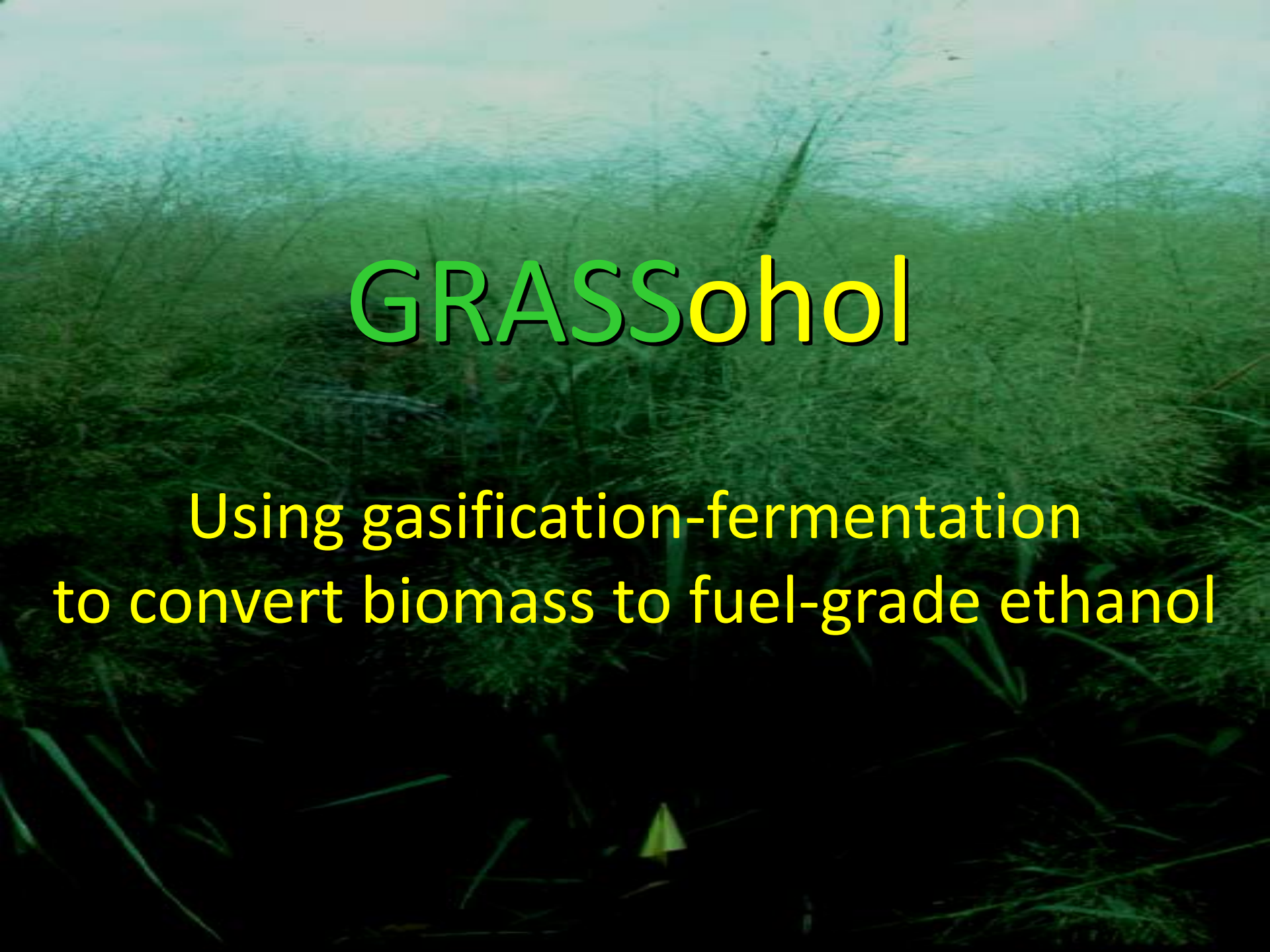
Research at OSU

- Feedstock Development
- Biomass Production
- Harvest, Handling & Storage Logistics
- Bioconversion Technologies
- Modeling and Economic Analyses

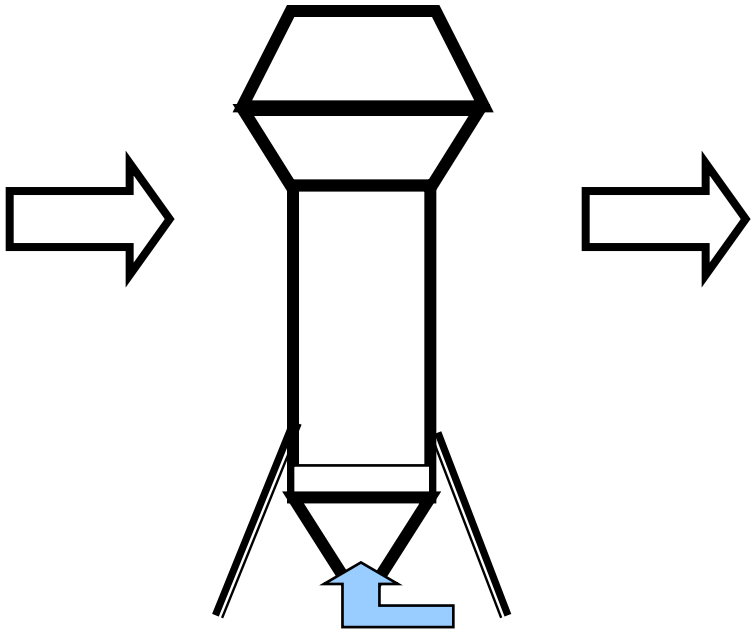
Selected Projects & Activities

- GRASSohol Project
- Sweet Sorghum Ethanol
- Oklahoma Bioenergy Center
- NSF EPSCoR Project
- Biomass Research & Development Initiative
- Sun Grant Initiative

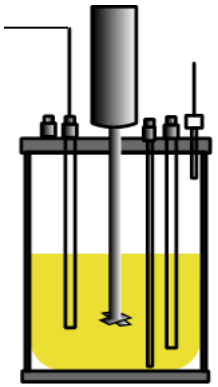

GRASSohol
Using gasification-fermentation
to convert biomass to fuel-grade ethanol

GRASSohol Process

Biomass

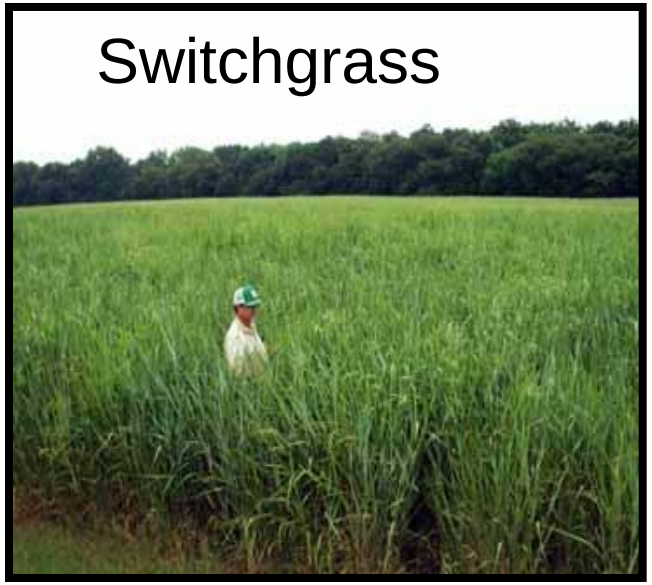


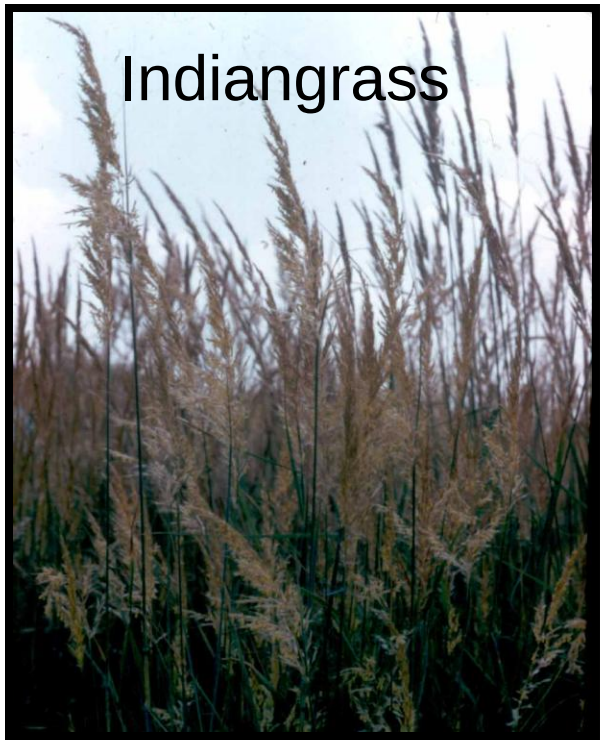
Gasifier



Fermentation

Traditional grasses with high production potential

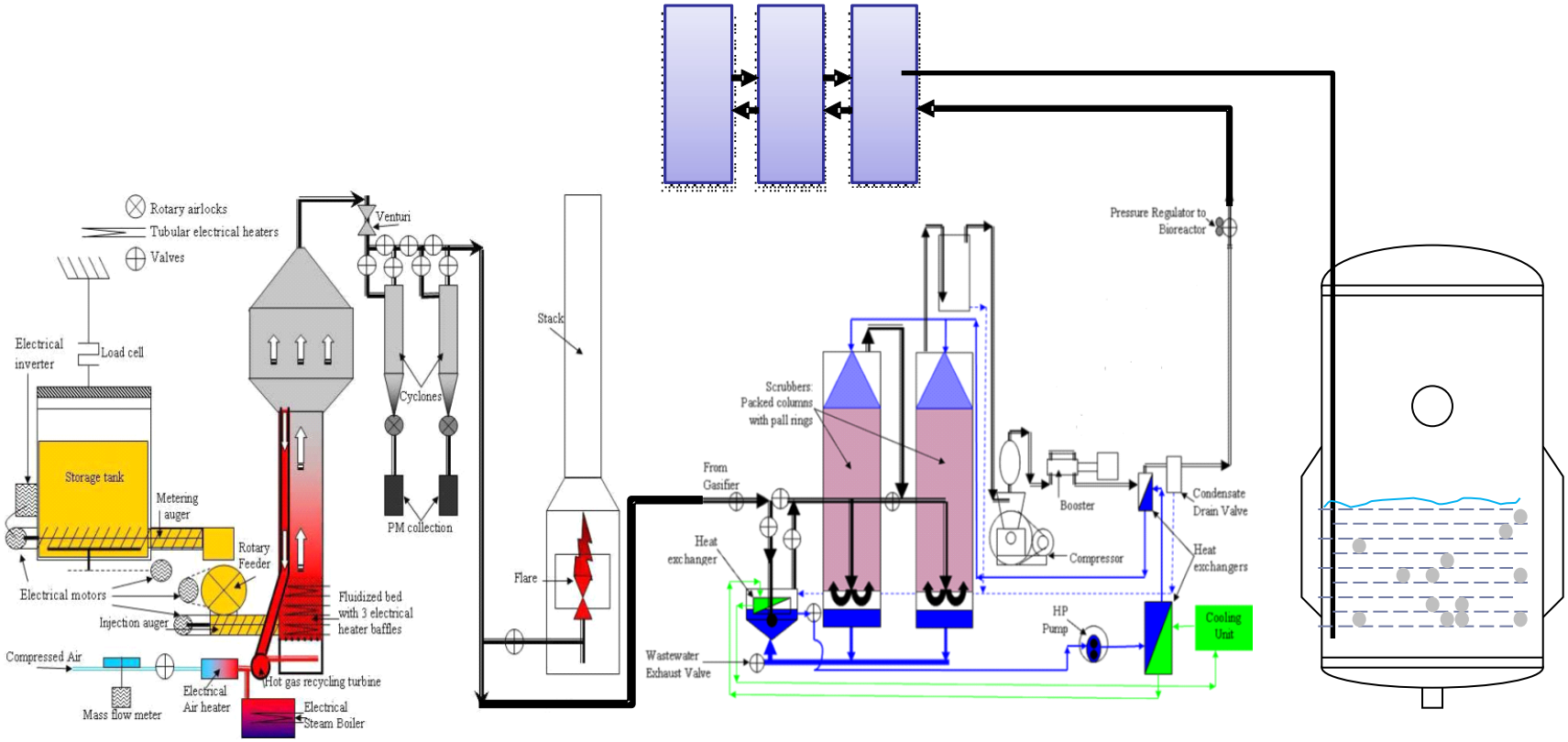




"Exotic" grasses with high production potential

GRASSohol Process

1200 L Syngas Storage Tanks



Fluidized Bed / Down Draft Gasifier **Syngas Scrubber System** **Fermentor**

Gasification and Cleaning System

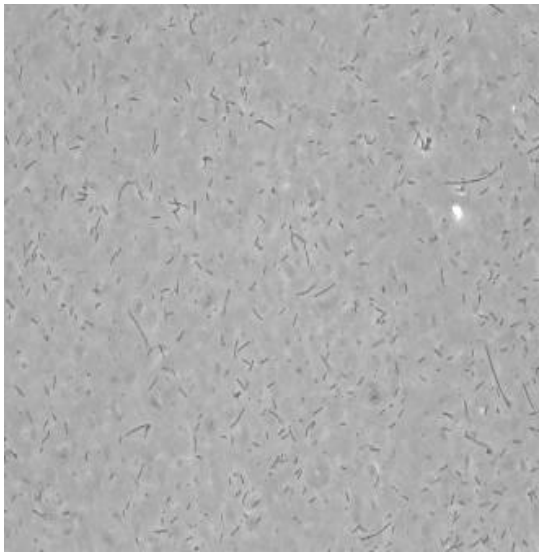
Gasification Research

- Reactors
  - Fluidized-Bed
    - Air Blown
    - Internal Supplemental Heat
    - Steam
  - Downdraft
- Maximize syngas quality (CO, H_2, CO_2)
- Tar Identification/Quantification

Bioreactor

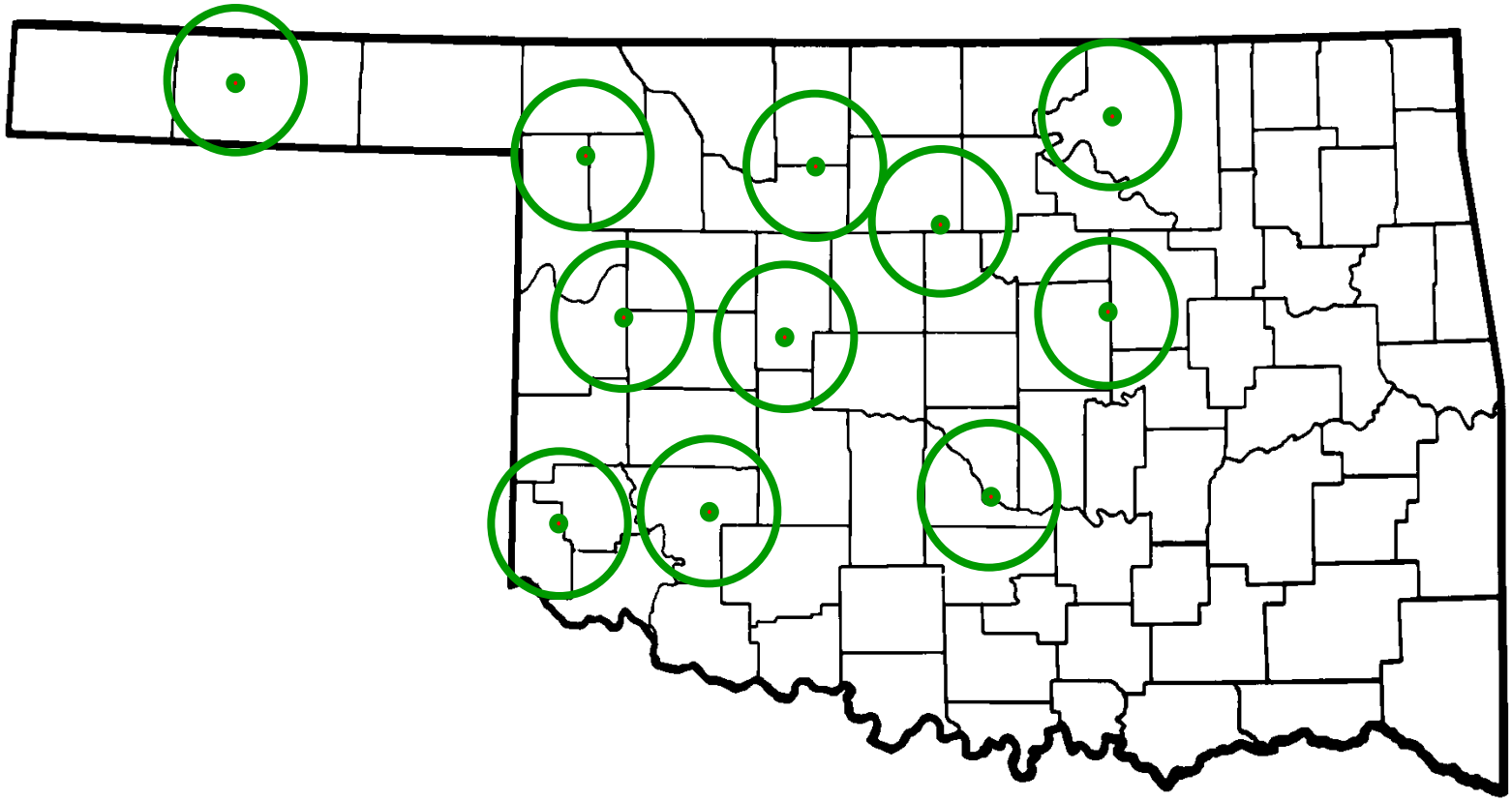
Microbial Catalysts

- Identified five unique, candidate microorganisms
- Novel clostridium species, gram positive
- Patent pending
- Successful transformation of acetogen strain P11 by plasmid pIKM1 by electroporation.

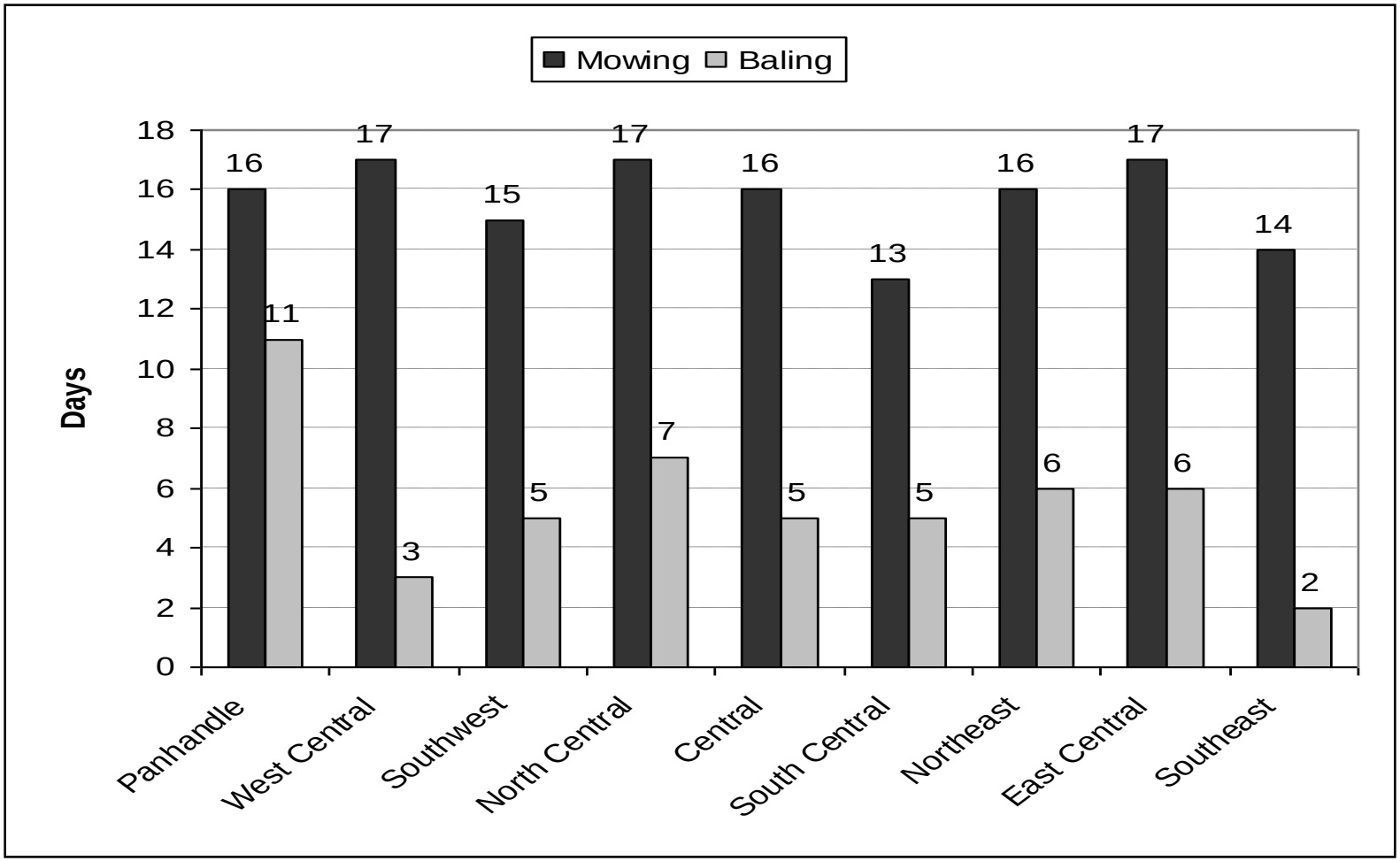


P7 – Clostridium carboxidovorans

Potential Biorefinery Plant Locations



Estimated Days of Mowing and Baling for October at the 95% Probability Level



Participants

- OSU
- University of Oklahoma
- Brigham Young University
- Mississippi State University

Funding

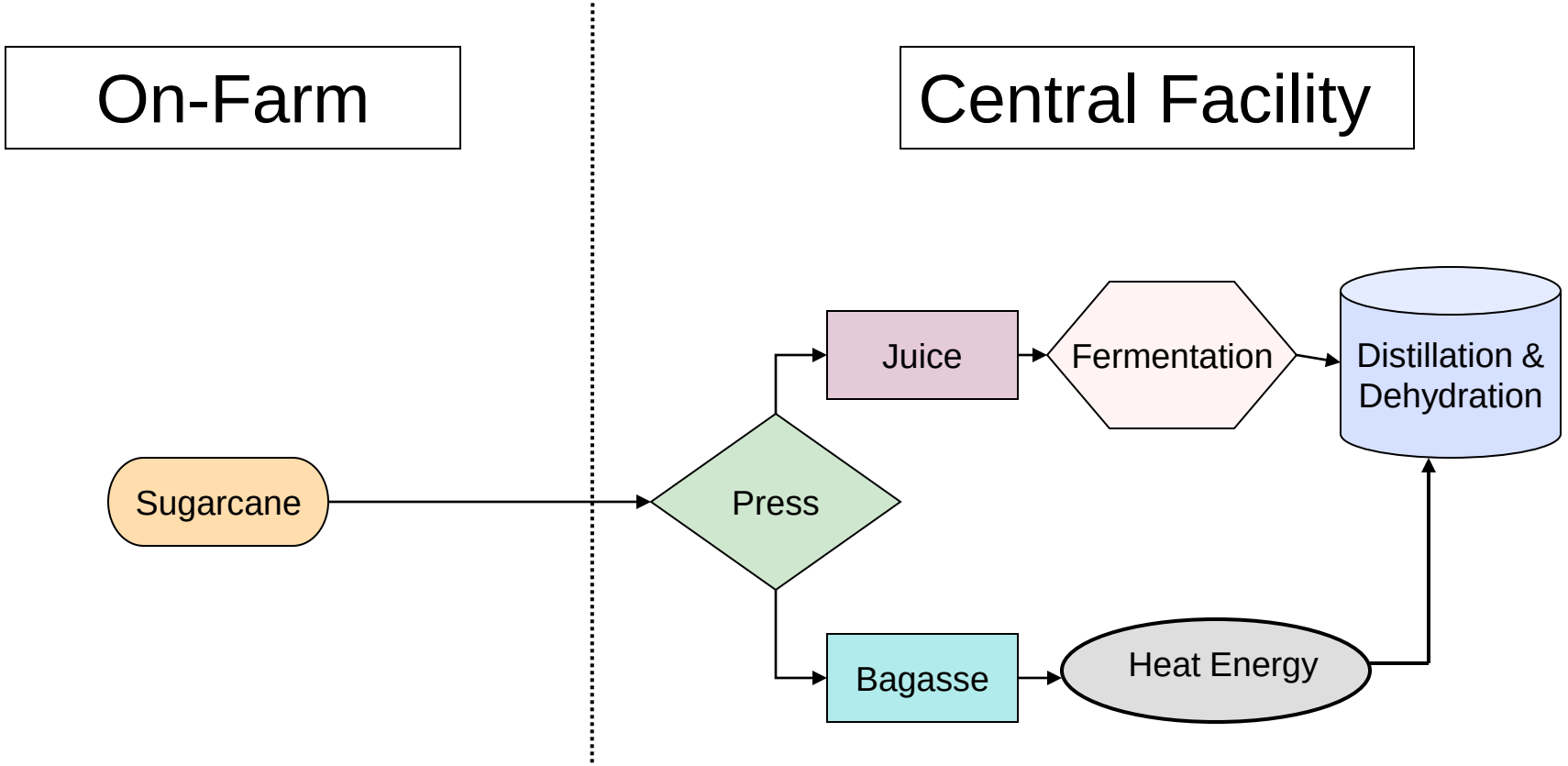
- Oklahoma Agricultural Experiment Station
- USDA-CSREES: Competitive and Special Grants
- Coskata, Inc.

Direct Fermentation of Sugars from Sweet Sorghum Juice

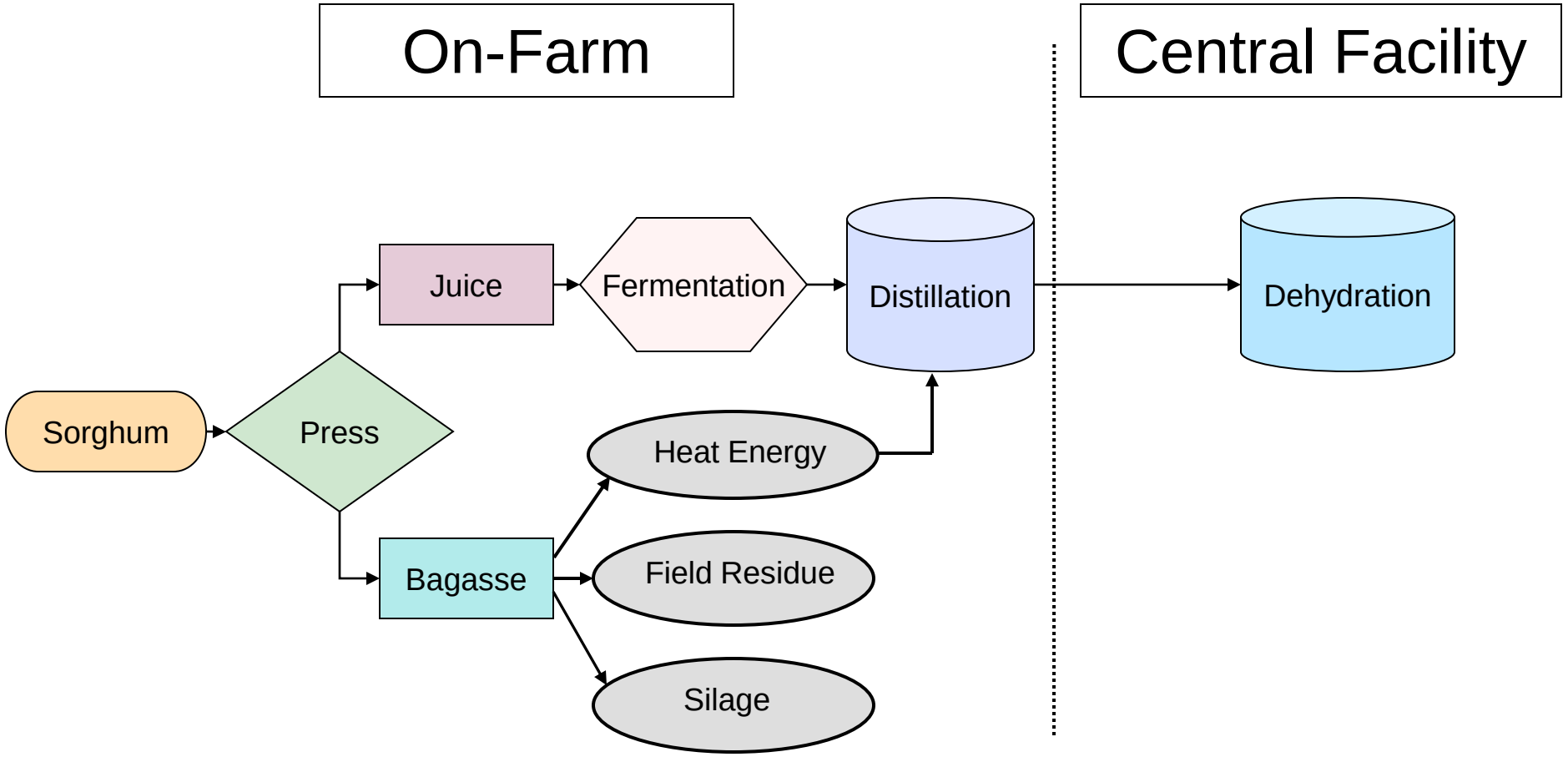
Sweet Sorghum

- High energy crop for ethanol production (15-20% directly fermentable sugar)
- Can be grown in temperate climates
- Low fertility requirements
- Low water requirement: 1/2 corn and 1/3 sugarcane

Traditional Sugar Processing



Potential In-Field Processing of Sweet Sorghum

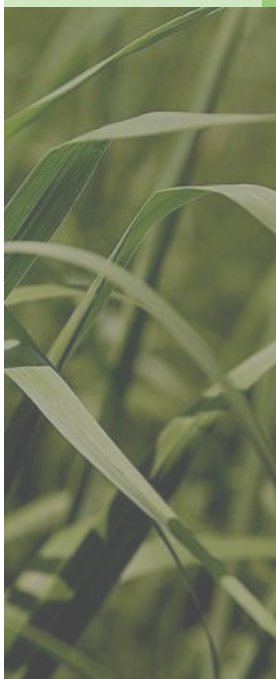


Sweet Sorghum Research

- Production
  - Fertility
  - Row spacing
- Sugar content
- Juice expression efficiency
- Fermentation efficiency

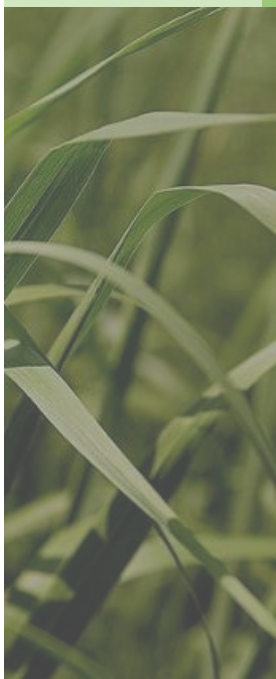
Oklahoma Bioenergy Center Act - 2007

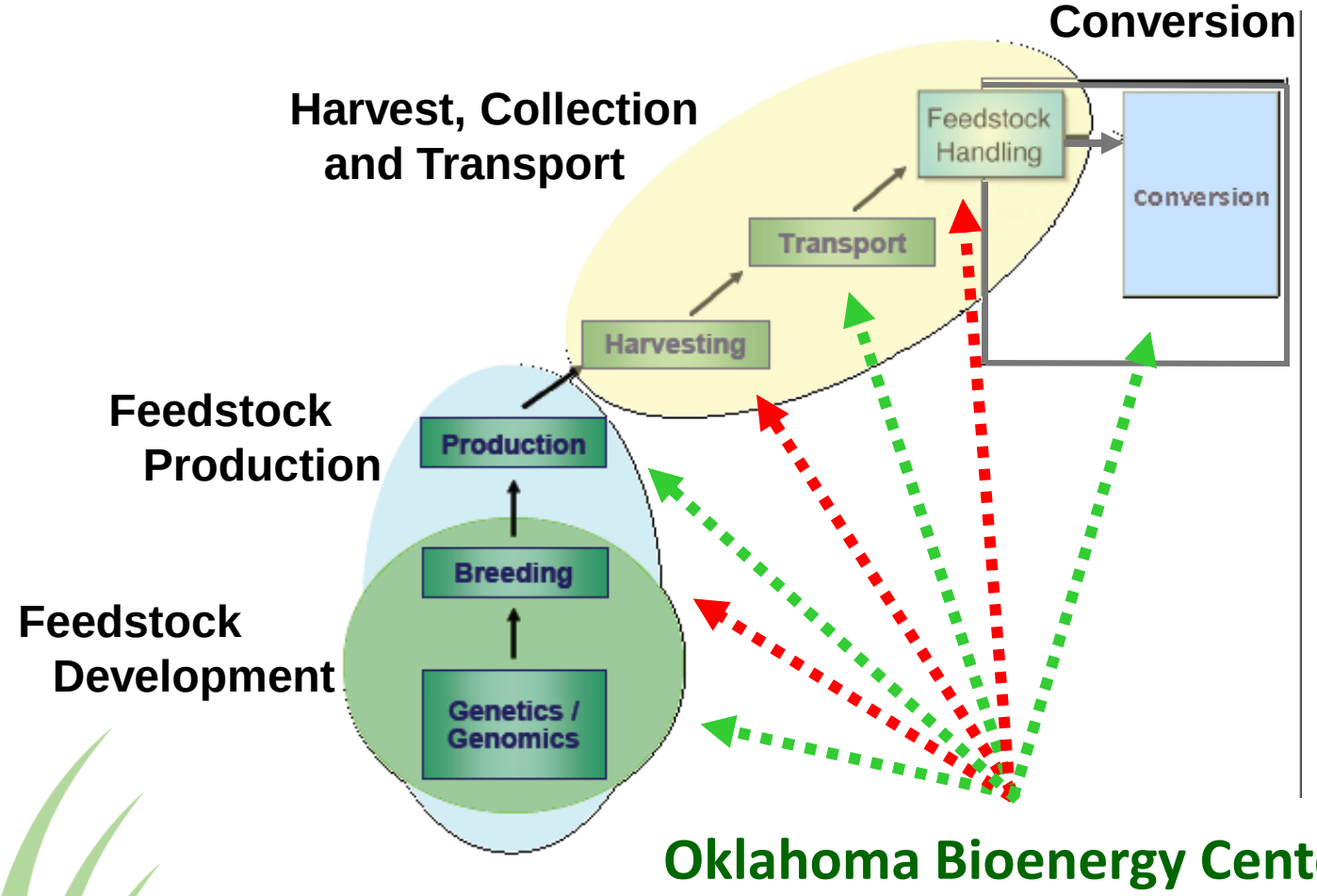
- Created the Oklahoma Bioenergy Center.
- $40 million over 4 years.
- Founding member institutions:
  - Oklahoma State University
  - University of Oklahoma
  - The Samuel Roberts Noble Foundation



Research Programs

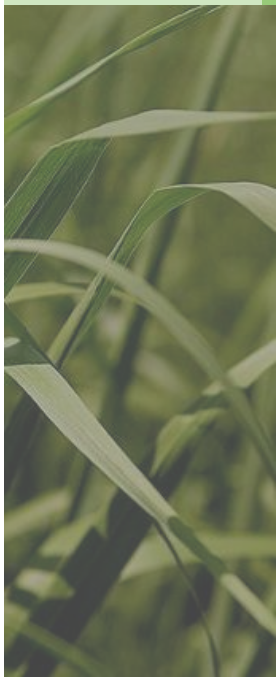
- Primary
  - Outcomes: Sustainable, economic production of **cellulosic ethanol** (or other high-value outputs).
  - Approach: Comprehensive, whole-system research that integrates solutions from each stage of the biofuels production/value chain.
- Secondary
  - Outcomes: Critical elements in production of **biodiesel and ethanol from non-cellulosic sources**.





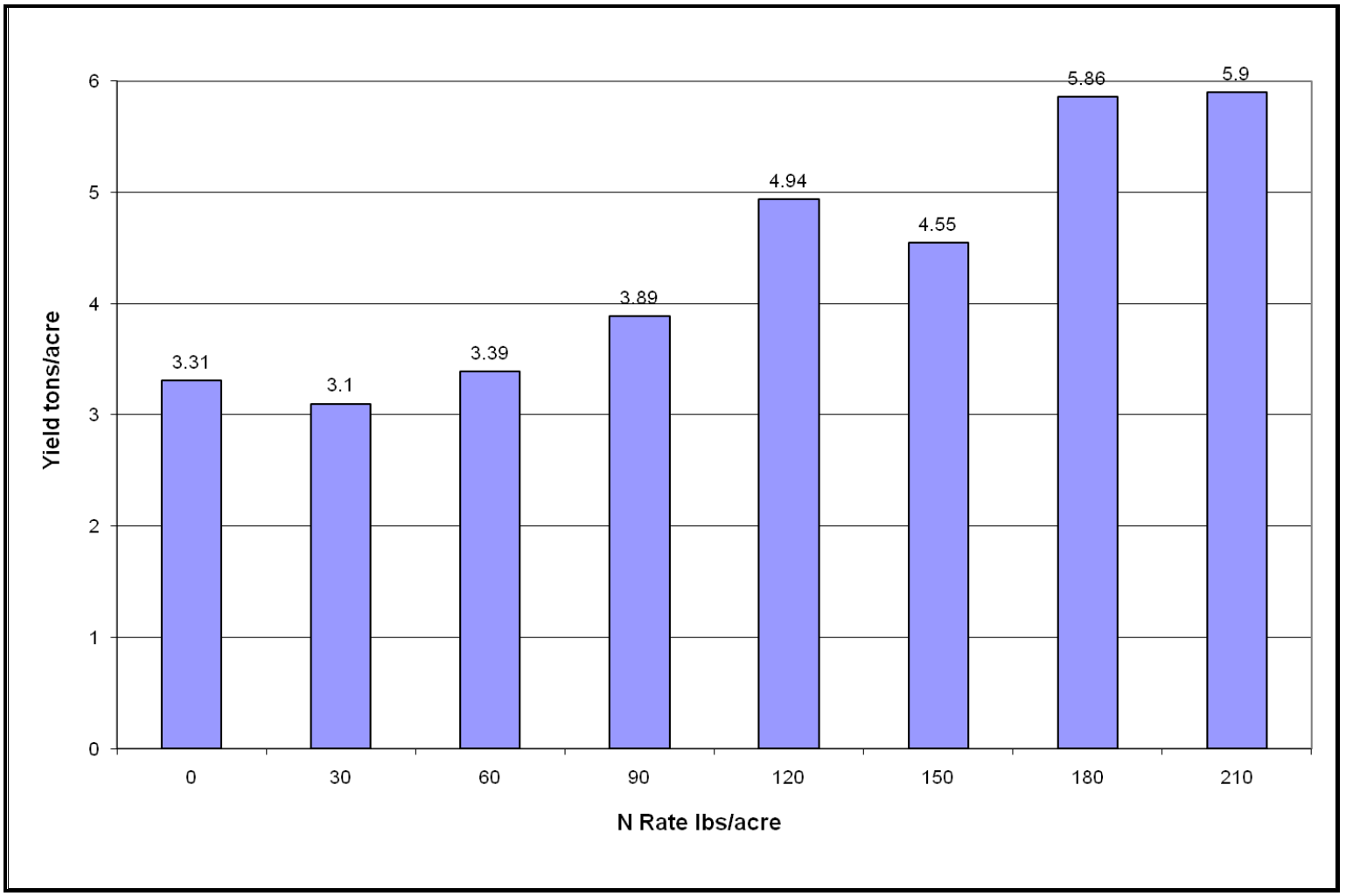
Oklahoma Bioenergy Center

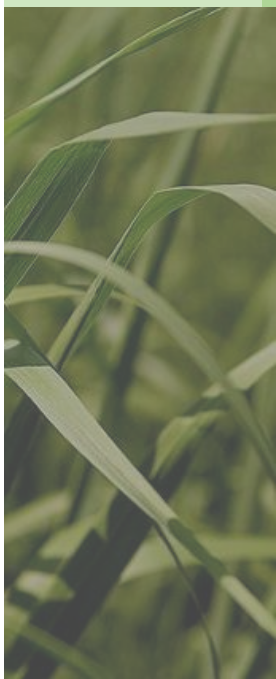
Feedstock Production



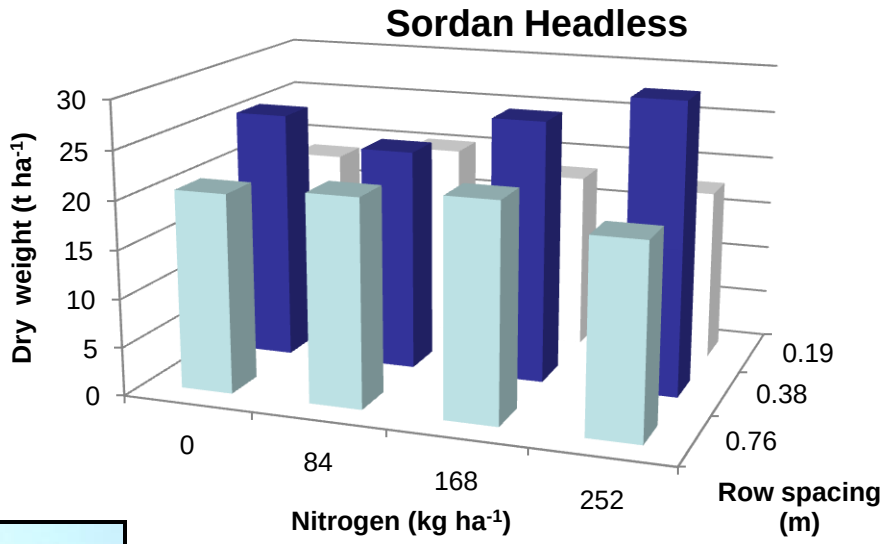
Switchgrass Yield and Quality based on Nitrogen Application

Switchgrass Yield based on Nitrogen Application

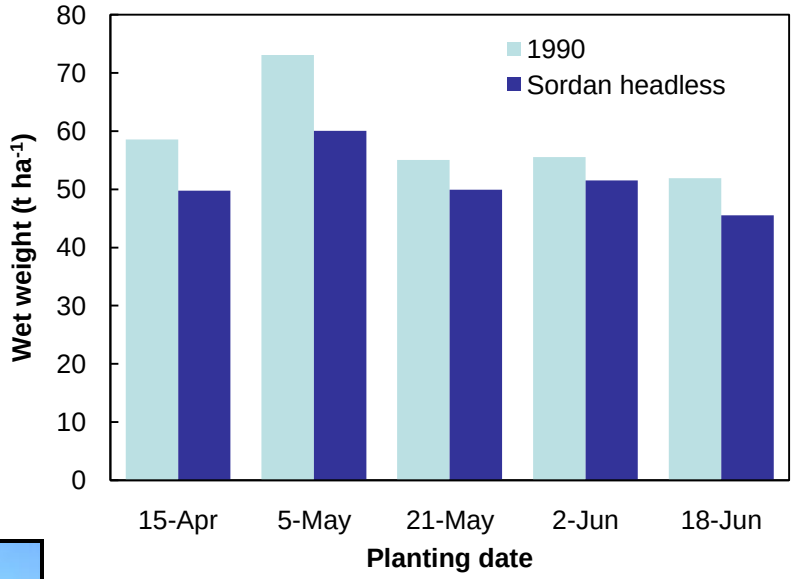




High Biomass Sorghum – Spacing x Nitrogen

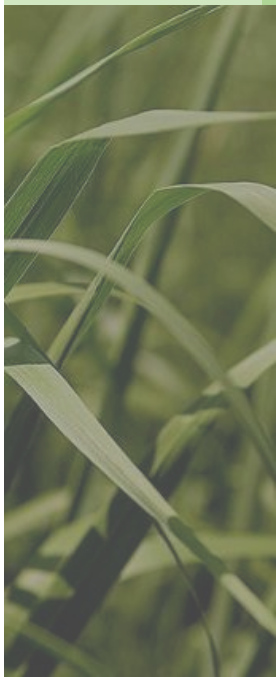


High Biomass Sorghum – Optimum Planting Date

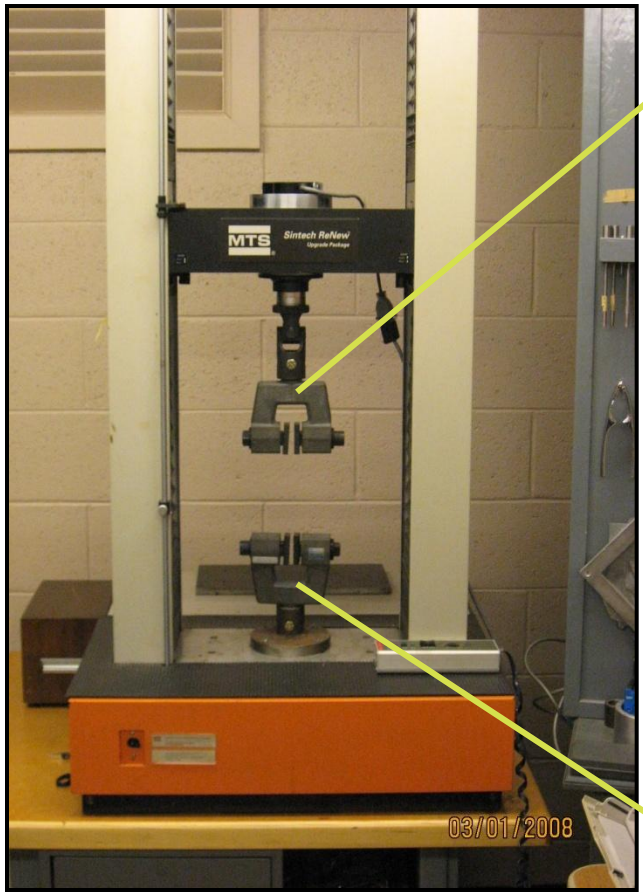


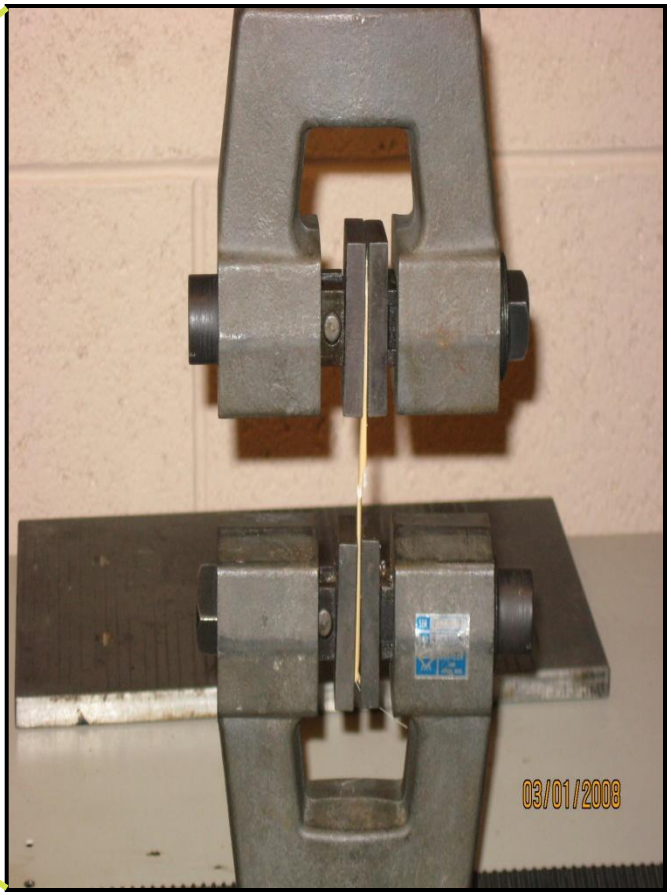
Agronomic Considerations for Oilseed Crops

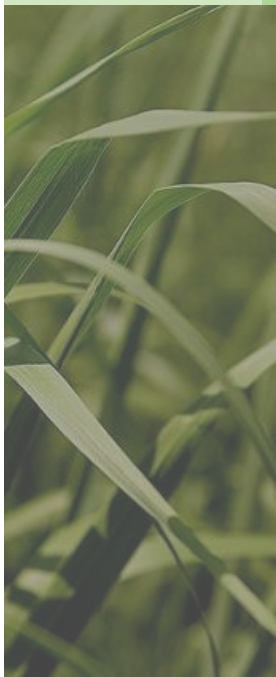
Harvest and Handling Logistics



Physical Properties of Switchgrass







Bale Storage

Building Leadership in Cellulosic Bioenergy

NSF EPSCoR RII Project

Future of Cellulosic Bioenergy?

Based on published proposed changes to the renewable fuel standard program, USEPA predicts **85%** of the production of dedicated energy crops in the U.S. in 2022 is expected to occur in Oklahoma.

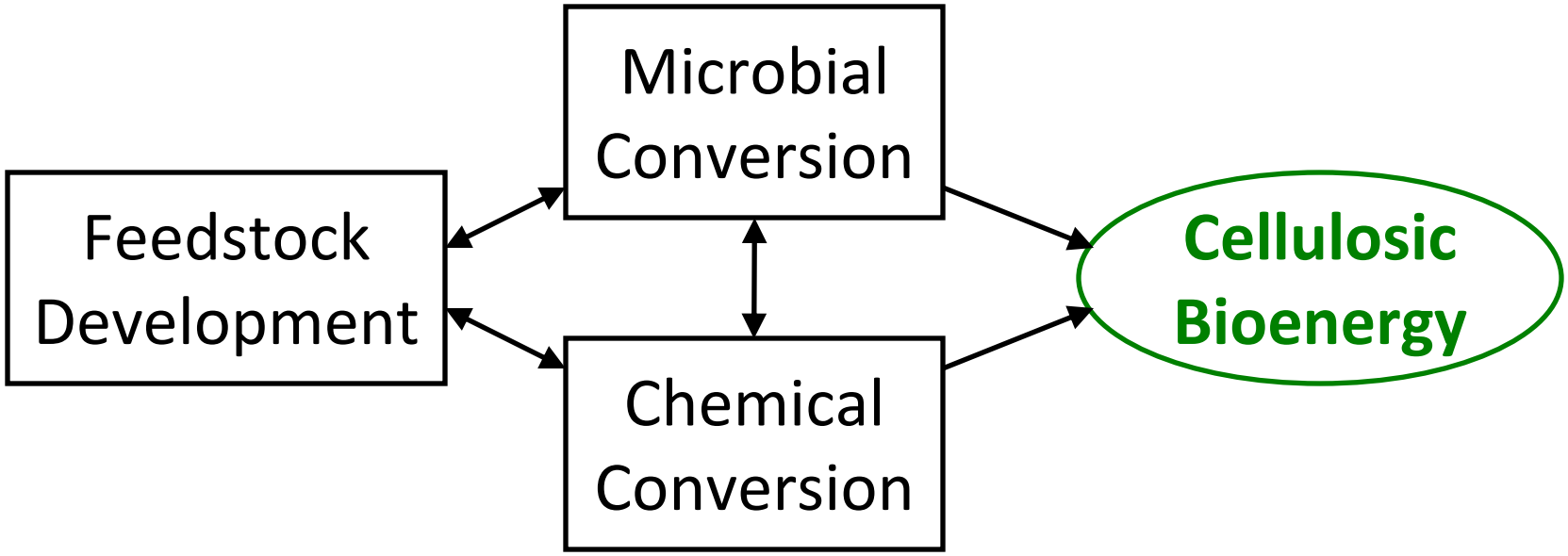
"The majority of switchgrass is projected to likely be grown in Oklahoma….."

(U.S. Environmental Protection Agency, 2009)

Objectives

1. To discover molecular mechanisms and tools for **biomass development** by genomics, functional genomics and genetic transformation
2. To understand the molecular basis and mechanisms underlying efficient **microbial conversion** of biomass to liquid fuels through direct and indirect fermentation
3. To improve existing and develop new catalytic/thermo**chemical conversion** processes of cellulosic biomass

Relationship of Objectives



- *Total Dry Matter (Carbon)*
- *Pest Resistance*
- *Drought Tolerance*

- *Efficiency*
- *New Processes/Fuels*
- *Cost Effectiveness*

- *Carbon Footprint*
- *Sustainability*

Sustainable Feedstock Production Supply Systems to Support Cellulosic Biorefinery Industries

Biomass Research and Development Initiative, USDA-CSREES

Participants

- OSU
- Samuel Roberts Noble Foundation
- Idaho National Laboratory
- AGCO Industries
- Stinger, Inc.

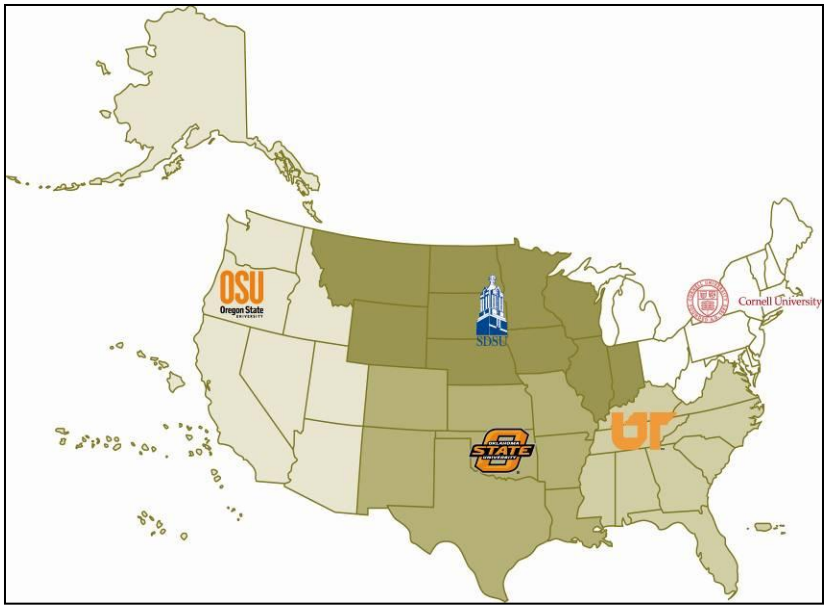
Collaborators

- Abengoa Bioenergy
- Ceres, Inc.

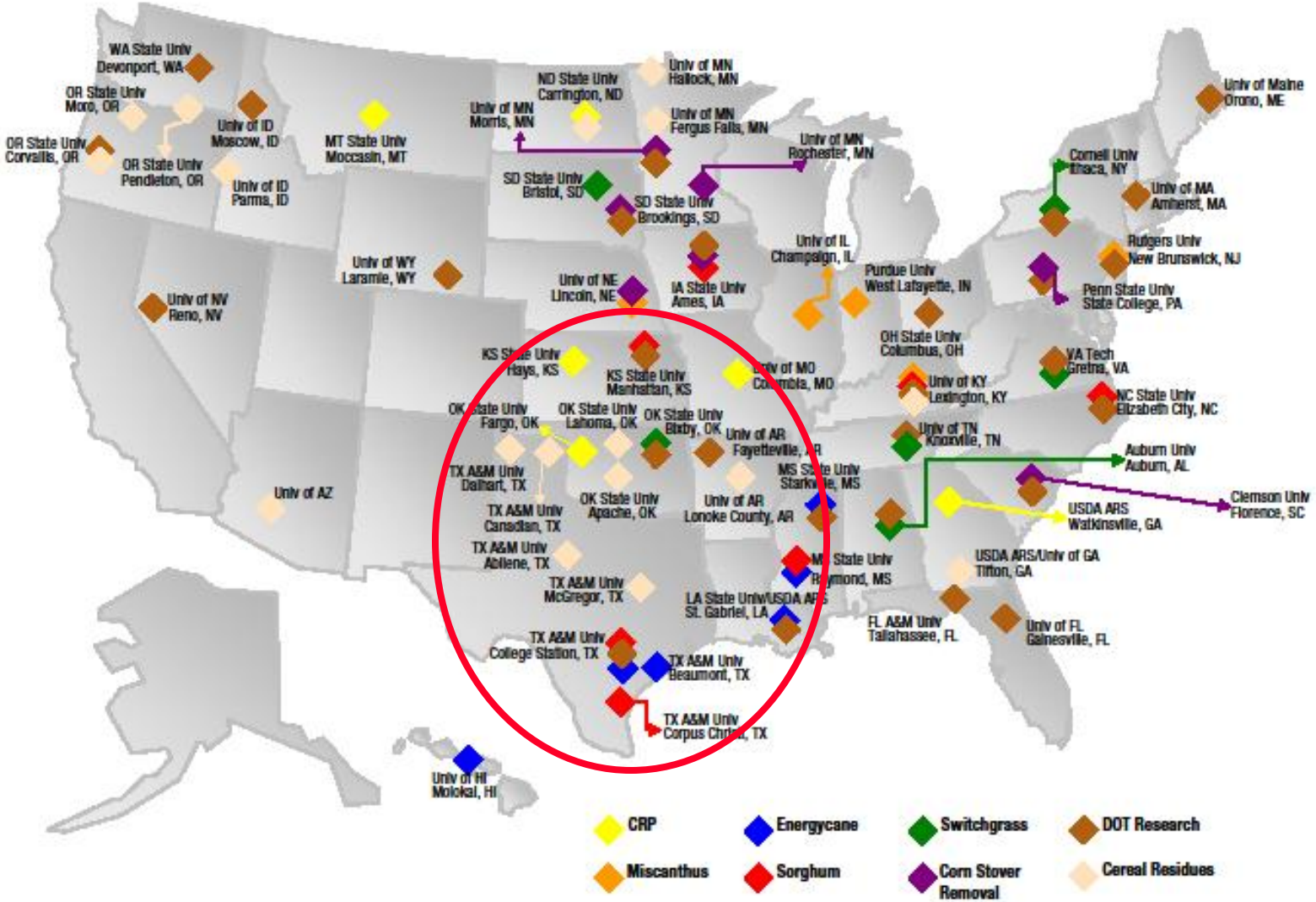
Objectives

1. Develop BMPs for sustainable **large-scale establishment and production**.
2. Development of **mixed-species** bioenergy production systems.
3. Evaluate and develop **dual-use production systems**.
4. Estimate **carbon sequestration** and climate change mitigation.
5. Determine potential to conserve **surface and groundwater resources**.
6. Model **spatial variability** of biomass yields and soil properties.
7. Identify **quality characteristics** of feedstock, using Abengoa Bioenergy as a customer of reference.
8. Determine **market bid price** for short- and long-term crop and pastureland leases.

- Develop biobased products
- Stimulate economic activity



Feedstocks Partnership



DOT Competitive Grants Program

Priorities

- Feedstock development
- Biofuels conversion processes
- Biofuels system analysis
- Economics, marketing and policy
- Environmental impacts

2007 RFA

- Seed Grants: 50 proposals, 10 awards = $693,435
- Integrated Projects: 38 proposals, 7 awards = $1,843,538

2009 RFA

- Seed Grants: 45 proposals, 6 awards = $388,152
- Integrated Projects: 35 proposals, 3 awards = $807,987

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